PROCEEDINGS

of the

REGIONAL WORKSHOP

on

IMPACT OF SHRIMP FARMING ON ARABLE LAND AND REHABILITATION OF RESULTANT SALT-AFFECTED SOILS/INTEGRATED SOIL MANAGEMENT FOR SUSTAINABLE USE OF SALT-AFFECTED SOILS

FAO Project TCP/THA/8922 / Fourth Meeting of FAO Global Network

20-24 November 2000

Ayutthaya, Thailand

Food and Agriculture Organization of the United Nations

Land Development Department, Ministry of Agriculture and Cooperatives, Thailand

FAO Global Network "Integrated Management for Sustainable Use of Salt-affected Soils"

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FAO Global Network "Integrated Management for Sustainable Use of Salt-affected Soils"

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Preface

The development of agricultural technologies and a better appreciation of the existing but under-utilised knowledge of resource management will be crucial in meeting the ecological needs and in achieving the anticipated food demands of the growing population in the future. The greatest challenge for the coming decades lies in the fact that the production environments are unstable and degrading. Land degradation is proceeding so fast that unless policies and approaches change, many countries will not be able to achieve sustainable agriculture in the foreseeable future. Soil salinization has been identified as a major process of land degradation. The greatest technical causes of decreasing production on many irrigated projects, particularly in arid and semi-arid areas, or failure of large areas in rainfed agriculture, are waterlogging, salinization and sodication. It was estimated from various available data that the world is losing at least three hectares of arable land every minute because of soil salinity.

Although many countries are using salt-affected soils because of their proximity to water resources and the absence of other environmental constraints, there is a clear need for a sound scientific basis to optimise their use, determine their potential, productivity and suitability for growing different crops, and identify appropriate integrated management practices. Because of this and the increasing awareness of continuing soil salinization and sodication, FAO's Regular Programme is supporting national institutions in countries having problems of salt-affected soils to strengthen their experimental programmes on adapted soil management practices. Since 1990, collaborative projects have been identified to develop management practices for sustainable use of salt-affected soils: experiments and demonstrations on pilot farms have been conducted in 22 countries in different regions - (i) Africa (Ghana, Kenya, Nigeria and Tanzania); (ii) Asia and Pacific (Bangladesh, China, Indonesia, Pakistan, Philippines, Thailand and Viet Nam); (iii) Europe (Hungary, Romania and Turkey); (iv) Latin America and Caribbean (Argentina, Brazil, Cuba and Mexico); (v) Near East (Egypt, Iran, Syria and Tunisia).

To avoid the fragmentation of technical research and development efforts in developing countries and to stimulate coordination of work between different international and national organizations in the management of salt-affected soils, a co-operative project was signed in November 1994 between FAO and UNEP, in association with the Subcommission on Salt-Affected Soils of IUSS.

The project was to establish a Network on Integrated Soil Management for Sustainable Use of Salt-affected Soils. The 22 countries involved in the mentioned FAO collaborative projects are 'Members' in the Network, in addition to other "Associate Members" running their country national programmes on management of salt-affected soils (Australia, Canada, Colombia, India, Italy, Spain, Sudan and Uzbekistan). One of the Network activities is to organise a workshop (Network Meeting) every two years. Three meetings were already implemented in November 1995 in The Philippines; in September 1997 in Egypt and the third in July 1999 in the Philippines for Asia Region and in September 1999 in Turkey for other Regions. The present workshop, held in November in Thailand was organised for Asia Region, and for other regions, another workshop was organised in Spain, both as the Fourth Meeting of the Network. Because of budget availability, the Thailand's workshop was organised within one of the activities of the FAO project FAO/TCP/THA/8922: Impact of Shrimp Farming on Arable Land and Rehabilitation of Resultant Salt-affected Soils in Thailand.

This 22-month project was approved by the FAO in October 1999, to be implemented by the Land Development Department (LDD), Ministry of Agriculture and Cooperatives, as the government executing agency. The project's objective is to assist the Government of Thailand to study the impacts of shrimp farming in freshwater arable land and in the demonstration of appropriate integrated techniques for rehabilitation of abandoned shrimp farms and improvement of affected lands by seawater intrusion and shrimp farming practices in arable lands, mainly rice production in support of food security programmes in the country through the introduction of appropriate management techniques for optimum production of such soil.

This is the Project Mid-term Workshop with the objective to determine the performance of the project and to exchange information and experiences with other collaborating scientists from neighbouring countries and international consultant. The participating countries, in addition to Thailand were Bangladesh, China, India, Indonesia, Malaysia, Pakistan, the Philippines, Vietnam and Australia. The immediate objectives of the Workshop were:

- Analyse and synthesise available information in the participating countries on the extent and cause of salt-affected soil and its impact with more focus on shrimp farming impacts.
- Strengthen the mentioned FAO Global Network for exchange and dissemination of information on appropriate management practices for sustainable use of salt-affected soils and improvement of coordination among scientists in participating countries from Asia Region through discussion during the workshop.
- Highlight successful experience(s) on management of salt-affected soils and analyse causes of success in relation to country programmes with more focus on shrimp farming impacts, as well as the mentioned FAO Global Network and collaborative projects.
- Identify priority areas, programmes and follow-up actions for enhancing productivity of salt-affected soils in support of food security.

During the workshop, country papers from participating countries on: Integrated Management for Sustainable Use of Salt-affected Soil: Extent, Causes and Management, with more focus on those resulted from seawater intrusion and shrimp farming practices; overview paper on FAO Networks on "Soil Management of Problem and Degraded Soils with Focus on Network on Soil Management for Sustainable Use of Salt-affected Soils/Outputs of Project TCP/THA/8922: Impact of Shrimp Farming on Arable Land and Rehabilitation of Resultant Salt-affected Soils"; and Rehabilitation and Management of Salt-affected Soil with Reference to FAO Project TCP/THA/8922 were presented in the workshop. The papers presented the international interest and concern of the development of salt-affected soils due to different causes including as well those resulted from seawater intrusion and shrimp farming practices in arable land. This proceedings provides a useful overview of available information related to salt-affected soils in participating countries.

In the light of the participatory discussions, the participants agreed on number of recommendations to increase exchange of experience and activities in the area of research and technology development, especially the assessment methodologies, extension and training, policies and legislation, strategies, publications, website, newsletter, and networking on salt-affected soils.

A.M. MASHALI

Acknowledgements

The contributions by the National Institutes (Coordinators), members of the Network on Global Network on Integrated Soil Management for Sustainable Use of Salt-affected Soils through participation, value discussions and presentation of their country papers in this Asian Regional Workshop (In association with the Forth Meeting of the Network held in Valencia, Spain in May 2001 and as one of the activities of the FAO Project TCP/THA/8922 on the Impact of Shrimp Farming on Arable Land and Rehabilitation of Resultant Salt-affected Soils) from Bangladesh, China, India, Malaysia, Indonesia, Pakistan, Philippines, Thailand and Vietnam and the overview papers from Dr Amin .M. Mashali and Dr Robert Crouch on FAO Networks on Soil Management of Problem and Degraded Soils and Rehabilitation and Management of Salt-affected Soil with reference to Project TCP/THA/8922, are greatly acknowledged. The efforts of the staff of the Implementing Agency of the Project, the Land Development Department (LDD), particularly Mr Chaiyasit Anecksamphant, the National Project Director and the Deputy Director General of LDD, Dr Rungsun Im-Erb, the Project Coordinator and the National Consultants and Dr Amin M. Mashali, Technical Officer AGL-FAO in the organization of this Regional Workshop are highly appreciated. Special thanks are due to Dr Samran Sombatpanit for the editing of the proceedings and to Dr Amin M. Mashali and Dr Rungsun Im-Erb for compilation of the materials for the Proceedings and their assistance and revision.

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Summary report

Introduction

The development of agricultural technologies and a better appreciation of the existing but under-utilised knowledge of resource management will be crucial in meeting the ecological needs and in achieving the anticipated food demands of the growing population in the future. The greatest challenge for the coming decades lies in the fact that the production environments are unstable and degrading. Land degradation is proceeding so fast that unless policies and approaches change, many countries will not be able to achieve sustainable agriculture in the foreseeable future. Soil salinization has been identified as a major process of land degradation. The greatest technical causes of decreasing production on many irrigated projects, particularly in arid and semi-arid areas, or failure of large areas in rainfed agriculture, are waterlogging, salinization and sodication. It was estimated from various available data that the world is losing at least three hectares of arable land every minute because of soil salinity.

Although many countries are using salt-affected soils because of their proximity to water resources and the absence of other environmental constraints, there is a clear need for a sound scientific basis to optimize their use, determine their potential, productivity and suitability for growing different crops, and identify appropriate integrated management practices. With recent emphasis and priority programme of FAO on Food Production in Support of Food Security (SPFS), issues related to land degradation, including salt-affected soils and their negative impact on food production, as well as land improvement for enhanced productivity, are receiving special attention. Rectifying soil degradation including salt-affected soils, and sustaining crop production through appropriate soil management and conservation are therefore important components in the effort towards world food security. Because of this and the increasing awareness of continuing soil salinization and sodication, FAO's Regular Programme is supporting national institutes in countries having problems of salt-affected soils to strengthen their experimental programmes on adapted soil management practices. Since 1990, collaborative projects have been identified to develop management practices for sustainable use of salt-affected soils: experiments and demonstrations on pilot farms are ongoing in 22 countries in different regions - (i) Africa (Ghana, Kenya, Nigeria and Tanzania); (ii) Asia and Pacific (Bangladesh, China, Indonesia, Pakistan, Philippines, Thailand and Viet Nam); (iii) Europe (Hungary, Romania and Turkey); (iv) Latin America and Caribbean (Argentina, Brazil, Cuba and Mexico); (v) Near East (Egypt, Iran, Syria and Tunisia).

Successful experience and initiatives for soil improvement in specific countries or socio-economic and agro-chemical environments have taken place but their wider dissemination for the benefit of other countries, even in the same region, is rather limited. Therefore, to avoid the fragmentation of technical research and development efforts in developing countries and to stimulate coordination of work between international and national organizations in the management of salt-affected soils, a cooperative project was signed in November 1994 between FAO and UNEP, in association with the Subcommission on Salt-affected Soils of IUSS.

The project was to establish a Network on Integrated Soil Management for Sustainable Use of Salt-affected Soils. The twenty-two countries involved in the mentioned ongoing FAO collaborative projects are "Members" in the Network, in addition to other "Associated Members" running their country national programmes on Management of Salt-affected Soils (Australia, Canada, Colombia, Italy, Saudi Arabia, Spain, Sudan and Uzbekistan).

Marine shrimp farming in Thailand has been practised in coastal lands for the last 70 years. Because of a shrimp disease outbreak in the coastal area and shortage of freshwater required to dilute the salinity in shrimp ponds, shrimp farming practices extended significantly from the coastal areas to the Central Plain, close to irrigation canals. Shrimp farmers in this region transfer salt or concentrated seawater to the shrimp ponds, which is gradually diluted before harvesting. In 1998 the total shrimp farming area covered approximately 80 000 ha. The intensive use of fertilisers, chemicals and antibiotics has severely affected the environment. Discharge of sludge, excess feeds and saline water into nearby irrigation canals as well as seepage of saline water to adjacent rice fields and underground has led to a significant build-up of toxicity and salinity. After 2-3 years of shrimp farming practices, the rice production of adjacent farms has been reported as only 30-40 percent of normal yields. In some severe cases rice farms went completely out of production and conflicts have risen between rice and shrimp farmers. In July 1998, the Government, concerned by salinity problems, introduced a ban on shrimp cultivation in freshwater zones and at the same time announced its intention to reclaim the land. It is estimated that seawater intrusion together with the impact of shrimp farming have turned 575 000 ha of land into salt-affected soils.

In order to reclaim the affected lands, to gain an in-depth understanding of the impacts and to demonstrate appropriate integrated technologies, technical assistance from FAO was requested to assist the Government in the development and consequent introduction of appropriate integrated low-cost, low-risk rehabilitation techniques. FAO in October 1999, approved the financing of a 22-month project TCP/THA/8922: Impact of Shrimp Farming on Arable Land and Rehabilitation of Resultant Salt-affected Soils" to be implemented by the Land Development Department (LDD), Ministry of Agriculture and Cooperatives, as the government executing agency. The project's objective is to assist the Government of Thailand to study the impacts of shrimp farming in freshwater arable land and in the demonstration of appropriate integrated techniques for rehabilitation of abandoned shrimp farms and for the improvement of salt-affected lands (resultant from seawater intrusion and shrimp farming practices in arable lands) mainly rice production in support of food security programmes in the country through the introduction of appropriate management techniques for optimum production of such soil.

As one of the major activities of the mentioned Project, this Mid-term International Workshop was to determine the performance of the project and to exchange information and experiences with other collaborating scientists from neighbouring countries and international consultant.

The immediate objectives of this Workshop were:

a) Strengthen the mentioned FAO Network for exchange and dissemination of information on appropriate management practices for sustainable use of salt-affected soils and improvement of coordination among scientists in participating countries from Asia Region through discussion during this Workshop.

b) Analyse and synthesise available information in participating countries on the extent and causes of salt-affected soil and its impact with more focus on shrimp farming impact.

c) Highlight successful experience(s) on management of salt-affected soils and analyse causes of success in relation to country programmes, as well as FAO mentioned Global Network and collaborative projects.

d) Identify priority areas, programmes and follow-up action for enhancing productivity of salt-affected soils in support of food security.

Attendance

The Mid-term Regional Workshop was attended by Senior Soil Scientists, members of the mentioned FAO Network, from eight countries of the Regional Office for Asia and the Pacific (RAP): Bangladesh, China, Indonesia, Malaysia, Pakistan, the Philippines, Thailand and Vietnam. Also India contributed by sending its country paper. An officer from FAO and an FAO consultant from Australia also participated in the workshop. In addition, the workshop was attended by 7 National Consultants from Thailand and 23 national staff from the Land Development Department (LDD), Department of Agriculture and Department of Pollution Control with a total of 40 participants.

Opening of the Mid-term Regional Workshop

On Monday, 20 November 2000, after registration of the participants, the Opening Session took place at the Krungsri River Hotel, Ayutthaya, Thailand, with a brief introduction by Mr Payon Koompai, Director, Ayutthaya Provincial Agriculture and Cooperatives Office, on behalf of the Governor of Ayutthaya Province (the Governor of Ayutthaya also attended the Opening Session) and Mr. Chaiyasit Anecksamphant, Deputy General Director, LDD, and National Project Director, TCP/THA/8922, as well as Dr Dong Qingson, Deputy Regional Representative, RAP, who stressed the importance of the subject of the Workshop for Thailand and the neighbouring Asian countries. Dr Amin Mashali, Technical Officer, FAO Headquarters, Rome made the last opening address and expressed the particular interest of FAO in the area of salt-affected soils and related subjects within the Framework of Combating Global Land Degradation.

PRESENTATION OF PAPERS AND DISCUSSIONS

The papers presented and discussions were in seven categories.

i. Presentation of country papers from participating countries and from India on Integrated Management for Sustainable Use of Salt-affected Soil in the country with more focus on those resulted from seawater intrusion and shrimp farming practices: Extent, Causes and Management. The outlines of the country paper are as follows:

1. Introduction:
    - Food production and security in the country; major production constraints particularly as a result to shrimp farming practices, seawater intrusion and other major causes and related cropping systems.
2. Problem identification, magnitude, extent and distribution of salt-affected soils in the country (extent in terms of total areas affected with names of the regions or provinces, etc.) with focus on shrimp farming practices and seawater intrusion
3. Causes and processes of formation of salt-affected soil in different regions with more focus on seawater intrusion and shrimp farming practices (anthropogenic causes: poor soil and water management, irrigation mismanagement - seepage from canals, insufficient water application, irrigation at low efficiency, insufficient drainage, improper cropping pattern and rotations, etc.)
4. Biophysical, environment and socio-economic impacts, etc. with particular references to the impacts of seawater intrusion and shrimp farming practices.
5. Main solutions, technologies applied in the country to combat each type of resulted salinization or sodication and examples of success stories of projects or programmes, regions, areas, etc. that controlled the development of salinity or improved the resulted salt-affected soils due to the shrimp farming practices or seawater intrusion; names of main institutes or organizations dealing with salt-affected soil problems and management in the country in general and of the problems of seawater intrusion and shrimp farming practices (government or private) in particular.
6. Other issues for controlling salt-affected soils in the country with focus on those resulted from seawater intrusion and shrimp farming practices including legal, economic and social aspects, policy and government responsibilities, land tenure and land use, institution arrangements, the role of private sector, farmer involvement and the role of farmer co-operatives and associations or extension services.
7. Research requirement in the country
    - Integrated research for decision-making support with particular attention to applied research and development, monitoring systems, regulation and predicting techniques for salinity development to study the impact of shrimp farming practices and seawater intrusion and related required management practices used in the country and to improve the productivity of the resulted salt-affected soils.
8. National agricultural plan for improvement of salt-affected soils in the country and regional coordination, if any, proposal for follow-up actions to address programmes of salt-affected soils in the country with more focus on salt-affected soils resulted from shrimp farming practices and seawater intrusion.

9. Information about the cooperative project with FAO, including title, starting date, aim and background, structure and scheme of the experimental sites (regions, areas or provinces, etc.), improvement practices or technologies used, results and their evaluation, conclusions and recommendations.

ii. Presentation of the results from the project (TCP/THA/8922) pilot farms by national staff. The major activities are concentrated in the three selected pilot experimental/demonstration pilot farms in Pranchin Buri, Suphan Buri and Nakhon Si Thammarat Provinces to present the condition of production constraints and salinity development as a result of shrimp farming practices in freshwater arable land and seawater intrusion.

The three sites were selected and the appropriate integrated management techniques were introduced to be tested and demonstrated in the abandoned shrimp farms and one in the adjacent salt-affected rice farm. In each site, a monitoring system is being conducted to study the real impact of shrimp farming practices and seawater intrusion on arable land and rice production.

iii. Technical paper by international consultant from Australia on Rehabilitation and management of salt-affected soils with reference to project TCP/THA/8922.

iv. FAO Networks on "Soil Management of Problem and Degraded Soils with Focus on Network on Soil Management for Sustainable Use of Salt-affected Soils/Outputs of Project TCP/THA/8922: Impact of Shrimp Farming on Arable Land and Rehabilitation of Resultant Salt-affected Soils.

v. Participatory discussions on the preparation and publication of Guidelines on Integrated Soil Management for Sustainable Use of Salt-affected Soils: Problem identification, magnitude, extent and distribution of salt-affected soils:

- Assessment of salinity/sodicity, vulnerability of soils to salinity/sodicity (warning system)
- Definition of salt-affected soils, mapping, etc.
- Causes and process of formation of salt-affected soils
- Research and interpretation methods of salt-affected soils including new techniques (modeling, GIS, expert system, decision support system, remote sensing, etc.
- Biophysical, environment and socioeconomic multidisciplinary impacts
- Main solutions, techniques available for management and improvement of salt-affected soils: Integrated and sustainable techniques
- Other issues for controlling salt-affected soil (legal, economic and social aspects, policy and government responsibilities, land tenure and land use, institution arrangements, the role of private sectors, farmer involvement, farmer corporations and extension service
- Research requirement (modeling, GIS, expert system, decision support system, remote sensing
- National agricultural plan for improvement of salt-affected soils, follow up action
- Availability of nutrients in salt-affected soils and soil, water and nutrient interactions.
- These issues were discussed in terms of availability of different plant nutrients i.e. nitrogen, phosphorous, potassium, calcium, magnesium and micronutrients. Factors

affecting nutrient availability in salt-affected soils such as nutrient form, nutrient losses by leaching, ion competition, complementary ion effects, etc. Nutrient deficiency in salt-affected soils.

- Plant nutrient and fertiliser management for salt-affected soils. Improved integrated nutrient/fertilisation management should prevent both nutrient deficiency or the excessive application of fertiliser, and include all available sources of nutrients in the farm, i.e. the organic matter application.
- Crop tolerance and suitability in salt-affected soils, salt tolerance criteria, factors affecting crop tolerance and examples and tables for tolerance of different crops to total salinity and specific ions

vi. Participatory discussion on the FAO Network on Integrated Soil Management for Sustainable Use of Salt-affected Soils:

- Future activities of the Network
- Action plan
- Newsletter/Internet Web Site
- Research and cooperation between members of the Network
- Suggestions for any modification of the field programmes in the experimental/demonstration pilot farms of the project TCP/THA/8922
- International Workshop on Integrated Soil Management for Sustainable Use of Salt-affected Soils to be held in Spain May 2001.

vii. In a participatory manner the following issues were discussed and related conclusions and recommendations were formulated:

- Major production constraints in the Region particularly as a result of shrimp farming practices, seawater intrusion and other major causes and related cropping systems.
- Problem identification, magnitude, extent and distribution of salt-affected soils in the Region with focus on shrimp farming practices and seawater intrusion.
- Causes and processes of formation of salt-affected soil with more focus on seawater intrusion and shrimp farming practices (anthropogenic causes: poor soil and water management, irrigation mismanagement, seepage from canals, insufficient water application, irrigation at low efficiency, insufficient drainage, improper cropping pattern and rotations, etc.)
- Biophysical, environment and socio-economic impacts, etc., with particular references to the impacts of seawater intrusion and shrimp farming practices.
- Main solutions, technologies applied in the Region to combat each type of resulted salinization or sodication and examples of success stories of projects or programmes that controlled the development of salinity or improved the resulted salt-affected soils due to the shrimp farming practices or seawater intrusion.
- Other issues for controlling salt-affected soils in the Region with focus on those resulted from seawater intrusion and shrimp farming practices including legal, economic and social aspects, policy and government responsibilities, land tenure and land use, institution arrangements, the role of private sector, farmer involvement and the role of farmer cooperatives and associations or extension services.
- Research requirement: Integrated research for decision-making support with particular attention to applied research and development, monitoring systems, regulation and predicting techniques for salinity development to study the impact of shrimp farming practices and seawater intrusion and related required management

practices used in the Region and to improve productivity of the resulted salt-affected soils.
National agricultural plan for improvement of salt-affected soils in the Region and coordination, actions to address programmes of salt-affected soils in the Region with more focus on salt-affected soils resulted from shrimp farming practices and seawater intrusion.

Other business

One day (Wednesday, 22 November) was devoted to visiting the Suphan Buri Station of the LDD, and one of the project's pilot experimental/demonstration farms in Bueng Banpho Village, Muang District, Suphan Buri Province and several small-farmers' rice fields affected by salinity due to shrimp farming practices in adjacent ponds.

To share knowledge and experience, the Workshop participants visited the mentioned pilot farm in Suphan Buri Province. The province is in the Central Plain to the west of Bangkok (100 km). It covers an area of 5 358 km^2 and is divided into 10 districts (main annual rainfall is 1 100 mm). The soils are formed from alluvium deposits. About 50% of the land area is under agriculture, 15% is forest and the remaining 35% urban centres and miscellaneous areas. Rice occupied 55% of the total agriculture area. Other crops included sugarcane, cassava, corn, sorghum, watermelons, cotton, water chestnuts, etc. It is reported that shrimp farming is being practised in an area of 1 360 ha in the province causing salinity development in the adjacent 14 000 ha of rice farms, differing in severity with lower rice production.

The selected pilot farm is divided into two demonstration plots: one in an abandoned shrimp farm and one in an adjacent salt-affected rice field and appropriate integrated management techniques to improve rice productivity have been introduced. The treatments in the two plots include: a) best management practice (BMP), i.e. O.M. + lime/gypsum requirement + drainage system + tolerant rice variety; b) BMP – O.M.; c) BMP – lime/gypsum; d) BMP – drainage, and e) BMP with traditional rice variety. Data from these different treatments will be used to compare technically the effects of each treatment and for the economic evaluation of these management techniques, and to select the appropriate required integrated package of efficient management and cost-effective, low-risk methods for improving productivity of abandoned shrimp farms and adjacent salt-affected farms which will be demonstrated for wider adoption by small farmers.

A monitoring study of the impact of shrimp farming on the soil of abandoned farms, the adjacent salt-affected soils, the irrigation canals and the environment is being carried out. Piezometer systems have been installed and soil and water sampling is continuing as part of the monitoring programme in the visited experimental site in Suphan Buri Province.

During the visit the participants had comprehensive discussions to clarify and identify production constraints of the soils in the selected pilot farms of project TCP/THA/8922 and to share views and experiences to select the required follow-up management techniques for the next experimental and demonstration work.

Conclusions

- Based on the papers presented and the discussions, it was clear that salinity is a problem in the region, particularly in coastal areas including the impact of shrimp farming on adjacent rice farms in coastal areas, as in Bangladesh, Vietnam, China and the Philippines.
- The policy on the management of salt-affected soils in the region is not effective. Farmers in the region should be made aware of this problem.
- Both researchers and extensionists are handicapped by the shortage of funds and other resources to enable them to work on the problem of salt-affected soils, including the impact of shrimp farming and seawater intrusion.
- Participants were asked to comment where possible on the draft FAO publication "Guidelines on Integrated Soil Management for Sustainable Use of Salt-affected Soils".

Recommendations

In the light of the discussions, the Workshop participants agreed on the following recommendations:

A. Project TCP/THA/8922

1) Because of the high cost of organic matter/rice straw and their limited availability to the farmer, the rate of organic matter treatment should be reduced to only 1 tonne/rai for the third site in Prachin Buri Province (under establishment) and the next season's crop in the three sites.
2) A buffer zone should be established between the treatments with drainage system and the treatment without drainage system in the two sites already constructed and to be constructed in Prachin Buri (under construction).
3) In the two sites already established, the irrigation canal should be separated from the drainage ditch. The drainage ditch and irrigation canal should be on either side of the plot. The same should be considered for the third site under establishment.
4) The ridge between the drainage ditch and the plot should be raised to at least 20 cm.
5) To reduce the cost of the drainage system, the spacing of the lateral tiles should be increased to at least 20 m in the project site in Prachin Buri Province and in the next season for all three sites. The adjacent open drain system should be constructed with the same spacing of 20 m for comparison of the efficiency and cost to be recommended to the farmers.
6) It is suggested that fertiliser application should be included as a treatment for future experimentation programmes, which are not yet established, and for the next cropping season. The application rate should be based on soil analysis of the plots to be compared with farmer's traditional application.
7) In the third site in Pranchin Buri Province, which is not yet established, salt-tolerant variety rice should be considered as one of the treatments and same treatment should be included for the three sites in the next cropping season for comparison and possible recommendations to the farmers.

8) For the monitoring system, piezometers should be installed in each of the treatments at two depths of 50 cm and 1 m.
9) It is suggested that EM.38 could be used even in standing water in rice fields for comparison between treatments after proper calibration.
10) The soil sampling should continue to be carried out after harvesting and before the new crop from each treatment and, if possible, once during the middle of the growing period as the soil dries up.
11) The water samples should be taken from the irrigation canals and from the piezometers in the plots of the three demonstration sites and from the piezometer system for the monitoring of the impact of shrimp farming on development of salinity on adjacent rice fields.
12) The extension programme should start from now by preparation of easy-to-understand pamphlets for the farmers.
13) The economic evaluation should start by the time each site is established. The evaluation should include all costs involved to be used for cost-benefit analysis.
14) It is recommended that chemical amendments, i.e. gypsum or lime should be according to the requirements, i.e. according to the pH value. If is higher than 7, gypsum should be used. For lower values than 6, lime should be used.
15) It is recommended that effective government regulations be enacted and implemented to ensure that shrimp farmers take responsibility for meeting the cost of rehabilitation of the adjacent affected rice fields as abandoned farms and other environmental impacts. In this regard, for example, high taxation system on shrimp farming may be considered.

B. Recommendations for Asia Region

1) Awareness about the extent of salt-affected soil and its impact on soil productivity, environment, and socio-economic conditions should be increased among the policy makers of participating countries in the region through newsletters, pamphlets, publications and mass media, and by using other means of communication.
2) National governments should be encouraged to develop and implement more effective land use planning and associated regulations to ensure sustainability of food production from salt-affected soils.
3) As more than one authority or institute in each country in the region are concerned and have related activities in the field of salt-affected soils, special institutional arrangements should be established to allow effective cooperation and avoid overlapping of activities at the national level.
4) More effective linkages among institutes of the participating countries in the countries in the region should be established to strengthen dissemination of information, experiences and development of efforts in the field of salt-affected soils including impact of shrimp farming. This may include inter-country visits and training programmes.
5) The methods of chemical, physical and biological analysis of soil, water and plants should be standardized in the countries of the Asia Region. The internationally well-known standard methods should be considered to allow across the border competition and exchange of information.
6) It was recommended that strong research programmes in the following areas should be undertaken by the participating countries in the region:

a. Proper cropping patterns to ameliorate salt-affected soils
b. Development of salt-tolerant crop varieties
c. Integrated soil, water and nutrient management
d. Reclamation techniques for salt-affected soils
e. Development of cheap and low-risk technologies for closed system shrimp farming
f. Development of technology of better integrated shrimp farming with rice farming
g. Development of methodology to better integrate mangrove management and shrimp farming
h. Develop methodology to evaluate the environmental and socio-economic aspects of shrimp farming

7) As far as possible, common terminology and definitions should be developed within the countries of the region for classification of salt-affected soils. However, each country may use locally developed classification criteria for its national use.
8) The participating countries of the Region should further develop methodology to update information about their salt-affected soils and their causes. This may include mapping of salt-affected soils in their country, assessment of man-induced salinization and the monitoring of changes on the soil productivity in relation to local conditions. Special attention may be paid to develop forecasting methods including assessment of soil vulnerability to salinity development, development of models, expert systems, GIS, remote sensing and decision support systems.
9) For technology transfer to the farmer as end-user, farmer-farmer asosciations-extensionists-researchers-engineers-scientists-policy makers should be strengthened in the countries of the region. Farmers should be active participants in the development of the appropriate management systems for salt-affected soils. In this regard, the extension institutions should be strengthened.
10) Environmental Impact Assessment including human health and biodiversity should be made mandatory for all land and water development projects, particularly in salt-affected soils.
11) The activities of the Network on Integrated Management of Salt-affected Soils should be continued and further strengthened through newsletters, Internet, publications, workshops, training programmes, etc.

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FAO Networks on Soil Management of Problem and Degraded Soils with Focus on Global Network on Integrated Soil Management for Sustainable Use of Salt-affected Soils

Introduction

Recent estimates indicate that the global demand for food, fibre and bio-energy products is growing at an annual rate of 2.5 percent and that of developing countries at 3.7 percent (FAO, 1993). World population has doubled in the past 40 years and may double again in the next century to approach 11 billion by the year 2100 (World Resources Institute, 1992). Historical evidence suggests that an annual growth in output of less than one percent can be expected from area increase at global level. Hence, optimisation of the productive potential of land including degraded and problem soils, i.e. fragile ecosystems, is considered to be a major contribution to meet the world food demand.

The majority of developing countries are facing great challenges to sustain and increase food production for their rapidly growing population. Countries with limited land and water resources, particularly those which cannot easily finance increased food imports, will be faced with serious hardship. The various forms of land degradation and improper use of problem soils are seriously affecting the land resources base contributing to considerable yield decline and loss in food production.

Soil degradation is a worldwide phenomenon. Of the land suitable for arable cultivation, it is estimated that over 500 million ha or 38 percent of the total have been degraded because human activities have accelerated the natural degradation process. As well as arable land, 21 percent of the permanent pastureland have been degraded. Nearly one billion ha of vegetated land in developing countries are subjected to various forms of degradation, particularly in vulnerable ecosystems, and poor and inappropriate soil management is the main cause of physical, chemical and biological degradation of cultivated land.

Marginal land and problem soils with several production constraints are being put under cultivation in an attempt to meet food demands without adoption of proper and efficient water and soil management practices. Of the approximately 13 048 million ha total land in the world, over 65 percent are problem soils with different production constraints (soil acidity, vertic properties, low fertility, steeply sloping soils, soils with high gypsum or calcium carbonate contents, shallow stony soils, saline and poorly drained soils).

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At risk from starvation, farmers are forced to strive for maximum production from the limited land resources available including such problem soils, neglecting the long-term husbandry and appropriate land management practices required. This results in accelerating different forms of land degradation processes, causing soil productivity decline in many areas especially under extensive farming practices and hence food security at household and country level.

With the recent emphasis on the FAO priority programme on Special Programme for Food Security (SPFS), issues related to land degradation and problem soils and their negative impact on food production, as well as land improvement for enhanced productivity, are receiving special attention. Rectifying soil degradation and sustaining crop production through appropriate soil management and conservation are, therefore, important components in the effort towards world food security.

Successful experience and initiatives for soil improvement in specific countries or socio-economic and agro-chemical environments have taken place but their wider dissemination for the benefit of other countries, even in the same region, is rather limited. Therefore, to avoid fragmentation of field oriented research and development efforts in soil management of problem and degraded soils, and to stimulate coordination work between scientists from different national organizations and institutes, FAO established several networks, of which the following were established within the Regular Programme of the Land and Water Development Division:

A. Global Network on Integrated Soil Management for Sustainable Use of Salt-affected Soils

B. Management of Degraded Soils in Southern and East Africa (MADS-SEA-NETWORK)

C. Protected Soils in Central and East European Countries (Pro-Soils in CEEC)

D. Management of Gypsiferous Soils in Near East Region.

1. Global Network on Integrated Soil Management for Sustainable Use of Salt-affected Soils

The development of agricultural technologies and a better appreciation of the existing but under-utilised knowledge of resource management will be crucial in meeting the ecological needs and in achieving the anticipated food demands of the growing population in the future. The greatest challenge for the coming decades lies in the fact that the production environments are unstable and degrading. Land degradation is proceeding so fast that unless policies and approaches change, many countries will not be able to achieve sustainable agriculture in the foreseeable future. Soil salinization has been identified as a major process of land degradation. The greatest technical causes of decreasing production on many irrigated projects, particularly in arid and semi-arid areas, or failure of large areas in rainfed agriculture, are waterlogging, salinization and sodication. It was estimated from various available data that the world is losing at least three hectares of arable land every minute because of soil salinity.

Based on the FAO/Unesco Soil Map of the World, the total area of saline soils is 397 million ha and that of sodic soils is 434 million ha, which are not necessarily arable but cover all salt-affected lands at the global level. Of the current 230 million ha of irrigated land, 45 million ha are salt-affected soils (19.5 percent) and of the almost 1 500 million ha of dryland agriculture, 32 million are salt-affected soils (2.1 percent) to varying degrees by human-induced processes (Oldeman *et al.*, 1991).

Management of salt-affected soils requires a combination of agronomic practices depending on a careful definition of the requirements based on a detailed, comprehensive prior investigation of soil characteristics, water quality, and local conditions including climate, crops, economic, social, political and cultural environment and existing farming systems. There is usually no single way to control salinity, however, several practices can be combined into an integrated system that functions satisfactorily (Mashali, 1995).

Although many countries are using salt-affected soils because of their proximity to water resources and the absence of other environmental constraints, there is a clear need for a sound scientific basis to optimise their use, determine their potential, productivity and suitability for growing different crops, and identify appropriate integrated management practices. Because of this and the increasing awareness of continuing soil salinization and sodication, FAO's Regular Programme is supporting national institutions in countries having problems of salt-affected soils to strengthen their experimental programmes on adapted soil management practices. Since 1990, collaborative projects have been identified to develop management practices for sustainable use of salt-affected soils: experiments and demonstrations on pilot farms have been conducted in 22 countries in different regions - (i) Africa (Ghana, Kenya, Nigeria and Tanzania); (ii) Asia and Pacific (Bangladesh, China, Indonesia, Pakistan, Philippines, Thailand and Viet Nam); (iii) Europe (Hungary, Romania and Turkey); (iv) Latin America and Caribbean (Argentina, Brazil, Cuba and Mexico); (v) Near East (Egypt, Iran, Syria and Tunisia).

To avoid the fragmentation of technical research and development efforts in developing countries and to stimulate coordination of work between different international and national organizations in the management of salt-affected soils, a cooperative project was signed in November 1994 between FAO and UNEP, in association with the Subcommission on Salt-affected Soils of IUSS.

The project was to establish a Network on Integrated Soil Management for Sustainable Use of Salt-affected Soils. The 22 countries involved in the mentioned FAO collaborative projects are 'Members' in the Network, in addition to other "Associate Members" running their country national programmes on Management of Salt-affected Soils (Australia, Canada, Colombia, India, Italy, Spain, Sudan and Uzbekistan).

1.1 Network objectives

The objectives of the Network are the dissemination of information, improved coordination among scientists and extension staff, strengthening field experimental programmes, and extension of appropriate management practices to increase productivity of salt-affected soils or of land irrigated with saline water in different regions.

1.2 Network activities

1.2.1 FAO collaborative projects and national programmes in the member countries of the Network

Collaborative projects have been conducted in 22 participating countries to develop integrated management practices for sustainable use of sȧlt-affected soil through experiments and demonstration pilot farms which are operated by national institutions concerned with the improvement of salt-affected soils in their countries. Another eight countries are associate members of the Network and are contributing to the Network with results from their own ongoing national programmes in specific areas related to management of salt-affected areas.

1.2.2 Workshops

FAO organises an International Workshop (Network Meeting) every two years on Integrated Soil Management for Sustainable Use of Salt-Affected Soils.

- The First International Workshop (First Meeting of the Network) was held in Manila, the Philippines, 6-10 November 1995. Results of the ongoing collaborative projects were discussed as well as information from technical sources, and plans were made for future joint research and cooperation. The countries that participated in the workshop were Argentina, Brazil, Egypt, Indonesia, Iran, Kenya, Mexico, Pakistan, Philippines, Tanzania, Thailand, Tunisia and Hungary and representatives from UNEP, FAO, IUSS (Subcommission on Salt-affected Soils) and IRRI.

- The Second International Workshop (Second Meeting of the Network) was organised in Cairo, Egypt, 21-26 September 1997, in collaboration with the Egyptian Union of Soil Science (EUSS) and the Ein Shams University, in conjunction with the International Symposium on Sustainable Management of Salt-affected Soils in the Arid Ecosystems - as the subject was related to Network activities. Representatives of institutions involved in the FAO collaborative projects and members of the FAO Network from 12 countries (country members of the Network up to September 1997 were 21): Argentina, Brazil, Egypt, Hungary, Iran, Kenya, Mexico, Nigeria, Syria, Tanzania, Tunisia and Turkey and three associate members: Canada, Italy and Spain, participated in the Workshop. Another three countries: Colombia, Saudi Arabia and Sudan (not yet members at that time) participated in the activities of the Network's Workshop and requested to become members. The Workshop (the second meeting) discussed results of the ongoing FAO collaborative projects or national programmes in the 15 countries, identifying the problems of salt-affected soils and working out possible solutions; preparing recommendations; drawing up the outlines of required guidelines to be published on:

  Integrated Management of Sustainable Use of Salt-affected Soil and establishing priority areas, programmes and follow-up action.

- The Third International Workshop (Third Meeting of the Network) was organised in Izmir, Turkey, 6-9 September 1999, in collaboration with the Union of Soil Science of Turkey (USST) and the University of Ankara. In addition to the representatives of USST and the IUSS Subcommission on Salt-affected Soils, the participating countries were: Argentina, Egypt, Ghana, Iran, Mexico, Romania, Spain, Syria, Tanzania, Thailand, the Philippines, Tunisia, Turkey, USA and Uzbekistan.

- In association with the above-mentioned Third International Workshop, an International Workshop was organised in Manila, the Philippines, from 26-30 July 1999, in collaboration with the Bureau of Soils and Water Management, Soil Resource Development Center (BSWM/SRDC), as one of the activities of the FAO Project TCP/PHI/6712: Integrated Management of Salt-affected Coastal Soils in the Philippines. Participating countries were Australia, Bangladesh, China, Cuba, India, Thailand, the Philippines, Viet Nam and the USA. (The total number of participating country members of the Network in the two mentioned International Workshops were 19 countries, as the USA is not a member of the Network).

- The Fourth International Workshop (Fourth Meeting of the Network) will be organised in Valencia, Spain, in May 2001, in collaboration with the University of Valencia. In addition to the participation of the IUSS Subcommission on Salt-affected Soils, the participating countries are: Brazil, Cuba, Egypt, Ethiopia, Ghana, Iran, Mexico, Poland, Romania, Spain, South Africa, Tanzania, Turkey and Uzbekistan

- In association with the abovementioned Fourth International Workshop, this Asian Regiona Workshop is being organised in Thailand, from 20-24 November 2000, in collaboration with the Land Development Department as one of the activities of the FAO Project TCP/THA/8922 on the Impact of Shrimp Farming on Arable Land and Rehabilitation of Resultant Salt-affected Soils. Participating countries are Bangladesh, China, India, Indonesia, Malaysia, Pakistan, the Philippines, Thailand, Viet Nam and Australia.

1.2.3 Newsletters

The Network has been preparing and publishing a Newsletter on Sustainable Productive Use of Salt-affected Habitat (SPUSH). SPUSH is a landmark on the way to coordinated activities, covering both studies and actual utilisation of salt-affected soils and leading to better cooperation and exchange of experience. Six issues have now been published: June 1995, December 1995, June 1996, December 1996, December 1997 and July 2000

The July 2001 issue has been delayed because the original idea was to only publish Network activities on the Network Internet Web Site but it has now been decided to also continue publishing the SPUSH Newsletter.

1.2.4 Network website

In connection with the Network's activities, FAO has established an Internet web site for the Network. The address of Network is <http:www.fao.org/ag/agl/agll/spush>

1.2.5 Publications

- Workshop Proceedings of the First International Workshop (Network Meeting) in Manila, 6-10 November 1995 (published)
- Workshop Proceedings of the Second International Workshop (Network Meeting) in Cairo, 21-26 September 1997 (Proceedings of FAO Network Workshop on Integrated Management of Sustainable Use of Salt-affected Soils and the International Symposium on Sustainable Management of Salt-affected Soils in the Arid Ecosystem (published).
- Workshop Proceedings of the Third International Workshop (Network Meeting), held in Manila, the Philippines, 26-30 July 1999 (under publication).
- Workshop Proceedings of the Third International Workshop (Network Meeting) held in Izmir, Turkey, 6-9 September 1999 (under publication).
- This is the Workshop Proceedings of the Fourth International Workshop (Network Meeting) of Thailand, 20-24 November 2000.
- Workshop Proceedings of the Fourth International Workshop (Network Meeting) to be held in Valencia, Spain, May 2001 (will be published as a CD-ROM).
- Guidelines on Integrated Management and Sustainable Use of Salt-affected Soils (to be published in the year 2002).

1.2.6 Development of models enabling the prediction of soil salinity build-up throughout the root zone over time as affected by rainfall, irrigation and crop growth

- A submodel to predict evapotranspiration using an approach consistent with FAO methodology.
- A submodel to predict root development and water extraction within salinized soil profiles and resultant relative shoot growth (compared to non-stressed conditions) by generalized crop type.
- A submodel to predict carbon dioxide concentration within the soil air of the root zone.
- A submodel to predict the pertinent soil hydraulic properties from soil type information or for reference soil textures.

1.3 Membership

Members of the Network are from FAO member countries in different regions; all having the problem of salt-affected soils. At present 22 Network member countries are involved in ongoing FAO collaborative projects to develop integrated management practices for sustainable use of salt-affected soils, through experiments and demonstration pilot farms that are operated by national institutions concerned with the improvement of salt-affected soils in their countries. Another eight countries, at their request, are associate members and are involved in their country national programmes on management of salt-affected soils.

Selection of these countries is based on three categories:

i) Coverage of different regions of the world and in countries with widespread salinity problems.

ii) Coverage of different causes of salinity, i.e. natural cycles (marine cycle as the main natural cause of salinity and sodicity) and anthropogenic cycles (soil and water mismanagement and irrigation with saline water) as the main causes of man-made salinization.

iii) Coverage of the well-known management practices according to dominant practices used in participating countries and their strategies for management of salt-affected soils.

However, in the first workshop (meeting) of the Network, held in the Philippines, 6-10 November 1995, the workshop participants suggested dividing future activities into four groups following the integrated approach, including several management practices to be adopted (organic matter, mineral fertiliser, chemical amendments, drainage and leaching, levelling, physical methods including ploughing, subsoiling, etc.; crop sequence, planting procedures, irrigation methods, mulching and using crop residues). Each country may participate in more than one group.

The four group titles are now:

i) Management of Coastal Salt-affected Soils (Australia, Bangladesh, China, Cuba, Indonesia, Philippines, Romania, Spain, Tanzania, Thailand, Viet Nam, with Thailand as the Coordinator);

ii) Management of Irrigated Salt-affected Soils in Drylands (Australia, Argentina, Brazil, Cuba, Egypt, Ghana, Hungary, India, Iran, Kenya, Mexico, Romania, Spain, Sudan, Syria, Tunisia, Turkey and Uzbekistan, with Argentina as the Coordinator);

iii) Management of Soils Irrigated with Saline Water (Egypt, Ghana, Iran, Italy, Mexico, Nigeria, Pakistan, Tunisia and Syria, with Pakistan as the Coordinator); and

iv) Management of Rainfed Salt-affected Soils in Drylands (Argentina, Australia, Canada, Ghana, Hungary, India, Pakistan, Sudan, Thailand, Tunisia and Turkey, with Tunisia as the Coordinator).

1.4 Food production and security

World population has doubled in the past 40 years and may double again in the next century, approaching about 11 billion by the year 2100 (World Resources Institute, 1992). Most of this increase will take place in developing countries. Asia and Africa will have populations of 4.9 billion and 1.6 billion, respectively, by the year 2025. In 1997, 4.8 billion of the world's 5.8 billion people (83 percent) were living in developing countries (FAO, 1997).

Of the 13 048 million ha total land area of the world, only 3 190 million ha are potentially arable, with 734 million ha in Africa, 628 million ha in Asia and 681 million ha in Latin America. Currently only 1 474 million ha or 46.2 percent of these arable lands are cultivated, of which 185 million ha in Africa, 451 million ha in Asia and 142 million ha in Latin America (FAO, 1997). Worldwide, the area of arable land has increased by less than

6 percent in the last 25 years. However, per capita arable land has decreased from a worldwide average of 0.38 ha in 1970 and has progressively declined to 0.23 ha in 2000, with a forecast of 0.15 ha by 2050 and even lower to 0.14 ha by 2100.

Although large areas of new land could be brought under cultivation, unused land is not always available to people who need it most, and opening new areas remains an expensive means of increasing agriculture production. Also further expansion of agricultural land is constrained in many parts of developing countries, for example, shortage of water for irrigation in arid regions. Therefore, the only alternative is to optimise the production of existing arable land including salt-affected soils.

At the beginning of the 1990s, the worldwide average consumption of food production per capita was 2 670 calories per day, a level considered adequate. However, this global average has little significance, as there are enormous variations in the amount of food available to each individual. In fact, inadequate food consumption levels prevail in a large number of developing countries (average of 2 434 calories per capita in developing countries compared with 3 399 in developed countries), with even wider gaps between and within the developing countries themselves. The number of chronically hungry people in the world increased from about 560 million in 1970 to almost 800 million in 2000, of which 60 percent live in Asia, 25 percent in Africa and 10 percent in Latin America and the Caribbean.

Agriculture output and food production increased in both developed and developing countries in the period 1975-1995, with a higher annual rate in developing countries (3 percent) than in developed countries (2 percent). In developing countries there were major increases in Asia, nearly stable in Latin America and a marked drop in Africa. However, the annual rate of growth in cereal production was higher than population growth in developed countries (twice as much), whilst in developing countries it was much lower (about one-fifth as much). Currently, it is 777 kg annual cereal output per capita in developed countries, compared with only 248 kg in developing countries.

The relation between land productivity and population supporting capacity is complex. In the Agroecological Zones Project (Higgins *et al.*, 1983), FAO made a major effort to assess the productive capacity of the land for different countries. They found that under traditional low-input systems of agriculture, there were 64 countries at risk of not being able to feed their population by the year 2000. This figure has subsequently been revised to 82. However, at moderate or high levels of inputs most, but not all, countries are estimated to be able to support their present populations. What is not certain at present is whether the cost of the inputs and other necessary measures to ensure that the more productive systems are sustainable can be met.

To meet the food demand will be no easy task, given that the higher yields have to be obtained primarily from soils that are already degraded. Even where previously unused land is available it will not be easy, as that land will be predominantly land previously considered unsuitable for cultivation because of the existing production constraints. However, although the food supply must expand, it must expand in a way that does not destroy the natural environment. For that to happen, a steady stream of appropriate integrated, site specific technologies that minimise erosion, desertification and salinization of the soil and other environmental damages must be introduced.

1.5 Food production and requirements in member countries

1.5.1 Countries with FAO collaborative projects

Africa Region

a) Ghana: Ghana is an agricultural country and its development has long been dependant on agricultural production and agro-based industries. Currently, the agricultural sector accounts for 45 percent of the Gross Domestic Product (GDP), contributes 60 percent of export earnings, employs about 70 percent of the rural labour force and provides over 90 percent of the food needs of the country in a sustainable manner. Ghana's agriculture is largely based on smallholder farms characterised by low input and low output. About 60 percent of the farms are less than 1.2 ha, 25 percent are between 1.2 and 2.0 ha and only 15 percent are over 2.0 ha in size.

Ghana with a total area of 23.8 million ha has only 13.6 million ha of land suitable for agricultural use, mostly under rainfed conditions of which only 5.3 million are under cultivation. Irrigated agriculture has not become very important in the agricultural sector. The irrigation projects in all the agro-ecological zones of the country cover a total area of approximately 10 000 ha but there are plans to increase these to 100 000 ha by the year 2020 (six agro-ecological zones exist in the country: high rainfall, semi-deciduous, forest-savannah transition, Guinea savannah, Sudan savannah and coastal savannah). Food crops include maize, millet, sorghum, in addition to cotton, bananas, oil palm, yams and vegetables.

Population pressure (population is 18 million at a growth rate of 3.2 percent) has resulted in reduced fallow periods and the use of marginal lands with inappropriate land management practices. About 36.9 percent of the population were poor in 1987-1988, but has dropped now to only 30 percent. Low agricultural production can be attributed to man's activities. Timber harvesting, annual bush burning, settlement and road construction, mineral mining especially gold mining is important in degrading the soil and the environment. Other contributing factors include government policies of withdrawing subsidies on agricultural inputs making the prevailing prices unaffordable. Farmers are no longer using fertilisers and agro-chemicals due to their high prices. Problems of transportation and marketing of commodities and unfavourable land tenure systems, as well as lack of credit, especially for small-scale farmers, adversely affect the performance of the agricultural sector. These activities have resulted in land degradation through deforestation, accelerated soil erosion, subsoil compaction, overgrazing, petroplinthite (ironpan) formation and salinity development.

b) Kenya: Kenya has a total land area of 57 million ha of which 4.5 million are arable and under permanent crops. The country falls on both sides of the equator, approximately 5° South and North and between 34° and 42° longitude. The country varies in altitude from sea level to more than 5 000 m asl. Climatic conditions vary from arid to humid.

On the basis of the ratio of annual rainfall (r) and average annual potential evaporation (Eo), Kenya can be divided into seven classes of moisture availability regions. Three of these classes (agro-climatic zones V, VI, VII), whose upper boundary of r/Eo ratio are 40, 25 and 15 respectively, are semi-arid, arid, and very arid, the so-called arid and semi-arid (ASAL) areas. These cover approximately 83 percent of the country. The arid zone (VII) alone covers nearly half of Kenya. Only approximately 17 percent of the country are of medium to high agricultural potential. The major production constraint is low rainfall coupled with low fertility status of most soils.

The total land under irrigation is about 80 000 ha, half of which has salt-affected soils as a result of poor irrigation and drainage management.

In medium to high rainfall areas, there is substantial crop diversity. Cash crops in these regions include tea, coffee, wheat, barely and horticultural crops, while subsistence crops include maize, beans, bananas and vegetables. Subsistence crops are usually intercropped. In the arid and semi-arid areas, adapted varieties of maize, beans, cowpeas, pigeon peas, sorghum and millet are grown at subsistence level.

Agriculture supports over 80 percent of the population (total population is 28.4 million). Maize is the most important food crop in Kenya and constitutes the staple food for over 95 percent of the population. Subdivision of land since 1979, led to uneconomically viable parcels of agricultural land. Population pressure has resulted in increased land pressure, leading people into fragile land, with a large decrease in per capita cultivated land.

c) Nigeria: Nigeria has a total land area of 91.1 million ha, of which 57 percent are either under crops or pasture while the balance of 43 percent represent the area under forest, rivers/lakes/reservoirs and others. Nationwide, the agricultural land use involves three systems of production, viz. rotational fallow agriculture, semi-permanent or permanent agriculture and mixed agriculture. The country is endowed with abundant natural resources, which include 68 million ha of arable land and 960 km of coastline, and an ecological diversity that enables it to produce a wide variety of crops such as maize, millet, sorghum, in addition to cotton, bananas, oil palm, yams and vegetables.

Nigeria is an oil-producing country and a member of the OPEC. Contribution of the agricultural sector to the GDP is about 38 percent, compared to 24 percent and 38 percent, respectively, for industry and services sectors. In spite of the apparent contribution of petroleum to the economy, the real strength of the national economy is founded on its agricultural sector base, human resources and huge market. However, at present the country is experiencing rapid decline and poor management of its resources and an uncontrolled environmental pollution that may threaten the agricultural potential of the country.

Nigeria has a population estimated at 118 million, with an annual growth rate of 3.2 percent. About 63 percent of the population live in rural areas. With urbanisation, population increased accompanied by increased petrol-dollar earning from export of crude oil, consumption patterns changed even in the rural areas leading to higher demands for wheat, rice and sugar, etc., much of which has to be imported.

d) Tanzania: The population of Tanzania is about 31.5 million. Agriculture is the main source of the Tanzanian economy and nearly 80 percent of the population earn their living through agricultural activities. The agricultural sector in Tanzania accounts for about 60 percent of the Gross Domestic product (GDP) of which the dominant sub-sector is food production. Food crops grown include maize, rice, sorghum, wheat, barley legumes, millet, bananas, sweet potato, Irish potatoes, cassava and a wide variety of horticultural vegetables and fruits. The major cash crops grown include coffee, cotton, sisal, tea, tobacco, cashew and pyrethrum. The livestock sub-sector is estimated to contribute 32 percent of the agricultural GDP. Some of the land is also being used for extensive grazing of cattle, sheep and goats.

Recent estimates by the Ministries of Lands, Agriculture and Cooperatives, and University of Dar-es-Salaam show that agricultural production in Tanzania is dominated by small-holder resource-poor farmers who are estimated to constitute about 70 percent of the total population. It is estimated that total land area with the potential for agriculture is 51.3 million ha, but the actual area being cultivated is less than 15 percent of this potential. The main farming system is smallholder, which occupies nearly 4.5 million ha. About 50 percent of the population have incomes under poverty line, of which 83 percent live in households where the main occupation is farming. Commercial farming occupies about 600 000 ha. Most of the agricultural land (80 percent) is suitable for rainfed agriculture (the annual rainfall varies from 600 to 2 000 mm) and about 64 agro-ecological zones have been identified for the country. The Ministry of Agriculture and Cooperatives, however, estimates that by the year 2000, 13 out of the 20 regions may not be able to meet their food demand from rainfed production only, given the current low level of output (by the year 2025, 17 of the total 20 regions will belong to this deficit category). Irrigation, therefore, seems to be the inevitable alternative that will rescue the country from chronic food shortage (the country has 5 million ha of potential irrigable land of which only 190 000 ha are presently under irrigation).

Asia Region

a) Bangladesh: Bangladesh has an area of 14.7 million ha. The population is disproportionately large, almost 125 million, with population density being more than 800 persons per sq km and it is growing at the rate of about 2 percent per year. Projections for the country show that, by the year 2020, the population may be around 175 million and probably will increase further to about 200 million by the year 2030. Agriculture, accounting for 30-35 percent of the GDP and more than 60 percent of employment, plays an important role in the economy of Bangladesh. Rice is the staple food of the country, and is the pivotal crop in the yearly cropping patterns on almost all agricultural lands. Bangladesh still remains a food-deficit country requiring on average 1.5 to 2.5 million tonnes of food grain imports annually.

There is a broad range of agro-ecological environments in Bangladesh because of differences in climate, physiography, soil type and hydrology. Depending on these factors, the country has been divided into 30 agro-ecological zones, which are relevant to the assessment of agricultural potentials of the various regions of the country. Bangladesh will need a large food production boost, which will not be possible unless use is made of all marginal land resources, which have hitherto remained under-utilised due to agro-ecological and also socio-economic constraints, together with the help of appropriate technological interventions.

b) China: China has an area of 135 million ha of arable land, of which 77 million ha are rainfed agriculture. In addition, 53 million ha are paddy fields of which 31 million ha are rainfed and 22 million ha are irrigated land. Groundwater and river water are commonly used as irrigation water resources in China, while drainage water and mixed water are only used in some arid and semi-arid regions. Soil salinity, sodicity, drought, soil erosion, low fertility and poor soil structure and texture represent the main constraints to agricultural production. The cropping systems vary from one crop per year in the Northeast China Plain to three crops per year in the South China hill region. The dominant cropping system comprises two crops annually.

It is recognised that China has successfully fed its people, representing 22 percent of world population (1.2 billion people), by using only 7 percent of the world's arable land. As long as the actual annual increment in the country reaches 1 percent during 1999-2010 and 0.7 percent by 2011-2030, China will achieve the expected goal of total food production. To ensure the certain increment of food production, the main practical measures will be to enhance the potential of current arable land and to exploit the potential of unused land resources, exerting functions of technological advancement and best use of non-grain food resources.

c) Indonesia: Indonesia consists of 13 677 islands, with a total area of 181 million ha, of which 18 million ha and 13 million ha are arable and permanent crops, respectively. Irrigated area covers 4.6 million ha. Total population in 1999 was 207 million. Sumatra, Java, Kalimatan, Sulawesi and Irian Jaya are the five largest islands. Swamplands cover vast areas, estimated at 33.4 million ha, which are divided into three zones: brackish/saline tidal lands; freshwater tidal land; and non-tidal lands. The coastal lands are in the brackish/saline land zone, estimated at 8.1 million ha. To maintain rice and other crops especially maize and soybean self-sufficiency, the government has launched different intensification, extensification and diversification programmes. As lands with relatively fertile soils have mostly been utilised, agricultural activities have been extended to problem soils, such as those of coastal lands, which consist of two dominant soil types: acid sulphate and peat soils. The type of land utilisation adopted by farmers depends upon the tidal and soil types. On potential acid sulphate soil with a pyritic layer deeper than 0.5 m, lands are used for sawah (lowland rice fields) or sorjan system. Part of the farmyards is used for fishponds or planting vegetables. Fruit crops and forages, local chickens, ducks, Bali cattle and goats have been developed in the area (chicken-fish system is called 'long-yam' and the duck-fish system is called 'long-tik'). Farmers usually plant local varieties of lowland rice once a year. The varieties are not only well adapted but also flexible to local conditions.

d) Pakistan: Pakistan covers about 80 million ha of land area comprising six different physiographic units: the southern high mountains, the Hindu Kush and western mountainous regions, the Potowar Plateau, the Salt Range and the Balochistan Plateau, the

Indus Plain and the desert area of Thal, and Cholistan. The climate of the country can be classified as arid to semi-arid with variable rainfall over most of the country.

About 20 million ha of land are currently under crop of which one-third is rainfed and the rest is irrigated. Except for the plateaux and mountain areas, groundwater is used as a supplementary source of irrigation water in the canal irrigated areas either directly or after mixing with canal waters. Use of sewage water for crop production is limited to areas around big cities for growing vegetable crops. Major cropping seasons are kharif (summer: cotton, rice, maize and sugar cane) and rabi (winter: wheat, barley, tobacco and oilseeds).

Inadequate supply of irrigation water at critical times of growth, lack of drainage, saline and sodic soils, low quality seeds, antiquated farm implements, imbalances in farm inputs, unsatisfactory agriculture and irrigation practices are some of the main production constraints affecting crop production in Pakistan. Since the introduction of canal irrigation, waterlogging and soil salinity have become the major problems impeding agricultural growth.

e) The Philippines: The Philippines is an archepelagic country consisting mainly of three major groups of islands: Luzan, Visayas and Mindanao. The geographical setting of these islands gives the country one of the longest coastline in the world (180 000 km). The country has a total land area of 30 million ha, which is subdivided into: agricultural area, grasslands/shrublands, woodlands, wetlands and miscellaneous land use areas. The farmers in these adverse ecosystems are perpetually poor and marginalised because their basic livelihood efforts, i.e. subsistence rice production, are disrupted annually by recurrence of typhoons, river and tidal flooding. The coastal landscapes are ecosystems with very adverse conditions: vulnerability to soil salinization, low productivity, which are aggravated further by factors such as yearly occurrences of typhoons. Despite the limitations of these low productivity salt-affected coastal farms, they form part of the country's limited arable lands where farmers can at best provide low input and traditional production technology. The total agriculture land is 9.5 million ha, of which about 31 percent are utilised to irrigated (total irrigated area is 1.5 million ha) and non-irrigated paddy rice. Corn covers 12 percent of the total agricultural land. Total production for rice and corn were estimated at 11.3 million tons and 4.3 million tons, respectively. However, such levels of production are insufficient to meet the growing needs of the population. Population estimate for the year 2000 is 75 million at a 2.3 percent growth rate. Rice and corn imports amounted to 731 000 tonnes and 302 900 tonnes, respectively. There was heavier dependency on importation of garlic, peanut and mango. On the other hand, local producers sufficiently provide for the domestic consumption needs for coconut, sugar and most of the fruits, vegetables and root crops. Thus, salt-affected areas are significantly important towards the reduction of food insecurity of the coastal communities. Despite low productivity of the salt-affected areas, farmers continue planting rice for their home consumption.

f) Thailand: The total area of the country is approximately 51.4 million ha. The coastline is 2 705 km long and borders the Gulf of Thailand in the east and the Andaman Sea in the west. The principal physiographic regions are: the Central Plain, the Southeast, the Northeast (Khorat Plateau), the Central Highlands, the North and West Continental Highlands and the Peninsular. Agricultural land is approximately 20.1 million ha and is used for paddy, field crops, fruit and tree crops, vegetables and flowers, livestock farms and others, with an area of 11.0, 5.2, 3.4, 0.15 and 1.3 million ha, respectively (rice is the major crop - other crops include maize, cassava, sugarcane, peanut, coconut, soybean, rubber, cotton and kenaf). The irrigated area is 4.7 million ha or 22.6 percent of arable land, of which 45 percent is in the Central Plain. Groundwater resources exist throughout Thailand. However, the quantity and quality vary according to local hydrogeological conditions.

At present, all potential agricultural land cultivation has been used to cope with the increasing demand for food by the growing population (total population is 60 million). This has led to diverse use of the land for many purposes, which has caused degradation of the soil and water resources, particularly anthropogenic soil salinization on arable land. This is believed to be a major cause of production constraints that would affect the National Action Plan for Food Security.

g) **Viet Nam:** Viet Nam has a coastline of more than 3 260 km, in an 'S' shape (Mong Cai to Ha Tien Province) with a total area of 33 million ha, of which 7.3 million ha are agricultural lands, 9.6 million ha forest, 0.97 million ha for other uses, 0.82 million ha for construction, and unused lands that occupy 45 percent (14.9 million ha) of the total area. Population is more than 76 million. Annual cropping land is 5.5 million ha and perennial cropping land is 1.3 million ha. The agricultural land is mainly concentrated in two major deltas (the Red River Delta in the North and the Mekong River Delta in the South), and in the narrow Central Plain. The irrigation projects in the country have a net design capacity to irrigate 2 million ha of the annual 5.5 million ha of farming land, including double and triple crops per year. Agricultural production in irrigated areas has made a great contribution to the food supply in the country. Although the net irrigated area occupies only 30 percent of the total cultivated area, 80 percent of agricultural products are grown in these areas. Intensive cultivation for increasing food production and food security has induced stress on land use including problem soils. In this regard, salt-affected soils play a significant role in food production and food security in Viet Nam.

Europe Region

a) **Hungary:** Total land area is 9.2 million ha of which total agricultural land is 6.3 million ha. Rainfed agriculture is 6.1 million ha, with only 167 000 ha under irrigation (142 000 ha from rivers and 25 000 ha from groundwater). Major production constraints include: extremely light texture (746 000 ha); acidity combined with erosion (348 000 ha); acidity combined with solid rock near to the surface (67 000 ha); salinity and or sodicity/alkalinity (757 000 ha); salinity or sodicity/alkalinity in the deeper layers (245 000 ha); waterlogging (161 000 ha); erosion (1 455 000 ha); extremely heavy texture (630 000 ha); erosion combined with acidity (348 000 ha); shallow depth (217 000 ha); with a total of 4 996 000 ha. Major cropping systems include: arable land (4.7 million ha); horticulture (109 000 ha); orchards (96 000 ha); vineyards (131 000 ha); and grasslands (1 148 000 ha). Major crops include cereals, pulses, industrial crops, potatoes, rough and succulent fodder and vegetables.

b) Romania: Romania has a total land area of 23.8 million ha, of which 9.9 million ha of arable and permanent crops. There are 0.65 ha agricultural land and 0.41 ha forest/grass land per inhabitant. Agricultural land capability classifications show that only 2.8 percent (411 000 ha) are class I, with very few limitations; 24.7 percent (3 656 000 ha) class II, with few limitations; 20.8 percent (3 082 000 ha) class III, with some limitations; 24.4 percent (3 613 000 ha) class IV, with severe limitations and 27.3 percent (4 034 000 ha) class V, with very severe limitations. In the last seven years significant changes of land use occurred: decrease of agricultural area especially of the arable crops with 768 978 ha and increase of grassland with 392 301 ha, vineyards with 20 879 ha and unproductive lands with 124 064 ha.

About 12 million ha of the agricultural land, including 80 percent of arable area, are affected by one or more limitations, such as frequent drought (7 100 000 ha), periodic waterlogging (3 781 000 ha), soil erosion by water (6 300 000 ha including 702 000 ha landslides), soil erosion by wind (378 000 ha), soil salinity (614 000 ha), moderate and strong acidity (3 352 000 ha), low and very low humus content (7 178 000 ha), low and very low available phosphorus content (6 246 000 ha), low total nitrogen content (4 812 000 ha), low available potassium content (694 000 ha), zinc deficiency (1 500 000 ha), chemical soil pollution (900 000 ha), pollution with oil and brine (50 000 ha), disturbance by various works (15 000 ha) and soil covering by solid wastes (18 000 ha).

Irrigation schemes were developed on 3.2 million ha, but by returning the irrigated land to former landowners under non-controlled conditions of agriculture, those lands have been abandoned, so that in 1998, the year most severely affected by drought, only about 300 000 ha were irrigated. Soil erosion control works were developed on 2.3 million ha, but also such works have been abandoned and largely destroyed after the application of Land Law No.18/1991. While the agricultural contribution to gross domestic product remained approximately the same, i.e. 19.9 percent in 1996, the budget share for Romanian agriculture continuously decreased from 13.4 percent in 1992 to 8.6 percent in 1996.

At the end of 1996, 45.1 percent of the total Romanian population (22.6 million) was in the rural area. The agricultural active population consisted of 3.3 million persons (34.6 percent, of which 51.3 percent women). By the application of Land Law No.18/1991, 10 693 577 ha of agricultural land were returned, up to a maximum 10 ha per family, to former owners. The present structure of the land ownership is represented by 71 percent with less than 3 ha per family, 18 percent with 3-5 ha per family, and 11 percent with more than 5 ha per family, with only subsistence agriculture possible. This has a negative effect on agricultural trade balance sheets, imports exceeding exports by twice the amount. Decreased average yields were recorded for all crops. At the same time, the areas cultivated with maize, wheat and sunflower increased, and those cultivated with soybeans, peas and alfalfa decreased.

c) Turkey: Turkey is located in the centre of the three continents Asia, Europe and Africa, on the Alpine Orogenic Belt, with different kinds of magmatic, sedimentary and metamorphic rocks. Collision of the three continents caused very irregular and high topography in Turkey. According to the climatological classification, Turkey is located on the subtropical belt of the Mediterranean Region, with average annual precipitation of 640 mm and average temperature changes between 0 and 20°C. Because of the geologic, climatic and topographic differences all soil orders except Oxisols can be found in Turkey. Aridisols and Entisols are very common soils in Turkey.

According to climatic and topographic conditions, Turkey is divided mainly into seven geographic regions. Because of the irregular topographic conditions and very high relief differences, shallow soil depth, soil erosion and high slope rates are the main constraints for the agricultural lands.

The size of Turkey's land resources and climatic features allow for all kinds of grain, vegetables, fruit and forestry products to be produced (total population is 62 million, of which 21 million in rural areas). The country has a total area of 77.8 million ha, of which some 28.5 million are used for arable farming. This area is being considered the maximum exploitable. There are no significant areas of agricultural land still to be developed. Turkey has 8.5 million ha of economically irrigable lands. Presently only 4.5 million ha are under irrigation. Most of the area is used for rainfed agriculture. Studies showed that it is possible to obtain 4-5 times more yields through irrigation compared with rainfed agriculture. At present, irrigated agriculture that is on 17 percent of cropped land contributes 34 percent of agricultural GDP derived from crops. After completing the Southeast Anatolian Project (SAP), approximately 1.6 million ha more of agricultural land will be irrigated. The misuse of arable lands has resulted in erosion problems of international significance, and the soil resource is being depleted.

Latin America Region

a) Argentina: The continental territory of Argentina covers a surface close to 280 million ha, of which 25 million ha are arable lands with wheat, rice, maize, barley and pastures for animal production being the major crops produced.

Based on meteorological, edaphic and water balance data, Argentina has been divided into three main natural ecological regions: humid and sub-humid (isohyet > 600 mm); semi-arid (between 400 and 600 mm isohyets) and arid (isohyet < 400 mm). The humid region has a precipitation that requires little or no additional water to obtain adequate crop yields and occupies approximately 68 million ha or 25 percent of the Argentina continental territory in the central northeastern part of the country. The semi-arid region extends from the Republic of Paraguay in the north to the Colorado River in the south and can sustain agricultural production with the aid of water conservation, dryland farming and/or irrigation. It covers 48 million ha. The semi-arid area can be divided into two different parts according to its particular climate situation and latitude: the northern (Chaco) and southern (Pampean) sub-regions. The arid region is formed by 170 million ha (60 percent of continental Argentina) in the western and southern parts of the territory. This region must receive irrigation water to be able to sustain and produce crops.

Total population is 35.7 million with only 3.7 million involved in agricultural activities. Irrigated soils in the country cover 1 650 000 ha. Approximately 36 percent (600 000 ha) of these soils are salt-affected, having different degrees of salinity effects. Irrigated soils are mainly located in the alluvial and/or colluvial river valleys of the arid and semi-arid regions of the country. Mendoza Province presents the largest irrigated area with 443 500 ha (26.9 percent of the total irrigated) followed by the provinces of Buenos Aires and Santiago del Estero with 176 500 ha (10.7 percent) and 163 900 ha (9.9 percent), respectively.

b) Brazil: Brazil has a total area of 845 million ha, of which approximately 66 million ha are arable and permanent crops (total population is 163 million, with 29.3 million agricultural population). The irrigated area is estimated to be 3.1 million ha corresponding to 4.5 percent of arable land. The Northeast of Brazil, the irrigation potential of which is 2.5 million ha, has actually only 700 000 ha irrigated land and the São Francisco River Basin, that is located in the semi-arid region, has an irrigation potential of 800 000 ha of which only 300 000 ha are under irrigation in both public and private irrigation sectors from rivers or groundwater resources. The semi-arid region of Brazil, where most salt-affected soils exist has an estimated area of 90 million ha corresponding to 54 percent of the Brazilian Northeast and 11 percent of country territory. Considering the climatic conditions, it is characterised by concentrated rainfall periods (3 to 5 months), with annual rainfall varying from 400 to 800 mm with uneven distribution. The Brazilian semi-arid region is basically characterised by crystalline and sedimentary soils, which are very dry, not well developed, shallow and stony with low water holding capacity. It is evident that irrigation has a high priority in this region as the only way for crop production to cover the requirements of the increasing population.

c) Cuba: The total land area is about 11 million ha, of which agricultural land is 4.5 million ha, most of which is under sugarcane, rice and pasture production. The main crop in the country is sugarcane. Irrigated agriculture covers 910 000 ha. Population is 11.1 million, of which 2 million are involved in agricultural activities.

d) Mexico: Total land area is 191 million ha, of which only 25.3 million ha are arable land, with a population of 95 million including 24 million involved in agricultural activities (year 1997). Water is clearly a major factor in all production activities. The fast growth of population and the consequent demand for agricultural products reflects diminishing water quality and quantity. Irrigation in Mexico is a recently established practice. From 1927 to 1976, a total of 1 040 dams were built in Mexico, and most of the irrigation districts (ID) were created during the past 50 years. During the 1980s and 1990s, this trend changed towards the construction of smaller irrigation units. Approximately 50 percent of the irrigated land in the country is located in three states: Sinaloa (21 percent), Sonora (17 percent) and Tamaulipas (12 percent). At present, the irrigated land is about 30 percent of the total land devoted to agriculture, and produces 50 percent of the national production and 65 percent of agricultural exports.

Mexico has an average annual precipitation of 777 mm, and this is usually insufficient for successful crop production in most of the agricultural lands of the country. Annual precipitation in Mexico ranges from less than 500 mm in the north (in some cases as low as 100 mm), to 2 000 mm in the south (in some cases as high as 5 000 mm). This variability makes irrigation necessary to sustain commercial agriculture. The main source of irrigation water comes from surface water (70 percent) stored in reservoirs, groundwater (25 percent) and wastewater (5 percent) complement the pool of this resource. This volume irrigates 6.1 million ha with a 50 percent global efficiency.

Rainfed areas include 13.5 million ha of rainfed agriculture, 40 million ha of forestry, and 80 million ha of livestock production. Approximately one million ha of cropped land per year are lost due to drought, and even though the ecological impact of drought has not already been quantified, it has been observed that it largely contributes to soil erosion, small farmer migration and overall land desertification.

Soil types are extremely variable in Mexico. Soil erosion by water is an increasing problem in Mexico. Topographic and climate conditions favour the natural erosive processes, and human activities have accelerated these processes to a large extent. A national average soil loss rate of 2.8 tonnes/ha/year has been estimated, which is equivalent to losing 536 million tonnes of soil material every year. Approximately 16 percent of the country are severely eroded, and 80 percent exhibit some degree of erosion. Currently, about 90 000 ha of land per year become unproductive.

Near East Region:

a) Egypt: The total land area of Egypt covers 99.54 million ha, of which approximately 96.5 percent are barren desert and the balance of 3.5 million ha is mostly irrigated agricultural land concentrated along the Nile Valley and its Delta. Rainfed agricultural area is confined to the coastal strip along the Mediterranean Sea where a few drought resistant and low water consumption crops are grown. Nile water is 55.5 billion cu m of which 7 billion cu m are for civil use, in addition to 8 billion cu m drainage water mixed with fresh Nile water re-used for agricultural production, 5.0 billion cu m from groundwater and 2.0 billion cu m from rainfall.

Wheat is the most important cereal crop (59.4 percent) of annual demand followed by maize (23.5 percent) and rice (15.1 percent). Existing cropping index of almost 2.0 indicates a very high cropping intensity. The cropping pattern is affected by a number of factors including government quotas, farmer food needs and degree of commercialisation, as well as soil and climatological limitations. The most common practice is a three-year rotation based on the major crops in the country: cotton, clover and wheat (interspersed with broad beans, rice and maize).

Egypt is an arid to semi-arid region and can be divided into five main physiographic units (the Western Desert, Nile Valley, Nile Delta, Eastern Desert and Sinai Peninsula). Agriculture produces 22 percent of GDP. Population is 65 million and growing at a rate of 2 percent annually (of which 40 percent live in rural areas). Per capita cultivated land becomes among, if not, the least in the world (0.13 acre/person). Low per capita income, compounded by the uneven distribution of national income, paves the way for poverty and hence insecurity. The average high per capita calories daily intake (3 231 Kcal) does not necessarily mean that food security has been realized for all the population (the lower 20 percent of the population get only 1 406 Kcal/day).

b) Iran: Iran covers an area of 163 million ha in Southwestern Asia. The country can be divided into five main physiographic units; (1) the Zagros Mountains in the west, (2) the Alborz Mountains in the north, (3) the Central Plateau, (4) the Caspian Coastal Plain and (5) the Khuzestan and Southern Coastal Plains. The annual area under agriculture is about 19 million ha, of which 8 million are under irrigation, 6 million under dry farming and about 5 million are left fallow (population is 71.5 million, of which 20.5 million are involved in agricultural activities). Approximately 90 percent of the country are arid and semi-arid. The average annual precipitation ranges from less than 50 mm in the Central Plateau to more than 1 600 mm on the Caspian Coastal Plains, with an average of about 250 mm.

Salt-affected soils are widespread in the country, particularly in Central Iran, where salinity is one of the main factors threatening sustained food production. According to the USDA Soil Taxonomy, the salt-affected soils of Iran are mostly classified as Aquisalids and Haplosalids. The Aquisalids are developed in the basins, where the groundwater table is shallow. The Haplosalids are mostly formed on the fringes of the playas, having a deep water table.

Irrigation, in addition to surface river water also includes 29 sq km of utilised water returned to the surface streams and groundwater each year. The total volume of water used by agricultural and industrial sectors is 81 sq km and 6 sq km, respectively.

A wide variety of crops, such as, cereals, cold-season and tropical fruits, and fodder crops are grown for local consumption and export. The 1999 statistics show that the total agricultural produce of the country is about 65 million tonnes, including 45.5 million tonnes irrigated annual crops, 7.90 million tonnes rainfed crops and 11.60 million tonnes fruit. The average yields of these crops vary according to the geographical locations and climatic conditions. There is a large gap between the potential yield and the actual yield obtained by farmers. Climatic conditions (low precipitation and high evaporation), water availability and its quality, and soil salinity are the main factors that prevent the achievement of high yields. It is estimated that in areas where salinity is present, the average yield losses are as high as 50 percent.

c) Syria: Syria, with a land area of 18.5 million ha, of which only 30 percent are arable and perennial cropland, is divided according to the amount of rainfall into five zones:

Zone 1 receives an annual average of rainfall of more than 350 mm. The total area reaches 2 701 000 ha, covering 14.6 percent of the country area. Wheat, legumes and summer crops are the main crops.

Zone 2 receives 250-350 mm precipitation annually. Main crops are wheat, barley and summer crops. This zone occupies 13.3 percent of the country area, i.e. 2 470 000 ha.

Zone 3 receives 250 mm precipitation annually. This zone has mainly grain crops, however, legumes can be grown. It covers 7.11 percent of the total area (1 306 000 ha).

Zone 4 (marginal zone) receives 200-250 mm precipitation annually. Only barley can be grown and can be used as permanent pastures. This zone covers 9.91 percent of the total area.

Zone 5 with steppe land makes up 55.1 percent (10 208 000 ha) of the total area of the country and receives less than 200 mm precipitation annually. Main crops grown are wheat, barley, cotton, lentils, vegetables and legumes as well as olive, citrus and apples.

The total cultivated area reached 4 642 000 ha in 1996, of which 1 126 000 ha were irrigated lands and 3 516 000 ha rainfed. Although the area of arable crops slightly increased between 1975 and 1990 (5.48 to 5.63 million ha), it then decreased to the figure mentioned for 1996. This is due to variability and unreliability of rainfall and high potential evapotranspiration; the number of abandoned farms in irrigated areas has been increasing fast due to production constraints posed by soils mainly in gypsiferous soils and salinity development, and the extension of constructions and urban activities, building and new settlements on agricultural land in rural areas. At the same time the cost of agricultural production has increased greatly and modern employment opportunities removed many farmers from farms. As a result agricultural production is severely affected.

Irrigation from groundwater represents 54.4 percent of the total irrigated areas. Over 91 percent of the surface water are from the Euphrates (55 percent) and Tigris (36 percent) rivers. The gypsiferous soils with a high content of gypsum are in excess of 21 percent of the country and occupy extensive areas in the irrigated arid regions.

d) Tunisia: The total land area is 15.5 million ha of which 2.8 million ha are arable land, 2.1 million ha are pastures and 1 million ha are forests. Irrigated areas cover 380 000 ha, with a plan within the next five years to reach 410 000 ha including use of groundwater. Total population is 9.3 million, of which 2.4 million are involved in agriculture activities. Soil salinization is one of the causes of soil productivity decline in irrigated areas. It is necessary to recall that the arid regions (Saharan zone not included) covers 6 290 000 ha, with 12 percent very degraded areas, 40 percent fairly degraded zones and 17 percent slightly degraded zones. The desert zones alone occupy 3 330 000 ha (20 percent of total surface).

1.5.2 Associate members:

a) Australia: Total land area is 768 million ha, of which 50 million ha are arable land. Irrigated agriculture covers an area of only 2.3 million ha. Population is 18.2 million, of which only 882 000 people are involved in agricultural activities.

b) Canada: The total land area is 922.1 million ha of which only 45.5 million ha are arable land. Irrigated areas are 710 000 ha. The population is 29.9 million of which only 848 000 are involved in agricultural activities. The 'bread basket' of North America occupies a mountain rain-shadow spread across a vast intercontinental plain. Glaciers rode over the northern half of the plain during Pleistocene, resulting in surface layers of unconsolidated glacial and meltwater transported parent material. Before the soil was ploughed and cultivated, it naturally supported a short-grass prairie in hydrologic harmony with the region's semi-arid climate. Since cultivation wheat has become the dominant crop, with 90 percent of the grain production exported worldwide. Summer fallow is commonly practised to accumulate enough water in the soil for one or two subsequent years of cropping. These two agricultural activities, cultivation and summer fallowing, aggravate natural weather-dependent movements of dissolved salts into crop root-zones.

Marine sediments underlying the glacial deposits supply the salts now giving rise to the root-zone salinity and associated dryland problems found throughout the region. Dryland salinity falls into one of two categories: visible or invisible. Both work against sustainable agriculture.

c) Colombia: Population is 38 million, of which only about 9 million are involved in agricultural activities. Approximately 80 percent of Colombia have a humid and tropical, or warm temperate climate. Of the 114 million ha total land area, there is an estimated 18.3 million ha of potential cultivable land, of which only 4.4 million ha are actually cultivated at present (1.9 million ha arable land and 2.5 million ha are permanent crops). Of an estimated 7.4 million ha of land, potentially irrigable or could be productive with installation of drainage or flood protection facilities, only an area of 750 000 ha are actually equipped with irrigation or drainage facilities at present. No available quantification data exists on the salt-affected areas nor identification of the type and extent of the saline problem.

d) India: Agriculture has been the prime mover of economic growth in the country and accorded highest priority since independence. It now contributes 28 percent of the gross domestic products and supports 46 percent of the labour force. As a result of sustained efforts, food grain production has increased from 50.8 million tonnes in 1950-51 to 200 million tonnes in 1998. Not only production but the productivity of major food grain crops has considerably increased. There has been an annual increase of 4 percent in the case of vegetables and 6 percent in the case of livestock products. The expected food grain requirement by 2020 is placed at 300 million tonnes. This additional production has to come from existing land and water resources, the availability of which for agriculture is decreasing.

The total geographical area of the country is 329 million ha, out of which 184 million ha are considered suitable for agriculture and the net cultivated area in 1994-95 was 143 million ha. The per capita availability of land for agriculture, which at present is 0.14 ha, will reduce further as population increases and land is claimed for urbanisation and industrialisation. Nearly 175 million ha of land suffer from various degradation processes like wind and water erosion, ravines, shifting cultivation, waterlogging and salinity. The utilisable water is only 690 billion cu m from surface and 432 billion cu m from groundwater. Agriculture is receiving 83 percent of the water supply. Water allocated to agriculture was irrigating a net area of 53 million ha whilst the gross irrigated area was 78 million ha in 1994-95. The gross irrigation potential projected for 1997 was 89.44 million ha. About 50 percent of the area are irrigated through groundwater.

There are climatic and soils variation in the country, therefore the types of crops grown also differ from region to region. In the country the important crops according to area are rice (22.6 percent), wheat (13.2 percent), sugarcane (2.2 percent), maize (3.2 percent), sorghum (7 percent), pearl millet (5.8 percent), groundnut (4.6 percent) and cotton (4.3 percent). Though there are several constraints to further improvement in production and productivity, the future projections indicate that India would be able to provide food security if land and water resources, particularly the salinity of irrigated lands, can be properly managed.

e) Italy: Total land area is 29.4 million ha of which 10.8 million ha are arable and permanent crops (8.1 million ha are arable land and 2.7 are permanent crops). Population is 57.3 million of which only 3.5 million are involved in agricultural activities. Irrigation covers 2.7 million ha. In Italy, some hazards of degradation/desertification can be recognized in the southern regions, i.e. Abruzzo, Molise, Campania, Puglia, Basilicate, Calabria and especially in Sardegna and Sicily. Sardegna and Sicilia are the regions with higher levels of degradation including salinization. In 1995, the Italian Government proclaimed the state of emergency for water in Sicily and Sardinia, caused by the considerable decrease in rainfall and subsequent reduction in water stored in reservoirs. (In Sicily the mean annual rainfall is usually less than 500-600 mm against mean evapotranspiration of 1 000-1 200 mm). The need for irrigation with available saline-sodic groundwater is evident in Sicily, considering that in the last 30 years no more than 300 million cu m of good quality water have been available for irrigation against a need of about 1 600 million cu m.

f) Spain: The total land area is 50 million ha of which 15.3 million ha are arable and 5 million ha under permanent crops. Population in 1997 was 40 million, with only 3.5 million involved in agricultural activities. Irrigation covers 3.5 million ha.

The Comunidad Valenciana (where most salt-affected areas in Spain exist) located at the eastern part of Spain, under a typical semi-arid Mediterranean climate (rainfall ranging between 230 to 500 mm and ETP between 950 to 1200 mm from north to south) extends along 485 km of coastal Mediterranean Sea.

Two main relief units can be distinguished: mountain areas of Triassic and Jurassic age (limestone and dolomite, quartzitic sandstones, conglomerates, clays and gypsiferous rocks) and flat coastal areas of the Quaternary (conglomerates, gravels, sands, silts, clays and peat formations). The alluvial and continental sediments, transported to the sea, have been modelled by the sea currents and formed several coastal lagoons (deltas, freshwater lagoons and sabkhas).

The Research Unit of Geomorphology and Salt-affected Soils of the Universitat de Valencia has performed since 1988 several studies on genesis and cartography of salt-affected soils in Valencia and in other countries. Its activities have contributed to the development of regional policies regarding the management and conservation of natural salt-affected ecosystems. 0

g) Sudan: Total land area is 237.6 million ha, of which only 13 million ha are arable crops. Irrigation covers an area of 2 million ha. Population in 1997 was 28 million, of which 18 million were in rural areas.

h) Uzbekistan: Republic of Uzbekistan is the largest independent state in Central Asia, with a total land area of 41.4 million ha. Two river basins are found in Uzbekistan. These basins form the Aral Sea Basin: i) the Amu-Darya basin in the south, covering 86.5 percent of the country; and ii) the Syr-Darya basin in the north, covering 13.5 percent of the territory.

Physiographically, Uzbekistan can be divided into three zones: i) the desert, steppe and semi-arid region covering 60 percent of the country, mainly the central and western parts; ii) the fertile valleys (including the Fergana valley, Samarkand oasis, Tashkent, etc.) that skirt the Amu-Darya and Syr-Darya rivers, and iii) the mountains in the east (Gissaro-Alay and Tien-Shan ranges).

Irrigated agriculture is the backbone of the Uzbek economy (total irrigated area is 4.3 million ha), accounting for 35 percent of GDP and 45 percent of employment. In the rural areas, irrigated agriculture and the processing of agricultural products is by far the main source of employment and income for the population (total population in 1997 was 23.7 million). The most important crops are cotton (which accounts for about 50 percent of the export earnings), wheat (1.7 million ha), potatoes, vegetables and fodder crops. Irrigation is vital under the prevailing arid climatic conditions.

Total potential agricultural land in the Uzbekistan is 27 606 200 ha, from which 4 700 000 ha are arable land. About 95 percent of agricultural products are grown in the irrigated area.

High rate of population growth and non-productive use of limited water resources for irrigation led to the decrease of irrigated area per capita, i.e. 1980: 0.23 ha, 1998: 0.17 ha. Although Uzbekistan has achieved food security since its independence in 1991, the fall in production of cotton for the past few years has been of serious concern to the government. The average yields of cotton and wheat are low and the cost of production high by international standards. However, the socioeconomic objective for the future is to produce as much food as possible in Uzbekistan, with a minimum of 3 000 calories per day per person. The necessary increase in food production will, therefore, require a major effort, including finances for investment and management of both land and water.

1.6 Extent and causes of salt-affected soils in participating countries

Based on the FAO/Unesco Soil Map of the World, Table 1 shows the regional distribution of salt-affected soils. It should be borne in mind that areas given in the table are not necessarily arable but cover all salt-affected lands. The table indicates that the total area of saline soils is 397 million ha and of sodic soils 434 million ha at global level. Of the current 230 million ha of irrigated land, 45 million ha are salt-affected soils (19.5 percent) and of the almost 1 500 million ha of dryland agriculture, 32 million are salt-affected soils (2.1 percent) to varying degrees by human-induced processes.

Salt-affected lands are reflected as saline seeps in dryland agriculture and secondarily salinized irrigated lands (Tanji, 1995). Table 2 shows that globally more than 77 million ha of land are salt-affected by human-induced salinization (Oldeman *et al.,* 1991). The authors have not distinguished between the extent of salt-affected land in irrigated and non-irrigated areas.

Dregne *et al.* (1991) estimated that about 43 million ha of irrigated land in the world's dry areas are affected by various processes of degradation, mainly waterlogging, salinization and sodication.

Table 1. Regional distribution of salt-affected soils (million ha).

Regions	**Total area**	**Saline soils**	**%**	**Sodic soils**	**%**
Africa	1 899.1	38.7	2.0	33.5	1.8
Asia and the Pacific and Australia	3 107.2	195.1	6.3	248.6	8.0
Europe	2 010.8	6.7	0.3	72.7	3.6
Latin America	2 038.6	60.5	3.0	50.9	2.5
Near East	1 801.9	91.5	5.1	14.1	0.8
North America	1 923.7	4.6	0.2	14.5	0.8
Total	**12 781.3**	**397.1**	**3.1**	**434.3**	**3.4**

Table 2. Global extent of human-induced salinization (million ha).

Continent	**Light**	**Moderate**	**Strong**	**Extreme**	**Total**
Africa	4.7	7.7	2.4	-	14.8
Asia	26.8	8.5	17.0	0.4	52.7
South America	1.8	0.3	-	-	2.1
North and Central America	0.3	1.5	0.5	-	2.3
Europe	1.0	2.3	0.5	-	3.8
Australia	-	0.5	-	0.4	0.9
Total	**34.6**	**20.8**	**20.4**	**0.8**	**76.6**

Salinity also poses a major management problem in many non-irrigated areas where cropping relies on limited rainfall. Dryland salinity has been a threat to land and water resources in several parts of the world although only in recent years has the seriousness of the problem become widely known. If it is accepted that 77 million ha of land are affected by human-induced salinization (Table 2), a global total of more than 33 million ha can be attributed to secondary salinization of non-irrigated lands. In rainfed agriculture intrusion of saline seawater to areas lying near the sea can cause land salinization during dry periods.

Based on the FAO/Unesco Soil Map of the World, Table 3 shows the distribution of salt-affected soils in participating countries. It should be borne in mind that, areas given in Table 3 are not necessarily arable but cover all salt-affected land. The percentage of saline soils in participating countries amount to 49.2 percent of total saline soils of the world and that of sodic soils to 45.8 percent of total sodic soils of the world.

Table 4 shows the extent of human-induced salinization (saline + sodic soils) in participating countries in irrigated, as well as rainfed, agricultural lands. The table shows that the percentage of human-induced salt-affected soils in participating countries (57.9 million ha) is about 78 percent of the global human-induced salt-affected soils (77 million ha).

Table 3. Total land area, arable and permanent crops and irrigated land (FAO, 1997) and distribution of land and extent of salt-affected soils in countries participating in the Network.

Country	Total land area million ha	Arable and permanent crops million ha	Saline soils million ha	%	Sodic soils million ha	%
I. Network member countries with projects collaborating with FAO						
a) Africa Region						
1. Ghana	22.8	4.5	0.2	0.9	0.6	2.6
2. Kenya	56.9	4.5	5.3	9.3	2.9	5.1
3. Nigeria	91.1	32.9	2.0	2.2	3.6	3.9
4. Tanzania	88.4	4.0	1.7	1.9	0.3	0.4
b) Asia Region						
5. Bangladesh	13.0	8.8	2.5	19.2	0.6	4.6
6. China	932.6	96.0	37.0	4.0	1.5	0.2
7. Indonesia	181.2	31.0	8.1	4.5	0.0	0.0
8. Pakistan	77.1	21.6	10.0	13.0	1.5	1.9
9. Philippines	29.8	9.5	0.6	2.0	0.0	0.0
10. Thailand	51.1	20.5	3.0	5.9	0.4	0.8
11. Viet Nam	32.5	6.8	3.8	2.0	0.2	0.0
c) Europe Region						
12. Hungary	9.2	5.0	0.5	5.4	1.8	19.6
13. Romania	23.0	9.9	0.5	2.2	1.1	4.8
14. Turkey	77.0	26.9	2.0	2.6	0.5	0.6
d) Latin America Region						
15. Argentina	237.7	27.2	33.1	13.9	18.5	7.8
16. Brazil	845.7	65.5	2.7	0.3	17.7	2.1
17. Cuba	10.9	4.5	0.7	6.4	0.3	2.8
18. Mexico	190.9	27.3	1.3	0.7	1.6	0.8
e) Near East						
19. Egypt	99.5	3.3	8.7	8.7	0.4	0.4
20. Iran	162.2	19.4	23.8	14.7	3.7	2.2
21. Syria	18.4	5.2	0.5	2.7	0.0	0.0
22. Tunisia	15.5	4.9	1.3	8.4	0.5	3.2
II. Network associate member with ongoing national programmes						
23. Australia	768.2	50.2	17.0	2.2	132.6	17.3
24. Canada	922.1	45.5	8.6	0.9	0.7	0.1
25. Colombia	103.9	4.4	3.0	2.9	0.3	0.3
26. India	297.3	162.5	6.2	2.1	2.4	0.8
27. Italy	29.4	10.8	0.4	1.4	0.0	0.0

28. Spain	50.0	20.1	2.4	4.8	0.0	0.0
29. Sudan	237.6	13.0	2.1	0.9	3.2	1.3
30. Uzbekistan	41.4	4.9	6.3	15.2	4.6	11.1
Total	**2 716.4**	**1 189.8**	**195.3**		**199.1**	
World Total			**397.1**	**49.2**	**434.3**	**45.8**

Table 4. Extent of human-induced salinization in participating countries (million ha).

Country	Irrigated area	Salt-affected land in irrigated area	Salt-affected land in rainfed area	Total human-induced salinization
a) Africa Region				
1. Ghana	(0.01)	(0.004)	0.3	0.3
2. Kenya	0.1	(0.03)	0.4	0.4
3. Nigeria	0.3	0.1	0.5	0.6
4. Tanzania	0.2	(0.05)	0.5	0.5
b) Asia Region				
5. Bangladesh	3.7	1.1	1.3	2.4
6. China	49.9	6.7	7.0	13.7
7. Indonesia	4.6	0.4	0.6	1.0
8. **Pakistan**	**17.2**	**4.2**	**2.8**	**7.0**
9. Philippines	1.6	0.3	0.2	0.5
10. Thailand	4.6	0.4	0.3	0.7
11. Viet Nam	2.0	0.3	0.2	0.5
c) Europe Region				
12. Hungary	0.2	0.2	0.5	0.7
13. Romania	3.1	0.3	0.2	0.5
14. **Turkey**	**4.2**	**0.4**	**0.2**	**0.6**
d) Latin America Region				
15. **Argentina**	**1.7**	**0.6**	**1.9**	**2.5**
16. **Brazil**	**3.2**	**1.0**	**0.5**	**1.5**
17. Cuba	0.9	0.4	0.4	0.8
18. **Mexico**	**6.1**	**2.0**	**1.0**	**3.0**
e) Near East				
19. **Egypt**	**3.3**	**0.9**	**0**	**0.9**
20. **Iran**	**7.3**	**2.1**	**0.6**	**2.7**
21. **Syria**	**1.1**	**0.4**	**0.1**	**0.5**
22. **Tunisia**	**0.4**	**0.1**	**0.3**	**0.4**
f) Associate Members				
23. **Australia**	**2.3**	**0.5**	**2.0**	**2.5**
24. Canada	0.7	0.5	1.8	2.3
25. Colombia	1.1	0.3	0.2	0.5
26. **Italy**	**2.7**	**0.2**	**0.0**	**0.2**

27.	India	57.0	5.5	1.1	6.6
28.	**Spain**	**3.5**	**0.9**	**0.3**	**1.2**
29.	Sudan	1.9	0.5	0.4	0.9
30.	Uzbekistan	4.0	2.0	0.0	2.0
	Total:	**188.9**	**32.4**	**25.6**	**57.9**

The causes and origin of salinity and sodicity must be identified so that they, and not the symptoms, can be controlled.

In semi-arid and arid areas of the world, the scarcity, variability and unreliability of rainfall and high potential evapotranspiration affect the water and salt balance of the soil. Low atmospheric humidity, high temperature and wind velocity promote the upward movement of the soil solution and the precipitation and concentration of the salts in the surface horizons. In arid regions, various types of Na, Mg and Ca salts are concentrated, mainly chloride and sulfate, thus salinization.

In less arid climates, salts are less concentrated and Na dominates in carbonate and bicarbonate forms, which enhance the formation of sodic soils. The sodication process involves the presence of soluble sodium salts in the soil solution and their adsorption on the exchange complex. The process of sodication includes desalinization in the absence of enough divalent cations and with insufficient drainage, evaporation of groundwater rich in $NaHCO_3$ and Na_2CO_3, decomposition of sodium alumino silicates, denitrification and sulphate reduction under anaerobic conditions; use of water with low salinity but with dominant HCO_3 anions for irrigation and migration and accumulation of sodic salts in arid climates. Desalinization in the absence of enough divalent cations and with insufficient drainage is the main cause of sodication in participating countries.

Two main salt accumulation cycles can be distinguished, i.e. natural and anthropogenic cycles. Natural cycles include marine cycles, continental cycles, development of saline seeps in rainfed agriculture and artesian cycles. Of these natural cycles, marine cycles have been considered the main natural cause of salinization in the ongoing collaborative projects in the countries participating in the Network. Marine cycles are connected with the accumulation of marine salts in areas lying near the sea or saline lakes. The seawater directly or indirectly influences soils and groundwater of these areas, giving rise to saline soils and groundwater with salt concentrations ranging between 25 and 100 g/liter.

Anthropogenic cycles of salinization or sodication are caused by: a) irrigation mismanagement (including insufficient water application, irrigation at low efficiency, seepage from canals and water losses on the farm, and irrigation with saline water or marginal quality water without proper soil and water management and agronomic practices); b) poor land leveling; c) dry season fallow practices in the presence of shallow water table; d) misuse of heavy machinery and soil compaction; e) excessive leaching with insufficient drainage; and f) use of improper cropping patterns and rotations. Poor soil and water management and irrigation with saline water, the main contributory causes of anthropogenic cycles, were selected in the ongoing collaborative projects in participating countries.

1.7 Extent and causes of salt-affected soils in member countries:

1.7.1 **Countries with FAO collaborative projects**

Africa Region:

a) Ghana: Total of 788 000 ha of salt-affected land have been mapped and classified mainly as Arenosols (70 000 ha), Solonetzs (600 000 ha) and Solonchaks (118 000 ha). The greatest extent of these salt-affected soils occurs within coastal scrub and savannah and mangrove swamps of the Lower Volta Basin in the Greater Accra and Volta Regions. With the exception of coastal sandy soils, the rest of the affected soils are heavy textured exhibiting halomorphic properties.

Most of the salt-affected soils of the country occur within the Accra-Ho-Keta Plains, which cover the southeastern corner of the country, extending eastwards along the coast from Accra to the border with Togo. They occur within the Coastal Savannah Agro-ecological zone. The major problems associated with these soils are their high salt content intolerable by crops, hydromorphic nature, heavy textures and poor nutrient contents. Impenetrable sodium-saturated pan occurs in some of these soils on the uplands (Agawtaw series). Elsewhere along the coasts of Western and Central Regions, outside the Plains, patches of these salt-affected soils occur.

Natural cycles are mostly responsible for salt accumulation in the soils of the Plains. The semi-arid nature of the Plains, with only 760 mm of unreliable annual rainfall and high potential evapotranspiration, greatly affect the water and salt balance. The high and constant temperatures, low relative humidities, and constant high wind velocity of the Plains are important factors in promoting upward salt movement into the exploitable volume of the soil. The soils have been salt-affected mostly as a result of intrusion and inundation by seawater on low-lying tidal flats and flood plains. Overland soils sprays blown from the lagoons and the sea (Gulf of Guinea of Atlantic Ocean) running along the coast of Ghana are important causes. Elsewhere within the Plains, the problem is attributed to natural cycles during the weathering processes of salt-bearing rocks (Agawtaw series). In the upland, salinity is due to poor soil and water management and poor drainage.

b) Kenya: Sodic and saline soils in Kenya cover approximately 8.2 million ha and occur mostly in Northeastern, Eastern, Coast and parts of the Rift Valley Provinces. Most salt-affected soils are unfavourable for crop production unless special management techniques are used or salt-tolerant crops are grown. Total irrigated land in Kenya is about 66 000 ha, of which more than 20 000 ha are estimated to be mainly saline. The Kimoriga scheme, for example, has been out of operation since 1966, due to salinity problems although some drainage systems were constructed. Part of the 400 ha Komleza Scheme that used to grow rice is also out of operation since 1966. The land was found to be sodic or saline-sodic. Most of the salt-affected soils resulted from natural geological cycles such as migration and redistribution of salts accumulated formerly in sedimentary salt-bearing rocks. Also deposition of salts during the process of weathering and soil formation by surface and groundwater results in salinization. Secondary salinization is caused by soil and water mismanagement through improper irrigation and poor drainage.

c) Nigeria: Sodic and saline soils in Nigeria cover approximately 5.6 million ha and occur mostly in the Sudan savanna in the northern states of the country. The main annual rainfall is about 850 mm with 524 mm, or over 60 percent occurring in the months of July and August with potential evapotranspiration exceeding 1 400 mm per annum. The rainfall is, therefore, unable to satisfy all year round crop production and hardly provides leaching, particularly on lands where subsoils are slowly permeable and internal drainage is lacking. Total irrigated area in Nigeria is about 300 000 ha, however, the cropped irrigated land is estimated at 150 000 which falls far short of the planned area that should be in production. About 20 percent of these lands, mostly in semi-arid northern Guinea and Sudan Savanna have been degraded as a result of salt accumulation in the soil. Examples of irrigation projects seriously salinized can be found in Hadejia, Kano and Sokoto-Rina Valleys and Turgon Tudu and Kalmalo Lake projects in the northwest. In the Northeast there are such projects as Yau and Abadon irrigation schemes on the northern shores of Lake Chad, which have similarly been affected by salinity.

Problems of salt-affected soils are attributed to natural cycles during the process of weathering in salt bearing rocks, mismanagement of soil and water, the use of low quality water for irrigation without provision of leaching and subsurface drainage.

d) Tanzania: Based on the FAO/Unesco Soil Map of the World, the actual extent of the salt-affected soils in Tanzania is estimated as 1.7 million ha saline soils (local estimations give an area of 2.9 million ha) and sodic soils as 300 000 ha (local estimation gives an area of 700 000 ha). One of the most affected sectors with respect to salt-affected soils in Tanzania is irrigated agriculture. Estimates suggest that 5 million ha are potentially suitable for irrigation in Tanzania. So far only 190 000 ha of this land are actually being irrigated in different schemes. In regions like Kilimanjaro, some of these schemes have already been abandoned because of the hostile soil conditions on the staple crops in the area. The frequent development of salt-affected soils in irrigation schemes is often related to poor soil management, which plays a big role in their degradation.

In Mlingano on ten estates, with the exception of Mufindi Tea Estate, it is suggested that they are already encountering major salt-related problems in their soils. Besides these, there are many smaller irrigation schemes classified as traditional irrigation schemes, which are community managed. Three of such schemes were all found to have developed saline and sodic soils largely because of mismanagement of the soils and irrigation/drainage principles. A further expansion into irrigated areas is expected in the regions of Kilimanjaro/Arusha (4 000 ha), Mbeya Region - Usangu Plains, Kimani Village (5 000 ha), Tanga (2 000 ha) and Tabora, Shinyanga, Dodoma, Mwanza regions (4 600 ha) as part of the Mbuga Development Project. As long as soil management may be a problem in these lands, it may be proper to regard them as potential salt-affected soils.

The occurrence of salt-affected soils across the country has been associated with various factors. The causes of salt-affected soils can be classified into three groups: (a) climate and inherent soil properties: in some parts of Tanzania soils become salted either because of the aridity of the surrounding environment or the soils have developed from a parent material which is more prone to development of saline soils such as in Pangani Valley and the Rift Valley areas in Arusha region, and the areas surrounding Bahi swamps in Dodoma which are in the northern and central parts of Tanzania, respectively; (b) landform/topography such as in Dodoma region in central Tanzania, around the Bahi swamps, Mahomanyika and Hombolo areas and Mtwara region in the southern end of the country; and (c) man-made causes including poor design of the irrigation schemes, seepage from irrigation canals and drainage systems which are not incorporated in the initial layout such as at Kileo and Kigonigoni in Mwanga District.

Asia Region

a) Bangladesh: The salt-affected zone of Bangladesh is essentially the coastal zone. The total area in the coastal regions of Bangladesh affected by varying degrees of salinity was about 0.83 million ha in 1966-75. Over the last two decades the area affected by salinity has expanded markedly from 0.83 million ha to 3.1 million ha. Presently, slight to strong soil salinity problems exist in 20 districts. Saline areas are situated in four of the thirty agro-ecological zones (AEZs) of the country [the Ganges Tidal Floodplains (AEZ-13), the New Meghna Estuarine Floodplains (AEZ-18), the Chittagong Coastal Plains (AEZ-23) and St Martin's Coral Island (AEZ-24)].

The causes of soil salinity include: (a) natural causes such as tidal flooding (the freshly deposited alluvium from upstream becomes saline as it comes in contact with seawater through the rivers, canals and creeks); tidal surges due to cyclones or exceptionally high tides push the salinity front further inland and into the groundwater; and (b) anthropogenic causes such as the reduced availability of freshwater, drying up of rivers and saline water intrusion from the sea into the Ganges basin area due to the withdrawal of the Ganges river water upstream outside the boundaries of Bangladesh; upland shrimp culture causing seepage of saline water from the shrimp ponds into adjacent agricultural lands increasing soil salinity; and irrigation from shallow tube wells of poor quality waters.

The soil and water salinity levels vary widely from place to place and with seasons in the year. Irrespective of location, the common trend is an increase in salinity with time from November-December to March-April until the onset of the monsoon rains. Usually July-August is the period of minimum salinity, January-February of intermediate salinity and March-April of maximum salinity corresponding with the peak dry season.

b) China: In China, 38.5 million ha are salt-affected in various degrees. The main types of salt-affected soils include:

- Coastal salt-affected soils, spreading along the coastal area of China, mainly caused by saline parent material and seawater intrusion. Large-scale water projects have also caused salinity problems.
- Fluvo-aquic and meadow salt-affected soils are widely distributed in the North China Plain, and other northern regions of China. These types of soils are formed under the influences of groundwater, surface water and cultivation. Irrational irrigation and poor drainage management play significant roles in formation and evolution of salt-affected soils.
- Solonetz and alkaline soils, mainly distributed in Inner-Mongolia and Northeast China regions and intervening in the North China Plain, are formed both under natural and anthropogenic processes. Cultivation and poor irrigation management has certain influences on the formation of sodic soils.

- Haplic solonchaks, mainly spreading in the inland region, such as Northwest China, are caused by strong evaporation of groundwater and surface salt accumulation.

- Potential salt-affected soils, mainly distributed in arid and semi-arid regions of China, are neither saline nor sodic at present but may result in severe salinization or sodication under human intervention, especially by inappropriate irrigation systems. Improper exploitation of land and irrational management (especially irrigation) in some areas has enhanced salinity problems or even induced secondary salinization or sodication.

In general, irrigation mismanagement including shortage of freshwater resources, irrigation at low efficiency, seepage from canals with insufficient drainage system and generally poor soil and water management are the main causes, particularly in Xinjiang Region. Soil salinity in coastal areas (Jiangsu Province) is due to accumulation of salt in soil from parent materials, seawater intrusion in both surface and groundwater and also due to poor soil and water management.

c) Indonesia: Indonesia consists of more than 13 000 islands, with a total area of 192 million ha. Swampland covers vast areas estimated at 33.4 million ha, which are divided into three zones: (i) brackish/saline tidal lands, (ii) fresh water tidal lands and (iii) non-tidal lands. The coastal lands are in the brackish/saline tidal land category and are estimated at 8.09 million ha. The coastal saline lands have been differentiated into four types: (i) beach ridges/dunes, (ii) potential lands, (iii) acid sulphate lands and (iv) peat lands. Parts of each type are saline because of brackish/saline water intrusion. Causes of coastal saline tidal land include seawater intrusion and soil and water mismanagement, and also agricultural activities extension in coastal problem soils (acid sulphate and peat soils) without appropriate soil management measures.

d) Pakistan: Of the 20.2 million ha being cultivated in Pakistan, about 16 million ha are being irrigated through canal and tubewell networks. Of the irrigated land, 26 percent are affected by salinity to different degrees. About 70 million ha land in Pakistan can be classified as falling in the semi-arid zone, including 11 million ha of deserts, e.g. Cholistan, Thar, Thal and Kharan. The desert areas have peculiar types of problems different from irrigated regions, i.e. high rate of evaporation and strong summer winds. Water is the most critical and limiting factor that prohibits using the area for agricultural production. The underground water is mostly saline.

Salt-affected soils in Pakistan (total of 11.5 million ha) are classified as slightly saline-sodic or saline gypsiferous (3.5 million ha), porous saline-sodic or saline gypsiferous (1.9 million ha), severely saline-sodic and saline gypsiferous (1.1 million ha), and soils affected due to use of sodic tubewells water (2.3 million ha). Over 2.5 million ha of irrigated areas are affected with severe surface salinity with 18 percent affecting lands in Sind, 3 percent in the Punjab and 2 percent in NWFP. The moderately affected areas are 10 percent in Sind, 4 percent in the Punjab and 2 percent in NWFP.

Accumulation of rain and floodwaters in natural depressions is the major cause of primary salinity. Secondary salinity due to man-made causes is related to seepage from canals, lack of drainage, use of poor quality groundwater for irrigation, and insufficient leaching and poor land management practices.

e) The Philippines: The extent of salinity-prone coastal land which is an integral component of the agricultural area has been estimated to range from 0.5 to 0.6 million ha, of which 0.2 million ha are considered seriously salt-affected soils. The distribution of these soils, mostly associated with coastal landscapes, is geographically situated as follows: Luzon 180 000 ha, Visayas 220 000 ha and Mindanao 160 000 ha. Although these are traditionally rice-producing areas, soil productivity in terms of rice yield is marginal since rice production ranged only from 30 to 50 cavans/ha (one cavan = 50 kg) in severe cases of salinity. The salinity-prone areas in the country are small compared to other countries in South and Southeast Asia, but they are potential and an important resource base for production of rice and other staple food.

The land resources study indicated that salt-affected areas are generally associated with tidal flats and flood-prone alluvial plains.

The degree of salinity in the coastal soils of the Philippines is generally related to typhoons, tidal river flooding, low elevation (generally 5 m asl or lower), impedance of natural drainage by tidal fluctuation, subterranean saltwater intrusion, overland salt sprays, and use of brackish water for irrigation of rice crops. The productive period of these areas covers only five to six months every year because of inadequate irrigation facilities. February to April are months of low rainfall and high salinity problems. On the other hand, an average of five to six strong typhoons visit the country every year that cause strong tidal surges, widespread flooding, and significant damage to crops and livestock.

Saline seawater intrusion into fresh groundwater or perched aquifer below the farming areas, surface saline seawater intrusion during high tidal movement, natural cycles during the process of weathering of salt bearing rocks, soil and water mismanagement including irrigation with slightly saline water from contaminated groundwater, rivers or irrigation canals being near or constructed along the sea are the main causes of salt-affected soils in the Philippines.

f) Thailand: Salt-affected soils in Thailand cover an area of approximately 3.4 million ha. Salinity can be caused by factors such as seawater encroachment, shallow and saline water table and inadequate drainage due to landscape characteristics. Salt-affected soils are mostly found along the coastal area and in the Northeast region of the country as follows:

1. Inland saline soils, covering an area of 2.9 million ha, exist in 18 provinces (Nakornratchasima, Roi-Et, Chaiyapum, Khonkaen, Loei, Mahasarakam, Ubonratchatani, Srisakhet, Udornthani, Nongkai, Sakonakorn, Burirum, Surin, Yasothorn, Nakornphanom, Kalasin, Mookdaharn and Amnartchareon) of the Northeast region.

2. Coastal saline soils occur along 2 600 km of the coastal belt covering an area of 0.58 million ha in 23 provinces (Bangkok, Samut Sakhon, Samut Songkhram, Samut Prakan, Petchaburi, Prachuab Kiri Khan, Chumporn, Surat Thani, Nakhon Si Thammarat, Songkhla, Pattani, Narathiwat, Pattalung, Krabi, Phuket, Trang, Pangnga, Satun, Ranong, Chachoengsao, Chon Buri, Chantaburi, Rayong and Trad).

Salt-affected soils in Thailand are caused both by natural phenomenon and anthropogenic soil salinization as follows:

(a) Inland saline soils are formed by the weathering of salt-bearing rocks.

(b) Coastal saline soils are formed from marine and brackish water deposits (active tidal flat areas and former tidal flat areas) and characterized by salt-tolerant mangrove vegetation.

(c) Deforestation and planting of shallow rooted crops (e.g. rice, field crops and pasture) are resulting in less consumption of rainwater and more excess flowing water down to the water table increasing the water table level and causing salinity.

(d) Constructions of reservoir near the salt source or in area close to shallow saline groundwater resulting in increasing shallow saline groundwater and transporting towards the soil surface.

(e) Salt making as in the Northeast region of the country. This activity results in the seepage of salt water to adjacent areas.

(f) Shrimp farming. Brackish shrimp farming in Thailand has been operated along the coastal areas for the last 70 years. The number of farms has rapidly proliferated in recent years. However, because of improper farming practices, soil and water pollution and shrimp disease outbreaks occurring in many cultured areas, brackish water shrimp farming has then been introduced into freshwater areas of arable land in the Central Plain. At present, shrimp culture is practised in approximately 72 000 ha of the arable lands in the Central Plain. The increasing number of farms has resulted in large areas of mangrove forests and agricultural lands being converted into shrimp ponds. Moreover, discharged saline water from shrimp ponds into irrigation canals or seepage of saline water from the ponds to adjacent rice farms has caused soil salinization in those areas.

g) **Viet Nam**: The salt-affected areas, which consist of saline and acid sulphate soils, are 4 million ha. The coastal saline soils excluding acid sulphate soils (2.0 million ha) occupy about 2 million ha along the coastal regions with seawater intrusion through river estuaries and creeks as the main causes of salinization. In Viet Nam salt-affected soils are concentrated in the two large deltas of the Red River and Mekong River. The effect of seawater intrusion is only 15 km in-land in the Red River Delta, but can reach 40-50 km in the Mekong River Delta. According to FAO-Unesco classification, saline soils can be divided into: (a) Gleyi-salic Fluvisols, mainly used for aquaculture (shrimp culture); (b) Hapli-salic Fluvisols, commonly used for cultivating only one rice crop in the rainy season. The main causes of salinity are the intrusion of seawater and salt-rich groundwater. As management practices, the farmers construct dykes and leach salts during rice cultivation or make beds for other crops; and (c) Molli-salic Fluvisols due to salt-rich groundwater are used for two rice crops. The management practices include proper water management and drainage systems.

Coastal saline soils in Viet Nam can be classified in the following four groups according to the degree of salinity:

- Mangrove saline soils, alternatively inundation of very salty tidal water (potential acid sulfate soils: 716 000 ha)
- Strong saline soils with a total soluble salt of more than 1 percent (400 000 ha)
- Moderate saline soils with a total soluble salt from 0.5 to1.0 percent (200 000 ha) and
- Slightly saline soil with a total soluble salt from 0.25 to 0.5 percent (600 000 ha).

Europe Region

a) Hungary: The total area of salt-affected soils in Hungary exceeds 2.3 million ha, which is more than 24 percent of the territory of the country. Salt-affected soils include both existing and potentially saline and sodic soils that have developed mainly in the Hungarian Plain and only in small spots in other regions of the country. More than 95 percent of the existing salt-affected soils are situated in the valleys of the Danube and Tisza Rivers. The salt-affected soils of the Trans-Tisza region belong to the group of solonetz type (alkaline soils with structural B-horizon).

Hydro-geological properties cause the formation of salt-affected soils in lowland areas. Mineralised groundwater, poor physical properties of the soil, high water table, former saline swamps and bogs, poor natural drainage or no drainage system and soil and water mismanagement cause the formation of salt-affected soils in other areas.

In the Hungarian Plain, extension of salt-affected soils exceeds 25 percent of the total area and there is a potential hazard of salinization/sodication/alkalization in the major part of this depressed lowland. The climate is characterised by 500-600 mm mean annual precipitation against 750-800 mm yearly potential evapotranspiration. This water deficit is equilibrated by surface runoff, seepage in the unsaturated zone and groundwater flow from the neighbouring territories, particularly from the whole extensive Carpathian Basin surface and subsurface water catchment area to the deepest parts of the Basin with poor natural drainage. It leads to the accumulation of soluble weathering products of a large watershed within a relatively small territory of the Basin, because the water evaporates but the transported soluble products remain in the affected region.

b) Romania: Distribution of salt-affected soils in Romania is as follows:

- Solonchaks occupy small areas (64 000 ha) especially in the driest part of the country (450 mm precipitation and 600 mm evapotranspiration) and are connected to low-lying or depressionary landforms with very shallow (1.5 m depth) and strongly saline (15 g/litre) groundwater. They are widespread in the Danube Delta (where some intrusions of marine water occur) and in the eastern part of the Lower Romanian Dunube Plain (Clamatzui Valley and Low Plain of Sireth). They are predominantly medium texture, their salt content is higher than one percent with pH 8.3 to 8.5 and low biological activity.

- Solonetz (144 000 ha): are more widespread than Solonchaks. They occur mainly in the sub-humid zone (400-600 mm rainfall and evapotranspiration 600 mm), and occupy dispersed areas corresponding to low lying and depressionary landforms with groundwater deeper (1.5-2.5 m) and less saline (15 g/litre) than Solonchaks. They are distributed in the Romanian Lower Danube Plain, Western (Tisza) Plain, in the flood plains of rivers and in the Plain of Moldova. Unlike Solonchaks, the Solonetz show a textural differentiated profile, have a high percentage of exchangeable sodium (15 percent of CEC) in natric horizon with columnar structure and a pH 8.5-10.

– Salinized and/or sodicized soils (400 000 ha): This group includes a large range of soil types, e.g. Alluvial soil, Gley soils, Vertisols and Chernozems with shallow (3 m depth) and mineralized groundwater. They are widespread mainly in the eastern part of the Lower Romanian Danube Plain and in the Western (Tisza) Plain. The salt content and/or the exchangeable sodium is less than 1 percent, and less than 15 percent, respectively, in the upper layers.

– Soils with potential salinity (1 021 000 ha): This group includes almost all soils of the sub-arid zone and zone with salinized groundwater table at less than 5 m depth. They are found mainly in Lower Romanian Danube Plain and Western (Tisza) Plain and are represented mostly by the phreatic phase of Chernozems developed on loess-like and alluvial deposits. Of this area human-induced salinity (by irrigation water and/or drainage works) cannot be accurately calculated but is estimated as 500 000 ha.

In general, causes of salt-affected soils include poor drainage system in low plains with salt-rich shallow groundwater in sub-arid and sub-humid zones, and the geological substratum of old marine intrusion of marine water and unfavourable soil physical properties, and human-induced salinity through irrigation mismanagement and lack of drainage system.

c) Turkey: Major salt-affected soils are located in Turkey as follows: Konya-Eregli, Aksaray and Malya Plains of the central Anatolian and alluvial plains of lower Seyhan, Igdir, Menemen, Bafra, Soke, Acipayam and Salihli of all the major river systems. The last soil survey indicated that 1.5 million ha of land have some degree of salinity and sodicity problems and 2.8 ha of land have both salinity and waterlogging problems (this survey gives estimated salt-affected soils as almost twice the figure given according to FAO/Unesco Soil Map of the World (2.5 million ha). This soil survey indicated that the mentioned 1.5 million ha that have some salinity and sodicity problems include 60 percent slightly saline, 19.6 percent moderately saline, 0.4 percent moderately alkaline, 12 percent slightly saline-alkaline, and 8 percent moderately saline–alkaline, respectively. Although sodium salts are the main components of the salt-affected soils, magnesium soils in Denizli-Aclpayam, potassium-alkali soils in Nide-Bor, Kayseri and gypsiferous soils in central Anatolian regions are also common in Turkey.

Climatic, geochemical and hydrological conditions of the country often promote salt accumulation in the groundwater and the soil profile, particularly in arid and semi-arid lowlands where groundwater contains considerable amounts of soluble salts. Saline soils often develop in the Konya Basin in association with marshes. In general, poor water management and agronomic practices without sufficient drainage systems are the major causes of salinity.

Latin America Region

a) Argentina: Of the 12 million ha irrigated land in Latin America, 1.7 million ha are in

Argentina, of which 600 000 ha are salt-affected soils. The Mendoza River in Argentina carries about 1.3 million tons of salt per year, which are applied to the land by irrigation. Also, the Rio Colorado has a considerable salt load reaching about 179 000 ha of the potentially irrigated land receiving river water. Salt-affected soils are widespread in the Lower Rio Colorado Valley, covering an area of 33 000 ha of the 80 000 ha irrigated area. Irrigation with saline water and intrusion of seawater through estuaries and rivers, mismanagement, natural fluctuation of water table close to surface, waterlogging, insufficient drainage system and poor maintenance of the collector and main drains are the principal causes of salt-affected soils in irrigated areas of Argentina.

b) Brazil: Although the information about the saline areas is not well defined, it is estimated that 20-25 percent of the irrigated areas nearby rivers and intermittent streams, mainly in alluvial soils, face salinity and/or drainage problems. The source of water for irrigation are surface reservoirs (dams) where the water is stored during the rainy season, rivers and groundwater in sedimentary areas having in general good quality water.

Besides the saline soils of irrigated areas, salt-affected areas by natural causes exist in large areas (2.4 percent of the total land area of Brazil). According to a soil survey made for the states of Bahia, Sergipe, Alagoas, Pernambuco, Paraiba, Rio Grande do Norte and Ceará, covering 110 million ha at a scale of 1:500 000, the salt-affected areas were estimated at 9.1 million ha corresponding to 9 percent of the surveyed area, including Soladic Planosol, Solodized Solonetz, Solonetzic Solonchack and Halomorphic soils.

Over-irrigation, poor soil and water management, seawater intrusion and insufficient drainage system with consequent rise in water table and waterlogging, shallow soils with low fertility and irrigation with saline water without proper management are the major causes of salt-affected soils in Brazil.

c) Cuba: Salt-affected soils cover 14 percent of the total land (about 1 000 000 ha) distributed in following provinces: Granma 250 000 ha, Holguin 170 000 ha, Camaguey 140 000 ha, Sandi Spiritus 100 000 ha, Villa Clara 80 000 ha, Ciego de Avila 75 000 ha. The rest are distributed in smaller areas in Isle de la Juventud, Pinar del Rio, La Habana, Matanzas, Cienfuegos; Las Pinas; Santiago de Cuba and Guantánamo Provinces.

In Cuba, natural saline soils cover a small area associated with the muddy zones nearby the sea. Salinization is due to seawater intrusion during extraordinary tides, typically caused by hurricanes. The peat and calcareous sediments that constitute most of the Cuban coastal marshes generally have intermediate salt concentration. In the southeastern part of the Guantánamo Valley, as well as in small coastal valleys of that province, the average yearly precipitation is less than 700 mm. Therefore, it is possible to find fully developed Solonchak soil of primary origin. However, in 90 percent of salt-affected soils in Cuba, the salinity is secondary due to:

(a) Highlands deforestation: As a consequence of the intensive deforestation, the soil water regime was altered due to the frequency of floods, the water table of the low zone increased, therefore the territory of the swamped zones increased, and the water table became saline and shallow and soils became salt-affected.

(b) Coastal marsh deforestation: As a consequence of seawater intrusion, secondary coastal Solonchak soils have formed. The coastal zones remained unprotected and in many areas the sea has destroyed them.

(c) Use of saline groundwater for irrigation: The intensive exploitation of groundwater in the karstic zone close to the sea has caused salinization of the groundwater. This problem first occurred in the 1950s in the Pinar del Rio Southern Plain, in relation to rice production.

(d) Rise of the water table: Due to the construction of a great number of dams and irrigation systems without drainage systems, raised the level of watertable to reach the soil surface and cause salinization.

(e) Use of poor quality irrigation water: The river waters that are formed in saline sedimentary rocks are frequently used for irrigation. In the eastern provinces, such names as 'Salty River' and 'Bitter Stream', indicating poor quality water (e.g. EC > 2 dS/cm) are frequent. In some cases the good quality water is carried to the fields through channels that run through saline soil zones and is therefore salinized. The increasingly frequent use of industrial waters for irrigation further aggravates the problem, due to insufficient drainage of most of the salt-affected soils in Cuba.

d) Mexico: Soil degradation due to salinity is strongly associated with irrigation schemes as well as water mismanagement in all the irrigated areas of the country. All the information concerning the soil salinity status in Mexico corresponds to the irrigation districts (ID), without considering the small and numerous irrigation units where information is usually limited and vague, if any. The most extensive saline areas in Mexico are found in cultivated lands. On average, 25 percent of the area of the top ten ID in Mexico are salt-affected and in some cases this area goes up to 70 percent like in the Ciudad Juarez Valley ID (northern Mexico).

It is roughly estimated that 20 to 30 percent of the 5.5 million ha of irrigated land in Mexico are salt-affected in some degree, considering an EC greater than 4 dS/cm as the basic indicator of excess of soluble salts in the soil saturation extract.

Surface irrigation (furrow or border irrigation) is practically the only irrigation system used in the ID in Mexico. The lack of appropriate devices to measure delivered volumes at individual fields, along with the erroneous belief that the more water applied the better for the crop, result in low application efficiencies in all ID in Mexico. Field managers also contribute to this problem by allowing much more water than necessary to be served, in order to prevent personal conflicts with the landowners. More efficient irrigation systems and adequate soil management (land shaping and levelling, soil reclamation practices, if necessary) are additional factors that should be considered in order to increase the efficiency of the entire system. The main source of soil salinity in Mexican ID is basically poor water management, which includes excess of applied water, low water quality and inappropriate or non-existent drainage systems.

In coastal areas, salinity has three main origins: underlying ancient marine sediments, cyclic salts and saline intrusion. Marine sediments are the most serious problem in coastal agricultural lands. Both wind and tides promote salty breeze to move up to 10 km inland. Once the salts are deposited on the soil surface most of them finally runoff back to the sea through natural streams (rivers and creeks). Typical cases in Mexico are located in the Bajo Rio Bravo and Bajo Rio San Juan ID, and San Fernando and Soto La Marina regions, all of them located in northeastern Mexico.

Saline intrusion is derived from aquifer overdrafts mainly in coastal plains, where salty water from deep layers is increasingly pumped out. This is a major problem in the Santo Domingo, Hermosillo and Guaymas Valleys in northwestern Mexico.

Inland salinity has two principal sources: undrained closed basins, and subsurface saline layers naturally deposited in time. Evaporation and salt accumulation in the surface layers are the main processes of salinity build-up in closed basins. Such is the case of the artificially drained Texcoco basin, near Mexico City, and the Del Carmen Lagoon in southeastern Mexico.

Near East Region:

a) Egypt: The majority of salt-affected soils in Egypt are located in the northern-central part of the Nile Delta and on its eastern and western sides. Other areas are found in Wadi El-Natroun, El-Kebeir, the Oases, many parts of the Nile Delta and Valley and El-Fayoum Province. Nine hundred thousands ha suffer from salinization problems in cultivated irrigated areas. Sixty percent of the cultivated lands of Northern Delta region are salt-affected, 20 percent of the Southern Delta and Middle Egyptian region and 25 percent of the Upper Egypt region are salt-affected soils.

In some coastal areas the extraction of groundwater has proceeded to the point where intrusion of saline seawater into aquifers has degraded the quality of these resources. Continued irrigation with such low quality groundwater has contributed to the expansion of land salinization. Saline soil distribution is closely related to environmental factors such as climatic, geological, geochemical and hydrological conditions.

Inundation of the soil by sea and lake salty water over a long time is the major cause of salinization in the mentioned soils, besides the tidal effect and the salty soil solution such as in Shalma and El-Hamoul South Burullus Lake. In Mariut and Tal-El-Kabeer areas, the main factor responsible for the deterioration of their soils is seepage from irrigation canals in Mariut and from Ismailia canals in Tal-el-Kabeer.

In general, poor soil and water management and intrusion of seawater are the main causes of salinization in addition to the use of slightly saline water (drainage or mixed water) for irrigation without proper management and agronomic practices.

b) Iran: Several studies indicated that the soils having various degrees of salinity, alkalinity, and/or waterlogging cover an area of about 27 million ha, including the irrigated lands, dry farming areas and rangelands. However, recent studies revealed that the magnitude of the salt-affected areas is much larger than that originally estimated.

According to the data extracted from the 1:1 000 000 soil map of Iran (in digital format), slightly to moderately salt-affected soils cover about 25.5 million ha and soils having severe salinity occupy some 8.5 million ha. The slightly to moderately salt-affected soils are mostly formed on the piedmonts (normally, on the distal parts of the alluvial fans) at the foot of the Zagros and Alborz Mountains. Lands having severe to extreme salinity are mostly located in the Central Plateau, the Khuzestan and Southern Coastal Plains, and the Caspian Coastal Plain.

Causes of salt-affected soils in Iran include:

1. Natural occurring salinity

– Geological composition of the parent material of the soils. Iran is rich in evaporate deposits, which were deposited episodically throughout the Phanerozoic. The best known evaporates are the 'Infracambrian', Hormuz salts of the southern Zagros and Persian Gulf region and their equivalent in Central Iran, the Permo-Triassic anhydrites of the Gulf and coastal Zagros, the Upper Jurassic evaporates in the Gulf region and eastern Central Iran, the lower Fars (Miocene) salt of the Zagros, and the Tertiary salts of the Great Kavir basin in Central Iran. Salinization of the surface water resources, mainly due to natural conditions, is one of the main causes of salt accumulation in the soils of the Central Plateau.

– Wind-borne salinity. Strong winds blowing most of the times during the year in the Central Plateau, contribute to the expansion of soil salinity in the region by distributing the accumulated salts at the soil surface to a wider area.

– Seawater intrusion. This phenomenon occurs mostly in coastal areas where saline seawater enters the inland channels or inundates coastal lowlands by tidal waves. Seawater intrusion into the shallow groundwater in the coastal areas has also led to salinization of soils in the Caspian Coastal Plain, and in the Khuzestan and Southern Coastal Plains in southwestern Iran.

2. Human-induced salinity

The human-induced soil salinity occurs mostly in numerous closed basins formed by geotectonic forces in the Zagros Mountain chains. The relatively large intermountain basins have been under irrigated agriculture for centuries. Therefore, the soils have a long history of human intervention. In these areas, salt accumulation in the soils is mostly due to mismanagement of soil and water resources. Poor soil and water management, overexploitation of groundwater and grazing are amongst the main causes of human-induced soil salinity. In recent decades, use of groundwater for irrigation purposes has increased considerably. Presently, it is estimated that the groundwater balance is negative by 4 billion cu m. Continuous use of saline water in these areas has undoubtedly increased soil salinity but there are no data available on the extent of the problem.

c) Syria: Salinity and waterlogging are extensively present in relation to irrigated agriculture in Syria. It is estimated that 532 000 ha or about 40 percent of the present total irrigated areas are salt-affected soil by varying degrees. At present 60 000 ha of previously fertile soils have been excluded from production and 100 000 ha have only 50 percent of their potential production. Examples of salt-affected soils are 125 000 ha salt-affected soils in the Euphrates Valley extending as a strip from Helebia-Zalabia in the west, down to the Iraqi border in the east; 150 000 ha salt-affected strip along the Khabour River from Ras el Ain in the north, down to Sowar town near Deirezzor City in the south; 13 800 ha in the Ghab Valley and 21 000 ha in the Jabool area, 25 km south of Aleppo City.

There is a strong relation between the secondary salinization and gypsum availability in the soil surface and subsurface. The gypsic lands are estimated to reach 20 percent of the total country area. Random pumping of groundwater for irrigation in marginal land resulted in salinity increment that has led to land salinization. The same can be said in the coastal area of the Mediterranean Sea. Over-pumping to irrigate fruit trees and other crops and vegetables, water wells that have become salinized due to seawater intrusion to the groundwater have subsequently resulted in soil salinity and decreasing productivity.

Over-irrigation without measures being taken to control salinity and proper soil and water management and insufficient drainage systems are the main causes of salinity. The dominance of gypsiferous soils along the water resources in the Euphrates, Balikh and Khabour Rivers cause pollution and salinization of freshwater. The scarcity of water resources in some areas calls also for the use of available drainage, saline water or treated wastewater for irrigation (in Ghab Valley) without proper soil and water management practices causing expansion of salt-affected soils.

d) **Tunisia:** Salt-affected soils in Tunisia represent 10 percent of the total area, i.e. 1.8 million ha (1.3 million due to natural causes and 0.4 million because of anthropogenic reasons), mainly in the central and southern parts of the country. Salt-affected soils occur to a considerable extent in irrigated areas - as an example, in the Kairouan Governorate 50 percent of its irrigated land is salt-affected. Seventy percent of the total water resources and 55 percent of groundwater are being used for irrigation, of which 30 percent contain over 3 g/litre salt (10 percent in the northern part of Tunisia, 20 percent in the centre and 50 percent in the south).

The aridity of the climate and high potential evapotranspiration, saline groundwater and seawater intrusion, poor water management/agronomic practices, use of low quality water for irrigation without proper management are the major causes of salt-affected soils commonly formed in depressions and low lying parts of the landscape.

1.7.2 Associate members

a) **Australia:** Salt-affected soils in Australia are classified under two major categories:

- Natural or primary salinity: land that has been salt-affected before European settlement.
- Induced or secondary salinity: land that has become saline because of the activities of man since European settlement – mostly related to agriculture.

The total area of salt-affected land in Australia is estimated to be approximately 32 million ha in arable and permanent cropland. Most of this is naturally saline occurring in arid and semi-arid rangeland areas. These soils have low productive potential and, when cropped, suffer structural problems due to sodicity (e.g. crusting, slaking), and are prone to surface erosion. It is estimated that natural salt-affected soils occupy approximately 29.5 million ha. Approximately 2.5 million ha are affected by secondary salinization processes. Of this total area, more than 2 million ha are dryland, i.e. non-irrigated soils and there is a potential for this to increase to approximately 12 million ha over the next 20 years. Secondary salinity, resulting mostly from agricultural activities is predominantly caused by changes in groundwater patterns that result from increases in water accession to aquifers. A change in the water balance underlies the expression of salinity problems in both dryland and irrigated soils. Depending on the soil structure, surface salinity problems occur when the water table rises to within 1 to 2 m from the surface. Salinity problems are usually associated with waterlogging. In dryland soils, clearing of deep-rooted (perennial) native vegetation and replacement with shallow-rooted (usually annual) crops has changed the patterns of water use. Because annual crops usually use less rainfall, excess water will move to deeper aquifers causing rise in the water table level. In irrigated soils, rise in groundwater, due to increased applications of water for irrigation affect large areas of the Murray-Darling Basin (Victoria, New South Wales and small area in Tasmania). At least 250 000 ha of irrigated land are presently affected. There is a potential for serious effects in a further 615 000 ha over the next 20 to 40 years.

b) Canada: In Canada dryland salinity falls into one of two categories: visible or invisible. Visible salinity observed as tell-tale white crusts on soil surfaces, not only creates poor rooting environment for plants but often pollutes water supplies, generates less crop residues lowering protection against soil erosion, delays the phenological development of crops, promotes weed growth, and accumulates excess soil water causing difficulty with farm machinery. Invisible salinity, on the other hand, is generally less severe. On the Canadian Prairies visible salinity affects some 2.2 million ha, with another 10 million ha estimated to contain enough root-zone salts to rate as invisible salinity.

Over 79 percent of agricultural land in Canada are located on the Prairies, 36.3 million ha as cultivated and tame land and 17.2 million ha as permanent pastures. A figure of 2.3 million ha has been estimated as severely saline land where non-irrigated crop yields would be lowered by 25 percent or more. An estimate of the Prairie agricultural land showing slight to moderate salinity, indicated that low-level salinity across the Canadian Prairies covers about 7 million ha of arable land and 3 million ha of permanent pasture.

Summer fallow and agricultural activities aggravate natural weather-dependent movement of dissolved salts into crop root zones. Marine sediments underlying the glacial deposits supply the salts now giving rise to the root zone salinity and associated dryland salinity found throughout Canada's semi-arid lands of the Northern Great Plain and Prairies (provinces of Alberta, British Colombia, Saskatchewan and Manitoba of Canada). Poor soil and water management is also a contributory cause of the development of salinity in these areas.

c) Colombia: Total of 750 000 ha are actually equipped with irrigation or drainage facilities at present, with no available quantification of the salt-affected areas nor identification of the type and extent of the saline problem. Some approaches to the extent of the affected area calculate it to be 3 percent of the total area of the country; this means that more than 3 500 000 ha are saline soils.

Salinity has several manifestations and there is no defined distribution of the problem in each region. Saline areas are located in the north coast between Panama and Venezuela borders and there are smaller areas in the Andean Valleys – Magdalena and Cauca Valleys, and in the flat upper savannahs as the Savanna of Bogotá (2 600 m asl). Salinity and sodicity are common but magnesium-affected soils are becoming more and more important as research assesses the problem and gives new tools to identify it. Physical damage to the soil structure and soil hydraulic conductivity, especially low structural stability and very poor soil permeability are main causes of salt-affected soils development.

d) India: Salt-affected soils have been estimated to occur in 8.6 million ha, of which about 3.0 million ha are coastal saline soils which have been reclaimed from the sea or have developed due to seawater intrusion (Punjab has 0.48 million ha almost in all districts; in Haryana, salt-affected soils are present in more than 0.55 million ha; in Uttar Pradesh an area of 0.35 million ha are suffering from waterlogging and salinity; Bihar where 1.8 million ha cultivated area suffer from surface accumulation of water and salinity; in Rajasthan total salt-affected area occupies 0.10 million ha, in addition to an estimated area of 0.75 million ha, out of the 1.2 million ha well irrigated area in the state is salt-affected; in Mahdya Pradesh salt-affected soils exist in 23 districts; Gujarat has salt-affected soils both in the inland and in the coastal zone; in Maharashtra, the salt-affected soils exist in the coastal districts to an extent of 0.06 million ha ; in Karnataka the two coastal districts of Uttar Kanada and Dakshin Kanada have about 0.04 million salt-affected soils; Andhra Pradesh has salinity to the extent of 0.03 and 0.02 million ha, whereas the spread of alkalinity is 0.10 and 0.12 million ha, respectively; in Tamil Nadu about 0.2 million ha saline and alkali soils exist in the coastal districts; in Orissa salt-affected area is mainly confined to coastal zone and West Bengal has 0.82 million ha).

A number of factors that may be geological, climatic and hydrological in nature are involved in the formation of salt-affected soils. The main causes include (i) weathering of rocks and salt brought down from upstream areas to the plains and their subsequent deposition along with alluvial material, which is responsible for primary salinity; (ii) capillary rise from subsoil salt beds or shallow brackish groundwater; (iii) impeded drainage; (iv) intrusion of seawater along the coast; and (v) salt laden sand blown by sea winds. Secondary salinization that is related to anthropogenic cycles of salt accumulation, results from human activities such as introduction of irrigation without proper drainage System, removal of natural plant cover and flooding with salt rich waters, high water table and the use of groundwater of poor quality, which occurs quite extensively in the states of

Haryana, Rajasthan, Gujara and Andhra Pradesh, for irrigation.

e) Italy: Information on the exact extent, distribution and degree of degradation is not available for all soils affected by salinity in Italy. However, most salt-affected soils are spotted about in semi-arid regions particularly in Sicily and in general the southern part of Italy, and amounted to 450 000 ha, including potentially salt-affected soils. Irrigation with saline sodic waters is practised in Sicily in many areas where these waters represent the only source of available water for irrigation (only 300 million cu m of good quality water is available against the need of 1 600 million cu m), causing secondary salinization and sodication. In semi-arid and dry sub-humid areas of southern Italy salinity is a result of seawater intrusion as well as poor soil and water management practices in these areas.

f) Spain: Several types of salt-affected soil have been recognised in Spain in the semi-arid region, particularly coastal areas of Communidad Valenciana. At the same time expansion of irrigated agriculture has caused the increase of areas affected by salinity in Spain. Now total affected area amounts to about 2.4 million ha. Soils may show primary salinity (Histosols), some of them potentially acid sulphate soils with other mineral soils as Sulfaquents containing sulfidic materials, Aridisols (salids gypsids) or in other types of soils (Inceptisols, Alfisols) in which salinity is due to secondary salinization process. The overexploitation of groundwater along the coastal area for irrigatipn (Comunidad Valenciana) has led to marine intrusion of the groundwater and the deterioration of its quality and more salinity development. In the Comunidad Valenciana several types of salt-affected soils can be found:

- Saline sodic soils, showing high values of EC and accumulation of very soluble salts, mainly chlorides and sulphates of sodium and magnesium, in depressed areas and in cultivated areas irrigated with water with high TDS, generally due to marine intrusion of over-pumped aquifers.
- Gypsiferous soils in inland areas where Triassic (Keuper) gypsum is present. They include extensive areas at the South.
- Potentially acid sulphate soils concentrated mainly in the lagoons with peat formation, accumulating large amounts of sulfidic materials. Some areas lack carbonates, developing acidity and aluminium toxicity, whereas in other the lithogenic or biogenic carbonates can partially counteract the developed acidity. Alkali soils are not present within the territory although a tendency to sodication is observed in some soils irrigated with saline water developing crusting and swelling features.

g) Sudan: Total salt-affected soils in Sudan is 4.8 million ha, of which 2.1 million ha are saline and 2.7 million ha are sodic/solonetz soils. The majority of salt-affected areas are located in the low rainfall regions in northern Sudan in the higher terraces along the Nile River, South Khartoum, North Gezira and the White Nile Scheme, north of Kosti due to climate conditions (desert, semi-desert and semi-arid), natural causes of weathering of salt bearing rocks, poor soil and water management in irrigated areas including insufficient drainage system.

h) Uzbekistan: Total land area in Uzbekistan, with potential for irrigation and the area currently under irrigation, are 11.8 million ha, of which about 69 percent are located in the desert and semi-desert zones with poor natural drainage, often suffering from the presence of mineralized groundwater and requiring artificial drainage; the remainder is in the Sierozem belt. As is typical of undrained lands in arid zones, the irrigated areas suffer from salt accumulation and secondary salinization.

The total area of salt-affected soils in Uzbekistan is 10.9 million ha, of which 1.8 million ha are characterized with a high degree of soil salinization. In the Syr-Darya basin salt-affected soils cover 3 million ha, of which 44 percent are moderately and highly saline with high gypsum content. These soils are located mainly in the Hunger steppe and Central Ferghana. Salt-affected soils in the Amu-Darya basin cover an area of 7.8 million ha. These soils are dominantly located in mean stream (Kashkadarya,Bukhara and Navoiy) and downstream area (Karakalpakstan and Khorezm).

The two major land degradation problems in Uzbekistan are the secondary salinization and waterlogging caused by high groundwater levels. Up to 54 percent of irrigated lands of mean and low streams of the Amu-Darya and Syr-Darya basins are classified as highly saline, while downstream (especially in Karakalpakstan and Khorezm) about 95 percent are saline, highly saline and very highly saline. In the zone of new irrigation of the Karshi steppe early and intermediate stages of salinization are observed. Salinity is closely related to drainage conditions. Moreover, since 1990, a reduction in the quantity of water allocated to each farm, lower water quality, and the decay of companies responsible for maintaining the drainage network have resulted in increased salinization.

Climate aridity, relief, hydromorphology and geological formations of the Pamir and Gissaro-Alay Mountains and the development history of Turan Province is the natural cause of salt accumulation and river salinization. Main source of soil salinization is the salt bearing in parent materials, mineralised groundwater and surface water quality.

Anthropogenic causes of formation of irrigated salt-affected soils include; irrigation and drainage mismanagement; discharge of drainage water to river network has caused deterioration of river water quality, increasing secondary salinization and reduction of crop yields and deterioration of ecological situation in upper reaches; poor on-farm drainage and land leveling; low water application efficiency; fertility mismanagement and the decay of companies responsible for maintaining the drainage network have resulted in increased salinization.

1.8 Biophysical, socioeconomic and environmental impacts of salt-affected soils

1.8.1 Effects on production

- Various degrees of salinity/sodicity can cause serious and severe decline in soil productivity and crop yields.
- To overcome reduction in yield farmers will increase inputs including seeds, fertiliser, etc.
- In salt-affected soils, response to any input is low, for example, soil crop yield response to fertiliser application will be less as salinity is a limiting factor.
- Less possibility for alternative land use. For example, farmers are forced to cultivate only salt-tolerant crops that might not always be high-income cash crops.
- Salinity will reduce efficient use of water (i.e. crop yield per unit water) causing reduction in return from capital investment and labour inputs.
- Salt-affected soil is more fragile with greater risk and always subjected to other forms of degradation. For example, salinity will reduce land green cover and soil becoming subject to other processes such as wind and water erosion.
- In salt-affected soil, saline water table through seepage into river and watercourses can enhance salinity of fresh river water.
- The required rehabilitation programme will need high investment cost such as in reclamation projects of salt-affected soils. In economic terms the cost of rehabilitation may reach 65 percent in moderate conditions or even 100 percent in severe conditions.

1.8.2 Impact on socioeconomic conditions

- Abandonment of the land where severe salinity degradation occurred, which increased the number of landless farmers.
- Reduction in food production, food supply, low food security leading to famine in some cases.
- Increased labour requirement: for example, reclamation of salt-affected soils needs more labour. Reduced crop yields and more required inputs in salt-affected soils will reduce labour use efficiency. Reclamation programmes and improved farming systems often involve high costs being a capital investment of the government.
- Lowered income of the poor small-scale farmers from agriculture: as a consequence farmers will be forced to work on land of others or migrate to cities searching for other sources of living or ultimately depend on famine relief.

1.8.3 Impact on the environment

Most studies of long-term experiments provide information only about biophysical impacts at the site of the experiment. There are also off-site environmental impacts of salinity development. These may be at least as important as those on-site. Chemical effects contribute because nutrients are leached from the soil during leaching processes of salt-affected soils and contaminate water supplies. Biological effects because of the loss of organic matter, which weaken the strength of soil aggregates, increase the loss of nutrients in run-off, and increase carbon dioxide and methane released to the atmosphere. Nutrient losses by leaching are most often observed where nitrogen fertilisers are being used injudiciously, and where organic manures are concentrated and the effluent arising is allowed to reach streams or rivers.

Where irrigation systems are established it will be important that proper attention is given to the inclusion of adequate drainage systems with methods to dispose of the saline drainage waters such that salinization does not become an environmental hazard.

The washing of nutrients and organic matter, and of nutrient rich topsoil, into streams and rivers is a serious cause of eutrophication. The nutrients and organic matter cause a proliferation of water borne organisms that use oxygen in the water and deplete it, at the expense of fish. Until now there have been few studies in which a comprehensive attempt has been made to quantify fully the off-site effects of salt-affected soil development on environment.

1.9 Impacts of salt-affected soils on production, socioeconomic conditions and environment in selected members of the Network as examples

1.9.1 Countries with FAO collaborative projects:

Africa Region

a) Ghana: The unfortunate situation for the communities not to generate enough agricultural produce due to the salty nature of their lands has adversely affected the people in their daily lives. The subsistence farming activities result in poor yields and the communities depend on food supply from other areas outside the communities. Most of the farms are less than one acre and are not properly maintained. The poor farm yields do not encourage the farmers to invest meaningfully, which results in land degradation and which further compound the land problems. The only meaningful vocation of the people for their household income is fishing in the sea, lagoons and the Volta River, using dugout wooden canoes.

The situation of the communities has resulted in low family income causing school dropouts and health care problems.

The poor nature of the vegetation has resulted in its over exploitation as the communities harvest trees, shrubs and mangroves for household fuel.

The youth, due to the poor living conditions in salt-affected areas, migrate to the cities for better living conditions and work.

b) Kenya: Soils characterised by high salinity or sodicity in Kenya are harmful to crops through the high osmotic pressure of the soil solution, which reduces the availability of water to the crops. Strongly saline soils have little vegetation cover and are subsequently susceptible to water erosion, whereas excess exchangeable sodium and high pH strongly influence the soil physical properties. The soil becomes more dispersed and less permeable to air and water causing dense impermeable crusts that greatly reduce seedling germination and water penetration. The reduced infiltration of water enhances erosion. When sodicity occurs in the deeper subsoil, wetting of the soil leads to structural collapse and subsequent caving in. This leads to the formation of tunnels which upon widening form deep and wide gullies. Sodicity also strongly influences the availability and transformation of essential plant nutrients restricting plant growth. Salinization in many cases has led to abandonment of the irrigated lands. The Kimorigo and Kamleza irrigation schemes in Taveta Sub-district, Coast Province, for example, have been out of operation since 1996 due to salinity problems although some drainage systems have been installed. Part of the Kamleza scheme used to grow rice, now the loss in productivity has led to economic loss for the country through loss in crop production. Increase in crop production cost due to increased use of fertilisers and changing tillage methods increases production costs and energy required for ploughing. More investment from the Government is required for soil rehabilitation.

c) Nigeria: The irrigated cropped lands in the semi-arid, northern Guinea and Sudan savannahs (the highest concentration of irrigation projects in Nigeria) have been degraded due to salt accumulation in the soils (Hadejia, Kano and Sokoto-Rim valleys and Tungan Tudu and Kalmalo lake projects in the northwest, as well as Yau and Abadan irrigation schemes in the Northeast). At the moment, these areas are experiencing rapid decline and poor management and uncontrolled environmental pollution that may threaten the agricultural potential of the country. The quality of the soils and water in those locations has been deteriorating with serious effects on crop yields. Technologies and resources available to farmers for abatement have been meagre, particularly in the old projects

The adverse effect of increasing salinity on the environment due to indiscriminate shrimp cultivation can be gauged from a case study in the coastal district of Satkhira where intensive shrimp farming is practised by influential entrepreneurs. Shrimp farming started in Satkhira in the 1980s within areas protected by coastal embankments. Shrimp is grown in strongly saline water brought in through illegally dug channels across the embankments. Out of the 170 000 ha of agricultural land in the Satkhira District, almost 61 000 ha are already under shrimp cultivation presently. The fast expansion of shrimp farming 'ghers' (the local term for the shrimp pond) has severely affected the natural vegetation, human and livestock populations. The once green and lively southern part of the Satkhira District now has taken on the look of a 'salt desert'. The natural vegetation has almost vanished; planted fruit trees in hundreds of villages have died away. At least 2 million cattle died during the last 15 years due to a drastic shrinkage of the grazing grounds. Drinking water sources of the rural population have become polluted with saline water causing diarrhoea and other gastrointestinal diseases which affected 0.8 million human beings over the last 15 years. Thousands of hectares of agricultural land (mostly rice lands) have been abandoned due to saline seepage from the shrimp ghers, rendering 0.2 million farmers jobless. Many farmers have been compelled to sell away their lands at nominal prices, the number of landless farmers having increased in the process. According to the gher owners, only 2 labourers are needed for a 10 ha gher, whereas rice cultivation in a 10 ha farm could employ at least 25 agricultural labourers. Thus, for every 100 ha of land brought under shrimp cultivation, 230 agricultural labourers became jobless. While the individual gher owner may have enjoyed windfall profits, the damage done to the environment and the human populace would run into the billions in financial terms. In addition, shrimp cultivation has resulted in undesirable social conflicts as political influence and muscle power are often used to establish and maintain the ghers.

In case of crop agriculture, soil salinity is the most important factor in farmers' decision-making process. Usually 30-50 percent yield losses occur depending on the level of soil salinity. The cropped areas and production relative to the total land areas are lower in the saline region than in the non-saline region. Because of variations in the level of soil salinity and availability of water from rainfall, the cropping patterns are distinctly different in the eastern region (mild to moderate soil salinity, high rainfall) from those in the western region (relatively strong soil salinity, low rainfall); while two crops (Aus-T. Aman-Fallow) or even three crops (Aus-T. Aman-Rabi) at some places are common in the former, the dominant cropping pattern is Fallow-T. Aman-Fallow in the latter, the fallowing being due to high salinity throughout the year except in the wet season. Due to the unavailability of salt-tolerant HYV crops the farmers grow mostly local varieties for which the average rice yield in the coastal districts is much less than that in the other districts.

b) China: The negative effects of salinization in China are mainly manifested in the following impacts:

- **Salinization restricting utilisation of the land resources for agriculture**: Large areas of land could not be used due to high salinity. Xinjiang Autonomous Region is the largest region with severe salinity problems in China. The total area of the land in Xinjiang is consequently resulting in total abandonment of the projects. The impact of the involvement of research institutes in finding solutions to the problem has not been felt. Due to the severity of salinity development in these areas and plant nutrient exhaustion, the average yield per unit land area is extremely low, less than 1.2 tonnes/ha for cereals. As a result, the total produce of most farmers is not even enough to cover their annual consumption. Because of these situations, the economic condition of the larger mass of the population in affected areas has been gradually affected, leading to poverty and famine.

d) Tanzania: Salt-affected soils are regarded as problem soils in Tanzania but very little has been done in terms of their management. This is perhaps because most of these soils have been found in close proximity to normal soils. Therefore, farmers have had some choice as to where they wish to cultivate. However, in view of the increased population and change in land tenure it is inevitable that some 'unlucky' farmers will have to cultivate these soils intensively. Agricultural yields in most of the salt-affected soils have been low. For instance, in the irrigation scheme of Kileo, farmers could harvest up to 3.5 tonnes of maize per ha in the non-saline non-sodic soils. In the salt-affected soils, however, yields can be as low as 1.4 tonnes/ha. A similar trend was observed for beans. This situation is familiar in many areas affected by this problem. Farmers completely abandoned another irrigation scheme in Kirya, when levels of sodicity in the area became too high for them to harvest any appreciable yields from maize or beans. In the sugar estate called TPC in Moshi, northern Tanzania, nearly half the 6 000 ha of the estate are too sodic and saline for any sugarcane production. The estate of TPC falls in the arid zone at the foot of Mount Kilimanjaro. This zone is hot and arid with as little rain as 700 mm per annum. When irrigation water evaporates it brings with it salts which are deposited on the soil surface and hence the observed trend.

Notwithstanding the negative effects of salt-affected soils, such areas have provided many people in Tanzania with a livelihood. Salt mining is one activity directly associated with saline soils. Salt mining employs many people along the coast regions bordering the Indian Ocean, as well in many upcountry regions where such soils have sufficient amounts of salt for harvesting. Livestock keepers frequently graze their livestock on the salt-affected soils where agricultural crops are not grown. The soils in Lower Moshi, under the Kilimanjaro Agricultural Development Programme, though being saline and sodic, are used for paddy production, hence the need to screen for salt-tolerant crops as the strategy to utilise these soils.

Asia Region

a) Bangladesh: Biophysical elements such as soil, vegetation and animals have been greatly affected by salinity. Many soils became unproductive, poultry and livestock populations in the coastal region have been reduced due to a decrease in grazing grounds. The greatest damage to the environment and socioeconomic conditions of the local populace have been inflicted by unregulated shrimp enterprises. About 25 million of the total 125 million people of Bangladesh are seriously affected by soil and water salinity in the coastal belt.

165.8 million ha, of which more than 13 million ha are subject to salinity limitation. The total amount of potential arable land in Xinjiang is 9.8 million ha of which about 60 percent are problem land due to salinity. Even among the cultivated land, only 49 percent are free from salinity problem or with slight salinity limitation. The rest is land with moderate salinity limitation or severe salinity limitation, which counts for more than 50 percent of the cultivated land in Xinjiang. Salt-affected soils in the Song-nen Plain of Northeast China amounted to more than 3 million ha of which only 43.8 percent have currently been used for agriculture. The rest remains abandoned due to salinity hazards.

- **Secondary salinization causing contraction of agricultural land**: Human-induced salinization has strong negative impacts on development of sustainable agriculture. Salinization induced by irrational irrigation in Northwest China, in the Great Bend of the Huanghe River, and in the North China Plain are examples of agricultural land contraction owing to salinization. In early 1950s, due to irrational irrigation, more than one million ha of salt-affected land formed in just a few years. Salt-affected soils occupied only 11-15 percent of the irrigated land in the Hetao irrigation district of Inner Mongolia, in 1954. The rate increased to 22 percent, 31.6 percent and 58 percent in 1963, 1964 and 1973, respectively. Xinjiang has seen the largest land loss in China. A total area of 3.4 million ha of previous wasteland has been exploited during the last forty years. However, only 1.86 million ha remain under agricultural utilisation and 1.54 million ha were abandoned soon after cultivation owing to the development of secondary salinization.

- **Influences of salinization on yield**: Even in slightly and moderately salinized land, salinization shows its significant influences on crop yield. Salinity restricts uptake of water and nutrients by crops. In the North China Plain, crop yield reduction owing to salinization and alkalization ranges from 10 to 50 percent. In the Song-nen Plain of Northeast China, yield reduction due to alkalization is more serious, ranging from 4 to 85 percent. In some grassland affected by alkalization in Northeast China, pasture yield is only 750 kg per ha. In Xinjiang, loss of crops due to salinity reaches 200 million kg, and loss of cotton 25 million kg annually. In an irrigation district in Xinjiang. due to secondary salinization, the yield of crops per unit area decreases by 35 percent. Hence, high inputs associated with low outputs caused by salinization accounts for large agricultural and economical losses.

- **Influences of salinization on adaptability of crop planting and crop quality**: Salinized land is not suitable for many salt sensitive or moderately sensitive crops such as bean, broadbean, corn, sesame, sunflower, alfalfa, clover, etc. Salinization is often associated with poor fertility level of land. Photosynthesis of plants, its efficiency and rate of protein accumulation of crops could be inhibited by low water and low nutrient availability and specific ion toxicity associated with salinization, which results in poor quality of crops in varying degrees.

- **Influences of salinization on forestry and animal husbandry**: Salinization has caused forestry and grassland degradation. Mongolia and Northeast China are important pasture areas. Salinization in these areas results in serious pastureland degradation. The degraded grassland is characterised by less grass species, poor grass quality and quantity, low grass product, as well as thinner vegetation. In the Song-nen Plain, with 17 million ha of arable land, one-third is salt-affected in various degrees. On the other hand, more than two-thirds of the pastureland are salt-affected in the plain. One-third of pastureland is abandoned due to serious salinization in Baicheng region of the plain. Animal husbandry has become hazardous due to loss of pastureland, poor pasture quality and low quantity in these areas.

Salinization also causes environmental and ecological problems. Although impacts of salinization on ecological environment show differences in patterns and extent, the common character is that it leads to lower environmental quality and damage of natural resources directly or indirectly. Some impacts already exist and others show long-term hazards and will appear in the future, including impacts of salinization on soil properties and land resources, impacts on vegetation and climate, on environment of water resources, on tourism resources and on living beings.

Salinization has potential hazards to sustainable agricultural development as follows: a) salinization causes reduction of reserve land resources; b) amelioration of salt-affected soils, especially Solonetz and Solonchak in arid zones, is restricted by high investment rate required; c) salinity problems influence utilisation of water resources for agriculture; d) salinization reduces benefits of water conservancy projects.

c) **Pakistan:** Besides reduced crop yields, desertification and land going out of production, the impact on local population due to salinization has been observed to be poor living conditions, health problems, crumbling mud and brick houses, reduced life expectancy in females, and difficulties in transportation and communication.

d) **Indonesia:** As the lands with relatively fertile soils have mostly been utilised, agricultural activities have been extended to coastal salt-affected soils. Crops productivity in coastal saline tidal lands can only be made by appropriate management practices that need government investments. Development of salt-affected soils has resulted in declines in yield of both cash and food crops in Indonesia. Salinity development and its attendant off-site effects of rural poverty, food insecurity, high cost of food production and rural-urban migration are now widespread socioeconomic impacts felt in coastal salt-affected regions in Indonesia.

e) **The Philippines:** Farmers located in six coastal municipalities of Camarines Sur, Philippines (most salt-affected region in the Philippines) were interviewed covering the wet and dry season cropping. On average, the farmers were 45 years old and had been farming for 17 years, and were well aware of salinity intrusion into their farms. The farms averaged 2.2 ha. About 63 percent of the farms are owned, 32 percent are shared, and 5 percent are leased. All of the farms were planted to high yielding rice varieties, applied with varying rates of inorganic fertilisers. Except for very few farms, all were planted twice a year but those with moderately to severely salt-affected soils hardly produced yields. Because of limited rain water supply during dry season, farmers provide supplemental water from pumps but found to be salty due to seawater intrusion and the effect of seepage from adjacent salt-affected areas. Farmers have continued to grow rice, as they have no alternative crops. A few, however, had expressed the desire to try watermelon, as water is limited during the dry season.

The farms that were not affected by salinity produced 3 tonnes/ha/season. On the other hand, farms affected with varying levels of salinity showed a clear decline in the rice yield. Even in slightly saline farms yields were 40 percent lower during the wet season than farms free from salinity. Yields in the dry season were dramatically lower than the wet season because of saltwater intrusion. The cost and return analysis revealed that rice cultivation may be only economical in slightly salt-affected farms during the wet season as indicated by the net return. Planting during the dry season exposed the farmers to high risks.

Financial uncertainty, particularly during the dry season, has motivated farmers to seek other non- and off-farm sources of income to support their families consisting on average of six members. They utilised their productive time for other economic activities since rice farming in their salt-affected farms was not of economical benefit. A few farmers knew that there are specific salt-tolerant varieties but claimed that these are not readily available in their locality.

The farmers, who depend on irrigation, are fully aware of the need to prevent saltwater intrusion into the irrigation canals, but they do not have the technical programme to control. On the other hand, those depend on rainwater utilised water in the creeks but are affected by saltwater intrusion.

f) Thailand: Environment and socioeconomic impacts of salt-affected soils are of great concern. Although inappropriate land use such as salt making and brackish water shrimp farming gives farmers high profits, they can cause serious impacts on adjacent areas and the environment. This includes reduced capacity of the land to provide long-term economic production, increased investment cost and problem of soil and water management.

In the Northeast region, inland saline soils are constantly expanding. Inappropriate land use results in soil salinization from the movement of saline water, and reduction of arable land and forest areas. A socioeconomic study carried out at Nakhon Ratchasima Province showed that 31 percent of salt-affected areas have gone out of cultivation. A systematic sampling of 427 farmers from 31 villages was conducted to find out the farmers' opinion on the prevention and improvement of salt-affected lands. Most of the areas are owned by large landholders (>3.2 ha). Seventy percent of these large landholders agreed to have their land reforested to prevent soil salinization while fifty percent of the small landholders (<1.6 ha) refused. The reasons were lack of expertise, excessively saline water, inadequate manpower and lack of capital.

The major problem created by expansion of shrimp farms is increased pollution of the environment. Soil salinization by shrimp culture was reported to severely affect 30 750 ha in Nakhon Si Thammarat and Songkhla Provinces. In the Central Plain, its impact is being scattered on adjacent shrimp ponds. Because of very strong salinity, the farmers have been forced to leave their cultivated lands. Moreover, the discharge of harmful by-products from shrimp ponds like excess feeds, fertilisers, chemicals and antibiotics have affected the environment in many ways. The effluent produced by shrimp farms has been reported to carry water discharge, total organic carbon, total nitrogen and sludge (wet weight) of 67 000, 89.6, 5.1 and 134 tonnes/ha/crop, respectively.

The Government reflected the deep concern of the country with regard to the conflict that has exploded between rice and shrimp farmers in arable freshwater areas, and the extent of salinity problems faced by the small farmers, with negative effect on their income and yearly agricultural production loss, and with the expected negative impact on food security of the country. Therefore, on 7 July 1999, the Prime Minister (using Section 9 of the National Environment Quality Act BE 2335 introduced in 1992 by the National Environmental Board) announced the Government's decision to ban shrimp cultivation in freshwater zones within 120 days. He also announced Section 10 of the same Act to reclaim the land after this period.

g) **Viet Nam:** Impacts of salt-affected soils include:

- At some river mouths, due to the scanty freshwater flow, tidal water penetrates into the hinterland, damaging nearby crops. Also, due to the drying up of the rivers, there is not enough freshwater to dilute the waste water discharged from leaching of salt-affected soils, as well as from industrial areas or cities, thus causing pollution of the water resources and accordingly, the loss of important aquatic products.

- For the safety of reservoirs in the rainy season the water must be regulated by draining out excess water through spillways. The storing and draining affect the water flow system of the rivers where reservoirs have been built, and may cause long drown-out flood threatening dams, dykes, and the lowlands. Some localities in the river basin which were easily drained before the dam are now uncultivable because the water level is always higher than ground level which makes drainage practically impossible.

- Irrigation and drainage of salt-affected soils also affects the environment. The reclamation of lowlands, barren lands, and submerged forests has affected natural life there. The digging of canals in the saline and acid sulphate lands makes the neighbouring lands saline and acid too. Especially in the rainy season, floods bring acid water to nearby areas, damaging the crops. The draining of water in the rainy season also does harm to aquatic life. Many species, found in abundance in the past, are now almost extinct.

- Mangroves for sea dyke protection in central Viet Nam: although Mangrove forests are not abundant in central Viet Nam, they fulfil a very important role in the protection of sea dykes, prevention of coastal abrasion, as buffers against typhoons, as wood reserves and as fishery habitats. Salinity development and shrimp farming in areas adjacent to the mangroves and the consequent drainage or seepage of salts from salt-affected areas or shrimp ponds to these mangroves destroyed large areas of coastal mangroves in Viet Nam. By 1993, only 38 percent of the mangrove forests which had existed in Minh Hai Province 10years before remained intact from the onslaught of shrimp pond development. Assuming that this ratio applies to mangrove wetlands in the whole Mekong Delta, in the Red River Delta and the Northeast, shrimp farm development (seepage of salts from shrimp ponds and salt-affected soils) has led to the destruction of some 148 000 ha of mangrove forests in Viet Nam during the last decade. This implies an economic loss of US$277 million. Even if the loss is attributed to only half of the non-Mekong Delta mangrove areas because their problem soils are much less, the total economic loss of US$209 million is still considerable.

Europe Region

a) Hungary: Salinity/alkalinity are among the most significant limiting factors of soil fertility in Hungary. There are only a few countries in the world, and none in Europe, where the ratio of salt-affected soils is as high as that of Hungary. More than 95 percent of the existing salt-affected soils are situated in the valley of the Danube and the Tisza, which is significantly reflected by the reduction of 30 percent of the total agricultural production of the region, with clear effects on the income and the economic conditions of local farmers. Even larger effects on the environment are observed by the deterioration of groundwater conditions; shallow or easily rapidly rising water table, high salt concentration and unfavourable ion composition are threatening larger areas as potential salt-affected soils.

b) Romania: The areas with salt-affected soils are characterised by a lower level of socio-economic sub-structure development and living standards as compared with the surrounding areas. The biophysical and socioeconomic impacts of the occurrence of soil salinization is reflected by low biodiversity of the affected areas and very low income of local farmers. As a result of the fast transition from the former socioeconomically centralised system to the present free market economy, attention of the government for the reclamation of salt-affected soils is very little. One can notice severe problems with such soils. For instance, on an area of 100 000 ha of such salt-affected soils in Arad, Buzau and Braila counties, the absence of concern for the application of adequate measures led to a significant decrease in crop yields, so that, between 1989 and 1998, this was 74 percent for barley (from 5 757 kg/ha in 1989 to 1 480 kg/ha in 1998), 59 percent for winter wheat (from 5 340 kg/ha in 1989 to 2 210 kg/ha in 1998), 50 percent for sugar beet (from 30 000 kg/ha in 1989 to 15 000 kg/ha in 1998), 65 percent for alfalfa (green matter) (from 31 697 kg/ha in 1989 to 11 000 kg/ha in 1998) and 100 per cent for soybean.

c) Turkey: Most of the areas under irrigation do not have enough drainage systems. Ç ukurova Plain was one of the most productive plains in Turkey. After a couple of decades of irrigation without proper drainage, salinization problems have been observed. Harran Plain (one of the most important irrigation areas in the Southeast Anatolian Project) also has potential salinity risk at the level of 30 percent because of the insufficient drainage systems. This caused reduction in food production of 30 percent in these regions with significant effects on the income of local agricultural farmers.

Half of the irrigation systems in Turkey are controlled by government agencies. The rest are controlled by the private sector. In the latter sector water use efficiency is very low. Because of the economic problems, especially in rural areas, and also lack of education, some of the forested lands and pastures were altered to agricultural lands. These degradation processes caused more runoff from highlands to lowlands. This situation brings about change of water-salt balance in lowlands causing salinity development and lower agricultural production.

The land tenure system with high profits, without taking precautions related to management practices, plays an important role in increasing salinization and gradual decline in soil productivity. Small landholdings, smaller than 10 ha, consist of 81.8 percent of the total landholdings in Turkey. These holdings cover 42 percent of the cultivated areas. Average landholding size is around 4.38 ha. This situation is one of the indirect factors causing secondary salinization. Lack of land consolidation is one of the major problems related to possible reclamation and management of salt-affected soils in Turkey and, therefore, continuing decline in soil productivity. It is estimated that the arable land demand is currently about 2.4 persons/ha, which will increase to 5 persons/ha in the near future. Therefore, there is an urgent need to successfully manage salt-affected lands and water resources in Turkey.

Latin America Region:

a) Argentina: Fruit horticulture covers almost 50 percent of the irrigated crops, sugarcane occupies close to 15 percent and alfalfa and other forage crops cover 11 percent of the productive irrigated areas. Topographic irregularities and irrigation practices generate salt-affected soils in all the agro-ecological regions of the country. Irrigated soils are mainly located in the alluvial and/or colluvial river valleys of the arid and semi-arid regions. Mendoza Province presents the largest irrigated area with 443 500 ha (26.9 percent of the total irrigated area) followed by the provinces of Buenos Aires and Santiago del Estero with 176 500 ha (10.7 percent) and 163 900 ha (9.9 percent), respectively. San Juan Province shows the highest proportion (79 percent) of salt-affected soils of irrigated area. The problem is widespread in Mendoza (near 50 percent), Santiago del Estero (54 percent) and other provinces have a very high proportion of salt-affected irrigated soils. In the mentioned areas crop production decreased in the last few years from 20 to 30 percent, particularly of the mentioned fruit, sugarcane and forage crops, with severe side-effect in several cases on the living standards and incomes of local farmers.

The construction of poorly planned irrigation works for crop production caused man-made salt-affected soils, especially as a consequence of limited and incomplete drainage networks. These problems have been detected in the Mendoza-San Juan area, the provinces of Santiago del Estero and Río Negro, and the Lower Valley of the Colorado River in the province of Buenos Aires.

The need for food requires more attention being given by the government to proper management and rehabilitation of such salt-affected soils and the careful use of poor quality irrigation water.

b) Brazil: The salinization problem has to be faced as a serious one in the country, particularly in the semi-arid part of the Northeast, e.g. in the Sao Francisco River Basin, because of the great risk for farmers cultivating their irrigated land without proper management practices. In these regions, crop production has been affected with clear reflection on the agricultural production of local farmers, pushing some of them to abandon their land and look for other sources of income to cover the needs of their families.

c) Cuba: The negative effects of salinization in Cuba are mainly manifested in the following impacts:

- Salinity development negatively affects the agricultural production, causes decrease of crop yields, and can make soils totally unproductive. Therefore, it is necessary to pay attention to the fact that more than 15 percent of the agricultural areas are in danger of turning into salt-affected soils. About 1-2 percent of salt-affected soils in Cuba remain abandoned due to high salt concentrations.

- Human-induced salinization often accompanies development of the irrigation and other human activities, making salinization hazard more severe in agriculture. This problem always affects regions with high population. In Cuba, salinization has a great impact, since salt-affected soils occupy fundamentally the plain areas, where the mechanisation of intensive agriculture is more easily developed, and because greater rural populations are concentrated in these areas. Salinization induced by irrational irrigation with poor drainage in the Cauto and Guantánamo Valleys in the eastern part of Cuba is the example of reduction in the agricultural production due to salinization.

- In strongly salt-affected soils the poor crop growth, low yield and poor quality of agricultural produce are very common. In Granma Province, crop yield reduction owing to salinization and sodicity ranges from 20 to 40 percent, and in Guantánamo Province yield reduction is more serious ranging from 10 to 70 percent. Hence, high inputs associated with low outputs caused by salinization results in large losses to agriculture and economy. The direct losses in the Guantánamo Province are estimated at US$4 million annually. If according to the total area and the degree of affectation, with simple extrapolation of this estimate to the rest of the provinces, the calculated national losses will come to US$150 million annually. This approximate loss of income includes only damages in productive salt-affected areas, but excludes the loss originating from abandoned saline areas.

- The adaptability of crops is influenced by salinity. Salinized land is not suitable for many salt-sensitive or moderately sensitive crops such as beans, corn, sunflower, etc. Through breeding of salt-tolerant species, planting of crops is possible in salt-affected land. However, there can be losses in quality and yield of crops.

- Salinization has caused forestry and grassland degradation. The area of Granma Province is 277 181 ha. The largest area of salt-affected agricultural land in this province is located in the Cauto Valley, which at the same time represents an important agricultural production zone in the eastern part of the country. About 45 percent of this valley are dedicated to pasture legumes and forage for animal production. Because large areas in the Cauto Valley are severely affected by salinity, the valley suffers considerable loss in total agricultural production, particularly in forage value. The degraded grasslands are characterised by fewer grass species, poor grass quality and quantity, low grass product, as well as thinner vegetation, influencing animal husbandry.

- At national level, the consequences of soil salinity are manifested in terms of decline in agricultural production, which affect the gross domestic product. It is difficult to calculate the rehabilitation cost of salt-affected soils, since it depends on several factors such as the salt concentration and ion types, the level of the water table, hydrophysical soil properties, available technology, reclamation materials, etc. Based on international information, US$6 000/ha is taken as the rehabilitation cost of severely affected land in Cuba; US$2 000 for the strongly saline, US$1 000 for the moderately and US$500 for the slightly salt-affected soils. Therefore, it is necessary to invest some US$1 500 million to recover the salt-affected soils.

- The rehabilitation of salt-affected soils must be approached according to a strategic plan at the national level, taking into account the available resources and an investment recovery plan of reasonable periods required. First of all the rehabilitation of moderately salt-affected lands must be carried out. The strongly salt-affected areas do not occupy more than 10 percent of the total affected areas (1 percent of the country's agricultural areas), but their recovery would take 40 percent of the financial resources and 60 percent of the additional water for the leaching. On the other hand, though the necessary expenses to eliminate salts of the slightly salt-affected soils do not surpass 15 percent of the broader expenses, the increase in production will remain masked by the effect of additional complementary factors (levelling, drainage, etc.) that the agricultural company should compulsorily carry out to improve production. Those areas should be improved gradually by the producers with the employment of the adequate cultural methods.

- Besides the very significant impacts on agricultural production, salinization also causes environmental and ecological problems. Although impacts of salinization on the environment show differences in patterns and extent, the common character is that it leads to lower environmental quality and damage of natural resources directly or indirectly. Some impacts already exist and other long-term hazards will appear in the future, including impacts of salinization on soil properties and local resources, on vegetation and climate, on environment of water resources, on tourist resources and on living natures.

d) **Mexico:** A poll among local farmers was carried out in the Rio Fuerte ID (1998). It was to analyse the effect of soil salinity on local agricultural production, from the farmers' point of view. Farmers believe soil salinity is solely inherent to the soil and they do not know why shallow water tables occur. The poll registered that 94 percent of those interviewed had some problem related to soil salinity and poorly drained soils in their fields.

Surprisingly, land tenure is correspondent with salinity and drainage problems. The 'ejido'-type land tenure presented the most affected soils compared to the private property (78 percent vs. 22 percent). Ejido is some sort of public land granted to a farmer in order to be exploited just by himself; this land is not allowed to be sold.

The impact of soil salinity and drainage deficient soils on land possession of affected soils is that about one-third of the landowners are transferring their lands; and this means renting, borrowing or having co-partnership for the land use, without losing their legal rights. This situation ultimately leads farmers to substitute agriculture as the main source of family income. Another income sources are day-labouring, livestock production (family scale), diverse jobs in the cities or in the big towns, self-employment, and if no other chance is available, migration. Other important factor is that young people tend to move to the urban areas because agriculture is not an attractive activity for them anymore.

Near East Region:

a) Egypt: Scarcity of arable land and decrease in per capita arable land area are attributed to many factors including population growth, soil contamination and development of salt-affected soils. Productivity and agricultural sustainability can be decreased by 9 percent and if the present trend in salinity development processes continue yield reduction may reach 16 percent by 2020. This will cause reduction in return from capital investment and labour inputs. Lower income of the small-scale farmers from agriculture will force them to work on land of others or migrate to cities or other countries. The potential impacts of salt-affected soils on water quality include the enrichment of water with nutrients, sediments, pesticides, salts, etc., influencing human health and creating ecological risks; lowering the suitability of water for irrigation and the navigability of rivers and increasing the cost of flood control and dams. In many cases, wastewater is used after minimal treatment even untreated water is used directly, threatening public health and exposing agricultural works and crop consumers to pathogens and toxic minerals. Potential hazards caused by reuse of drainage water are the contamination of crops leading to decrease in crop production and infection to humans and animals. The toxicity of drainage water used for irrigation is higher than the allowed toxicity limit for plants (pesticides and fertiliser drained from the soil to the drainage system).

b) Iran: It is to be noted that farmers in salt-affected areas are usually less fortunate in terms of economical capabilities. Generally, the worst salinity situations in Iran are present where farmers are relatively poor and face economic difficulties. Therefore, they are unable, even reluctant, to employ new technologies without financial help from the government. Some of them think that nothing can improve the yield under their conditions; therefore, they do not care much about their crop. This negative attitude aggravates the impacts of salinity. It is important that credit policies be supported by the pertinent government agencies to help farmers overcome the problems associated with the harsh environment and make greater contributions to the agricultural development of the country.

The future life of these people is at stake and highly dependent on what happens to their soil. Therefore, any sustainable development programme for the rural areas in Iran should seriously pay attention to the problems caused by the salinity of soil and water resources.

Among the major obstacles that prevent the achievements of high yields in Iran is the salinity of soil and water. It is estimated that in areas where salinity is present, average yield losses due to this problem may be as high as 50 percent. The problem of salt-affected soils poses one of the most serious threats to food production and sustainability of natural resources in the country.

c) Syria: The salinity problem in Syria is considered to be the major constraint to agricultural production. It has led to lowered productivity compared to world standards. A substantial portion of the irrigated lands is affected with different levels of salinization.

Waterlogging is the second major problem that affects soil productivity in Syria. The Euphrates basin projects are the main agricultural projects in Syria, where salinity is affecting 30 percent of these lands. In the lower Euphrates Basin in Deir Zor Province, salinity has resulted in 44 000 ha going out of agricultural production with salinity reaching 16 dS/m, in addition to 30 400 ha being highly affected with too low productivity. The soils of the lower Euphrates Basin (120 000 ha) are totally saline. Salinity is spread out in the Central Euphrates Basin (28.500 ha). Saline lands in the Upper Euphrates Basin (Raqqa Province and Maskane Plains) are estimated as 15 000 ha, out of 64 000 ha irrigated lands. Due to the problems created by shortage of water and cultivable land resources, population pressure and development of salt-affected soils, particularly in irrigated areas, self sufficiency in food remains a difficult objective in Syria. Production constraints in irrigated salt-affected soils are all faced by the farmers in using such land that resulted in lowering of their income from agriculture production and even abandoning many farms. The number of abandoned farms has been increasing rapidly with severe effect on national agriculture production.

d) **Tunisia:** Salt-affected soils are found in all the territory, but more so in the central and southern parts of the country, and in the arid and semi-arid regions such as in the Mejerdha Valley. The immediate impact of salinity development in these areas is either a decline in crop yield or an increase in the level of the inputs needed to maintain or improve yields which cannot be afforded by local small-farmers. The resultant low income and food security in affected areas results in movement of high number of people from rural areas to urban centres seeking employment or additional sources of income.

1.9.2 Associated members

a) **Australia:** In contrast to many other natural resource degradation problems that are important in Australia, salinity has more serious off-site costs on urban populations, infrastructure and environment. Awareness of these wider effects and the larger costs has, through public education programmes, changed the issues from a purely 'farmer's problem' to a problem shared by the whole community. Salinity problems are coming to be ranked as the very highest priority natural resource management issue in Australia.

Just as there is great variation in the estimates of the areas of land affected by salinity, there is similar variation in the estimates of the economic impacts. Estimates are difficult due to the wide range of off-site costs of salinity.

The true cost of damage to vegetation including highly valued environmental sites, wetlands, fauna and flora diversity is quite high. It is predicted that in the state of Victoria, in a 'do nothing' scenario, there will be a significant decline in the quality of 44 000 ha of state and internationally significant wetlands, in excess of 100 species of flora and 100 species of fauna which will be seriously threatened over the next 15 to 20 years.

Off-site water quality effects are due to effects on water supply and water treatment for urban uses, effects of shallow saline water tables on telephone cables, gas pipelines, roads and bridges and any industries that use water for example for processing products or for cooling purposes. Urban effects show through damage to parks and gardens, domestic hot water services, motor vehicle radiators, damage to building foundations. In the Southwest

WA cropping and grazing zone, salinity of streams in agricultural areas has been rising – in 1985, 43 percent of runoff were suitable for human purposes. By 1996, 52 percent of this runoff was no longer suitable for human purposes. Capital costs of providing alternative water supplies due to this salinization of surface water has been calculated at US$143 million.

In Victoria, the impact of deterioration of surface water quality to urban and industrial users is estimated at $18 million/year.

Declining incomes in rural areas affected by salinity also have significant social and economic effects throughout rural communities.

To offset some of the costs of salinity control, better land management and reduction of soil erosion and nutrient runoff from land (with reduced eutrophication of streams) should be implemented.

b) Canada: Root-zone salinity causes plants to grow slowly and produce less. Studies also show effects on the final height of wheat plants at harvest as well as their yield of grain. Average height declined by increasing salinity, but more gradually than the declination in relative yield. A figure of 2.3 million ha, based on federal and provincial soil survey data, have been estimated for severely saline soils where yield of non-irrigated crops would be lowered by 25 percent or more. The 1994 wheat crop was grown on 10.5 million ha across Western Canada and produced 22 million tonnes of grain valued on average at US$214/ton. As the effects of slight to moderate salinity reduced yields by an average of 12 percent, the loss of revenue, equalled to about US$113. If Canada's research and development cost to combat soil salinity approaches US$1 million annually, and with these efforts, the 12 percent is reduced even to 8 percent, the benefit-cost ratio of this investment would equal 38 to 1 annually.

c) Colombia: Salinity areas are located in the north coast between Panama and Venezuela borders, and in the Andean Valley, particularly in magnesium-affected areas. In these areas the soil became more dispersed and less permeable to air and water causing dense impermeable crusts that greatly reduce seedling germination and water penetration. The reduced infiltration of water enhances the erosion effects in these areas. The quality of the soils and water in these locations has been deteriorating with serious effects on crop yields. Technologies and resources available to farmers for abatement have been meagre, consequently resulting in total abandonment of their lands. Due to the severity of the problem developed in these areas and plant nutrient exhaustion, the average yield per unit land area is extremely low, less than 1.2 tonne/ha for cereals. As a result, the total produce of most farmers is not even enough to cover their annual consumption. Because of this situation, the economic condition of the larger mass of the population in affected areas has gradually deteriorated, leading to poverty.

d) **India**: Salinity in India is a major issue affecting the sustainability of irrigated as well as non-irrigated areas particularly in the states of Rajasthan, Gujarat, Haryana, Uttar Pradesh, West Bengal and Orissa. There are both on-site and off-site effects on infrastructure, environment, public health and other means of livelihood. Economic losses due to salinity in the state of Gujarat alone have been estimated at US$225 million.

- The impact of salinity manifests itself in several ways. As the salinity increases, not only does the productivity decline but sensitive crops also go out of cultivation and are replaced by salt-tolerant, low value crops and other plant species. Salt-affected areas in southern Gujarat in Ukai Kakerpar Canal Command or coastal areas around Ramnathpuram in Tamil Nadu are some of the examples where in place of high value crops, *Acacia juliflora* flourishes. In extreme cases, soil is hardly able to support any period of vegetation and only some salty bushes and halophytes are able to survive.

- Due to very poor infiltration rates in alkali-affected watersheds, the monsoon rains that occur in the form of concentrated storms create surface water ponding and a large percentage of the rainfall is converted into surface runoff.

- Degradation of surface water quality: during the initial monsoon period salt concentration in the surface runoff may be as high as 6 dS/m. Development of waterlogging and salinity affects the groundwater quality in several ways. When the water table is high the water, which is laden with fertilisers, pesticides, salt and bacteria, does not have the opportunity to pass through enough soil profile before it joins the groundwater. Rural communities in India are dependent on local groundwater for domestic water supply. This is a serious problem in several places including parts of Haryana and eastern Uttar Pradesh.

- Deterioration of infrastructure: rise in the water table leads to waterlogging and excessive wetness of the soil reducing its bearing capacity and causing sinking of roads and buildings. Also, foundations of buildings are affected by salt that ultimately leads to their collapse. This situation exists in parts of Haryana, Punjab and Karnataka where roads in the waterlogged salt areas are in a bad shape and buildings have been damaged.

- The consequences of land resource degradation are being witnessed at the farm, regional and national levels. At farm level, the adverse effects generally constitute a threat to sustainability of land resources and decrease in farm production. The decrease in farm production may occur because of a decline in resource productivity, abandonment of crop production or cutback in resource use. A few farm-level studies in different command areas have shown that pure yield and income effects of salts in the soil were quite high. At regional level, the consequences are normally in terms of labour displacement, widening income disparities and adverse effect on sustainability of secondary and tertiary sectors. At national level, the consequences of soil salinity and waterlogging manifest themselves in terms of decline in agricultural production, which affect gross domestic product. It may also bring down the export potential of important crops or increase the import bill.

e) Italy: Irrigation with saline-sodic water is practised in Sicily in many areas where this water represents the only source of available water, causing the development of secondary salinization and sodication in large areas, groundwater salinization and consequent reduction in crop yield and income of local farmers.

f) Spain: Salt-affected soils show harsh conditions for normal plant growth due to a) plant osmotic stress caused by high ionic strength of soil solution, b) specific ion toxicity, 3) unfavourable physical conditions and combinations of these. Biota living in these soils is reduced and crops are affected in various degrees, reducing yield with increasing salinity.

Finally the production is so low that farmers abandon their lands. In many irrigated areas in Spain and in the Comunidad Valenciana in particular such as in Torreblanca, Castellon, the high productive potential of their soils is seriously threatened by increasing salinity.

The salinity occurrence, combined with severe drought in the southern part of the Comunidad in the past years, has led not only to the crop loss but even to some tree loss. The crops cultivated in salt-affected soils are melons, tomato, cotton, artichokes, asparagus, palm trees (in order of increasing salinity), and rice in flooded salt-affected soils. Decrease in yield is quite noticeable particularly under mismanagement (e.g. lack of adequate drainage system). In non-cultivated salt-affected areas that include some Natural Parks, reeds, *Typha dominguensis*, *Juncus* and halophytes are extensive. Halophytes are used for livestock feeding.

g) Sudan: In salt-affected soils located in the low rainfall regions in northern Sudan along the River Nile, south Khartoum, north Gezira, the Managil Scheme and the White Nile Schemes north of Kosti, the production potential of the soils has deteriorated with serious effects on crop yields. Technologies and resources available to farmers are very limited, consequently resulting in total abandonment of their lands. Due to the severity of the problem developed in some areas, the average yield per unit land is extremely low, about 40 percent of normal soils. As a result, the total produce of most farmers is not even enough to cover their annual consumption. Because of these situations, the economic condition of the larger mass of the population in affected areas has been gradually affected, leading to poverty, famine or migration of high numbers of people from rural areas to urban centres seeking employment or addition sources of income.

h) Uzbekistan: The disappearance of the Aral Sea, the fourth greatest lake on earth is well known to the world. Since the 1960s, when the full-scale development of cotton production through irrigated agriculture in Central Asia was started, the irrigated area in Central Asia increased from 4.5 million ha to 7 million ha. The population in the region rose from 14 million to 50 million. The water requirements for the economy rose from 60 to 120 cu km per year, of which 90 percent for irrigation. The excessive use of water by irrigation led to the gradually drying up of the Aral Sea and to the desertification of its deltas. Its waters changed from brackish (10 g salt/litre) to hyper-saline (40 g salt/litre), making it an unsuitable habitat for most of its often endemic species. During the last 20 years, the lake level sank gradually by 17 m. The people in the immediate vicinity of the sea and the river deltas suffered catastrophic socioeconomic consequences including: complete loss of the economical importance of the lake (fishing and navigation disappeared); degradation of the lake and delta ecosystems and loss of biodiversity; elimination of large agricultural areas in the deltas due to insufficient freshwater and increasing salinization of the soils; increased difficulties of producing good quality drinking water. These led to a drastic decline in employment possibilities in the vicinity of the lake and a dramatic decline in the health situation.

There is a direct relationship between yield of agricultural crops and salinization. Crop capacity losses due to soil salinity in cotton yield reaches about 18-26 percent to 43 percent in severe cases in about 28 percent of the 4.3 million ha irrigated lands, that is more than US$200 million per year. The same tendency is seen also for food crops (cereals, etc.). Increasing soil and water salinity is a serious threat for the rural population.

According to the World Bank estimation, up to US$2 billion (about 5 percent GNP of Central Asia) are lost because of soil salinity.

Basically two major bottlenecks threaten the productivity and sustainability of irrigated agriculture: constrained farmers' incentives to improve production and productivity and the deterioration of the production base. The lack of incentives and funds for proper operation and maintenance (O&M) and rehabilitation of irrigation and drainage (I&D) infrastructure has led to serious deterioration of the irrigation and drainage systems (off-farm and on-farm), weaknesses in canal operations and management at all layers within the irrigation system, huge water losses, widespread and severe water and soil salinization and declining crop yields. It is estimated that the deterioration/losses of the resource base for agricultural production is costing the country US$1 000 million annually.

Strengthening of geological cycle led to worsening of river water quality and pollution of agro-landscape, mainly in the low stream of the Amu-Darya and Syr-Darya Rivers, particularly serious problem in the low stream of the Amu-Darya, where the river is the main source of potable water supply and irrigated agriculture. Hundreds of drainage lakes have appeared in the desert filled with salty runoff. A large volume of salt enters drainage lakes or else drainage water returned to the rivers. About 60 million tonnes of salt are added annually to the rivers in this way, polluting river water. For example, Yuzhny Collector brings 13 million tonnes of salts every year into the Amu Darya River.

The resulting consequences for biodiversity are gloomy: from the original 178 animal species that lived in the deltas, only 38 species remain. The remaining fish population has dwindled. Game, birds and other wildlife, including species of ducks, swans, pelicans, cormorants, muskrats, and deer are becoming rarer.

Through the disappearance of most of the once vast areas of soil-retaining black saxaul woods, tugay forests and reeds and the consequent desertification, many of the original habitats have disappeared.

The socioeconomic consequence of the ecological crisis of the development of salt-affected areas in Uzbekistan is expressed in loss of large part of biodiversity, poor vegetation, fishery, stock breeding and pasture stock breeding formation of salt and dust storms, worsening of domestic - potable water quality, changes of climate and population health. The index for sickness prevalence for both adults and children in Karakalpakstan can be considered as very high compared to other regions. This is especially the case of Muynak, Shumanai and Karauzak Districts of North Karakalpakstan, with a dramatic increase of tuberculosis, nervous system diseases, anaemia, rheumatism, bronchitis, arthritis, etc.

1.10 Management and rehabilitation of salt-affected soils:

Salt-affected soils exist under a wide range of hydrological and physiographical conditions, soil types, rainfall and irrigation regimes and different socioeconomic settings. Therefore, there is no single technique or agricultural system that will be applicable to all areas and conditions.

Management of salt-affected soils requires a combination of agronomic and management practices, depending on careful definition of the main production constraints and requirements based on a detailed, comprehensive investigation of soil characteristics, water monitoring (rainfall, irrigation water and water table), and a survey of local conditions including climate, crops, economic, social, political and cultural environment and existing farming systems. Management of salt-affected lands for agricultural use is largely dependent on the water availability, climatic conditions, crop standing and the availability of resources (capital, inputs and time)

Several practices should be combined into an integrated system that functions satisfactorily for different production constraints and soil types to give higher economic benefit on a sustainable basis. Summaries of the hydraulic, physical, chemical, biological and human aspects to improve productivity of salt-affected land are discussed below. The mentioned management technologies are only those practised within the FAO collaborative projects with the national institutes participating in the Network.

1.10.1 Hydraulic practices

Leaching
To prevent the excessive accumulation of salt in the root zone, irrigation water (or rainfall) must, over the long term, be applied in excess of that needed for ET and must pass through the root zone in a minimum net amount. This amount in fractional terms is referred to as the leaching requirement. Leaching requirements should be minimized as far as possible in order to prevent raising the groundwater and minimize the total load to the drainage system. Leaching requirements of 10 and 20 percent can be used depending on the degree of existing salinity.

Drainage
When underlying layers are permeable and relief is adequate, natural drainage may function well. Since such conditions are rare in areas where saline and sodic soils occur, a drainage system will usually be required. Various types of drainage are used all over the world: <u>surface</u> drainage in which ditches are provided so that excess water will runoff before it enters the soil; <u>subsurface</u> drainage for the control of the groundwater table at a specified safe depth, consisting of open ditches or tile drains or perforated plastic pipes; <u>mole</u> drainage where shallow channels left by a bullet-shaped device pulled through the soil can act as a supplementary drainage system connected to the main drainage system (open or closed); and <u>vertical</u> drainage by pumping out excess water from tubewells when the deep horizons have an adequate hydraulic conductivity. The depth and spacings of the drainage system should be based on soil type (soil permeability, the existence of hardpans, or impermeable layer, etc.) and the local economic consideration.

1.10.2 Physical management

Several mechanical methods have been used to improve infiltration and permeability in the surface and root zone and thus to control saline and sodic conditions, including land levelling, deep ploughing and tillage, subsoiling and planting procedures.

Land levelling to achieve a more uniform application of water for better leaching and salinity control.

Tillage for seedbed preparation and soil permeability improvement.

Deep ploughing is most beneficial on stratified soils having an impermeable layer. It loosens the soil aggregates, improves the physical condition of this layer and increases air space and hydraulic conductivity.

Planting procedures Special planting procedures that minimize salt accumulation around the seed such as planting on sloping beds or raised furrows in single or double rows are helpful in getting better stands under saline conditions.

1.10.3 Chemical practices

These include using chemical amendments and mineral fertilisers. Using chemical amendments neutralises sodic soil conditions (exchangeable Na and any sodium carbonate), followed by leaching for removal of salts derived from the reaction of the amendments with sodic soils. Gypsum, sulphur and sulphuric acid are commonly used. Since the benefits expected from reclamation of salt-affected soils would not be obtained unless adequate plant nutrients are supplied as fertiliser, the proper types and balanced amounts of mineral fertilisers should be used.

d. Biological practices

The biological practices include using organic matter, farm manure, growing legumes, mulching, crop residue and selection of salt-tolerant crops:

Organic manure incorporated in the soil. This has two principal beneficial effects on saline and sodic soils: improvement of soil permeability and release of carbon dioxide and certain organic acids during composition. It also acts as a source of nutrients.

Mulching to reduce evaporation losses and thus decrease or prevent soil salinization.

Crop residue application. This is one of the easiest methods to improve water infiltration, especially for small farmers who do not have the resources to implement more costly corrective measures.

Salt-tolerant crops. Judicious selection of crops that can produce satisfactorily under moderately saline or sodic conditions has merit in some cases. Barley, wheat, sugar beet, millet, rice, salt-tolerant forage and grasses for animal production are examples.

e. Human aspects

Farmers should become active participants in the development of appropriate management systems and should become the main originators of technical solutions to their environmental problems. Any management option considered available should be field-tested under farmers' conditions and acceptance of newly developed technologies ascertained.

Management of salt-affected soils requires a combination of agronomic and management practices depending on a careful definition of the main production constraints and requirements. Therefore, the integrated management approach, as a package of the required management techniques, should be always implemented.

1.11 Management and rehabilitation technologies practised in participating countries

1.11.1 Countries with FAO collaborative projects

Africa Region

a) Ghana: The Accra-Ho-Keta Plains have diverse agricultural practices as a result of the different soils types. Large-scale irrigation project are located at Dawhenya, Weija, Ashaiman, Akuse and Okyereko producing mainly rice and vegetables. Large scale commercial production of pineapple for export is practised on salt-free soils west of Accra. Cassava, maize, sweet potatoes and curcubits production is confined to well-drained non-saline upland soils.

Two major breakthrough or successes in the use of salt-affected soils in the Plains are recorded. These have been the large-scale production of vegetables on the sodium-saturated soils of Agawtaw series. The second has been the large-scale production of shallots on beach sands. In both cases the salt contents are flushed out with freshwater and plots fertilised.

Large tracts of land of sparse grass vegetation with salt-affected soils especially Agawtaw series are being used. Beds are raised about 30 cm high and watered regularly with freshwater to flush out the salts. Seedlings are then transplanted onto the beds. Organic matter, especially poultry manure and cow dung, is applied before the transplanting of the seedlings. The beds are heavily mulched. Minor quantities of inorganic fertilisers especially 15:15:15 may be applied. The vegetables produced are mainly peppers, onions, cabbages, lettuce, cauliflower, okra and watermelons. Maize and cassava may be produced on old beds.

Large-scale commercial production of shallots (*Allium aecalonicum*) has long been the main agricultural activity of the communities of the Keta District of Volta Region. The sandy soils are flushed with freshwater regularly to remove the salts. Long and wide beds are made about 50 cm high and watered almost daily with freshwater from shallow wells dug in between the beds. The sandy soils are fertilised with organic manure from bat droppings, cow dung, poultry manure and small fishes (onchoris). These are used in combination with low rates of inorganic fertilisers, mostly urea and 15:15:15. Halfway through the growing period of three months, the crop may be inter-sown with garden eggs, tomatoes, pepper and maize, which benefit from the residual effects of the applied manure.

b) Kenya: Although there are some attempts directed toward reclamation and increasing productivity of salt-affected soils through drainage systems, the available information is still insufficient to recommend appropriate integrated management techniques. Leaching soils to remove soluble salts is the most effective method known to reclaim these soils. In Kenya about 75 percent of the agriculture lands receive less than 500 mm of rainfall annually, coupled with potential evapotranspiration rate of at least 1 500 mm. Therefore, salinity problems cannot be solved by rainfall leaching. As such, application of irrigation water is the only possible method of leaching excessive salts. This requires good irrigation water and good permeability of the soils. Leaching in some cases might cause permeability to decrease and pH to increase particularly in saline-sodic soils as the soil changes to sodic soil.

Special planting procedures are used in the management of salt-affected soils to minimise accumulation of the salts around the seed and the root zone. Use of organic manure resulted in the improvement of soil permeability and acted as a source of nutrients. Improvement of salt-affected soils in Kenya through installation of drainage systems has proved to be an expensive venture due to cost involved. Also, maintenance of these drainage canals requires a lot of effort, and unless there is good coordination between the farmers, the probability of their failure to operate is very high.

c) Nigeria: Management of salt-affected soils in Nigeria concentrates on leaching and planting procedures for increasing productivity. Farmers also use organic manure as available.

d) Tanzania: Reclamation of salt-affected soils in Tanzania is an area that has not received adequate attention. Commercial crop estates have conducted most reclamation efforts perhaps due to the economic loss they suffer under such soils. In areas where saline soils were forming due to improper drainage like the sugar estates, adequate drainage has reclaimed most of the soils with considerable success. For the sodic and saline-sodic soils, efforts in utilising chemical amendments for their reclamation have been hampered by the high costs of such amendments. Despite the fact that Tanzania has an abundant local gypsum resource at Makanya in Kilimanjaro region, its use has been confined to the manufacturing of cement. Similarly pyrite is available in Geita close to Lake Victoria but it has so far not been mined.

In a sugarcane plantation, just outside Moshi Town in northern Tanzania, use of the locally available gypsum (Makanya gypsum) and various combinations with sugarcane filter mud, lime, sulfur and magnesium carbonate were used at small scale and gave high yield of sugarcane growing under sodic conditions. In practice, however, many chemical amendments like gypsum, sulphuric acid, and iron pyrite have been used for reclamation of sodic soils with good results. The choice of chemical amendment to be used for sodic soil reclamation depends on many factors like, the type of soil, the time available for reclamation, the amount of water available for leaching, adequate soil drainage, the extent of reclamation, economic considerations, etc. The primary disadvantage is high cost involved in using these amendments.

Gypsum and pyrites were used more effectively when combined with organic materials like farmyard manure, green manure, compost, etc. Green manuring of sodic soil with *Sesbania aculeta* and *Leptochloa fusca* resulted in reduced sodicity in an experimental farm.

There are adequate amounts and types of organic materials in Tanzania that can be tested in combination with the gypsum and the pyrite provided there is motivation to do so.

Establishment of alternative salt-tolerant crops in the affected soils is an area that, if pursued, may hold a lot of potential in Tanzania. Literature is rich with a variety of crops that grow on salt-affected soils. Most of these crops are not found in Tanzania. It would be interesting to introduce some of these crops into Tanzania and monitor their performance as well as educate the general population in their potential in providing food, fodder, timber and fruits.

Asia Region:

a) Bangladesh: Increasing agricultural productivity of the coastal saline soils has been one of the major national agricultural development concerns in Bangladesh. Since salinity is the main productivity constraint in the coastal zone, the government, through the Bangladesh Water Development Board, started construction of coastal embankments in the mid-1970s to prevent the intrusion of saline water into agricultural lands. Until now, 3 700 km of embankments with 900 sluice gates have been constructed at different points of the coastal zone. This project has been partially successful in reducing soil salinity in areas within the embankments. However, thousands of ha of land still remain saline.

- The development of salt-tolerant rice varieties has been one of the major research thrusts of the Bangladesh Rice Research Institute (BRRI) during the last few years and two varieties, BRRI Dhan 40 and BRRI Dhan 41, have been recently released for growing in the coastal region during the wet season. These varieties have the potential of giving about 2.0 tonnes/ha higher yield than the local traditionally cultivated varieties under moderately saline conditions (soil EC_e around 6 dS/m) in the wet season. The Bangladesh Agricultural Research Institute (BARI) is working on several profitable cropping patterns for the different areas.

- There are also a few HYV rices developed earlier by BRRI that have shown tolerance of moderate soil salinity although these were not bred for salt tolerance. These varieties, BR22, BR23 and BRRI Dhan 32, are grown by some farmers in moderate saline areas in the wet season.

- There are some non-rice crops that have quite a good degree of salt tolerance. These crops are grown in the rabi (winter) season, especially in the eastern coastal region (Chittagong-Noakhali-Feni region) taking advantage of the residual soil moisture and relatively low soil salinity following T. Aman rice (main crop). The rabi crops could be vegetables like sugar beet, spinach, chili, grass pea, mustard, sesame, etc. In fact, although at a slow pace, the farmers are trying to increase the cropping intensity.

- Farmers use fertiliser doses as advised by the local extension workers who, in turn, recommend the doses from the National Fertiliser Guide Book. There is, however, a great scope of improving crop performance using site-specific soil test based fertiliser doses as observed by BRRI researchers. However, integrated nutrient management packages for the different coastal locations have not yet been developed. Research in this field is urgently needed.

b) China: Main solutions and technologies applied in China for combating salinization and for using salt-affected soils include:

- **Construction of drainage-irrigation systems**: In saline areas complete and rational drainage-irrigation systems are essential in improving water-salt regime, controlling water-salt movement in soil, preventing volume accumulation of salts in the surface soils and accelerating steady desalinization of the soil.

- **Drainage and rice planting**: Drainage and rice planting is one of the traditional practices of ameliorating and utilising saline land. This practice usually does not need special leaching. The land thus becomes suitable for paddy-upland rotation. Research results show that in coastal areas, 3-5 years of drainage-and-rice-planting lowered the salt content of the groundwater to 1-3g/litre, increased the thickness of the freshwater layer to 1.5 m or more and reduced soil salt content to 0.1 percent or so. In sodic soils, application of organic manure and chemical amendments such as gypsum, phosphogypsum, etc. helped to achieve better results.

- **Combination of wells, ditches and canals and comprehensive amelioration of saline land**: According to China's experience over the last two decades, in saline areas, developing pump wells (20-60 m deep) to make use of groundwater resources for irrigation and setting up irrigation-drainage engineering systems with various forms of combinations of wells-ditches-and-canals have contributed greatly to the management of soil salinization. For example Renming Shengli (People's victory) Canal Irrigation Region, using water diverted from the Huanghe River in Henan Province, China. The construction of the combination of well-canal irrigation got underway in 1964.

- **Addition of organic manure to improve soil fertility:** Organic matter available for use includes crop stems and straws, green manure, barnyard manure, compost, etc. Growing of green manure is promoted in light of the local conditions. Besides growing green manure solely in the field, rotation and inter-cropping of grain crops or cotton with green manure of different varieties can also be adopted to expand green manure sources, which can ameliorate soil, improve soil fertility and inhibit salt accumulation.

- **Application of techniques of water saving agriculture:** In practice, application of low-quota irrigation, pipe-transfer of irrigation water and other integrated water-saving agricultural measures have successfully increased efficiency of water resources with selection and planting of water-saving crops.

- **Regulation of regional water resources:** Clearing drainage ditch and canal, and improving regional river water system are helpful in enhancing drainage capacity. With rational planning and construction of drainage water pumping/irrigation station, increasing pumping capacity has shown good results.

- **Proper management of brackish water irrigation:** Irrigation with saline water shows some successful experience. Main approaches include a) direct irrigation with brackish water during certain crop growth stages; b) alternative irrigation with freshwater and brackish water; c) mixed irrigation with fresh water and brackish water. In some area with large saline groundwater, improving groundwater quality by pumping saline groundwater and replacing it with freshwater is a good way. Results of experiments and extension of such approach in Hebei Province show a significant increase in area of non-saline groundwater.

- **Integrated biological-agronomic management:** In the coastal area of China, development of aquaculture by setting up large-scale fish pond or shrimp pond is a good practice on use of coastal salt-affected land, and is also practical on leaching salt and desalting water bodies (including groundwater). Such kind of so-called 'step-up utilisation' strategy is successful in Jiangsu and Zhejiang. Building up of coastal forestry band is also a good way to improve agro-ecological condition in salt-affected regions. Other agronomic management measures, such as soil surface covering with plastic films or crop straw, can also effectively prevent strong soil evaporation and salt surface accumulation. Crop yield could be greatly increased by such simple means applied in wheat and cotton planting.

- **Introducing and application of salt-tolerant crops:** Selecting various salt-tolerant varieties of crops to fit different saline ecological environments and tapping the inherent tolerance of the varieties are important measures to improve the efficiency of the reclamation, amelioration and utilisation of salt-affected soils.

c) Indonesia: The reclamation of swampland for agriculture is usually carried out by constructing drainage canals. Basically three systems are used in Indonesia: a traditional system, well known as 'parit kongsi' in Riau or 'handi' in South Kalimantan; a fork system designed by the University of Gajah Mada and a perpendicular drainage system, practised in South Sumatra. Modification of the specifications and a combination of the last two systems have been carried out in several places. Primary drainage canals are directed to the sea with flapgates, which prevent the entrance of seawater and direct the drain water out of the scheme.

Overdraining made the pyrites oxidise in acid sulphate soils, because the groundwater fell down below the pyritic layer. In the wet season of 1994/1995, the seedlings in the nurseries died – especially those in the lower part of the area. The groundwater brought up all toxic substances produced by the oxidation process of pyrites. Water surface should be kept high enough in the drainage canals by constructing overflow dams at the mouth of secondary and even of primary canals. An intensive shallow drainage system is recommended for these acid sulphate soils. The spacing of the shallow drains is 6 to 9 m depending on the intensity of the salinity or acidity problems. A rice-fish system is usually recommended in the system.

A polder system was also used to control the water and its salinity in order to develop the Pulau Nyiur, Riau Island to extend and intensify rice and 'palawiji', especially maize and soybean. Rainwater is kept as much as possible inside the polder by closing all outflows from the island through constructing dykes along the coast and overflows structures at the mouth of every creek and canal. There are separate canals for irrigation and for drainage. To run the system, pumps are required, either to irrigate or to drain.

Good management of salt-affected soils should include the application of high amounts of N, P and K fertilisers and strict control.

In Indramayu, farmers make beds 1.2-1.6 m wide and about 0.5 m apart separated by furrows of 0.5- 0.6 m deep. The furrows are filled with about 0.15-0.20 m depth water so that the topsoil of the bed will not become saline. The same system is practised by farmers at Sei Kakap. They plant sweet potatoes on dykes 1.5-2.0 m apart. Farmers also plant horticultural crops on the dykes. Before planting the rice all dykes are dug, levelled and all weeds and plant residues are buried. Farmers are planting the rice without harrowing or puddling the soil.

d) Pakistan: Approaches tried in Pakistan to control and arrest the problems are: (a) commissioning of government-sponsored large salinity control and reclamation projects (drainage projects over about 8 million ha); (b) leaching of salts by applying increased irrigation water and chemical amendments, organic wastes and plants (small local-level interventions); and (c) promoting saline agriculture bioreclamation techniques using tolerant crops, bushes and trees, and fodder grasses. The sustainability of the first approach used since the early 1960s is becoming highly questionable

e) The Philippines: The application of the Balanced Fertilisation Strategy (BFS) includes seven formulae of mixed organic and inorganic fertilisers to provide the required nutrients for specific areas affected by nutrient deficiencies and soil salinity. The BFS emphasizes the need to recycle crop residues and farm wastes along with a balanced combination of organic and inorganic fertilisers. For saline soils, the recommended BFS is NPK rates at 95-20-15, in addition to 5 kg zinc sulphate, five bags of commercial organic fertiliser and one bag of chemical ameliorant. Studies reveal positive results on the use of this technology.

In 1997, PhilRice, in collaboration with the Bicol Integrated Agricultural Research Center, officially released through the Philippine Seed Board two salt-tolerant varieties (PSBRC 48 and PSBRC 50) that were jointly developed. However, these varieties were not widely adopted by the rice-growing farmers in salt-affected coastal soils. Up to 1998, IRRI has screened more than 55 000 rice varieties and breeding lines for salinity tolerance. Tolerance donors have been used successfully as parents in hybridization activities at IRRI and within national programmes.

f) Thailand: The preventive method is being practised on both inland and coastal salt-affected areas. In inland areas, biological measures are being used to prevent soil salinization caused by saline groundwater interaction. Certain salt-tolerant plant species, including *Acacia ampliceps* and *Azadirachta indica,* are used to lower the groundwater level through water consumption. In the coastal areas, dykes or bunds are constructed to prevent salinization by seawater intrusion.

Concerning improvement and reclamation of salt-affected soils in slightly saline and moderately saline soils, planting of green manure crops such as *Sesbania rostrata*, cultivation of salt-tolerant varieties and addition of organic matter are recommended methods to improve saline soil conditions and to increase yield. Reclamation of salt-affected soils that includes leaching of salts and drainage systems to lower the groundwater level is mostly practised in the high or very high salinity areas. The farmers in the coastal areas have used indigenous technologies to reclaim their lands. The lands are improved by ridging and growing coconut or other salt-tolerant crops on the ridges. The width of the ridges is usually 6-7 m. Continued leaching, use of salt-tolerant crops, amendments such as gypsum and organic matter are recommended to assist in this process.

The slightly to moderately salt-affected lands are generally used for rice cultivation. Some other crops such as vegetables and peanut are also grown. The agronomic package programme has been recommended to farmers through demonstration and training programmes for increasing rice production. It comprises land levelling, leaching, application of organic amendments and use of salt-tolerant varieties of older seedlings and at higher seed rates. Split applications of fertiliser, mulching and green manuring are also recommended.

Reforestation in the potential salt source areas is recognised as one of the land management practices for minimizing groundwater recharge. In Northeast Thailand, it is suggested that neem, eucalyptus, tamarind, Manila tamarind should be grown in the recharge area as farmers' choice. While the highly salt-tolerant tree *Acacia ampliceps* is planted in the discharge area with halophytes or highly salt-tolerant grasses. Positive effects in lowering groundwater level in the recharge and discharge area are found after one year's planting. In the 8th National Economic and Social Development Plan (1997-2001), the Land Development Department plans to plant forests in 800 000 ha in the Northeast to control salinization through groundwater movement.

The severely salt-affected lands that cover about 1.5 percent of the Northeast region is regarded as wastelands. Some selected salt-tolerant tree species and halophytes could be grown in these soils. Halophytes are introduced as forage crops. Plants from the USA and Australia are screened in comparison with some native species. The promising species are *Sporobolus virginicus* and *Distichlis spicata*.

g) Viet Nam: Management practices include:

1. A strategic plan for water resource exploitation and protection has been worked out for ong-term and short-term irrigation development on large rivers and key areas.
2. Improvement of drainage-irrigation systems: irrigation is essential to leach out salts, thus, a rational drainage-irrigation system to strengthen drainage capacity and control groundwater table is a must to control salinity development.
3. Improving soil fertility by applying organic manures, including rice straw, crop residues, green manure, farmyard manure, compost, etc.
4. Protect coastal mangrove forests with aquaculture resources.
5. *Rhizophora apiculata* forest planting combined with shrimp farming (Penaeus indicus, *Panaeus mergriensis*). Eighty percent of the shrimp and fish rearing area were planted with mangrove forests.
6. Normally cropping patterns on coastal saline soils are as follows:

- Tidal rice-shrimp breeding: in the saline soil area situated far from the source of freshwater, farmers make small dykes (0.7-1.4 m of diameter) surrounding the fields of approximately 2 to 4 ha, to control seawater intrusion. Rice varieties resisting salinity have been cultivated in the rainy season. Rice yields can reach 2.5-3.0 tonnes/ha with two harvests of shrimp in the dry season.

- One rice crop in rainy season: in the saline areas situated far from freshwater source or even seawater, the farmers wait for rainfall to cultivate one crop of summer rice. In the dry season the surface of the soil cracks, the saline water comes up to the surface causing soil salinization. The salinity is rather high at the beginning and decreases by the end of the harvest. Rice yields of 3.0-3.5 tonnes/ha can be obtained. This is the traditional rice cultivation.

- Two rice crops in rainy season: farmers can profit from the long duration of the rainy season (150-190 days) to cultivate two short-term rice crops by applying dry-broadcasting techniques. This is a new achievement in the Mekong Delta. After harvesting summer rice, the land is ploughed to cut off the capillary rise of the saline water. Just before the rainy season the land is prepared and divided into beds with shallow drains (20 cm), farmers broadcast rice seeds. When it rains, soluble salt is washed into the drains and rice seeds can germinate. The second crop is followed in the middle of the rainy season and harvested at the beginning of the dry season.

6. Making dykes to prevent seawater intrusion. In the Red River Delta, where population density is high, typhoons and floods often happen. People have to make large and long dykes surrounding the seashore to reclaim the new land. These dykes are 10 m wide and cover an area of about 10 000 ha. Along these dykes, deep channel digging is necessary for preventing the penetration of the seawater into the newly reclaimed area where highly salt-resistant plants can be grown during the first three years. Then local rice varieties can be grown. There is only one rice crop in the rainy season but if freshwater is available in the dry season, another rice crop can be added. Incorporation of organic fertiliser, rice straw, rice husk and soluble silicate is highly effective in increasing rice yields up to 5-7 tonnes/ha/year.

Europe Region

a) **Hungary**: The radical amelioration of salt-affected soils includes i) control of saline/alkaline groundwater by the construction of proper drainage systems, ii) application of soluble Ca-containing amendments, iii) improvement of the vertical drainage of soils and horizontal drainage conditions by using organic manure and crop residues, iv) leaching the accumulated salts and draining them from the area. These complex measures are expensive and at present, not economic. However, for sustainable use of salt-affected soils the following practices are applied:
- rational land use and cropping pattern;
- adequate agrotechnics for surface water management and soil moisture control;
- reduction of ecological constraints and practising rational plant nutrition in the slightly or moderately salt-affected areas and
- proper infrastructure for extensive (low-input) farming and/or wetland management in the strongly saline/sodic regions.

In the case of solonetz soils, the leaching out of salt and drainage are unavoidable, parallel with the use of chemical amendments. Application of gypsum as well as deep ploughing and subsoil loosening is useful. In all cases, the types and utilisation of salt-affected soils must be carefully adjusted to local conditions. In the case of soils containing sodium carbonate, the application of acid chemical amendments as one factor of reclamation is nearly always necessary.

b) Romania: The main management practices used are drainage; land levelling and modelling for leaching; gypsum is used as a chemical amendment (in Romania: phospho-gypsum, wastes from phosphorus fertiliser factories); leaching; chiselling; fertilisation; salinity- or sodicity-tolerant crops; proper crop rotations; monitoring of salinity development and improvement; etc. To obtain good results, these measures are always applied in an integrated approach.

The drainage system recommended is in accordance with the permissible critical limit of water table depth and salinity as follows: steppe zone (2.5-3.3 m and 1.5-3.0 g/litre, respectively); forest steppe zone (1.8-2.4 m and 0.5-1.5 g/litre, respectively); and for forest zone (less than 1 m and 0.5-0.8 g/litre, respectively). Drainage should accomplish the discharge of salt leaching waters, desalinization of the plant root zone and desalinization of water table to the limits mentioned. Under the conditions of a deep drainage system (2.5-3.5 m deep and 300-500 m apart), it is recommended to add a shallower drainage system (0.6-1.4 m deep and 40-70 m apart). At the same time the drainage system is supplemented with mole drainage, 8 and 12 cm diameter and with a slope of 1-3 percent.

In soils with high exchangeable sodium content, phospho-gypsum is used as a chemical amendment (such as used in a moderately sodic alluvial soils in Traianu - Valea Encii). Under the drainage and amendment conditions, leaching is applied, which represents the basic treatment for salt-affected soils improvement. The leaching of salts may be of several types according to the way of land development or the water application: leaching by flooding the crops as in the case of paddy cropping; leaching by flooding following the crop harvesting on the levelled lands; leaching by furrows or strips during the cropping season on specially prepared lands; continuous leaching maintaining a certain water stratum at the soil surface according to the leaching rate; intermittent leaching consisting of application of the total leaching rate step by step at certain intervals, without permitting the soil re-salinization; prophylactic leaching by applying water from time to time when some soil re-salinization tendency is noticed.

Within the framework of salt-affected soils improvement, particular attention is paid to cropping plants tolerant to salinity according to the improvement stage. In the first improvement stages, use of the most salt-tolerant plants and in the last improvement stages, when soils become more fertile and with lower salt contents, growing crops more sensitive to salinity such as rape, soybean, corn, etc.

Within the national programme for reclamation of salt-affected soils, rice cropping was one of the most profitable farming systems. Thus since 1980, the area cultivated to rice increased from 19 800 ha to 49 000 ha in 1989. Unfortunately, it then decreased to only 4 000 ha in 1997. As Romania faces a severe economic crisis, investments for land reclamation decreased significantly. The issue of salt-affected soil reclamation is focused on those areas where very important socioeconomic problems arise.

c) **Turkey:** Main management practices applied in Turkey in an integrated approach include: construction of appropriate drainage systems in connection with irrigation systems when starting any irrigation project; applying proper management practices (organic manure, fertilisers, salt-tolerant crop varieties, minimum tillage practices); use of high quality water for irrigation; selecting better irrigation methods (sprinkler, drip, etc.) for improved water management and applying new advanced technologies such as GIS, RS, and computer modelling for monitoring and management of salt-affected soils.

Reclamation also includes use of leaching water requirement to reduce soil salt content to 4 dS/m and the amount of amendment (gypsum) according to the requirements, as applied in Great Konya Basin, Ayd n-Söke Plain, Denizli-Ac payam Plain and Burdur-Yar köy Plain. In Turkey, studies are focused on:

1. Assessment of the full extent of salt-affected soils suitable for reclamation: some successful project examples are: I d r, Konya-Ere l i, Aksaray, Gediz, Lower Seyhan, Menemen, Bafra, Söke, Salihli, Kayseri-Karasaz, Eski ehir-Alpu, Denizli-Ac payam Plains and Çank r K z l rmak Basin.
2. Hydrologic and drainage response to drain excess water.
3. Development and calibration of computer-based models (DRAINMOD, SALTMOD, Gypsum and Leaching Water Requirement).
4. Characterisation of the properties of wastewater and drainage water for re-use and its impacts.
5. Diagnosis and predicting of soil salinity and alkalinity, applied research and modelling for salinity development and management using GIS and RS techniques.
6. Ecology of halophytic vegetation in salt-affected lands.

Latin America Region

a) **Argentina**: The soils of the Lower Valley of the Colorado River (LVCR) in south-central semi-arid Argentina have been irrigated for about 90 years with waters obtained from the near-by river using 'flooding' irrigation after levelling of the land. The area has been cultivated to mixed pastures (*Medicago sativa, Agropyrum elongatum. Festuca* spp. etc.) for either seed production or grazing, and to horticultural crops, mainly onion (*Allium cepa*), garlic (*Allium sativum*), tomato (*Lycapersicum esculentum*), several varieties of melon (*Cucumis melo*), water melon (*Citrullus vulgaris*), apple (*Malus sylvestris*), etc. Now the salt-affected areas developed in the basin of the LVCR are being reclaimed using the construction of effective and active drainage system (this is the basic and key point of the whole rehabilitation process); rainfall leaching in humid and/or wet years; leaching with the water from the Colorado River, cropping to barley and using it as a green manure; surface soil application and disking in the soil of gypsum or sulphur. The barley-vetch green manure production showed also that the crop (barley) is very effective in reclaiming salt-affected soils.

Crop production in the central Pampean region has been impaired due to the development of salt-affected soils (cropping pattern in the region includes wheat/soybean-corn and wheat/corn-soybean). The programme to reclaim the salt-affected soils in the region include leaching under supplementary irrigation system, use of straw cover as mulching (2 to 10 tonnes soybean residues/ha) and gypsum requirements (1 to 3 tonnes/ha)

In some reclamation projects in the basin of LVCR, reclamation of salt-affected soils includes construction of shallow drainage ditches, leaching with low-salinity river water and use of green manure (barley crop grown close to maturity and then ploughed-in the soil as a source of organic matter). The cropping pattern during the reclamation period includes barley accompanied by a legume (*Lotus corniculatus* and/or *Medicago sativa*).

In irrigated areas in Argentina, the more important cultivated crops are wheat, barley, fruticulture, including grape production. Cash and horticultural crops cover almost 50 percent of the irrigated crop; sugarcane occupies close to 15 percent; alfalfa and other forage crops cover 11 percent of the producing irrigated areas.

b) Brazil: The main technology used in Northeast Brazil to reclaim saline soils is sub-surface drainage, and for sodic soils it is the use of gypsum followed by sub-surface drainage. The results obtained up to now are highly positive.

c) Cuba: The policy of reclamation of salt-affected soils in Cuba has been directed fundamentally toward those soils with moderate salt content, where leaching, drainage system establishment, and some cultural methods can be beneficial; or in those where serious reason exists for the introduction of intensive production systems, as is the case of soils devoted to rice production.

Main solutions and technologies applied in Cuba for combating salinization and for using salt-affected soils include:

- Establishment of drainage-irrigation systems: main drainage canals and field drainage systems are the fundamental conditions for ameliorating and utilising salt-affected soils. The irrigation has two functions, one is to meet the water demand of crops and the other is to leach salts out of the soil using calculated excess water leaching requirements.

- Drainage and rice planting: this is one of the traditional practices of reclaiming and utilising saline land in Cuba. This practice usually does not need special leaching. After flooding the field with diverted water, rice can be planted and yield 4-5 tonnes/ha/year. During the rice growing period the field is often flooded, thus accelerating soil desalinization. After rice cultivation the land can be cultivated for rice-pasture legumes cropping system.

- Application of organic manure and chemical amendments such as gypsum, sulfuric acid, etc. helped to achieve better results.

- Combination of wells, ditches and canals and amelioration of salt-affected soils. In Cuba, in the last ten years, development of pump wells (30-70 m deep) to make use of groundwater resources for irrigation and setting up irrigation-drainage engineering systems with several combination forms of wells-ditches-canals have contributed greatly to the management of salt-affected lands. This situation is common in Cauto and Guantá namo Valleys.

- Organic matter application to improve soil fertility: also using green manure plants solely in the field or in rotation, inter-planting and inter-cropping of pasture legumes can also be adopted to increase soil fertility and reduce salt accumulation, as well as to promote combination of agriculture with animal husbandry.

- Use of salt-tolerant crops: even planting or protecting natural halophyte vegetation contributes to controlling further salinization of the soil. Salt-tolerant plants can be used as forage for animals. The reclamation effect of growing salt-tolerant rice varieties in saline and sodic soils is well known in Cuba.

- In the sugarcane cropping project in Guantánamo Valley, with the hydrotechnical practices (leaching and buried drainage), combined with the sloth application (100 tonnes/ha) and deep subsoiling, it was possible to obtain yields between 152 and 218 tonnes of cane per ha and between 21 and 31 tonnes/ha of sucrose content.

- In the Cayama zone, salt-affected soils were improved using granulometric light composition of the sloth with leaching application (13 168 cu m/ha); and surface drainage.

- Another example of technology applied in Cuba is the establishment of a package for the rehabilitation and management of salt-affected soils devoted to rice cropping that includes the optimum drainage parameters (drain spacings of 150-200 m with a 1.2 and 2.5 m depth); subsoiling (distance between chisels 5 m at 40-60 cm depth), with an irrigation norm (15 000 cu m of water/ha) permitting the leaching of 50-100 ppm of total soluble salt in the first irrigation (1 to 3) and avoiding puddle and lagoon formation in the field. Also organic amendments were applied (sloth and manure at the rate of 60 tonnes/ha) chemicals (calcium sulphate at 20 tonnes/ha) and a new NPK fertilisation formulation (161-100-50 tonnes/ha). The joint application of the package has permitted rice yields to increase from 1.5 to 3.5 tonnes/ha (more than 10 000 ha in the state and private sector).

d) Mexico: Remote sensing was found to be a more efficient and cost-effective technique for soil salinity assessment, compared to the traditional one (extensive soil sampling), as long as extensively planted crops are dominant in the study area. Satellite imagery has been utilised as the basic diagnosis tool to assess 233 000 ha salt-affected areas in the Rio Yaqui ID, the 97 000 ha in Rio Mayo ID and the 228 000 ha in Rio Fuerte ID, all of them in the Northwest, using four reference crops (maize, wheat, sorghum and cotton).Open drain systems for flood control are quite common in the southeastern part of the country, where precipitation is high (> 1 500 mm). However, subsurface drainage for salinity control in the northern arid and semi-arid regions in Mexico is an open field for research and technology transfer. Before the 1990s, only some IDs in the Northwest had a few areas with installed sub-surface drainage. The Rio Yaqui, Rio Fuerte and Valle del Carrizo

IDs had a few 10-50 ha fields installed with sub-surface drainage, some of them deficiently designed.

Unfortunately, other kinds of associated practices to reclaim salt-affected soils, like soil fertility management and organic matter application (incorporation of crop residues, green manure, animal manure), are not well known by the farmers. It is important to promote these practices among farmers through permanent extension programmes wherever soil salinity exists, and generate new technological alternatives in research centres and universities.

The private sector is not really involved in these kinds of problems, except some companies that manufacture, sell and install drainage pipes. Mainly government institutions are aware of the magnitude of the problem, led by the Water National Commission (CNA), which is promoting and investing in extensive soil reclamation projects.

Near East Region

a) Egypt: The reclamation of saline soils in Egypt (depending on salinity level, the extent of the problem and many other factors) includes the construction stage during which all construction work including land levelling, construction of irrigation and drainage systems, roads, buildings, are completed; the leaching stage during which the excess salts are leached to a level and depth that permits the start of cropping; the leaching-cropping stage during which the growth of crops combined with leaching affect further reclamation (during this stage the input to the land is less than the output); the normal cropping stage during which a variety of crops can be grown with outputs from land exceeding inputs. If the leaching is achieved before the month of November a salt-tolerant winter crop such as barley, rye grass, berseem clover, can be cropped. If the leaching is completed before the month of May, a summer crop such as nuseila (*Echinochloa stagnina*) and rice can be grown.

Management practices during the combined leaching cropping stage include use of excess irrigation water according to leaching requirements; cropping in rotation that ensures effective leaching of accumulated salts; keeping a plant cover to protect soil surface from evaporation during the summer as much as possible; ploughing deep enough before leaching; subsoiling and deep ploughing with proper fertilisation is essential; for row crops planting on the slope of a furrow below the zone of salt accumulation and re-levelling very carefully following the removal of each crop to ensure uniform distribution of water.

Incorporating organic matter into the soil has been applied in Egypt, particularly in sodic soils for improvement of soil permeability and release of carbon dioxide and certain organic acid during decomposition, and to act as a nutrient source. Crop residue

application is one of the easiest methods to improve water infiltration. Growing legumes has improved soil structure and acted as a source of nitrogen in the soil for the next crop. Green manure has a similar effect on soil properties and as a source of nutrients as organic manure.

Improved fertiliser management in salt-affected soils can be of significance because it ensures balanced plant nutrition that prevents deficient or excessive application of fertilisers.

Additional fertiliser may be needed to compensate for leaching and other losses. Such compensation is always needed where leaching is continuously used or under waterlogged conditions.

Sprinkler irrigation is considered in Egypt as an ideal irrigation method for frequent irrigation and with small quantities of water at a time. Salt leaching can be accomplished under this system with a uniform water application. Trickle or drip irrigation has been found particularly useful when irrigating with water of high salinity. In Egypt, it is expected that drainage water will be a source of over 7 000 million cu m of water for agriculture in the year 2000, while it was 4 500 million cu m in 1990. The Egyptian Law No. 48 identified the maximum limits of the re-used water in terms of its content of salt and other elements.

b) Iran: During the past decade balanced fertilisation was applied to various crops cultivated on the salt-affected soils, irrigated with saline water. The preliminary results demonstrated that in saline soils split application of N-fertilisers (mostly ammonium sulphate) in a higher rate than that conventionally applied gives better yield. This was also the case when relatively higher amounts of potassium sulphate were applied. In Qom region application of the fertiliser rate $N_{225}K_{120}$, resulted in wheat-grain yields going up to 5 600 kg/ha.

Recently reclamation of saline and sodic soils has been carried out by acidification through application of sulphuric acid and sulphur powder enriched by Thiobacillus bacteria.

The first scientific investigations on salinity problems in Iran started about 30 years ago. These investigations were confined to some leaching tests and the effects of salinity on crop yields. Most of these studies were carried out in Khuzestan, Fars and Esfahan Provinces. In later years other research programmes such as the use of soil amendments for improving soil physical properties were conducted in the same locations and some other parts of the country. In this respect, a lot of work was done on the use of sulphur for improving infiltration rates of sodic soils.

During the last three decades leaching practices using leaching required values were applied in 13 provinces. Also, use of some salt-tolerant crops such as Kalar grass in the first stage of salt-affected soil reclamation is being used.

Management plans have been prepared to overcome the problems of salinity and waterlogging. Development of modern irrigation and drainage networks accompanied by leaching has reduced soil salinity in many parts. Management has also changed the spatial

distribution of the salt-affected soils. Examples are found in the Moghan Plain, and after construction of the Drudzan Dam near Shiraz, the capital city of Fars Province, in 1972.

Using these techniques, beneficial effects on the reduction of soil salinity and alkalinity in the two regions were obtained.

c) Syria: Management practices on salt-affected soils include establishing sufficient tile drainage network that meets field requirements; maintenance of irrigation and drainage networks periodically to avoid water table rise and to stop seepage from channels and use of salt-tolerant crops.

Salinization processes are found in the whole Syrian portion of the Euphrates River. Therefore it can be admitted that the ecological situation in the Euphrates River basin (lower Euphrates basin) is in danger. Salinity development has led to a reduction in the productivity and deterioration of the population situation in terms of income, unemployment and labour migration from rural areas to towns.

d) Tunisia: Because of the necessity of maximising national utilisation of soil and water resources, the country programme is to define appropriate integrated management techniques to improve the productivity of small farmers fields in salt-affected areas. The management practices include use of sub-surface drainage, leaching requirements, appropriate tillage system, addition of gypsum, organic matter, mulching and applying crop residues, special planting procedures and selecting salt-tolerant crops (alfalfa, barley, date palm, vegetables such as lettuce, carrot and onion).

1.11.2 Associated members

a) Australia: Technical solutions aimed at preventing increased salinity problems or mitigating existing problems are almost exclusively applied within the framework of agreed regional and sub-regional catchment management plans that involve the community as widely as possible in decision making, in implementing actions and in monitoring outcomes. These are carried out in a range of government agencies and funded through a mix of government funds with direct 'user pays' contributions. Techniques using satellite imagery (Landsat MSS and TM images) or aerial geophysical data combined with terrain maps are widely used by several organizations in Australia to monitor the development of salinity problems and to predict areas at risk in the future and to guide management responses.

Options for mitigating salinity effects on agriculture fall into the following two broad categories:

Dryland salinity:
Changes in current land management systems and practices – usually to restrict the entry of rainfall into the groundwater systems. These usually involve attempts to change crop types on recharge areas to achieve use of a higher proportion of rainfall, thereby reducing the amounts of water entering the groundwater. More recently, the accepted theory that selection of agricultural plants with higher community water use than existing crop plants can have a significant positive effect on groundwater systems is being questioned. Apart from differences between annual and perennial communities, the difference in water use within these groups under naturally occurring, water-limited, field conditions use is constant, so changes are unlikely to be significant in effect on groundwater recharge.

Seeking new uses for salt-affected soils. The saline agriculture approach uses plants that are already adapted to high salinity in management systems that do not require reclamation of the salt-affected soils as a first step before any worthwhile production is obtained. Farmers will gain some economic returns as the land is slowly reclaimed. In dryland areas, these systems involve the establishment and utiliszation of halophytic grasses, shrubs and trees. In this regard there are two approaches to saltland pastures: 'Natural Saltland Pastures' (many areas of primary saltland in Australia already support natural 'pastures' of halophyte shrubs and grasses. These can be managed for light grazing by animals according to the seasonal production); and 'Sown Saltland Pastures' (land that is of high salinity growing poor cover of annual salt-tolerant grasses is sown with halophytic shrub species at densities of 1 000 to 2 000 plants per ha. After establishment some leaching can take place from winter rainfall and other species with lower salt tolerance but higher forage value have been used). Species favoured for saltland pastures include: *Atriplex* *amnicola, A. undulata, A. nummularia, A. cinerea, Maireana brevifolia, Puccinellia ciliata, Thinopyrum elongatum* and *Trifolium michelianum.*

Irrigated land salinity:
Some work has been done in Australia on irrigation of the shrub species in relation to a Serial Biological Concentration System approach to disposal of saline groundwater in irrigation areas. Productivity under saline irrigation can be increased more than ten times compared with dryland conditions. No use is made in Australia of organic amendments, e.g. organic matter, crop residues animal manure, specifically targeted at remediation of conditions of high salinity.

Because of the higher value of irrigated agriculture (land and production) a wider range of technologies is applied to salinity problems. At lower salinity, information from various sources on the relative salt tolerance of a wide range of crop and forage plants is used to assist in selecting plants suited to the particular salinity category. Limited plant breeding and selection research is also funded to develop varieties of particular plants with improved salt tolerance for irrigation areas. Engineering works (shallow tubewell pumping, tile and surface drainage, local evaporation basins) are important in irrigation areas to control shallow saline water tables and waterlogging. Generally there is not sole reliance on engineering solutions to solve salinity problems, where they are used it is always in combination with various on-farm land and water management measures to control rootzone water table levels. These include better matching of irrigation applications to crop water use requirements and patterns, laser levelling of irrigated soils to improve efficiency of water applications and surface drainage of irrigated land.

b) Canada: Management of salt-affected soils includes:

- Preventing and retarding the accumulation of water and salts at near surface. Agronomically, a balance between water needs and supply for vegetation is sought. This includes: growing crops that use water before it moves below the rootzones such as alfalfa hay crops upstream of the saline sites; drain any surface water such as ponds and ditches which contribute to subsurface accumulations; mulch soil surfaces to deter evaporation; form seedbeds so as to present salt accumulation far from crops; keep irrigation leaching fraction at a minimum; increase infiltration rate; and install wind shelterbelts to reduce evaporation.

- Lowering groundwater tables and potentiometric heads to reduce salinization rates. This includes pumping of groundwater from upper aquifers; growing deep-rooted plants; practicing favourable cropping strategies (minimising summer fallow) and engineering surface and sub-surface drainage.

- Removing salts from the rootzone. This includes removing salts with harvested halophytes and leaching salts from the rootzone.

- Effective leaching can be promoted by improving infiltration and transmission of water including cultivating and ploughing; surface mulching; adding amendments for soil conditioning; organic and green manuring and when appropriate fallowing. Leaching is best accomplished by irrigating sufficiently with designed leaching fractions.

Even under dryland cultivation some additional water for leaching can be obtained.

- Living with the problem. This may be necessary, especially in the short term, until more permanent controls can be developed. Growing plant crops that tolerate salinity exemplifies this approach. The usual sequence followed by prairie farmers as their salinity problem persists is to convert wheat to barely, barley to alfalfa, alfalfa to broomgrass and broomgrass to tall wheatgrass.

c) Colombia: Successful rehabilitation of salt-affected soils includes effective drainage systems; non-saline good quality water for salt leaching; use of chemical amendments (gypsum, sulphur, etc.); use of biological systems (barley and its straw as amendment) and deep ploughing to alleviate soil compaction.

d) India: Reclamation techniques for the two distinct categories of salt-affected soils in India, namely, alkaline/sodic and saline, have been developed and applied in the field. Three approaches for reclamation of alkaline/sodic soils have been developed for different situations including reclamation for maximising crop production (agrochemical technology); reclamation based on cultivation of salt-tolerant crops with reduced dose of amendment or no amendment (bio-reclamation) and reclamation for planting trees and grasses (alternative land use). Package of practices for the first two technologies has been developed. The agrochemical technology (the agrochemical package includes recommendations on pre-reclamation management, amendments use, choice of crops and cropping sequences, nutrient management, water management and agronomic management) has been implemented on a large scale in the states of Haryana and Punjab, for reclaiming 0.7 million ha of land. Bio-reclamation for crop production is being extended in resource scarce areas of Uttar Pradesh. Salt-tolerant trees and grasses have been grown mostly on community and forestlands. Technology for reclamation of waterlogged saline lands concentrates on the use of subsurface drainage. Drainage design criterion for monsoon climates has been established and tested on a pilot scale. Also, the methodology for re-use of drainage effluents has been extensively tested and refined. Large-scale pilot projects are being implemented adopting this technology. Techno-economic analysis shows that the technology is highly profitable but it requires community participation on a large scale.

e) Italy: Long-term field experiments are one way to develop suitable irrigation strategies but these are expensive, site specific and time consuming. An alternative solution is application of computer simulation models to be used to examine some different possible combinations of existing field conditions (soil, climate and water) and to provide accurate and quick estimate of crop growth, water and salt balance. Several studies were carried out in this regard to show a) the relevant influence that reductions in hydraulic conductivity due to increasing sodicity (ESP) play in water transport in the soil/crop system; and b) possibility for predicting the hazard of salinization/sodication due to irrigation with saline/sodic waters.

f) Spain: A national plan for river transfers from different Spanish regions, although very controversial, is now under political discussion for remedial of the scarcity of water in the Comunidad Valenciana. In parallel, a modernization of the irrigation systems from furrow to sprinkler and mainly to drip irrigation, as well as amelioration of the water transport infrastructure to avoid water losses by evaporation and spills, and even some initiatives to desalinize water are making more rational use of water resources.

Traditionally orange trees are irrigated by flooding or by furrow, but the high income for farmers having this crop as well as the increasing scarcity of water and worsening of its quality have moved the farmers to introduce drip irrigation facilities, with fertigation. This saves water and allows control of the fertilisation rate according to the needs of the tree along its cycle.

g) Sudan: The management practices include expansion of wheat, legume production to the irrigated areas including using salt-tolerant varieties, chemical amendments (gypsum) and organic (FYM) and wheat straw, irrigation intervals and chemical fertilisers.

h) Uzbekistan: The works at Lake Sudoche would test wetland restoration by re-use of drainage water. Thus these activities will demonstrate means of wetlands restoration which will be applicable to further projects in the Aral Sea Basin.

Uzbekistan Drainage Project and Environmental Assessment of Irrigation and Drainage Project in the Amu-Darya Basin were started in 1996. Three scenarios of water-related sector at various intensities of political, agricultural reforms and investments in the future have been carried out: diversion and management of drainage flow, decreasing salt mobilization and an abandonment of highly saline soils, leaching practices improvement and other technical solutions and their environmental assessment were worked out by the projects.

Existing practices of irrigation and leaching do not provide adequate desalinization of moderate and highly saline lands. Economic changes, restructuring and privatisation in the agriculture of Uzbekistan demand new methods and technologies to combat salinization and environmental rehabilitation of land use and water management, having real benefit and attraction for farmers and water users' associations.

At present, projects of inter-farm water use and management in agriculture have started in Uzbekistan and other Aral Sea countries.

WUFMAS Project (TACIS EC) on test plots in ten farms of the Republic – Bukhara, Khorezm, Surhandarya, Karakalpakistan and others began in 1996. The project includes a systematic measure of production factor and output, agronomic and soil observations, monitoring of water quality and drainage and other investigations.

Inter-farm Irrigation and Management Project (EC) aims to demonstrate the possibility of improvement of on-farm irrigation and management of agriculture on hardly ameliorated lands of the Hungry Steppe in Uzbekistan. Farm restructuring, rehabilitation of irrigation infrastructure and soil management will be developing by means of improving fertility management, salinity control, and irrigation efficiency and leaching practices.

There are new applied technologies to combat each type of salinization that include:

- Rehabilitation of degraded saline soils on the basis of effective ways of leaching soils by furrows with consequent seeding of salt-tolerant crops and fodder crops and introducing of fertilisers and soil treatment. The advantage of this way, in comparison with leaching on basin check method, is water saving in 1.4-1.5 times and high efficiency of soil desalinization, significant reduction of before sowing works and efficiency of land use and others. Cotton yield increased from 0.60 to 1.25 tonnes/ha.

- In developing irrigation of saline lands in Uzbekistan, biological drainage technologies have been started. One of the advantages of the technology is biological desalinization of drainage waters and creation of additional biomass (fodder, domestic fuel, etc.) with minimal investment. The positive results of biological drainage use are received in the Hungry Steppe.

- Different management techniques are practised including leaching requirements, applying special planting procedures, drainage systems and chemical amendments (gypsum) and balanced fertilisers.

1.12 Other issues related to land degradation, institutional framework and policies

There is a wide range of other constraints to the adoption of technologies to control salinity development and improve productivity. The most important of these is the insecurity of tenure. There is a need for confirmed land tenure to ensure that the land users have a continuing interest in the productivity of the land. Traditional land rights have come under increasing strain as population density has grown and land has had to be increasingly fragmented as family numbers have grown and as members of each family require land to support their families. Problems of lack of secure tenure have been accentuated wherever land alienation has occurred. Land has often been cleared for development of 'commercial' farming. The displaced farmers may be restricted to areas of less inherent productivity than the lands they formerly occupied, and to which their traditional farming techniques are unsuited. Other constraints include lack of capital for required inputs, inadequate infrastructure for movement of people, marketing of produce and purchase of inputs, inadequate understanding of the sources of the problems and lack of awareness of the methods by which they may be resolved. Non-involvement of farmers in the development and evaluation of technologies for restoration of salt-affected soils is the obvious reason. Farmers themselves are the best extension agents but they first have to understand how they will benefit from any changes.

Therefore, during the three meetings of the Network held in the Philippines, Egypt and Turkey the following related recommendations were confirmed:

1. Strengthening of research programmes on different aspects of salt-affected soils and requesting the Network participants and the authorities of various related ministries in their countries to give full support and funds for coordinating research in terms of equipment, tools, staff, etc. This should include design and implementation of programmes to create national awareness on the use, rehabilitation and management of salt-affected soils.

2. Strengthening the dissemination of information and experiences and development efforts in soil management of salt-affected soils in participating countries through the established Network (FAO Global Network on Soil Management for Sustainable Use of Salt-affected Soils), and stimulate coordination work between different national and international organizations in the field of salt-affected soils. This should include inter-country visits and training within participating countries to share knowledge and experience.

In this regard, government awareness in participating countries should be increased through newsletters, publications and enhanced communications. Production of a simple pamphlet on salt-affected soil and its extent, impacts on soil, environment and socioeconomic conditions could be useful to increase awareness of policy makers and civil servants of the governments of participating countries. In addition, there is an important role of the education of the younger generations (schools and universities), to be made aware of salinity problems. In this regard, universities should be encouraged to orient part of their education programme on soils to focus some courses on different aspects of soil salinity and to try to benefit from the practical experience of scientists and specialists working in relevant authorities or institutes as lecturers.

3. As more than one authority or institute in each participating country are concerned and have related activities, data, maps, reports, research and development programmes, special institutional arrangements may be made to allow effective cooperation at a country level. It is up to the country to decide on the formation of such arrangements.

4. Standardisation of accurate and reliable methods of physical, chemical and biological analysis of salt-affected soils. Methods of soil and water sampling and analysis in participating countries should be standardised for better comparison of results and available data. In this context, it would be useful for the Network participating countries to initiate joint comparative studies of commonly used soil and water analytical procedures in contact with ISO and IUSS. The international dimension of these standard methods and procedures will allow across border competition and exchange of information.

5. Transmission of information and technologies necessitates a hierarchy of 'transfer bodies': farmers-farmer associations-extensionists-researchers-engineers-scientists, making possible mutual understanding, common language and permanent contact. To neglect one or more of these information transmission stations (because for example, visually high cost) is neither rational nor efficient. Farmers should become active participants in the development of an appropriate management system and should become the main originators of technical solutions appropriate to improving productivity of their salt-affected soils.

6. Various technologies have been presented during the meetings of the Network for the improvement of salt-affected lands. The prescribed results and long-term experiences showed that improperly planned and implemented reclamation, irrigation and drainage practices may lead to the failure of sustainable salt-affected soil management projects and result in environmental side-effects. Since rehabilitation and management of salt-affected soils requires a combination of agronomic and management practices depending on a careful definition of the requirements, it is recommended that the effect of integrated management approaches should be technically tested and economically evaluated under different conditions (soil type, hydrological, socioeconomic, etc.). Information from results obtained should be disseminated between participating countries.

7. Independent evaluation and verification of technologies and uniform data collection are needed for effective technology transfer. However, cost comparisons between countries are difficult and lead to the choice of different technologies to address similar problems. Further information sharing among countries is needed to determine the long-term effectiveness of any suggested management technologies.

8. The preconditions of a rational and efficient soil salinity/sodicity control are adequate knowledge on present situation of the soil (information on present status of the characterization of soil and water), assessment of its spatial and time variability and changes (monitoring the rate of deterioration), and on existing salinization/sodication process (causes and mechanisms). Therefore, it is recommended that participating countries start to develop methodologies to update information about their salt-affected soil; to assess human-induced soil salinization/sodication; and to monitor changes in soil productivity in relation to local conditions. Particular attention has to be paid to the possible forecasting (prognosis, prediction) of salinization and alkalization processes and assessment of soil vulnerability to such processes and on that basis on their prevention). The elaboration of an integrated early system for salinity development is highly recommended (development of models, expert system, decision support system).

9. As a result of coordinated Network activities, the following priority problems have been identified that need further investigation and practical solutions at national level:

- Sustainable irrigation technologies with saline water, drain water, sewage water, etc. (polluted water).
- Management of farmer inputs, particularly fertiliser, organic residues, agricultural chemicals in salt-affected soils.
- Unfavourable changes in the groundwater quality due to groundwater overexploitation.
- Unfavourable changes in the physical/hydrophysical properties of soils in the moisture regime of the soil.
- Landscape deterioration.
- Quantification of salinization/sodication/alkalinization processes, the influencing factors and their mechanisms.
- Precise definition of salt-affected soils accepted internationally and for local conditions.
- Elaboration and international harmonisation of irrigation water quality criteria (depending on the concentration and ion composition of water, soil characterisation, land characterisation, land use and cropping pattern, applied agrotechniques).
- Vulnerability assessment of soils/lands from the viewpoint of various soil degradation processes including salinization, sodication and soil pollution.
- Increase of salt-tolerant crops (breeding with the application of gene-surgery, selection, production of salt-tolerant plants).
- Integrated salinity/sodicity/alkalinity researches (soil-plant-water-food chain-atmosphere system).

10. In production (development) the decision is made by the farmer, influenced by economy regulations (credit, support, tax reduction, price policy of agricultural products and required input materials, etc.), and by extension (advisory service). But for 'sustainability' this market oriented policy alone is not satisfactory. For an appropriate

control of 'off-site' and 'long-term' effects stimulating economy regulations and precisely formulated legal documents are required. For the sustainable use of salt-affected soils an independent National Plan is not required but it is advisable that stimulating regulations are built up into the National Agricultural Development, Environment Protection or National Resource Management Programmes and Plans of Action.

11. Soil salinity in irrigated land is widespread and common through all participating countries; however, it should be related to other associated topics such as human health issues, toxic element effects (boron, molybdenum, selenium, nitrates, etc.), wildlife, environment and crop production.

12. Soil salinity assessment should continue to be based on the following soil chemical properties: electrical conductivity, total dissolved solids, ESP and pH. However, the methodologies to be used for salinity assessment (traditional, remote sensing, handhold sensors, non-point source modelling) will depend upon several factors such as the scale, accuracy required, cost of project and available funds and the area to be surveyed.

13. Definition and mapping of salt-affected soils should be standardized in order to use the same technology worldwide, A general methodology to monitor and evaluate the causes and processes of the genesis of salt-affected soils by using efficient techniques (GIS, modelling, expert systems, remote sensing, etc.) should be improved and if possible standardized. GIS technology is seen as an essential tool for the monitoring of salinity status.

14. Soil salinization should be considered as part of a global land degradation process with direct impact on the environment, biomass production and socioeconomic status of a region. The presence of toxic elements for human and animal health like boron, arsenic, selenium, fluoride, molybdenum, etc. are a consequence of the formation of soil salinity build-up. For this reason, it is very important to monitor, prevent or remedy the effected physical, chemical and biological properties of the soil, taking into account the impact on the economical condition of the country. Recommendations on soil management of salt-affected soils should consider the social and economic impacts on the farmers rather than only maximising yield.

15. Farmers should receive more information on soil and water management, and reclamation of salt-affected soils, mainly on:

- Biological techniques for sustainable land reclamation including the effect of organic matter application. Organic amendments are considered useful including animal manure as well as crop residues.
- Strategies and alternative solutions of management, including rehabilitation of irrigation and drainage systems.
- Fertility management, as an important component of any integrated soil management of salt-affected soils. Adverse effects of salinity are considered to be partly mitigated by optimum fertilisation practices. It is generally considered by participants that there are special nutrient requirements under saline conditions and that plants responded to fertilisation under saline conditions more than under non-saline conditions based on field experience and field trials. Among the needed nutrients, zinc sulphate and K are recommended for rice cultivation.

16. Water classification was not considered useful due to the interaction of water quality with factors such as climate, crop selection, soil type, etc. Among the various water quality parameters those of sodium adsorption ratio, electrical conductivity, pH and residual sodium carbonates and alkalinity are considered useful. However, water quality criteria need to be based on economical rather than arbitrary yield reduction. In general EC of 2.0 dS/m serves as the standard criterion for a saline soil (saturation extract). Actual values used for defining potential problems range from 0.75 in the coastal areas of Thailand, to a value of 7.0 in Tunisia. It is agreed that the upper limit for irrigation water salinity (on sandy soils) is around EC = 10 dS/m.

1.13. Other issues, recommendations, institutional framework, policies and major national programmes to combat salt-affected soils in participating countries

1.13.1 Countries with FAO collaborative projects

Africa Region

a) **Ghana**: Apart from physical and chemical conditions of the salt-affected soils to make them productive, there are a number of issues that must be addressed before the communities can adopt prescribed technologies which include:

- The communities must show interest in using the ameliorated lands for agricultural production. The prescribed crops adapted to saline conditions must be preferred by the communities. Rice is one crop that is surely to be recommended. The communities in affected areas must be educated enough before they will go in for rice farming.

- Credit and input availability will dictate the rate of acceptability of the generated technologies. With the government present policy of removal of subsidies on agricultural input and the present high interest rates on credits charged by the banks, farmers will find it difficult to secure adequate funds to undertake the ventures.

- Staff of the Extension Service of the Ministry of Food and Agriculture must be available and well trained in the proper uses of these soils before they can raise the levels of know-how of the communities.

- Adequate quantities of freshwater must be available for use in affected areas. Apart from groundwater the nearest source of freshwater is the Volta River. Harnessing these for use in the farms will be very costly and beyond the affordability of the farmers.

- It will be difficult for the people to forego their century-old vocation of fishing in the sea, lagoons and creeks and adopt agricultural practices in their salt-denuded lands.

- Conditions of land tenure must encourage farmers to invest in the farming projects. The present conditions elsewhere in the country do not favour heavy investment by farmers since they cannot buy the land. The land is leased to them at short duration and at difficult terms.

- The salt-affected soils of the country especially the Muni, Songaw, Truku, Keta and Ada soil series which have serious morphological and salt content problems are left unused as a result of lack of appropriate technologies. The only works conducted on these soils have been their mapping, description and classification. There have been no research studies on their drainage, salt content and fertilisation problems to bring them into production.

- There is a need for the ministries, research institutions and universities to work in an integrated manner to bring these soils into production. Techniques for development and management of salt-affected soils must be undertaken to alleviate the plight of the communities within the Plains. In doing so, there is the need to seek adequate information from organizations in sister countries that have already developed appropriate technologies on drainage, levelling, fertilisation and selection of adapted crops in an integrated system.

b) Kenya: Related issues to management of salt-affected soils in Kenya include:

- Reliable knowledge of soil and land characteristics is essential to respond to the various environmental and land degradation problems. Several global studies related to land resource assessments have been carried out such as the World Map of the Status of Human-Induced Soil Degradation (GLASOD) and World Soils and Terrain Digital Database (SOTER) projects. The main objective of this global assessment was to strengthen the awareness of decision makers and scientists on the dangers resulting from inappropriate water and soil management.

- In most areas of the ASAL, land is communally owned. Soil and water management techniques in salt-affected soils are long-term measures requiring regular maintenance. Group ownership and non-adjudication of land militate against adoption of permanent management measures. On the other hand, increased subdivision of land parcels makes it difficult to undertake optimal soil and water management layouts in salt-affected soils.

- Construction and maintenance of management structures such as drainage systems are labour intensive and therefore require substantial capital, especially during the construction phase.

- Use of crop management practices such as mulches and crop residues in the semi-arid areas is difficult, firstly because of the absence of the crop cover when it is most needed and secondly because crop residues are mainly used for animal feed. Crop residues, especially maize stover, are used as a dry season livestock feed. Labour for the construction of drainage structures, however, competes with labour for transporting boma manure to the field, herding, etc.

- Implements that can cultivate and plant in salt-affected soils are currently lacking.

- It has been argued that the level of risk associated with crop production in salt-affected soils makes it difficult for the smallholder farmers to realize the full benefits to rehabilitate them.

- Lack of knowledge of managing salt-affected soils has been cited by many farmers as one reason for not adopting specific measures. Although there have been some attempts to reclaim and increase productivity of salt-affected soils, mainly through the drainage systems, the information available is still insufficient to recommend the appropriate management techniques. Leaching (flushing with irrigation water) and planting procedures are considered to be the common ways of supplementing natural rainfall for leaching salts in areas with adequate drainage.

- In Kenya, before independence, soil conservation was mandatory by law. Now the resident population considers this as forced labour. The social stigma has lingered on in some areas even after independence though this legislation is practically null and void. After attainment of political independence, the government gave the commitment to resettle the landless and displaced people on the formerly held (white settlers) extensive rangelands. This led inevitably to fragmentation of already marginal land.

- In principle, the government policy is that reclamation of salt-affected soils on individual farms should be done by the farmers themselves. The main contribution of the government is the digging or cut-off drains, which will take care of excess water flowing from areas outside the farm (plateaux, large hillsides, roadside ditches). But policies are government commitments subject to availability of funds

- In 1980, the Permanent Presidential Commission on Soil Conservation and Afforestation was established to coordinate soil conservation and afforestation activities, including salt-affected soils. In 1996, the National Environmental Action Plan (NEAP) was launched with a related proposal for controlling land degradation and desertification. There are several established regional and sub-regional organizations which coordinate different soil management and conservation programmes such as Southern African Development Community (SADC), Inter-Governmental Authority on Drought and Development (IGADD).

c) Nigeria: At the moment, the country is experiencing rapid decline and poor management of its resources and an uncontrolled environmental pollution that may threaten the agricultural potential of the country. These adverse situations can be averted if the country invests its oil wealth to develop and manage these resources, including its land and water resources in a sustainable manner.

- Domestic agricultural production witnessed stagnation. Agricultural policies to reverse the situation became inconsistent with every new regime changing existing policy before it had time to mature. Data for planning was generally inadequate in scope and duration. Data on agriculture production in most cases provided estimates of output rather than actual measured production and invariably lacking in estimates of requirement and whether or not surplus or deficit exists.

d) Tanzania: Many soil management and conservation schemes in Tanzania have been implemented without a sound scientific basis or socioeconomic consideration. Both traditional and contemporary strategies have been employed in attempts to rehabilitate degraded lands including salt-affected soils. Some of the programmes such as HASHI and HADO have registered very limited success due to their top-down approach while a few of the more recent programmes such as SCAPA have been quite successful, because the programme is largely community-based and focuses on a multidisciplinary approach to address the problems, including a strong component of farmer participation.

Management and reclamation of these soils must consider the socioeconomic, biophysical, chemical and environmental aspects of the whole task. Therefore the following roles should be considered for some of the key players involved:

- The government (Ministry of Agriculture and Cooperatives) creates a forum which will enable scientists involved in the research, reclamation, management, and utilisation of salt-affected soils and other stakeholders to meet regularly and exchange experience and to give salt-affected soils a priority, with respect to funding research and dissemination of the generated technology on their management and utilisation as a matter of policy.

- Research to test the locally available management practices for effective reclamation programmes including use of high-value tolerant crops and fodder and the cost. Research should be of participatory nature for the community. Considerable emphasis will be directed towards exploiting the locally available gypsum and pyrite resources and breeding programmes for salt-tolerant varieties of various crops. Breeding of varieties tolerant to salts has never been accorded any attention in Tanzania. The suitability and effectiveness of various locally available organic materials in the reclamation of salt-affected soils, either when applied alone or in combination with various inorganic materials should be investigated. The capacity of the present research set-up, with respect to monitoring systems, decision support systems, modelling and salinity prediction through remote sensing techniques and other GIS applications should be increased. At present this area is in its infancy.

- Private industry to fund reclamation, management or utilisation research in salt-affected soils in whole or in part; to take part in the development and testing of the technology generated by research as well as its dissemination and to develop the pyrite mine at Samena for the purpose of availing the raw material for reclamation work.

- Non-governmental organizations to mobilise, specially the resource-poor farmers in the affected areas; develop and test different reclamation technologies in conjunction with researchers in a participatory manner; identify at community based level, the various research programmes that may help alleviate the problem; and mobilise the affected communities into using their own resources to overcome the problems caused by salt-affected soils in their farming systems by identifying alternative ways of utilising these soils.

Asia Region

a) Bangladesh: Many factors including socioeconomic limitations govern the land use patterns in Bangladesh:

- In the coastal areas land use is further complicated by the presence of fluctuating soil salinity levels, on the one hand, and more recently by the tendency of profiteering by the shrimp businessmen. Unauthorised digging of channels for the intrusion of saline water for shrimp culture creates agronomic problems and also social conflicts and public health hazards. Although badly needed, there are no effective government regulations to rationally look after the conflicting interests of the shrimp entrepreneurs and local farmers.

- Appropriate extension programmes for the diffusion of modern technologies are lacking. Extension personnel trained in saline soil management is inadequate.

- Large-scale land ownership, unfavourable land tenure systems and dominance of absentee landlords discourage the adoption of modern crop production technologies by the vast majority of small farmers. Poor communication and marketing facilities retard agricultural development.

- Research requirements in the country include: continuous monitoring of salinity and development of models for the prediction of the degree of salinity. Evaluation of soil and water salinity in the coastal areas is occasionally done by the Soil Resource Development Institute (SRDI) and the Bangladesh Water Development Board (BWDB). SRDI has produced a soil salinity map of Bangladesh using the GIS technique. However, continuous monitoring of soil and water salinity is required given the fluctuating soil and water salinity levels. The Space Research and Remote Sensing Organization (SPARRSO) of Bangladesh has to take the responsibility to carry out the required remote sensing and ground techniques, and improvement of soil physical conditions to facilitate speedy and effective salt leaching during the wet season. The application of organic matter like green manure, crop residues, rice husk, saw dust, animal dung, farmyard manure, etc. will be especially useful. Most of these products are used up by the small farmers as kitchen fuel and thus these are almost never recycled to the soils. The Department of Agricultural Extension and NGOs working in the rural areas may help farmers realize the benefits of the application of organic matter to their fields; and proper fertiliser application to maintain an appropriate ionic balance in the soils (crop research institutes such as the Bangladesh Rice Research Institute (BRRI) and the Bangladesh Agricultural Research Institute (BARI) can conduct such research for rice and other crops. Research should also cover water management and crop management aspects.

- National institutions and organizations like the Bangladesh Agricultural Research Council (BARC), Bangladesh Rice Research Institute (BRRI), Bangladesh Agricultural Research Institute (BARI), Bangladesh Water Development Board (BWDB), Soil Resource Development Institute (SRDI), Department of Agricultural Extension (DAE) and a few NGOs have been working for the development and dissemination of agricultural production technologies for the coastal saline areas for quite some time now. The Ministry of Agriculture is in the process of planning a coordinated research and development effort and providing necessary policy guidelines for the overall development of the coastal zone.

- The Ministry of Agriculture formed a 'Task Force for the Development of the Coastal Areas of Bangladesh'. This task force consisted of representatives of BRRI, BARI, BWDB and SRDI. The task force, under the leadership of BARC, reviewed the problems and potentialities of agricultural production in the coastal areas of Bangladesh, and submitted its recommendations to the Ministry. At present meagre research and development work is being carried out by different organizations, and with little coordination.

- Shrimp areas must be clearly demarcated and prevented from disturbing agricultural land. Adequate controlling regulations are needed. The mangrove forests (the Sunderbans) must be preserved at all costs. The coastal afforestation programme should be strengthened. This will accelerate land accretion and consolidation.

b) China: The government, scientists, extension service, and farmers themselves, all play important roles in controlling salt-affected soils of China. The government highly encourages scientists', extension services and farmers' activities on the control of salinization. In China, some successful regionalisation has been contributing significantly on salinity management and salt-affected soil utilisation such as regionalisation introduced in Tian-Ran-Wen-Yan Canal Basin of North Henan. Principles and practices of salinity management in one basin can be used in another basin or region with similar bio-climatic and social-economic conditions of which the followings are some considered issues:

- Decision making on expansion and planing of irrigation layout has been conducted by taking all possible negative impacts into accounts.

- Some advantageous policies are drawn up for farmers in affected areas such as tax deduction. As a result, coastal regions attract more investment on land exploitation and utilisation and on management of salt-affected soils. In China, the farmland is usually contracted from the local government to the farmer as 'responsible land'. One family often operates farmland less than 1.0 ha. Land tenure varies from 5 years to 50 years, although long-term tenure has been encouraged recently. In some regions farmers are cooperating to form a large farm, where on-farm irrigation/drainage facilities will be greatly improved and abilities against salinization will be enhanced. Short land tenure is not good for long-term investment of land, especially in problem soils such as salt-affected soils. Therefore, appropriate land tenure should be longer than ten years in salt-affected regions. In China, land tenure in some coastal salt-affected regions can be extended up to 50 years.

- In some regions, especially river water irrigation districts, irrigation charges are collected according to the land area rather than to accurate water amount consumed by the farmers. Therefore, some farmers have not paid much attention to saving water and preventing rise of groundwater table on farmland. In the regions where irrigation water charges are collected according to water consumed, the water table is easier to control than in other regions, owing to farmers' enthusiasm both in regard to saving water costs and maintaining land quality.

- Research on salt-affected soils in China is suggested to include: monitoring, assessment and prediction of soil salinity (remote sensing and GIS techniques can be used as tools of middle and long-term monitoring of salinity evolution and even prediction of secondary salinization); optimal model and technique systems on salinity management and utilisation of salt-affected soils (the model should be integrated with as many choices of techniques on salinity management as possible, to be suitably used in different natural conditions, management patterns, agricultural layouts); multiple-objective decision support system (the system should be developed to assess, analyse and compare advantages and disadvantages of all aspects involved, and to help on decision-making in an optimal manner); and studying human-induced salinization impacts on environment and ecology, besides those on agriculture.

- Overall national agricultural planning for improvement of salt-affected soils is one of the effective ways to solve nationwide salinity problems. Recently improvement of salt-affected soils is included in the national agricultural plan for improving low-to-middle-yield soils (including all problem soils) in China. Such agricultural plan covers all provinces and regions where salt-affected soils and other problem soils are distributed.

- In China, the Commission of Salt-affected Soils of the National Soil Science Society has been actively involved in improvement of soils and planning, by organising workshops, exchanging information and putting forward some project proposals.

- Institutions from the Chinese Academy of Sciences (such as the Institute of Soil Science), agricultural universities and the Chinese Academy of Agricultural Sciences are the main forces dealing with salinity problems and management of salt-affected soils in the country.

c) **Indonesia:** The government has launched different programmes to reach self-sufficiency in rice and other food crops, especially maize and soybean. To cope with this target, agricultural activities have been extended to problem soils including coastal salt-affected lands.

d) **Pakistan:** Approaches tried in Pakistan to control and arrest the problems are: (a) commissioning of Government-sponsored large salinity control and reclamation projects (drainage projects over 8 million ha); (b) leaching of salts by applying increased irrigation water and chemical amendments, organic wastes and plants (small local level interventions); and (c) promoting saline agriculture bio-reclamation techniques using tolerant crops, bushes and trees, and fodder grasses.

- The R&D infrastructure in the country for salinity and waterlogging includes the Drainage Research Centre at Tandojam (Sind), the International Waterlogging and Salinity Research Institute, the Punjab Directorate of Land Reclamation and the Mono Reclamation Experimental Station.

e) **The Philippines:** The mitigation measures for salt-affected soils go beyond the provision of technologies. As the communities in these areas are very poor, the provision of poverty alleviation measures – non-farm or off-farm livelihood activities – that will improve their financial conditions to enable them to access and afford available technologies appropriate for their production problems is critically important.

- A long-term research that will record, monitor, and evaluate changes in productivity, soil quality, and cost of interventions is a major requirement for research on salt-affected soils. A multidisciplinary, integrated research is important as the farmers in affected areas are resource poor, less educated, have no access to capital and technology, food insecurity, and their production cycles are uncertain and vulnerable to recurrent attacks of increasing unpredictability of adverse climate changes.

- The 1997 Agriculture and Fishery Modernization Act (AFMA) in the Philippines, provides a two-pronged measure for making the farmers competitive and productive. One deals with research, technology development and extension and the other on the basic needs programme that emphasises livelihood options for resource-poor farming communities. The AFMA National Research Agenda has just developed a specific research network on natural resources where the Bureau of Soils and Water Management (BSWM) is designated as the national coordinator. The Network under the unified research plans and programmes will tap, interconnect, and harmonise all research efforts in the country. The Network shall focus on the subject matters that relate to sustainability of the use and re-use of soil and water resources in the country. On the other hand, the BSWM is likewise a recipient of a 5-year programme that will deal with research, development, and application of appropriate soil and water management technologies for marginal soils including coastal salt-affected soils in the country.

f) Thailand: Although the degraded soils, particularly saline soils, can be solved by present technologies, land deterioration has continued to be a problem. Salt production and shrimp farming that have caused salinity problems in large areas have also continued to grow. Legislation can be a better measure so that the government can impose policies to protect arable land from various harmful activities. In 1989, the government banned illegal salt production in the Northeast region, and in 1998 also banned shrimp farming in freshwater areas of the Central Plain.

- Legislative issues were introduced in the country on: i) effective use of natural resources; ii) conservation of land resources, rehabilitation and development of degraded lands; and iii) pollution prevention and eradication.

- The importance of research on soil salinity is of primary concern in Thailand, as expansion of salt-affected areas by both natural and anthropogenic sources and their adverse effects on agricultural production and surrounding environment have continued. This is presently focused on the use of integrated technologies to increase crop yields, sustainable use of salt-affected soils and land resources. Varying from place to place, based on soil characteristics and other environmental circumstances, the research on soil salinity in Thailand covers: monitoring of soil salinization (this could be done using remote sensing and GIS techniques); fundamental study on the mechanism and formation of salt-affected soils; soil and water management including practical models for different salt-affected areas of the country, depending on various environment and socioeconomic circumstances; and crop management (selection of crops and varieties most tolerant to salinity, rotation of crops and development of cultural practices).

- An agricultural plan for improvement of salt-affected areas was included in the National Economic and Social Development Plan. In the period of the 5th and 6th plans (1982-1991), it placed emphasis on increasing crop yield with low-cost and practical techniques for farmers. The areas in the low land in the Northeast, which are suitable for rice cultivation, were the primary focus. The 7th plan (1992-1996) considered the reforestation area for salinity control in 800 000 ha. In the 8th plan from 1997 to 2001, the Land Development Department plans to improve salt-affected lands.

g) Viet Nam: High salinity is a major constraint to crop production especially during summer due to lack of irrigation water to leach salts from the root zone, poor drainage during the rainy season, lack of high-yielding salt-tolerant crop varieties and also to existing land tenure and land use system (land allocation to the farmers is practised but land use planning by integrated management to protect and improve soil fertility and environment is problematic).

- Research should cover establishment of database management of natural resources on coastal salt-affected soils using GIS technology; monitoring, assessment and prediction of soil salinity (practical computer model should be developed for salinity assessment); different management activities under different land use patterns; dynamics of salt intrusion along the river systems from estuaries and its control; salt-tolerant rice varieties, especially high quality rice; mangrove forest protection in appropriate combination with fish-shrimp culture and land use policy and environmental protection in salt-affected soils regions.

- The Government of Viet Nam is allocating a large part of agricultural land, forestland and barren land (unused land according to the Land Law) to people with the aim to effectively use the land, planting new forests and protecting existing natural resources. The farmers in these areas have the right to use their lands for a long time to improve and conserve soil fertility at the same time with effective use of lands to develop crop yields and production. But the forest land use planning and forest land allocation could not carry this out in good time due to shortage of funds and of a proper and feasible methodology. Farmers received agricultural land and forestland certificates.

- The government pays more attention to investment for construction of protection systems on flat land, especially for seawater control by establishing dykes and linking culverts for increasing food production and food security.

Europe Region

a) Hungary: The government put some principles in its plan for sustainable use of salt-affected soils areas including: rational land use and cropping pattern; adequate agrotechnics for surface water management and soil moisture control; reduction of ecological constraints and practicing rational plant nutrition in the slightly or moderately salt-affected areas and proper infrastructure for extensive (low-input) farming and/or wetland management in the strongly saline/sodic regions.

- The problems of salt-affected soils and their management are investigated in the country through i) the Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, Budapest, ii) the Department of Soil Science and Microbiology of the Debrecen Agricultural University, iii) Debrecen Institute of Soil Tillage and Amelioration of the Debrecen Agricultural University, Karcag.

b) Romania: Research concerning reclamation of salt-affected soils has a long tradition (beginning in the 1950s) in Romania. The leading institutions are the Research Institute for Soil Science and Agrochemistry, Bucharest and the Central Research Station for Improvement of Salt-affected Soils, Brăila. Investigations have been carried out in several experimental fields located in the main areas with salt-affected soils as follows: Socodor, Arad County (reclamation of sodic soils mainly Solonetz from the Western Plain by Oradea, Agro-Zootechnical Experimental Station); Ruşeţu, Buzău county (reclamation of saline soils mainly Solonetzs and Solonchaks from the Călmăţui Valley); Polizeşti, Brăila County (reclamation of salinized soils by rice cropping by RIISA and Brăila Experimental Station); Măxineni-Corbu Nou and Gulianca, Brăila County (intensive reclamation of salt-affected soils and of salinized soils by RIISA and Brăila Experimental Station). On the basis of the research results a series of methodologies and procedures was prepared in classifying, mapping, and reclamation of salt-affected soils.

- The survey of salt-affected soils was the responsibility of RIISA, as coordinator, and of the county soil survey and testing agencies.

- The reclamation of salt-affected soils was of concern in order to increase the incomes of farmers applying higher inputs, especially within the irrigation schemes where the higher investments were available, the cost being completely supported by the state.

- Salt-affected soils represented a special issue within the national soil quality monitoring system according to a special procedure since 1977. As a result, significant areas of salt-affected soils were improved. Within the national programme for salt-affected soil reclamation, rice cropping was one of the most profitable farming systems. Thus since 1980, the rice cultivated area increased from 19 800 ha to 49 300 ha in 1989. Unfortunately, it then decreased down to 4 000 ha in 1997. Most of these former paddy soils could be rehabilitated with economic profit.

- As Romania faces a severe economic crisis, investments for land reclamation decreased very significantly. The issue of salt-affected soil reclamation is focused on those areas where very important socioeconomic problems arise.

c) Turkey: The General Directorate of Rural Services (GDRS) has carried out reclamation studies all over the country. Issues related to reclamation of salt-affected soils include completion of detailed soil survey to have enough inventory data about salt-affected soils and to characterise each of them on different scales; determination of areas having potential salinization problems especially in irrigated areas; construction of drainage systems with irrigation systems; only using high quality water for irrigation; providing coordination of government agencies and research institutes; organization of private sector irrigation; monitoring changes in salt-affected soils and irrigated soils and to apply new advanced technologies such as GIS, RS, and computer modelling for monitoring and management of salt-affected soils.

- In Turkey, studies are focused on the assessment of the full extent of salt-affected soils suitable for reclamation (some of the successful project examples are Iğdır, Konya-Ereğli, Aksaray, Gediz, Lower Seyhan, Menemen, Bafra, Söke, Salihli, Kayseri-Karasaz, Eskiş ehir-Alpu, Denizli-Acıpayam Plains and Çankırı Kızılırmak Basin); hydrologic and drainage response aspects of managing water excess; development and calibration of computer-based models (DRAINMOD, SALTMOD, Gypsum and Leaching Water Requirement); characterization of the properties of waste and drainage water of importance to re-use them and their impacts; diagnosis and predicting of the soil salinity and alkalinity (applied research and modelling for salinity development and management using GIS and RS techniques) and ecology of halophytic vegetation in salt-affected lands in Turkey (Soil and Fertiliser Research Institute and some research institutes of GDRS, with the collaborative work of universities that have carried out a five-year research programme for diagnosing halophytes and characterising saline, sodic and boron-affected soils).

Latin America

a) Argentina: Institutes involved on studies and management of salt-affected soils in Argentina are: Secretariat de Agricultura Ganaderia; Instituto Nacional de Tecnologia Agropecuaria, Insituto Nacional de Ciencia y Tecnicas Hidricas; Laboratorio de Humus y Biodinamica del Suelo of the Universidad Nacional del Sur; Corporacion de Fomento del Valle Inferior del Rio Colorado, Pedro Luro and agricultural experimental stations, universities and specialized institutes throughout the country.

b) Brazil: Brazilian governmental institutions like Superintendência do Desenvolvimento do Nordeste (DNOCS), Companhia de Desenvolvimento Nacional de Obras Contra a Seca (CODEVASF) and Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), mainly through the Agricultural Research Center for the Tropical Semi-Arid (CPATSA) have joined efforts to develop research studies in order to alleviate the situation.

c) Cuba: The government, scientists, extension services, and farmers play an important rolė in controlling salt-affected soils in Cuba. The extension service conducts demonstrations on large scale and work on the extension of the technologies to the farmers.

- Legal aspects related to the control of salt-affected soils in Cuba appear in the Decree No. 179 of February 2, 1993. This deals with their protection, use, conservation and regulation, as one of the principal national legislation related to the environment. The law states that any new systems or management practices to be established must protect the soil against salinization and before the rehabilitation of salt-affected lands, a planning adapted to avoid environmental effects, economic losses and social conflicts should be prepared. Example of the implementation of such law is in the Genetic Enterprise "Manuel Fajardo", in Granma Province. In other places where the soils are strongly saline and the cost for recovery is very high, the lands have been turned from cropland into pasture for cattle raising.

- In Cuba, some successful regionalisation has been contributing significantly to the management and use of salt-affected soils including Guantánamo and Cauto Valleys, which are densely populated zones and have most of the salt-affected soils. The fundamental objective has been to introduce gradually a rehabilitation and management system that permits the local populations to improve their living conditions, and to prevent environmental damage such as degradation and salinization.

- However, in addition to the efforts of the Cuban government, technical and economic assistance through international cooperation projects based on the planning of the land use at community level is required to combat salt-affected soils.

- The research programme in the country includes monitoring of soil salinity and development of models for the prediction of salinization; optimal model and technological system for use and management of salt-affected soils (in Cauto and in the Guantánamo Valleys, such models and techniques should be developed in more detail); and development of multiple decision support systems.

- In Cuba, the national plan for the improvement and conservation of salt-affected soils is directed by the Ministry of Agriculture, in coordination with the Ministry of Science, Technology and Environment that generates and establishes procedures and methodologies on the use, management and conservation of salt-affected soils. The credit and technical assistance of this plan are provided by the Cuban Government. In the execution of the plan various public and private institutions are involved, that stimulate the training of farmers for the conservation and management of salt-affected soils and generate conservation services at the local provincial and district level, taking into account the possibilities and needs of each zone within the country.

d) Mexico: The private sector is not really involved in such kinds of problems as the case of salt-affected soils, except some companies that manufacture, sell and install drainage pipes. Mainly government institutions are aware of the magnitude of the problem, led by the National Water Commission (CNA), which is promoting and investing in extensive soil reclamation projects. Other related institutions are the Mexican Water Technology Institute (IMTA) and some research centres like the National Research Institute of Agriculture, Livestock and Forestry (INIFAP), as well as some state and federal universities.

- Current research includes using satellite images, SIG and a portable sensor to assess soil salinity and poorly drained soils (four reference crops were used: maize, wheat, cotton and sorghum) encompassing about 160 000 ha and a geographic information system (GIS) was used to estimate poorly drained areas in November, the most critical month.

- The Federal Government (Ministry of Agriculture and Hydraulic Resources) formerly controlled all irrigation districts (ID) in Mexico. In the late 1980s, after several economic recessions during the 1970s and 1980s, most of the ID infrastructure became obsolete and deteriorated, and together with subsequent personnel cuts, reflected on an overall deficient administration and operation. Since 1989, the Mexican Government, through the newly-created Comision Nacional del Agua or National Water Commission (from the then federal office in charge of the administration, regulation and conservation of the water resources nationwide), has transferred most of the IDs of the country to the landowners for self operation and administration, so they could be financially sound, and the available resources could be better utilised. The process of ID transference basically included the formation of local growers' associations, through which the Federal Government granted the use of the water and hydraulic infrastructure, as well as the ID operation and conservation, to landowners in terms of Water Concession Titles. This situation encouraged the Instituto Mexicano de Tecnologia del Agua (IMTA) or Mexican Water Technology Institute, jointly with local growers' associations, to promote extensive reclamation projects using adequate technologies according to particular situations.

- Nowadays, the National Water Commission is promoting the installation of subsurface drainage systems, through the Programa de Desarrollo Parcelario or Field Development Programme, in which the government covers 50 percent of the cost of the materials (pipes and accessories) and the installation work as well; the other 50 percent are covered by the landowner. This programme has been implemented mainly in the northwestern IDs (Culiacan, Valle del Carrizo, Rio Yaqui, Rio Fuerte, among others). By 1999, the project also covered the Valle del Carrizo, Rio Mayo and Colonias Yaquis ID.

Near East Region

a) Egypt: The government activities for reclaiming salt-affected soils and improvement of their productivity are concentrated through three main programmes. The first programme is introducing tile drainage systems to cover all cultivated areas in Egypt, under the supervision of the Egyptian Ministry of Public Work and Water Resources (Tile Drainage Authority). The second is a land improvement programme and the third is a reclamation programme of new lands. The last two programmes are under the supervision of the Ministry of Agriculture and Land Reclamation.

- By the end of 1988, more than 5.5 million acres of cultivated land in Egypt were covered with a network of open collector drains. For that area, more than 3.2 million acres were provided with tile drains at the field level. Tile drainage systems expanded to cover a total area of 5.2 million acres by the end of 2000.

- Since its establishment in late 1970 by the Ministry of Agriculture and Land Reclamation, the Executive Authority for Land Improvement Projects (EALIP) has had the overall responsibility of all types of land improvement in Egypt including salt-affected soils, with the main function to promote activities and actions that lead to increased yield and productivity of old lands. It has a yearly plan to improve 750 000 acres in different Governorates of Egypt. EALIP undertakes soil improvement programmes that include gypsum application, subsoiling, land levelling and reshaping for better water management and improvement of the drainage and canal systems for salinity and waterlogging control.

- Reclamation of new land including virgin salt-affected soils in Egypt covers new land with high saline water table, virgin saline or potentially saline soils with relatively deep water table, e.g. desert areas and oases; and reclamation of waterlogged salt-affected soils in the Nile Delta.

- Agriculture Extension Programmes are quite active and cover all over the country at village level through the Agriculture Extension Sector of the Ministry of Agriculture and Land Reclamation.

- Research programmes on all aspects of management of salt-affected soils and related soil mapping, monitoring systems, modelling, expert system, GIS, have a long history in Egypt and are running within the activities of the Soil, Water and Environmental Research Institute, Agricultural Research Center; National Research Center and Soil Science Departments of different universities all over Egypt.

b) Iran: Several research plans are prepared for conducting long-term investigations on soil salinity including: preparation of soil salinity/alkalinity map; establishment of a number of representative sites for monitoring changes in salt-affected soils in the country; selection and/or breeding of salt-tolerant varieties of different crops including highly salt-tolerant plants such as Kalar grass; study of the conjunctive use of saline and non-saline waters for crop production and the optimal use of fertilisers under saline conditions and increasing the organic carbon content of the soil.

- For more than 30 years, different researches focused on solutions to salinity problems in Iranian agriculture have been carried out by Soil and Water Research Institute (SWRI). However, other organizations such as the Ministry of Power, Ministry of Jihad, and some faculties of agriculture have also been engaged in certain studies pertinent to this subject. So far, most of the research findings concentrated on leaching requirements and, to a lesser degree, the type of suitable amendment materials such as sulphur, gypsum, and sulphuric acid (this has been carried out in Khuzestan and Fars Provinces in government projects). Farmers and private sector are always involved (intermittent leaching is common under farmers' conditions).

- Small-scale and large-scale reclamation projects should receive due attention as such projects may prevent small rural communities from abandoning their land and migrating to the cities. Such migration results in social and environmental problems in rural and urban areas.

- Farmers should become familiar with different possible alternatives of production systems under saline conditions. Using crops for production of fuel, wood, paper, dyes, and animal feed are examples for which salt-tolerant species are available and could replace the existing crops. Establishment of pilot projects to demonstrate the sustainable methods of managing saline agriculture is highly recommended. It is important that credit policies be supported by the pertinent government agencies to help farmers overcome the problems associated with the harsh environment and make greater contributions to the agricultural development of the country.

c) Syria: In the Khabour and Euphrates Basins, the expansion of irrigated agriculture without implementing the required drainage systems has led to the rise of the saline water table with subsequent salinity development. Use of saline well water in irrigation increased the salinity problems in Syria. During 1993-1996, the Euphrates Basin study was completed by many different foreign companies. These studies confirmed the necessity to develop the northeastern region of the country. The studies also concluded that irrigable areas by the Euphrates water amounted to 528 000 ha. After construction of dams and hydroelectrical stations, it was realized that it was too ambitious to achieve that figure because the implementation materials had not been developed and even parameters and specifications of such materials were not clearly identified. The reclamation programmes according to real priority have been ranked (1997) as 168 000 ha in Balkish Basin, 147 000 ha in the Euphrates Plain, 40 000 ha in the Upper Mayadin Plain and 25 000 ha in the Al-Rassafeh Plain. These programmes are being implemented through the General Organization for Investment and Development of the Euphrates Basin and General Administration for the Development and Exploitation of the Euphrates Basin, Ministry of Irrigation.

- The Directorate of Soils of the Ministry of Agriculture and Agrarian Reform was established with the responsibility of all studies and experimental work to be carried out in Syria, related to agriculture development including soil survey, soil fertility and salt-affected soils. The Directorate cooperates in these fields with the Directorate of Research, Agriculture Extension Department and the Provisional Directorates of Agriculture all over the country.

d) Tunisia: The Directorate of Soils, Ministry of Agriculture, is a special unit in Tunisia responsible for all studies and experimental work to be carried out in the country, related to agricultural development including soil survey, water quality, soil fertility and salt-affected soils.

1.13.2 Associated countries

a) Australia: There is a need to study the use of wide variety of institutional policy tools to address salinity issues. These include measures at federal, state and local government levels and include taxation rebates for approved activities, flexible use of state and local government rates and charges, the possibility of imposition of an "environmental levy" on measures that have an adverse effect through salinity on the environment.

- For dryland salinity conditions, main research areas required include investigations into landscape salinity processes; trees and other techniques for groundwater management – recharge reduction; salinity guidelines for land clearing; vegetation of saline areas; managing discharge areas; shallow groundwater as a potential source of water; low-cost pumping systems for control of shallow water tables and salinity hazard mapping. Main research areas required for irrigation areas affected by salinity include developing improved irrigation management practices to maintain rootzone salt balance and prevent waterlogging; investigations into water and salt balance in the crop rootzone; developing crop and forage species with improved salt tolerance; economic modelling and developing effective and economic drainage disposal options for different situations.

- All salinity control and management activities in Australia are now coordinated through the Land and Water Resources Research and Development Corporation (LWRRDC) established since 1990 by the Federal Government. Within LWRRDC, there are two main programmes aimed respectively at irrigation and dryland area salinity: (a) the Murray-Darling (MD) Basin Salinity and Drainage Strategy (SDS); and (b) the National Dryland Salinity Programme (NDSP), which operates in parallel with the SDS of the MD Basin which was established in 1993. These draw together many activities that were previously carried out under other individual programmes aimed at dryland salinity. The aim of the NDSP is to achieve better coordination of research, development and extension activities directed towards better management of dryland salinity across Australia.

b) Canada: Membership of Canada in the FAO Network is to exchange experiences and views between the ongoing Prairie Salinity Network in Canada and the FAO Network. The objectives of the Canadian network are to solve dryland salinity problems, understand the physical nature of the problem and to recommend an ameliorating strategy to address the problem (including satellite geo-positioning systems to define the salinity, mathematical models and use of salt-tolerant crop varieties to ameliorate salinity damage).

Since 1980, on-farm salinity investigation has depended on electromagnetic induction meters, the EM38 and the EM31. The EM38 measures to 1 m depth, and EM31 detects to 3.5 m. Development of the Global Positioning System (GPS) permits continuous all-weather navigation and areal tracking within agricultural fields. Both technologies were used together to provide rapid, low-cost soil salinity assessments.

- Assessing the occurrence, extent and severity of salinity has been a major activity on the North American Prairies. Farmers formed local organizations to work with government agencies, which provided technical assistance and financial support to assess agricultural salinity problems. Lowering government funding has greatly reduced this activity. The Salinity Assessment Monitoring and Prediction System was created. Seven saline sites throughout the Prairie were instrumented and are being monitored for change in salinity status. Also, soil survey information obtained over the years has been gathered and collected resulting in defining a Salinity Risk Index.

c) Colombia: The National University of Colombia, Palmira, approved a research programme on saline soils, which is the only well-organised programme existing in the country. The programme is running in cooperation with other universities and specialised institutions in the country. The main concept is to identify the problem and its causes and processes of formation, its spatial and time variability and the assessment of the present situation to work out possible solutions, management practices and sustainable use of salt-affected soils.

- COLCIENCIAS, the national institution for development of science and technology, has approved a special research plan in Mg-affected soils to be executed in two years. Sustainable agriculture production in Mg-affected soils is more difficult than in soils affected by other kinds of salinity problem. Amelioration of Mg-affected soils is not effective at present because there is not a thorough understanding of the mechanisms by which Mg negatively affects soil structure.

- Salinity, sodicity and magnesium problems affect the most important potentially productive areas, which are considered the future of the competitive agriculture of the country. Population affected by the different salinity problems could be greater than 4 million.

d) India: Technology for reclamation of waterlogged saline lands in India concentrates on the use of sub-surface drainage. Drainage design criterion for monsoon climate has been established and tested on a pilot scale. Also, the methodology for re-use of drainage effluents has been extensively tested and refined. Large-scale pilot projects are being implemented adopting this technology. Techno-economic analysis shows that the technology is highly profitable but it requires community participation at a large scale.

- A number of institutions at central and state levels have been established to facilitate land reclamation programmes. These include scientific institutes to provide research back up (such as the Central Soil Salinity Research Institute, Karnal; the Land Reclamation Corporations; Command Area Development Authorities, NGOs, etc.) to support implementation at the field level. There is a well-laid out policy to provide financial support for alkaline land reclamation programmes in the country.

- The thrust areas of the perspective research plan include: (a) development of a methodology for preparation of a database on salt-affected soils through the use of remote sensing and GIS. Manpower is being trained and infrastructure to undertake these studies is being strengthened; (b) salinity management on a sustainable basis is essentially a problem that has regional dimensions. Developing acceptable technology for varying physical, social and economic environments calls for decision-support models for the system at various levels. Models of regional agro-hydro-salinity and integrated hydraulic and economic optimization are required to be developed; and (c) high cost of agro-chemical and hydraulic technologies compared with bio-reclamation technology needs priority attention. Development of crop varieties tolerant to high moisture and salinity that would facilitate the use of high salinity land and water will be pursued vigorously.

- Rehabilitation of degraded lands and checking their further spread has been identified as one of the major priority area and finds place in the policy documents prepared by the Government of India. States are preparing their master plan for drainage and land reclamation. The Central Government is assisting states through special schemes of land reclamation and command area development programmes. International linkages to facilitate land reclamation programmes, such as the World Bank, SAARC, ILRI and FAO have been established. More such linkages should be further planned.

e) **Italy:** A large number of national agencies deal with the problem of desertification including salt-affected soils in Italy. At the State level, the responsibility is of the Ministero dell'Ambiente through the National Environment Agency; at regional level, responsibilities are shared among Assessorati. In Italy none of the different government levels (national, regional and sub-regional) have specific rules aimed at solving or preventing desertification including salt-affected soils.

- The first act specifically aimed at combating degradation was the ratification of the International Convention on Desertification. The problem of soil degradation in Italy has been recently discussed in an international session (Forum on Local Development in Support of CCD). Some other international conventions have been already ratified by the Italian Government as the National Plan for Sustainable Development, the Convention on Climate Change and the National Plan for Biodiversity.

- The National Environment Agency has been created only recently, the corresponding activities at the regional level should be carried out by the Regional Agencies, none of that are located in southern Italy.

- The purpose of the specific study contributing to the FAO Network activity is to show: a) the relevant influence that reductions in hydraulic conductivity due to increasing sodicity (ESP) play in water transport in the soil-crop system; and b) possibility for predicting the hazard of salinization/sodication due to irrigation with saline/sodic waters.

f) **Spain:** The contribution to the FAO Network includes several studies and research projects which will advise the government on: a) the issue of integrated soil management of natural salt-affected areas (dryland salinity); and b) problem of main seawater intrusion in the agricultural coastal area, its impact on the quality of groundwater and irrigation water (secondary salinization induced by irrigation with saline water), and the appropriate soil and water management measures. A map of salt-affected soils in the Comunidad Valenciana at detailed scale is under preparation.

- The Research Unit of Geomorphology and Salt-affected Soils of the Universitat de Valencia has performed since 1988 several studies on genesis and cartography of salt-affected soils in Valencia and in other counties. It has contributed to the development of regional policies regarding the management and conservation of natural salt-affected ecosystems. In 1995, it organised and hosted the International Symposium on Salt-affected Lagoon Ecosystems, in collaboration with the ISSS, UNEP and FAO. Research focuses mainly in geochemistry of soils and water, modelling of soil salinity and halophytes. Several projects (granted by the EU, local government and in collaboration with other countries), on-going or finished, reflect the country's activities on salt-affected soils.

g) Sudan: The majority of salt-affected areas are located in the low rainfall regions in northern Sudan in the higher terraces along the Nile River, South Khartoum, North Gezira and the White Nile Scheme, north of Kosti, due to climatic conditions (desert, semi-desert and semi-arid).

- The Government of the Northern State is planning to develop about 400 000 acres in the higher terraces which are affected by salinity. The surveyed areas of the saline/sodic soils belong mainly to Aridisols. The Reclamation and Conservation Department of the Land and Water Research Centre, Agriculture Research Centre is the main Unit in Sudan dealing with studies on salt-affected soils.

h) Uzbekistan: The State Committee for Land Resources (SCLR) of the Republic of Uzbekistan is in charge of land resources research, planning, development and usage. It also monitors the main land capability indicators of irrigated and rainfed lands. The Water Resources Department of the Ministry of Agriculture and Water Resources Management is in charge of water resources research, planning, development and distribution. It also undertakes the construction, operation and maintenance of the irrigation and drainage networks at national, provincial and local level. It plans the required measures for irrigation and drainage network maintenance and for the reclamation of degraded lands, including leaching, repairing and cleaning of drainage collectors and network rehabilitation.

- The Agricultural Academy of Sciences (AAS) is in charge of agricultural research and extension. The Uzbek Scientific Cotton Institute and Soil Science and Agrochemical Institute of AAS carry out multi-year experiments and trials in different regions of Uzbekistan. The Ministry of Agriculture and Water Resources is also in charge of agricultural research and extension, on-farm agricultural and land reclamation development, and on-farm operation and maintenance of the irrigation networks.

- The Uzbek State Institute "Uzgipromeliovodkhoz" (the former "Sredazgiprovodkhlopok" Institute), is the largest design-survey and scientific institute designing irrigation systems, reclamation and rehabilitation of irrigated lands in Uzbekistan, Pre-Aral, in Central Asia and in other countries. The Goskompriroda (Environment State Committee) is in charge of water quality monitoring and control of industrial and municipal pollutants.

- Integrated research for decision support systems with particular attention to the development of National and Regional Information Systems as a tool for sustainable use of salt-affected soils is of particular importance and necessity. In Uzbekistan National GeoKadastr and Informational Centres of different ministries and institutions have been created, but current economic problems limit their development and mastering. Remote sensing (Bukhara Project) and GIS technologies are available but with very limited use. Since 1995-1996, implementation has begun at the level of the regions (provinces), districts and planning zones by the TACIS EC-WARMAP-WARMIS Project of Aral Basin Information System.

- The implementation of modelling and expert systems is also limited due to the lack of special equipment, software and absence of qualified personnel.

- The National Action Plan, as the major component of the Sustainable Development Strategy of Uzbekistan, is to increase agricultural production and improve food security through the reclamation and rehabilitation of degraded lands in the Amu Darya and Syr Darya Basins. It is fully consistent with addressing environmental damage from mismanagement of soil and water management. As part of the National Plan, an Irrigation and Drainage Development Strategy for the Republic of Uzbekistan will be started in 2000. The Project will be financed from the Netherlands Trust Fund with the World Bank. Recently a National Environmental Action Plan (NEAP) has been completed for Uzbekistan. The NEAP identifies the scarcity and pollution of surface water and groundwater, the salinization and degradation of land, and the desertification and biodiversity losses as key environmental problems in the country.

1.14 Management practices selected for ongoing collaborative projects in participating countries

The selected management practices used in the experimental/demonstration programmes of the ongoing collaborative projects between FAO and national institutes in 22 countries participating in the Network are summarized below. According to the objectives of different collaborative projects, as well as the ongoing activities and management practices applied in the participating countries, the experimental programmes concentrate sometimes on using specific management practices. The following can be concluded from the ongoing FAO collaborative projects in participating countries. More detailed results can be obtained directly from the country concerned or from the FAO Network Coordinator, A.M. Mashali (please see list of participating countries, institutes and coordinators of the Network).

Africa Region:

a) Ghana:
Project *"Integrated Management of Salt-Affected Soils for Sustainable Crop Production in the Lower Volta Plains"*

Most of the salt-affected soils are not used for production due to lack of appropriate technology. Farmers flush out the salts with non-saline water from shallow wells dug by the beds. Organic manure from bat droppings, cow dung, poultry manure and small fish are mostly used. Low rates of inorganic Fertilisers, mostly urea at 15:15:15 are also used in combination with the organic manure. Shallow rooted crops are grown in soils with serious salinity problems. Therefore, the collaborative project with FAO paves the way for the effective and sustained use of salt-affected soils with integrated approach technologies.

The project started in May 1999 with two experiments. The first experiment sited on Oyibi series is on "The effects of sources and rates of chemical amendments on physico-chemical properties of salt-affected soils using maize as the test crop". Gypsum, burnt-ground, oyster shells, and magnesium sulphate at different rates of application are used.

The second experiment sited on Muni series is on "Effects of organic sources and their rates on soil salinity decline and crop production". Cow dung and poultry manure available locally were used at different rates of application.

The field work is being implemented under on-farm conditions with the main objective to disseminate among farmers the developed integrated soil management technologies package to improve production and increase farmers income from salt-affected soils in the Lower Volta Plain.

b) Kenya:
Project: *"Management of Salt-affected Soils in Taveta and Marigat Irrigation Divisions in Kenya"*

The project started in 1994. The experimental/demonstration works are concentrating on leaching and planting procedures for increasing productivity of maize as the main crop in Kenya. The project site is in irrigated semi-arid conditions with very high evapotranspiration rate (2 000 mm/year) and low rainfall (600 mm/year). The soils are of clay-loam texture. Treatments include three different crop management systems namely: planting on the ridges, planting on the sides of the ridges and inside the furrows. Hybrid maize (511) and local variety were used as test crops. Planting procedures affected seed germination for both maize varieties significantly (ratio of 144:110:87) where planting was done inside the furrow, on the side of the ridge and on the top of the furrow, respectively. Leaching treatments alone did not have any significant effects on the maize yield because of the poor drainage system in the area. However both treatments jointly significantly increased maize yield. After leaching treatments, the pH decreased to near normal (from initial of 8.3 to 6.8). Results were demonstrated and recommended to local farmers with similar salinity problems (EC varies from 6.6 to 7.8 dS/m)

c) Nigeria:
Project: *"Management of Soils Irrigated with Saline Water for Wheat Production in the Semi-arid Sudan Savanna of Nigeria"*

The project started in1997. A preliminary water quality analysis report of the Jakara Dam reservoir water ranks it unsuitable for irrigation. As demand for food increases, the country cannot afford to simply abandon such projects. It is within this context the field experimental work within the FAO collaborative project was to advise on the appropriate integrated management techniques to improve the production of small farmers' fields irrigated with such low quality water. The experimental work is located at Minjibir, Gezawa

Local Government area of Kano State. The integrated soil management programme included leaching requirements, soil amendments, organic matter, subsurface drainage and three varieties of wheat as a tolerant and essential grain crop in Kano State.

The project started in March 1997 when the land was dry enough for trenching to commence. A tile sub-surface drainage system was constructed at spacings of 20 m. The factor level combinations used were drainage (undrained and drained); wheat varieties (TZESR-W, TZESR-Y and local variety) as compared with the effects on maize production; leaching factors (0, 8, 12 and 16 percent); amendments (zero gypsum and 5 tonnes/ha); and organic poultry manure. The results are showing the great effects of the drainage with leaching factors at 8 and 12 percent. The use of gypsum was expected to perform as the poultry manure but may be, because the soil is not yet sodic, from the results so far this is not the case. The results also show more effects of the integrated technologies to increase yield of maize than wheat because of higher salt-tolerance of the wheat.

d) Tanzania:

Two projects: *"Management of Salt-affected Soil in Tanga and Arusha Region"* (started in 1994) and *"Use of Makanya Gypsum for Reclamation of Sodic Soils: The Case of Kileo Irrigation Scheme in Mwanga District, Kilimanjaro Region"* (A new project to start in November 2000) The first project's experimental work has been initiated (Irrigation Division, Ministry of Agriculture) at the new Kitiva Irrigation Scheme where implementation is completed. Farmer motivation in the area so far is very encouraging. However, 30-40 percent of the scheme have already been affected by salinity build-up. Therefore the collaborative project concentrated in this scheme on studying the effect of irrigation without appropriate soil management practices on soil characteristics, and on the effects of management techniques including gypsum, mulching, crop residues (rice straw), drainage system (with 30 m drainage spacings and without drainage system) and organic manure. In sodic soils, Makanya gypsum is used in maize and bean areas. Detailed survey and analysis of the soils of the study were carried out before field works started.

Results show significant differences in yield in both maize and beans between trials treated with organic matter, crop residues and planting proceedings (planting on ridges and on sand bed). The highest yields were obtained by the use of organic matter combined with drainage. The results indicated that the use of inorganic Fertiliser together with organic matter gave grain yield ranging from 3.2 tonnes/ha without drains and 4.8 tonnes/ha with drains. The effect of using crop residues gave yields ranging from 3.2 tonnes/ha without drains to 4.9 tonnes/ha with drains. Application of recommended gypsum at the rate of 12.5 tonnes/ha mixed with organic matter at the rate of 10 tonnes/ha with 10 percent leaching fraction increased total yield in the range from 3.7 to 4.4 tonnes/ ha. Seedlings transplanted in the beds yielded 2.4 tonnes/ha to 3.5 tonnes/ha with and without drains, respectively. These results are compared with only 1.8 tonnes/ha in control treatments. The appropriate management package was demonstrated and disseminated to the farmers.

The major objective of the second project is to reclaim sodic soils of Kileo Irrigation Scheme by using locally available Makanya gypsum as a chemical ameliorant. Specifically, the study intends to develop appropriate land reclamation techniques for sustainable use of salt-affected agricultural land; assimilate reclamation technologies in farmer land management practices for increased crop yields; and to develop and propose land management policies appropriate for agricultural development in the salt-affected soils. In view of the large occurrence of sodic soils, suitable irrigation water and easy accessibility, two pilot demonstration experimental farms will be selected in the Irrigation Scheme of Kileo. The field work will be under on-farm conditions at basin level, and will be carried out by the National Soil Service, Agricultural Research Institute, Mlingano, Tanga, Ministry of Agriculture and Livestock Development.

Asia Region

a) Bangladesh:
Project: *"Rehabilitation and Management of Coastal Salt-affected Soils of the Khulua and Baguhat Districts"*

It is planned that this cooperative project, to be conducted by BRRI, will start in 2001. The objectives are to strengthen the field experimental programme and extension of appropriate management techniques for increasing productivity of coastal salt-affected soils in Khulua and Baguhat Districts and to increase farmers' income through sustainable rice production.

The activities include identification, determination and characterization of coastal salt-affected soils in the two mentioned districts; and to test and demonstrate to local farmers a package of appropriate integrated rehabilitation and management techniques to include application of chemical amendments as available (gypsum, lime and sulfur); crop residues and organic matter; the best leaching regime to permit good seedling establishment of tolerant rice varieties and the required inorganic Fertilisers under existing saline conditions.

b) China:
Project: *"Integrated Management and Sustainable Utilisation of Coastal Salt-affected Soils in Jiangsu Province"*

The project started in April 1996. The available information is not adequate to suggest a full set of appropriate integrated techniques on management of coastal salt-affected soils. Therefore, the collaborative project includes a series of soil surveys, field experiments, on-farm management trials and modelling in typical areas related to salinity problems in Jiangsu Province. Two experimental sites were selected, one in medium- to low-yielding salt-affected soils and the other in abandoned salt-affected land. Various measures and their combination in an integrated approach are tested including improving on-farm drainage-irrigation facilities using wetland rice for leaching salts, balanced nutrition application, green manure application, application of amendments, tillage systems and special planting procedures. The work also includes studies on national utilisation of groundwater and measures preventing saline water intrusion and selection of salt-tolerant varieties of crops or halophyte forage for better use of saline soils. The improvement models for monitoring salt-water dynamics under various agricultural management conditions and technologies gained from this collaborative project are now demonstrated in the coastal areas.

The objectives of the project are to develop and identify integrated techniques on management of coastal salt-affected soils and create applicable models on sustainable Utilisation of such soils; to establish a demonstration block to extend techniques and models to the farmers; and to enhance farmers' productivity and outputs from salt-affected soils toward sustainable development of agriculture and food production in coastal salt-affected land of Jiangsu.

It is suggested that the following practices and techniques can be used in this area to combat salinity problems and to improve agricultural and food production, including monitoring of salt-water dynamics of salt-affected soils under various agricultural management conditions; selection and application of salt-tolerant varieties of crops for optimal use of the soil; balanced Fertiliser management of salt-affected soils; rice planting for enhancing salt-leaching; mulching for reducing surface salt accumulation and organic matter application for regulating salt-water dynamics. The appropriate efficient drainage system is essential in all cases.

Further activities are required on research, extension, policy making, decision making, farmers' training, information exchange and national planning, to combat salinization and to make full use of the coastal salt-affected soil resources.

c) Indonesia:
Project: *"Reclamation and Management of Coastal Saline land for Sustainable Agriculture"*

The project started in November 1994. Government strategy focused on rehabilitation and development of existing agriculture over large areas of the coastal saline tidal land. Cultivation of crops in coastal saline tidal land is possible only with appropriate soil management measures. Therefore, the experimental work concentrated in coastal saline tidal land using careful leaching, special treatments, planting procedures and organic manure as management practices. High-value crops such as vegetables and fruit trees have been considered to attract farmers to use such land as management practices are costly in terms of capital and labour.

The experimental/demonstration works are being conducted under farmers' field conditions at Pendowoharjo, Delta Upang, and at Karang Agung, South Sumatra. With mentioned integrated management practices, yield of red pepper, onions and squash/pumpkin, increased compared with the untreated farms from 2.0 to 3.0, 3.0 to 5.0 and 6.0 to 25.0 tonnes/ha, respectively. Banana gave yields of 12.4 kg per bunch. Four rice varieties were also tested under the same treatments and gave in the wet season for lowland local varieties: Cisadane 3.3 tonnes/ha; IR 6023, 3.1 tonnes/ha compared with four new rice lines that ranged from 3.8 to 5.1 tonnes/ha. Under the mentioned management practices with the application of sufficiently high amounts of NPK Fertilisers and through good management, crop production in general significantly increased. The planting procedures followed were beds 1.2 to 1.6 m wide, each about 0.5 m apart, separated by furrows of 0.5 to 0.6 m deep.

In the saline coastal areas of Indramaya, Java, which are affected by intrusion of brackish saline water through small rivers during the dry season, experiments with gypsum as chemical amendments were also conducted. During the dry season no significant differences were obtained may be because the soil was not yet sodic. However using blanket NPK Fertilisers resulted in yield increases.

d) Pakistan:
Project: *"Management of Desert Soils Irrigated with Saline Water for Fodder Production"*

The Project started in 1993. It is essential that additional land resources be explored to meet the requirement of increasing population. Hence the value of arid and desert areas becomes more imminent. Cholistan is a major desert in the Punjab Province. The groundwater is saline and not suitable for drinking purposes but it could be used to grow salt-tolerant fodder grasses. Therefore, the collaborative project concentrated on growing of high yielding forages (*Cenchrus ciliaris*, millet, barley, Alfalfa and *Leptochloa fusca*) in the Cholistan desert environment using saline water for irrigation to improve quality and quantity of livestock. Management practices include chemical amendments (gypsum), organic matter, mineral fertiliser and judicious selection of salt-tolerant forage and grasses. Leaching of salt by applying leaching fraction of 10 percent and drainage system (drainage projects in Pakistan cover an area of more than 8 million ha) are also used in the integrated package approach.

The use of improved management technology introduced by the project in the Cholistan Desert (at the Dingarh Field Research Station) resulted in successful growth of different varieties of local fodder grasses and imported varieties of palatable bushes and trees. Soil management practices, e.g. ridges, hoeing, addition of gypsum, etc. have been adopted to increase the growth of grasses and minimize salt accumulation in the soil. The grasses have grown well under irrigation with saline water. Results on vegetation canopy, growth parameters, soil salinity build-up, biomass and carrying capacity of tree plantations, natural grazing land and grass cultivation were introduced. The fodder grasses grown have changed the character of the area. Before the experiment the area was dominated by sand dunes and hummocks under sparse vegetation, defenseless against very active wind erosion. Now it is fully covered with grass presenting a view of an excellent pasture in the desert.

e) The Philippines:
Project: *"Management of Salt-affected Coastal Soils in the Philippines"*

The Project started in 1994 in the Bicol River Basin. Salt-affected soils in the Philippines are dominantly located in coastal areas that are encroached by seawater. Therefore, the collaborative project concentrated on demonstrating to the farmers the effect of seawater intrusion and irrigation with saline river water on rice production using appropriate integrated management practices including water management, chemical amendments, salt-tolerant rice varieties (PSBRC 48 and PSBRC 50), crop residues (incorporation of agriculture wastes such as rice straw) in the soil and the Balanced Fertilisers Strategy (BFS) which includes seven formulae of mixed organic and inorganic fertilisers to provide the required nutrients for specific areas affected by nutrient deficiencies and soil salinity. The BFS emphasises the need to recycle crop residues and farm wastes along with a balanced combination of organic and inorganic fertilisers. As a result of the studies carried out within the project fieldwork, the recommended BFS for saline soils is NPK rates at 95-20-15 in addition to 5 kg zinc sulphate, five bags of commercial organic fertiliser and one bag of chemical ameliorant. According to the results from the project, the concept of BFS in saline soils was introduced during the 1997 dry season rice-cropping calendar. Great differences were found among the three fertiliser systems used (farmers' practices, recommended inorganic fertiliser rates and the BFS, consisting of the usual NPK rate as mineral fertiliser in addition to organic manures and crop residues, $MgSO_4$ and gypsum application), both on extreme and moderately saline rice soils. With BFS, a yield of 5.6 tonnes/ha rough rice was achieved which is 4.3 tonnes/ha higher than yields obtained with untreated farms. According to these results and on the same line, in December 1997 the FAO funded a TCP project for the Philippines entitled "TCP/PHI/6712: Integrated Management of Salt-affected Coastal Soil" giving recognition to the basic objective of "developing low-cost, low-risk technologies for management of salt-affected soils under local conditions". Guided by this objective, the project gave priority consideration to soil amelioration, management and plant nutrition in setting up the field trials in three selected sites (Aparri Village, Region II; Cagayon Valley in Luzan Island; Gainza Village, Region V, Bicol Region in Luzan Island and Butuan Village, Region X in Northern Mindanao Island). The three sites are continuing to serve as an access to farmers for the proven appropriate integrated management techniques for coastal salt-affected soils (rice straw, BFS including commercial organic fertiliser, rice varieties tolerant to salinity, water management including pumping-out of saline water and pumping-in of freshwater in rice fields as required and recommended rate of BFS inorganic).

f) Thailand:
Project: *"Management of Coastal Saline Soils in Thailand"*

Project started in 1991. The coastal saline soils in Thailand are potentially fertile, but non-productive due to various limiting factors, in particular high salinity and poor structure. The special remedial action being practised includes selection of crops, careful leaching, organic amendments (compost, rice husk ashes, organic wastes from the sugar industry and rice husks), and special planting procedures. Since such treatments are costly in terms of capital and labour, the collaborative project using the mentioned management practices concentrated on growing crops with high value like cantaloupe/melon and asparagus. Special recommendations also include reforestation of recharge areas, development of effective mulching, using chemical amendments and design of better water management.

The project has been carried out in Suphan Buri Province of the Central Plain. The project aimed to improve and increase crop yields in the coastal salt-affected areas, and extend the improved techniques to farm level. The project comprised two experiments on the production of high-value crops, namely, asparagus and cantaloupe, in the irrigated salt-affected areas of the Central Plain. The treatments included application of organic amendments (compost, rice husk ashes, bagasse and rice husks). The EC values of the soil ranged from 5.0 to 43.6 dS/m before the experiment. Results showed that the treatments with organic amendments at the rates of 56 and 75 tonnes/ha give the highest yields. The experiment on cantaloupe was carried out in farmers' fields in U-Thong District, Suphan Buri Province. The EC of the soil ranged from 5.3 to 25.4 dS/m and of the groundwater from 5.4 to 10.0 dS/m at a depth of 60 cm, and of the irrigation water from 0.17 to 0.29 dS/m. Application of compost containing higher N and P as soil amendments for cantaloupe should increase yield more than the application of rice husk, bagasse, or husk ash. Yield increased with increasing rates of organic amendments.

The government reflected the deep concern of the country with regard to the conflict that has exploded between rice and shrimp farmers in arable freshwater areas and the extent of salinity problems faced by the small farmers, with negative effect on their income and yearly agricultural production loss and with the expected negative impact on food security of the country. In order to effectively reclaim the affected lands and to gain an in-depth understanding of the impacts and demonstrate appropriate integrated technologies and farm salt-affected areas, technical assistance from FAO was requested to assist the government in the introduction and consequent development of appropriate integrated low-cost, low-risk rehabilitation techniques. Therefore, FAO funded a TCP Project that started in December 1999 entitled "TCP/THA/8922: Impact of Shrimp Farming on Arable Land and Rehabilitation of Resultant Salt-affected Soils in Thailand", with the objective to assist the Government of Thailand to study the impacts of shrimp farming in freshwater arable land and in the demonstration of appropriate integrated techniques for rehabilitation of abandoned shrimp farms and for the improvement of salt-affected lands (resultant from seawater intrusion and shrimp farming practices in arable lands), in support of food security programmes in the country. The integrated management package are being demonstrated in three selected sites in Suphan Buri, Pranchin Buri and Nakhon Si Thammarat Provinces, each site includes two plots, one in the abandoned shrimp farm and one in adjacent salt-affected rice growing area. The package includes appropriate drainage system, organic matter, lime or gypsum as required, deep tillage and salt-tolerant rice varieties. Nutrient deficiencies will be corrected by applying the rates of fertiliser recommended from soil analysis.

g) Viet Nam:
Project: "*Integrated Management and Sustainable Utilisation of Coastal Salt-affected Soils in Viet Nam*"

The project started in1997. In Viet Nam, because saline soils are concentrated in the Red River Delta (the intrusion of seawater goes inland for 15 km) the experimental and monitoring work is located within the Red River Basin in the Rang Bong Farm, Nghia Hung District, Nam Dinh Province, with rice as the traditional main grain crop. In addition to the soil survey of the area, the experimental demonstration farm included studying the effect of seawater intrusion and irrigation with saline river water on soil properties, and using the integrated management approach to improve productivity of coastal salt-affected soils using leaching requirements, addition of organic matter, applying crop residues (rice straw) and selected salt-tolerant rice varieties. However, the main objective is to find out an appropriate fertiliser level in order to increase the production of rice under saline conditions.

The project objectives are also to strengthen the field experimental programme of the National Institute of Soils and Fertilisers and extension of appropriate management technology for increasing productivity of saline soils in the coastal land of Viet Nam. The treatments include: spring rice, variety Dzau An Do with growing time of 185 days; summer rice, variety Tam Thom with growing time of 165 days; 4 tonnes/ha rice straw + 90 kg N + 60 kg P_2O_5 + 30 kg K_2O/ ha; 4 tonnes rice straw + 3 tonnes FYM + 120 kg N + 90 kg P_2O_5 + 60 kg K_2O/ha; 4 tonnes rice straw + 6 tonnes FYM + 150 kg N + 120 kg P_2O_5 + 90 kg K_2O/ha (types of fertilisers are urea, single super phosphate and KCl). The results obtained for two years and the recommendations are as follows:

The appropriate fertiliser level for spring rice is: 4 tonnes rice straw + 3 tonnes FYM + 120 kg N + 120 kg P_2O_5 + 60 kg K_2O/ha.
The appropriate fertiliser level for summer rice is: 4 tonnes rice straw + 3 tonnes FYM + 90 kg N + 60 kg P_2O_5 + 30 kg K_2O/ha.

Field days and training were organised for extensionists, policy makers, and farmers in salt-affected areas at the site and in some parts of neighbouring provinces.

Europe Region

a) Hungary:
Project: "*Integrated Soil Management for Sustainable Use of Salt-affected Soils in the Trans-Tisza Region*"

The project started in 1996. There have been several attempts directed at reclaiming the salt-affected lands of the region, nevertheless, the available information is still insufficient to recommend appropriate integrated management techniques to improve the productivity of farmers' fields. Therefore, the aims of the project are to provide a scientific basis of physical, chemical and biological characteristics of heavy textured sodic soils in the Trans-Tisza Region on the basis of long-term field experiments, prevention of salinization and sodication processes from the shallow groundwater and evaluation of impact of human activities on the above processes.

Experimental sites include: i) complex long-term amelioration experiment (Karcagpuszta), to study the effect of surface and subsurface drainage systems (with different spacings), application of subsoil, $CaCO_3$ and $CaSO_4$, tillage and deep loosening, and sprinkling irrigation on soil properties and crop yield; and ii) monitoring system (Jász-Nagykun-Szolnok county, 4 255 ha) for the control of secondary salinization/alkalization of irrigated soils.

In respect of the drainage system, spacing of 5 m was the most effective but not economically or practically acceptable. However, the wider drain distances (15 m) with a depth of 1 m average also regulated the water table level with a better cost-benefit ratio. Without the drainage system the chemical amelioration was only effective in the drier years. Among the chemical variants the spreading of $CaCO_3$-containing subsoil (500 cu m/ha) gave the best results. The integrated package in long-term management programme including drainage system, chemical amendments, deep ploughing and subsoil loosening with good water management particularly the use of sprinkler irrigation is recommended in similar heavy clay salt-affected sodic soils.

In the monitoring system, regular measurements have been conducted in 62 representative soil profiles of various types of hydromorphic soils with different type, degree type, degree and depth of salinity/alkalinity; and influenced by variable groundwater conditions (depth, seasonal fluctuation, chemistry, salt concentration and ion composition). Under the precisely registered given natural conditions and land use practices (cropping pattern and irrigation technology) Na accumulation was observed in 29 profiles, mainly in soils with certain original salinity/alkalinity in their deeper layers.

Conclusions from the experimental results and observations include:

- Under the present socioeconomic circumstances, the expensive complex amelioration of strongly saline/alkali (Solonetz) soils is not economic, rational and sustainable in the Trans-Tisza Region and similar territories.

- The improvement of slightly saline/alkali soils can be rational, especially in cases where their relatively small areas (spots) are located within a homogeneous crop field.

- Particular attention should be paid to the prevention of salinization/alkalization processes. Its necessary requirement is an adequate integrated environmental monitoring system for the early warning of environmental hazards and side effects.

b) Romania:
Project: *"TCP/ROM/8821: Rehabilitation of Polluted Soils in Romania"*

The project started in 1998. Within the activities of the project, five sites were selected to introduce, test and demonstrate the required integrated approach for efficient management and cost-effective low-risk methods for cleansing polluted land for wider adoption by small-scale farmers, in order that land be used appropriately for environmentally safe and contamination-free agricultural production in the country. The selected sites represent different types of pollution: surface oil pollution, animal and municipal wastes, mining activities, industrial heavy metal pollution and salt-affected soils.

Regarding the improvement of salt-affected soils, the selected site is in the eastern part of the Romanian lower Danube Plain at the Brăila Central Research Station for Improvement of Salt-affected Soils. The selected experimental field is fully equipped with water management facilities: open and tile drainage (20 and 40 m spacings), sprinkler irrigation with possibilities of supplemental irrigation for salt leaching, etc. A complex set of reclamation works are being conducted including: removal of native vegetation, the existing drainage system at 20 and 40 m spacings comparing with no drainage, deep loosening, phosphogypsum as chemical amendment (5 tonnes/ha), organic fertilisation (manure 40 tonnes/ha), inorganic fertilisation ($N_{150}P_{100}K_{80}$), leaching, normal tillage works, mulching and cropping pattern including the selected set of salt-tolerant crops and sensitive crops (Sudan grass, sorghum and sunflower as tolerant crops and then maize as sensitive crop). The effect of the integrated approach is very significant with over 30 to 100 percent increase in yield compared with the control. The experience gained in the Brăila experimental field is to be extended over a large area with salt-affected soils in the eastern part of the Lower Romanian Danube Plain, in other regions of the country and even in neighbouring countries.

c) Turkey:
Project: *"Management of Salt-affected Soils in Kocas Region of the Great Konya Basin (Central Anatolia)"*

The project started in 1996. The damage caused by salinity was first recognised in areas where irrigation systems were established. Most of the field experiments conducted on saline and sodic soils supported the assumption that the main cause of salinity in Turkey is directly related to inadequate drainage with the exception of some local areas where the parent material is very rich in sodium salts. Therefore, the collaborative project is to strengthen the field experimental programme and extension of appropriate integrated management techniques for increasing productivity of salt-affected soil and increasing farmers' income in the Koçaş Region. An integrated management package was introduced in the Koçaş Agricultural Station, representative of the salt-affected soils of the Aksaray Plain. Alkalinity was the main problem within the study area. The ESP values extend up to 55 percent. To reduce ESP values, two leaching water regimes and two gypsum levels were applied with two drain spacings (25 and 40 m spacings). However, the integrated approach includes installation of an open drainage system (40 and 25 m spacings), leaching requirement (two levels of irrigation), addition of chemical amendments (gypsum), farmyard manure, special planting procedures, appropriate tillage system (two plough depths) and selection of tolerant field crops including alfalfa, barley and sugar beet. The fieldwork also includes studying the effect of irrigation with good quality water or saline water on soil properties and the mentioned field crops. A 120 cm irrigation level and gypsum application of 10 tonnes/ha under 40 m spacings drainage system were found the most economically effective.

Latin America Region

a) Argentina:
Project: *"Management of Salt-affected Soils of the Lower Rio Colorado Valley"*

The project has been conducted since 1991. Salt-affected soils are widespread in the Lower Rio Colorado Valley. Therefore, the experimental work concentrated on studying the effect of using specific management treatments on the productivity of wheat, barley and millet. Two typical salt-affected soils of the area are being treated with several chemical and biological amendments and the changes in their properties are being monitored. The two soil types include coarse loamy Mollic Fluvaquent and a fine loam Entic Haplustoll of the Lower Valley of the Colorado River (LVCR). Five treatments are being evaluated: check (T), leaching (L), cropped to barley as a green manure (C), sulphur (S) and gypsum (G). Results till 1999 indicated that ECe decreased from 22 in the initial soils to 3-5 dS/m in the treatments following this decreasing order: T > S > G > L > C. The exchangeable sodium percentage (ESP) followed a similar trend. Therefore, the C (barley) treatment was more efficient than the rest.

Groundwater as a complementary water source has been recently incorporated in the Cordoba Province of the central Pampean region of Argentina. Therefore, another study was initiated in 1996 and recent results (1999) suggest that groundwater of the region may be suitable for irrigation if soil sodicity is controlled by using gypsum application according to the requirements.

The general integrated successful practices include laser-guided land leveling, effective active drainage systems, good quality leaching water requirements and chemical amendments (gypsum or sulfur) using barley straw as amendment and deep ploughing.

Results also suggest the important effect of the rainfall and therefore additional leaching factor if required. In 1995 and 1996, the annual precipitation was only 400 m. Under such conditions leaching should receive more water from the irrigation system than normal in order to continue the leaching processes.

b) Brazil:
Project: *"Management of Salt-affected Soils of the Middle Sao Francisco River Valley"*

The project started in 1995. The objectives of the project are to strengthen the field experimental programmes, to introduce the efficient use of integrated management techniques for increasing the productivity of salt-affected soils, and to study the effect of irrigation with saline water in the semi-arid region of the Middle Sao Francisco River Valley in Northeast Brazil as well as to increase the farmers' income through sustainable production of field crops tolerant to salinity (mainly vegetable crops).

Two experimental/demonstration farms were established, the first in the Experimental Station of CPATSA-EMBRAPA, Petrolina, to evaluate the effect of different levels of salt content of the irrigation water and application of soil conditioner (polimaleic acid) on the yield of sugarbeet (salt content of irrigation water was of 0.1, 4.0, and 8.0 dS/m). The yield varied from 29 tonnes/ha to 26 tonnes/ha for saline water plus the soil conditioner with water of 4.0 and 8.0 dS/m, respectively, indicating that sugarbeet is quite tolerant to salinity. The soil conditioner did not significantly affect the crop yield. However, at the lower 4.0 dS/m irrigation water, it increased the yield by 45 percent.

In the second experimental farm in the Irrigation District of Manicoba, Juazeiro, the effect of integrated soil management techniques on improving productivity of salt-affected soils was demonstrated. After leveling, the land was divided into four main plots by field drains. Two plots (replicates) are at calculated and double calculated drainage spacings. Each of the plots was divided by ridges into six subplots. One subplot received integrated management, i.e. mulching, organic matter, leaching factor 10 percent, deep ploughing and gypsum application according to requirements. The five other subplots were treated with the same integrated management practices minus one treatment in each subplot (i.e. minus organic matter or mulching or deep ploughing or gypsum requirement or leaching).

Data shows the economically significant effect on increasing productivity of tomato using the integrated approach of 25 tonnes/ha comparing with only 6.7 for no treatments. The increase in the yield due to other management practices but without drainage system is not economically significant.

c) Cuba:
Project: *"Rehabilitation of Salt-affected soils of the Cauto Valley, Cuba, through the use of legume pasture species for animal production"*

At present the Instituto de Investigaciones Agropecuarias 'Jorge Dimitrov' is working on the improvement and management of salt-affected soils devoted to pasture, specifically in the Cauto Valley, Granma Province, through the cooperative project with FAO, which started in January 1999. The objectives are to strengthen the field experimental programme and extension of appropriate management techniques for increasing productivity of salt-affected soils in the Cauto Valley and to increase farmer income through a sustainable production of pasture legume species for livestock.

The effect of salinity on germination, growth and dry matter yield from different pasture legumes is included in the ongoing programme. In area 1 (Jucarito) two treatments of soil improvement were carried out, related to leaching and organic matter application, cultivated with *Sesbania rostrata* and compared with a control; while in area 2 (Jiguaní), four combinations were carried out of Rhizobium-legumes (*Leucaena leucocephala* - strain Jd15, *Sesbania rostrata* - strain Jd14, *Macroptilium atropurpureum* - strain Jd10 and *C. ternatea* - strain Jd19) and compared with a control without crops.

The suggested integrated management approach includes the establishment of a drainage system (150-200 m apart with a depth of 1.2 and 2.5 m), subsoiling 5 m apart to a depth of 40-60 cm, leaching fraction of 10 percent, crop residues and legumes as organic amendments at the rate of 60 tonnes/ha and gypsum at the rate of 10 tonnes/ha, salt-tolerant pasture legumes varieties (IACUBA-25 and IACUBA-26), selection of best Rhizobium legumes, crop residues and legumes as organic amendments and balanced NPK fertilisers.

d) Mexico:
Project: *"Reclamation and Management of Salt-affected Soils of the El-Carrizo Valley District"*

The project started in 1995. The reclamation programme started in the Valle del Carrizo ID, where field experiments were established to define appropriate management strategies in order to increase the productivity of salt-affected soils. The Valle del Carrizo ID is part of the extensive coastal plain that runs along northwestern Mexico. Water is supplied by the Josefa Ortiz de Dominguez Dam, which is a 600 million cu m reservoir. The total area of the district is 43 259 ha, all surface irrigated. Natural climatic conditions (low precipitation and high evapotranspiration), and poor water management have caused 23 500 ha to become salt-affected and waterlogged areas.

In 1995, a subsurface tile drainage system was installed in a highly affected field abandoned for over 20 years. This field was carefully characterized by slope gradient, spatial distribution of soil salinity, hydraulic conductivity (auger hole and Ernst methods), and water table fluctuation in time (according to the soil conditions and water table behavior, a 28 m drain spacing was calculated). In addition to technical criteria, economical criterion was also taken into account to determine the drain spacing. This criterion was based on the soil texture and the potential yield as a function of the water table depth between two pipelines. A benefit/cost ratio curve showed that a 50 m spacing decreased the potential yield only by 15 percent, but substantially decreased the cost of the system by 50 percent. It was then concluded that the 50 m spacing was the more convenient for practical purposes.

The experiment included two pipeline spacings, 25 and 50 m, parallel to the shape of the field and almost perpendicular to the slope gradient. Integrated management practices (cleaning, cross disking, mulching, organic matter, leaching, deep ploughing, gypsum application and land leveling and bordering) started the land reclamation process. The field was flood irrigated and successive soil leachings lowered the salt concentration so that wheat could be established. The experiment was divided into five treatments for each drain spacing, and consisted of five leaching efficiencies, 0 percent, 10 percent, 20 percent, 30 percent and 40 percent. Four observation wells were established to monitor water table fluctuations, and the outflow from the pipelines was simultaneously recorded for several days after water applications on a daily basis. Wheat was planted on December 1995 and harvested on April 1996. Surprisingly, a 5 tonnes/ha yield was obtained, exceeding the average ID by 1 tonne/ha during that cycle. No significant difference was observed between the two drain spacings. Moreover, there was no significant difference among leaching efficiency treatments with respect to the EC decrease in the soil saturation extract, however, salinity decreased to permissible levels for wheat cropping.

These results represented great savings for landowners considering that the tubes and its installation are the major cost of the soil reclamation process when pipe drainage systems are used. The average cost of the installed pipe (PVC corrugated) drainage system is US$600/ha.

The results of the mentioned integrated system applied within the FAO collaborative project have been transferred to different irrigation districts in northwestern Mexico.

Training courses for local technicians have been organised in the National Irrigation and Drainage Technology Transfer Center located in the Valle del Carrizo ID. Two manuals on salinity and land drainage have been published; also two videotapes about land drainage and soil reclamation have already been edited. In the same fashion an important project supported by CAN related to sub-surface drainage design of 10 000 ha in three IDs in northwestern Mexico was developed. At present, approximately 12 000 ha of salt-affected land have been reclaimed by means of sub-surface drainage. Comparatively, this can be considered a good achievement taking into account that back in 1994 there was roughly only 2 500 ha installed with pipe drainage in the whole country.

Near East Region

a) Egypt:

Two Projects: *"Increasing productivity of land Irrigated by Marginal Quality Water through Use of Organic Manures" (started in 1991)* and *"Appropriate and Field Tested Integrated Reclamation and Rehabilitation Technologies for Salt-affected Soils" (started in1998)*

In view of the expectation in terms of better Utilisation of scarce land and water resources, increased export prospects and provision of employment opportunities, the agriculture development programme in Egypt aimed at maximising production per unit area of crop under a protected cultivation system. Expansion of protected cultivation includes areas of limited good quality water supply. Therefore, the first collaborative project concentrated on using saline water for irrigation of crops under protected cultivation using organic manure and gypsum to improve soil physical properties, particularly soil structure, permeability and tilth and on correcting nutrition imbalances.

The results gained in highly calcareous clay soils suggest that mixing cattle manure with the surface layer is the best way to improve soil physical conditions. Manure will also improve the availability of micronutrients and plant production. The results obtained in sandy soils indicated better plant growth, root distribution even under high water table and the use of low quality water for irrigation. On both sites integrated management practices including preparation of beds (planting procedures), leaching fractions, fertigation system with balanced Fertilisers for tomato, pepper and cucumber were followed.

The Executive Authority for Land Improvement Projects (EALIP) of the Ministry of Agriculture and Land Reclamation also has a collaborative project with FAO. The Authority plays a central role in implementing the strategy of the government for better Utilisation, conservation and restoration of land productivity, particularly salt-affected soils in old soils in farmers' fields. Therefore, to disseminate its experience in this field, the second collaborative project (with EALIP) concentrated on the integrated management approach for salt-affected soils including gypsum application, subsoiling, land leveling, drainage system, irrigation management, use of organic matter. The Authority usually has a yearly plan of improving productivity of about 200 000 ha but using an individual single technique (i.e. subsoiling or land leveling or gypsum requirements or cleaning of drainage system always in a single operation). Within the FAO project the Authority tried the integrated approach in two provinces in Kafr El-Shiekh and Fayoum. Through the use of this integrated approach yield for wheat, maize and cotton increased by 30 to 55 percent depending on the original condition of the salt-affected soils. The information and experience obtained from such cooperation has been disseminated to other country members of the Network.

b) Iran:
Project: *"Management of Soils Irrigated with Saline Water for Sugarbeet and Cotton Production"*

The project started in 1994. The first scientific investigations on salinity problem in Iran started about 30 years ago. These investigations were confined to some leaching tests and the effects of salinity on crop yields. Most of these studies were carried out in Khuzestan, Fars and Esfahan Provinces. In later years, other research programmes such as the use of soil amendments for improving soil physical properties were conducted in the same locations and some other parts of the country. In this respect, a lot of work was done on the use of sulphur for improving infiltration rates of sodic soils. In Iran six million ha are under irrigation from rivers (conductivity up to 2 dS/m) and groundwater (conductivity between 3 and 10 dS/m). One of the main crops is sugarbeet, which is a salt-tolerant crop. Therefore, the experimental/demonstration programme within the collaborative project with FAO concentrated on increasing productivity of land irrigated with saline water, particularly for sugarbeet and cotton, using chemical amendments (gypsum), organic matter and special planting procedures at the Roudasht Soil Reclamation Research Station in Esfahan Province. The different irrigation water quality used are with EC 2, 5, 8 and 11 dS/m and gypsum treatments are without and with 5 tonnes/ha gypsum, planting procedures with furrow and row in beds system, leaching fraction of 10 and 20 percent. The results showed that with the increase in salinity of irrigation water the weight of sugarbeet increased by 15 percent up to salinity of 5 dS/m (from 36.6 to 41.5 tonnes/ha). But with increase in salinity water to 8 and 11 dS/m, the yield decreased to 32 tonnes/ha. The use of gypsum and the change in the cultivation methods from row to furrow caused a decrease in yield of 3 to 16 percent respectively (the use of gypsum had no any significant effects). The highest production of cotton was obtained using irrigation water with EC of 5 dS/m but only under the integrated management approach using organic manures, row in bed cultivation, 10 percent leaching fraction always under the appropriate drainage systems.

c) Syria:
Project: *"Management of Salt-affected Soils of the Euphrates Valley"*

Project started in 1996. As demand for food increases, Syria cannot afford to simply abandon salt-affected areas because of their proximity to water resources and they are usually fertile soil within the Euphrates Valley. Therefore, the expanded programme within the collaborative project with FAO is carried out in pilot farms in farmers' fields in the Euphrates Valley, using the integrated approach, i.e. installation of drainage system spacings (50 m and 25 m), leaching requirements, addition of chemical amendments (gypsum) and applying crop residues, special planting procedures and selected salt-tolerant field crops such as wheat, cotton, sugarbeet and alfalfa. The study also included salt balance in the root zone, effects of irrigation on soil physical, chemical and fertility properties and leaching requirements. The effects of different rates of NPK fertiliser under saline conditions, with cotton as a test crop, are also tested.

Through the use of this integrated approach yield for cotton, sugarbeet, wheat and alfalfa increased by 40 to 50 percent depending on the original condition of the salt-affected soils. The information and experience obtained from such cooperation has been disseminated to other country members of the Network.

d) Tunisia:
Project: *"Salt-affected Soils Irrigated with Saline Water, in the Nahal Oasis of Gabes in South Tunisia"*

The project started in 1995. In Tunisia, because of necessity of maximising national utilisation of soil and water resources, the experimental programme is to define appropriate integrated management techniques to improve the productivity of small farmers' fields in salt-affected areas where irrigation is practised using saline water of 3 g/litre (because farmers have no access to water of better quality to irrigate their crops). The experimental work included use of subsurface drainage (250 and 50 m spacings), leaching requirements, appropriate ploughing system, addition of gypsum, organic matter, mulching and applying crop residues and special planting procedures and selected tolerant crops (alfalfa, barley, date palm, vegetables such as lettuce, carrot and onion). The work also included study of the effect of irrigation with saline water (3g/litre) on soil properties of some Oases in South Tunisia. The study covered preliminary analysis of the soil, monitoring of water table, monitoring of EC values in well-drained and in undrained sites. The results show the downward movement of salts in the profiles of the drained plots. In the undrained plots some decrease in the salt content in the top layer might have been caused by leaching of an exceptionally high precipitation in the area in 1996 and 1997.

Through the use of the integrated approach, yield for vegetables such as lettuce, carrot and onion, alfalfa and barley increased by 30 to 70 percent depending on the original condition of the salt-affected soils and salinity of the irrigation water and the type of crop. The information and experience obtained from such cooperation has been disseminated to other country members of the Network.

2. Management of Degraded Soils in Southern and East Africa (MADS-SEA-NETWORK)

Drought and increasing climate instability have had a high profile in sub-Saharan Africa (SSA). Land degradation (mostly human-induced) is potentially an even more critical problem. Increasing population pressure, cultivation of the marginal agro-ecological environment susceptible to various types of land degradation and inappropriate soil management are resulting in serious soil productivity decline, especially under extensive farming practices. Of the approximately 2 976 million ha total land area in Africa, 2 146 million ha are problem soils (72 percent) with different production constraints (soil acidity, vertic properties, steeply sloping soils, low fertility, shallow and stony soils, saline and poorly drained soil). Of these areas about 490 million ha are affected by different types of degradation. Poor and inappropriate soil management is the main cause of physical, chemical and biological degradation of cultivated land. Soil degradation is the most critical environmental problem affecting sub-Saharan Africa. In many parts of SSA fallow periods are being reduced considerably and farmers are increasingly cultivating marginal lands susceptible to various forms of degradation. This is manifested by declining yields, decreasing vegetation cover, salinization, fertility decline and increasing erosion. If the vicious circle of land degradation cannot be stopped, the source of existence of large parts of the population will be severely damaged. It is therefore imperative from the point of view of both environmental considerations and production requirements to develop a better regional collaboration to respond successfully to this threat.

Therefore, the FAO Land and Water Development Division (AGL), in collaboration with the Subregional Office for Southern and East Africa (SAFR), the Agriculture Technical and Extension Services and the Chemistry and Soil Research Institute of the Department of Research and Specialist Services of Zimbabwe, organised an Expert Consultation on Integrated Soil Management for Sustainable Agriculture and Food Security in Southern and East Africa, held in Harare, Zimbabwe, 8-12 December 1997. One of the recommendations of the Consultation was to create a new Network on management of degraded soils. The first activity of the Network was the evaluation of ongoing networks in the region. Based on this evaluation, activities of the proposed network were identified including supplementary fieldwork to control other land degradation processes not included in the ongoing networks, newsletters, Internet, workshops and farmer-to-farmer visits.

Subsequently, in collaboration with SAFR and the Chemistry and Soil Research Institute of the Department of Research and Specialist Services of Zimbabwe, AGL organised an Expert Consultation on Management of Degraded Soils in Southern and East Africa, held in Harare, 8-11 December 1998. During the discussions of the Consultation, the participants confirmed the establishment of the Network on Management of Degraded Soils in Southern and East Africa "MADS-SEA-NETWORK" and considered the Consultation as the First Meeting of the members of the Network. At the time of the Consultation, there were eight members of the Network: Ethiopia, Kenya, Malawi, South

Africa, Tanzania, Uganda, Zambia and Zimbabwe. Now ten countries are members of the Network as a result of the new participation of Ghana, to represent West Africa, and Egypt, to represent North Africa.

2.1 Network objectives

- To assess the extent of soil degradation and promote soil management options;

- To exchange ideas, experiences and technologies as well as assist in policy and project formulation related to land degradation control and land productivity improvement;

- To publicise the Network activities and findings through the media, such as newsletters, Internet, workshops, radio and various publications.

2.2 Network activities

2.2.1 FAO Letters of Agreement with national institutes from the member countries of the Network (nine members, except Egypt):

- To act as a focal point and source of information in the country on all aspects related to soil degradation and its management and rehabilitation (physical, chemical and biological degradation) as a member in the established FAO Network on Management of Degraded Soils in Southern and East Africa;

- To review available and existing information related to soil degradation in the country, i.e. chemical degradation (fertility decline, acidification, salinity, pollution, etc.), physical degradation (crusting, compaction, erosion, etc.) and biological degradation. This analysis, synthesis and evaluation included case studies carried out in different agro-ecological and farming systems, existing documents and newsletter, technical publications, government reports or previous relevant studies, methodologies for assessment of soil degradation, field work carried out in the country on all aspects related to soil degradation and its management and rehabilitation.

- Representatives of the institutes presented summarised versions of the reports on the above revision analysis, synthesis and evaluation of available and existing information data, achievements, results and studies related to soil degradation and its management and rehabilitation in their countries at the Expert Consultation held in Harare, as the first meeting of the mentioned established FAO Network.

- In-depth case studies were carried out following the framework decided by the members of the Network (during the mentioned Expert Consultation) on Soil Degradation, Management and Rehabilitation under different agro-ecological and farming systems in the countries.

- To continue to act as a source of information (as a member of the established FAO Network) related to soil degradation, management and rehabilitation in the country, and to participate in the preparation and to contribute to any suggested publication, Internet system or newsletter for exchange of information and experience related to the Network's activities.

2.2.2 Collaborative Project with the Chemistry and Soil Research Institute, Department of Research and Specialist Services, Zimbabwe, (as a case study) to:

- Apply and test in field demonstration trials, appropriate integrated soil management and rehabilitation techniques (appropriate package of technologies required) based on problems identified for increased productivity of degraded soils in Zimbabwe. The integrated practices (package) included (according to the existing production constraints) use of lime to reduce nutrient imbalances or to control acidity, increase of fertiliser use efficiency (mineral fertilisers) through appropriate agronomic practices, high quality manure (organic matter) or available organic farm products (composting materials) as organic amendments, appropriate crop rotation, legume intercropping and agroforestry, improvement of fallowing with legumes, nutrient balance based on actual soil analyses and crop requirements, available rock phosphate, combination of organic and inorganic fertilising (integrated plant nutrition systems), use of crop residues, mulching, manipulation of biological processes during handling and storage of manure to reduce nutrient losses and increase availability of nutrients, soil and water conservation practices (conservation tillage, ploughing, contour ridges, tied ridging, etc.), resistant crops and active farmer involvement.

- Collect experimental data, monitor changes in soil, crop improvement and evaluate results.

- Disseminate obtained information and results and transfer the improved and appropriate integrated soil management practices to other countries having similar problems of soil degradation through the Network.

2.2.3 Technical Report on "Guidelines on Management and Rehabilitation of Acid and Fertility Declined Soils in South Africa". The report reflects as a case study the experience of South Africa in management and rehabilitation of acid and fertility declined soils, and covers production constraints and factors limiting production in acid and fertility declined soils, definition, extent and causes of the problems and some success and failure examples with reference to action taken in a non-sustainable system (failures) and action that be taken for a sustainable (success) system.

2.2.4 In relation to the establishment of the Network, the following Sub-regional Workshops were organised:

- The Expert Consultation on Integrated Soil Management for Sustainable Agriculture and Food Security in Southern and East Africa, Harare, Zimbabwe, 8-12 December 1997. The countries that participated in the Consultation (Eritrea, Ethiopia, Kenya, Malawi, Namibia, South Africa, Tanzania, Uganda, Zambia and Zimbabwe) supported the need for establishment of a Network on Management of Degraded Soils.

- The First Meeting (Expert Consultation) of the Network on Management of Degraded Soils in Southern and East Africa (MADS-SEA-NETWORK) held in Harare, 8-11

December 1998, with the participation of eight members of the Network (Ethiopia, Kenya, Malawi, South Africa, Tanzania, Uganda, Zambia and Zimbabwe). Results of the review papers in member countries as mentioned in activity 2.2.1 were discussed, the Network was officially established, its activities agreed upon and plans for future joint research and cooperation were made.

- The Second Meeting (Expert Consultation) of the Network (18-22 September 2000) which was organised in Pretoria, South Africa, in collaboration with the Institute for Soil, Climate and Water, Agriculture Research Council (ARC).

2.2.5 Network newsletter

As agreed on in the first meeting of the Network a newsletter on Management of Degraded Soils in Southern and East Africa will be published every two years. The first issue has been published in August 2000. The second issue is to be published in 2002.

2.2.6 Network Web Site

The Network established an Internet Web Site. The Land and Water Development Division at FAO Headquarters is implementing the mentioned Web Site in connection with the member countries. The address of Network is <http:www.fao.org/ag/agl/agll/madssea>

2.2.7 Publications

- Expert Consultation *Proceedings of the Expert Consultation on Integrated Soil Management for Sustainable Agriculture and Food Security in Southern and East Africa*, held in Harare, Zimbabwe, 8-12 December 1997 (published).

- Expert Consultation *Proceedings of the First Meeting of the Network* held in Harare, 8-11 December 1998.

- Report on Survey and Evaluation of the existing ongoing Network on Soil Degradation in Southern and East Africa (completed). The report includes:

Identification of the titles of the ongoing networks, membership (countries and institutes), major activities (field work, publications and newsletters, workshops, etc.); modalities and mechanisms and topics and subjects covered by the networks, years of activities (starting dates, duration, etc.); achievements and outputs; evaluation of such networks and their achievements; suggestions on the activities to be carried out through the newly established FAO Network on Management of Degraded Soils in Southern and East Africa, including supplementary field work required to control different land degradation processes not covered or achieved by the ongoing networks.

- An Overview Paper on *Soil Degradation in Sub-Saharan Africa: The Growing Threat*, included in the Proceedings of the First Meeting of the Network.

- Expert Consultation *Proceedings of the Second Meeting of the Network*, held in South Africa, 18-22 September 2000 (published).

- Technical Report on Collaborative Project with the Chemistry and Soil Research Institute, Department of Research and Specialist Services of Zimbabwe (published within the Proceedings of the Second Meeting of the Network, held in South Africa).

- Technical Report on *Guidelines on Management and Rehabilitation of Acid and Fertility Declined Soils in South Africa* (published within the Proceedings of the Second Meeting of the Network, held in South Africa).

- *Guidelines on Management of Degraded Soils in Sub-Saharan Africa* (is under preparation, to be published in 2002).

3. Network on Management of Gypsiferous Soils

To optimize the productive potential of the land including problem soils in order to ensure the needed food and fibre supplies for the people and to minimize environmental degradation, it is necessary to evolve and propagate proper and efficient soil-water-nutrient-crop management practices. Projects sometimes failed to develop locally adapted farming systems or appropriate management techniques for improving productivity for such problem soils because the implementation did not fully take into account the chemical and physical characteristics of the soils, their fertility and problems posed by the soils.

Many kinds of problem soils are formed in the Near East Region under arid and semi-arid climate conditions. Gypsiferous soils are included as one kind of problem soil if gypsum is present in considerable amounts. There is incomplete information on the exact area of gypsiferous soils in the world. According to available information (based on the FAO/Unesco Soil Map of the World and the author's studies), the total area, which is not necessarily arable land, is of the order of 88 million ha. Most areas of gypsiferous soils in the world are mainly found in the Near East Region, as well as in China, Ethiopia, Mali, Namibia and Spain.

The importance of gypsiferous soils in agriculture, and the relatively scanty information on its management, was FAO's rationale for developing a network on management of gypsiferous soils for increased productivity in some countries of the Near East. The countries that participated in the Network were Algeria, Iraq, Syria and Tunisia with Iran and Spain as associate members.

3.1 Network objectives

The objectives of the Network are to disseminate information, improve coordination among scientists or engineers, strengthen field experiment programmes and extension of appropriate management practices, which will increase and sustain productivity of gypsiferous soils.

3.2 Network activities

3.2.1 FAO collaborative projects

FAO's Regular programme supported national institutes in countries having problems in management of gypsiferous soils in the Near East Region, to strengthen their experimental programmes on adopted integrated soil management practices. Collaborative projects in four countries (Syria, Algeria, Iraq and Tunisia) developed integrated management practices for sustainable use of gypsiferous soils through experiments and demonstration pilot farms established and operated by national institutes. The fieldwork continued till 1997, and was to study and investigate the following main subjects:

- Management techniques including tillage requirement, salinity and leaching of the soil, irrigability and land preparation:

1. Effect of irrigation system and water quality on soil characteristics and formation of sink holes;

2. The suitability of the soil for selected field crops, vegetables and fruit trees. Crop rotation and the effect of the depth, forms and thickness of different gypsum layers on root volume and penetration;

3. Fertility constraints and the required elements and rate of application to overcome macro- and micronutrient deficiencies;

4. Use of chemical compounds to convert and coat gypsum particles with less soluble compounds;

5. Effects of different amendments, additives and organic manure on productivity of gypsiferous soils.

3.2.2 Workshops

The following workshops were held:

- A workshop was held in Damascus, Syria, 17-22 December 1995, to discuss results of the mentioned collaborative projects, information from technical sources in countries having similar problems in management of gypsiferous soils: extent, present use and management practices for sustainable agriculture and jointly plan future cooperation.

- A workshop was held in Aleppo/Raqqa, Syria, on Management of Gypsiferous Soils, 12-14 August 1997, to discuss results of the mentioned collaborative projects, information from technical sources in countries having similar problems in management of gypsiferous soils: extent, present use and management practices for sustainable agriculture and jointly plan future cooperation. The outputs of the workshop including materials presented in the workshop and results from the Network, and the existing Arabic version of the FAO Soils Bulletin on the subject, is being published as an FAO Soils Bulletin in Arabic. This may be translated later into English.

3.2.3 FAO Project TCP/SYR/4553: Introduction of Integrated Management Techniques for Improved Production of Gypsiferous Soils

In order to introduce the appropriate integrated techniques for management and farming of gypsiferous soils, FAO in April 1997, agreed to finance a two-year project with the above mentioned title. The objective of the project was to improve agriculture productivity of gypsiferous soils through introduction of appropriate management techniques for optimum productive and practical use of such soils, thus improving self-sufficiency in food and fibre production in Syria. The main output of the project was a package of integrated soil management practices suitable to be transferred to farmers working in irrigated gypsiferous soils.

3.2.4 Publications

- FAO Soils Bulletin No. 62, 1999, on Management of Gypsiferous Soils.

- An FAO Soils Bulletin is being published in Arabic on Management of Gypsiferous Soils. This publication will include materials presented in the mentioned workshops, results from the Network and existing Arabic version of FAO Soils Bulletins on the subject.

4. Network on Protected Soils in Central and Eastern European Countries "PRO-SOIL-IN-CEEC-NETWORK"

Soils having concentrations of potentially toxic chemicals that significantly exceed natural background values are considered contaminated soils. This does not necessarily imply toxic effects on human health or environmental degradation. Soils are considered polluted if one or more chemicals exceed eco-toxicity relevant concentrations. Soil pollution can be defined as the accumulative adverse effect by chemicals on the various processes in the soil leading to soil degradation. The term soil pollution more specifically addresses the presence of toxic levels of substances in the soil. However, it also includes pollution associated with loss of organic matter, decrease in soil biological diversity and physical degradation.

Estimates of areas of land affected by specific types of human-induced soil degradation for the world have been produced by the International Soil Reference and Information Centre (ISRIC) under the aegis of UNEP, and in collaboration with FAO (World Map of Status of Human-Induced Soil Degradation at a scale of 1:10 million – ISRIC/UNEP 1990), and known as GLASOD. It identifies four degrees of degradation (light, moderate, strong and extreme). Five types of human intervention were identified as resulting in soil degradation: deforestation and removal of natural vegetation (579 million ha), overgrazing of vegetation by livestock (679 million ha), improper management of agricultural land (552 million ha), overexploitation of vegetative cover by domestic use (133 million ha), and industrial activities leading to chemical pollution (22 million ha).

However, the soil pollution problems include not only chemical pollution (excessive application of nutrients, e.g. fertilisers, pesticides, herbicides, heavy metals, etc.) but are also associated with human-induced acidification, salinization (excess of salts at toxic level to plants), loss of organic matter, decrease in soil biological diversity, physical degradation, and erosion by water and wind. In Central and Eastern European countries the estimates of the actual extent of degraded and polluted land and of areas at risk, remain open to improvement as well as to the need to harmonise procedures of measurement and threshold levels used.

The Government of Romania reflected the deep concern of the country, with regard to controlling environmental degradation due to different types of pollution processes, safeguarding the health of small farmers and ensuring contamination-free agricultural production in the country. Therefore, the government requested an urgent need for technical assistance to introduce, test, and develop the required integrated approach for efficient management and cost-effective, low-risk methods for cleansing polluted land for wider adoption by small-scale farmers in order that land be used appropriately for environmentally safe and contamination-free agricultural production in the country. FAO in July 1998, approved the financing of a 22-month project TCP/ROM/8822 on Rehabilitation of Polluted Soils in Romania, to be implemented by the Research Institute for Soil Science, Agrochemistry and Environmental Protection (RISSA), Academy of Agriculture and Forest Sciences (AAFS), Ministry of Agriculture and Food, as the government executing agency.

As one of the major activities of the mentioned project, a mid-term international workshop was organised to determine the performance of the project and give the opportunity to exchange information and experiences with other collaborating scientists from neighbouring countries and international consultants on physical, chemical and biological pollution.

With recent emphasis and priority programme of FAO on the Special Programme on Food Security (SPFS), issues related to land degradation including soil pollution and its negative impact on food production, and that the land be used appropriately for environmentally safe and contamination-free agricultural production as well as land improvement for enhanced productivity are receiving special attention. Rectifying soil degradation including soil pollution and sustaining crop production through appropriate soil rehabilitation, management and conservation are, therefore, important components in the effort towards food security.

Successful experience and initiatives for rehabilitation and management of polluted soils in specific countries or socioeconomic and agro-ecological environments have taken place but their wider dissemination for the benefit of other countries, even in the same region, is rather limited. Therefore, the participants in the Mid-term Workshop of the Project TCP/ROM/8822 agreed to create a new Network (Pro Soil in CEEC) with the membership of the Workshop participating countries (Bulgaria, Czech Republic, Lithuania, Poland, Romania and Slovak Republic). Information associated with the Network and invitation for membership in the Network were sent to the other member countries of the Central and Eastern European Region. Estonia, Latvia and Ukraine are also members of the Network now. It was also agreed that Romania be the Network Focal Point at this stage and that Canada, England and the USA be considered associate members supporting activities of the Network.

4.1 The Objectives of the Network

1. To disseminate information as well as foster improved coordination among scientists and extension staff within the regional countries on issues related to soil pollution.

2. To assess the extent of soil pollution and promote soil management options.

3. To exchange ideas, experiences and technologies as well as assist in policy and project formulation related to soil pollution control and land productivity improvement.

4. To publicise the Network activities and findings through the media, such as newsletters, Internet, workshops, radio and various publications.

5. To source funding for various activities of the Network.

6. To promote applied research programmes in participating countries on management of polluted soils

4.2 Activities of the Network

1. *FAO Letters of Agreement* with national institutes from member countries of the Network (Romania, as a focal point of the Network, and Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Poland, Slovak Republic and Ukraine), to act as a focal national institute and source of information in the country in all aspects related to soil pollution, and its rehabilitation and management (physical, chemical and biological pollution), as a member in the Network.

2. *Develop a uniform methodology* based on the results from the SOVEUR Project, GCP/RER/007/NET: Mapping of Soil and Terrain Vulnerability in Central and Eastern Europe, for assessment of soil vulnerability and the status of soil pollution in participating countries, with a view to identifying broad areas of soils considered at risk from re-mobilisation of specific contaminants subsequent to environmental change.

3. *Workshops*: Organization of a sub-regional workshop every two years in relation to the Network to discuss priority areas, progress, programmes and follow-up actions on rehabilitation of polluted soils, highlight and exchange of successful experiences on rehabilitation of polluted soils in relation to country programmes. The mentioned workshop held in Braila, Romania, 12-16 July 1999, was considered the First Meeting of the Network.

4. *Newsletter:* Publication of a Network Newsletter on the subject every two years. The first issue will be published in 2002.

5. *Network Web Site:* FAO is establishing, in cooperation with participating countries, an Internet Web Site for the Network.

1. *Publications:*
- *Proceedings of the International Workshop on Rehabilitation and Management of Polluted Soils*, Braila, Romania, 12-16 July 1999.
- The reports produced by the Project TCP/ROM/8822 (of which summaries may be included in the mentioned Network Web Site), to be distributed to participating countries.
- Nine reports and related maps produced by the Project GCP/RER/007/NET: Mapping of Soil and Terrain Vulnerability in Central and Eastern Europe (SOVEUR) for the 13 participating countries in the Project (Belarus, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Moldova, Poland, Romania, Russia (west of the Urals), Slovak Republic and Ukraine), of which nine countries are members of the Network. The products were published as a CD-ROM.
- Report, as a member of the Network, from the Research Institute for Soil Science, Agrochemistry and Environmental Protection, Romania on the National Soil Quality Monitoring System (based on detailed analysis of samples collected from 972 grid systems, 16 km apart). The report contained a synthesis of the data regarding the evaluation of soil quality including polluted soils in Romania.
- *Guidelines on Management of Polluted Soils* including summaries of the country papers presented in the mentioned workshop (First Meeting of the Network) as case studies.

5. FAO/TCP/THA/8922: Impact of Shrimp Farming on Arable Land and Rehabilitation of Resultant Salt-affected Soils in Thailand

This 22-month project was approved by the FAO in October 1999, to be implemented by the Land Development (LDD), Ministry of Agriculture and Cooperatives, as the government executing agency. Activities were started by the appointment of the NPD and creation of a national multidisciplinary team that undertook the collection of all basic information. This includes the hydrodynamic characteristics of soils, soil physico-chemical and mineralogical properties, physiography, soil and water quality aspects, quality of existing irrigation rivers, ongoing agriculture and irrigation projects within the identified project sites (where the project's three pilot farms were selected), i.e. Nakhon Si Thammarat, Pranchin Buri and Suphan Buri Provinces, survey of the existing shrimp farms (number and size) and salt-affected soils resultant from the impact of previous shrimp farming practices in the three mentioned provinces, present land use, existing cropping pattern/cropping sequences being adapted by the farmers and data on crop production under various levels of salinity and/or sodicity.

5.1 Project objectives

The project's objective is to assist the Government of Thailand to study the impacts of shrimp farming in freshwater arable land and in the demonstration of appropriate integrated techniques for rehabilitation of abandoned shrimp farms and for the improvement of salt-affected lands (resultant from seawater intrusion and shrimp farming practices in arable lands) mainly rice production in support of food security programmes in the country through the introduction of appropriate management techniques for optimum production of such soil. The aim is to introduce, test and demonstrate to the farmers sound integrated soil, water and crop management techniques in representative pilot experimental demonstration farms to overcome production constraints in the resultant salt-affected soils under local conditions.

It has been decided that these pilot farms will continue as demonstration farms after project completion to disseminate to the farmers the appropriate integrated low-cost, low-risk rehabilitation techniques for their salt-affected soils. As follow-up, special arrangements have been established within LDD to act as a focal point to continue transfer of technology to be achieved by the project.

5.2 Expected outputs

The outputs of the project are:

1. Study on national soil/water monitoring system of the impact of shrimp farming (in brackish water coastal areas and freshwater arable land) on the soil of abandoned farms, the adjacent salt-affected soils, the irrigation canals and the environment. The study will consider the results from the ongoing preliminary monitoring study carried out by the LDD in Prachin Buri Province, in addition to a detailed monitoring system to be carried out by the project in both Prachinburi Province (freshwater arable land) and in Nakhon Si Thammarat Province (brackish water coastal land). Also, prediction models on the impact of shrimp farming will be produced by the project based on the results from these monitoring studies.

2. Guidelines on integrated low-cost, low-risk technologies for rehabilitation of abandoned shrimp farms and the adjacent resultant salt-affected soils, under local conditions.

3. Appropriate integrated methods for rehabilitation and amelioration of affected soils applied in three demonstration sites located in: a) the coastal land of Nakhon Si Thammarat Province; b) the eastern part of the Central Plain Region in Prachin Buri Province; and c) the western part of the Central Plain Region in Suphan Buri Province, in freshwater arable land.

4. National staff (12 persons) trained as focal points and capable of carrying out agricultural development programmes and rehabilitation projects in salt-affected areas (abandoned shrimp farms and adjacent arable land in coastal as well as freshwater zones).

5. Six national staff sent on study tours in two groups each of three persons, one group to U.S.A. and the second group to Spain and Egypt where work on rehabilitation of salt-affected soils is advanced and technologies to overcome rehabilitation problems related to coastal and inland salt-affected soils are available (completed).

6. Six national laboratory technicians trained in analytical methods and data interpretation of salt-affected soils in Region 11 of the Department of Land Development in Surat Thani Province in the South.

7. Ten farmers in each of the three demonstration sites trained as innovators/leaders on rehabilitation of salt-affected soils.

8. Extension pamphlets, curriculum and material published and disseminated to small-scale farmers in affected areas in coastal, as well as freshwater zones.

9. *Proceedings of the Mid-term Workshop on the Impact of Shrimp Farming in Arable Land and Rehabilitation of Resultant Salt-affected Soils.* Exchange of experience with neighbouring countries having similar shrimp farming practices and resultant salt-affected soil problems can be considered as one of the outputs of the workshop and the project.

10. Socio-economic evaluation of the demonstrated rehabilitation integrated techniques, including the socioeconomic viability of introducing fresh aquaculture components into the system.

11. Final document on project activities and achievements, the economic uses and appropriate rehabilitation techniques for increasing crop production of the resultant salt-affected soils caused by shrimp farming practices, as a basic reference for large-scale development and rehabilitation projects in salt-affected areas in the country.

5.3 The project activities (in addition to others) include the following:

- Selection of three sites in Pranchin Buri, SuphanBuri and Nakhon Si Thammarat Provinces to present the conditions of production constraints and salinity development as a result of shrimp farming practices in freshwater arable land and seawater intrusion. The three sites were selected and the appropriate integrated management techniques were introduced to be tested and demonstrated in rice and abandoned shrimp farms. In each site, one pilot demonstration farm was selected in the abandoned shrimp farms and one in the adjacent rice salt-affected area. In each site, a monitoring system is being conducted to study the real impacts of shrimp farming practices and seawater intrusion on arable land and rice production.

- Project TCP/THA/8922 Mid-term Regional Workshop on Impact of Shrimp Farming Practices on Arable Land and Rehabilitation of Resultant Salt-affected Soils/Integrated Management for Sustainable Use of Salt-affected Soils. This is the present workshop with the objective to determine the performance of the project and to exchange information and experiences with other collaborating scientists from neighbouring countries and international consultant. The participating countries, in addition to Thailand are Bangladesh, China, India, Indonesia, Malaysia, Pakistan, the Philippines, Vietnam and Australia.

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Rehabilitation and Management of Salt-affected Soil with Reference to FAO Project TCP/THA/8922

Summary

Salt is very soluble and moves readily with soil water. Reclamation of salt-affected soils in any country depends on effectively manipulating the soil water regime to induce salt removal. Marine shrimp farming in Thailand imports brine solutions from the coast to increase salinity in the culture water. This water escapes to the wider environment through seepage and dilution of pond water as the shrimp progress to maturity. The resulting high salinity is severely restricting production on the surrounding paddies.

In terms of soil reclamation the principal aim of project TCP/THA/8922 is to determine and demonstrate the most appropriate integrated rehabilitation programmes for paddies affected by the salt from the shrimp ponds. By increased understanding of the processes responsible at each site to diagnose the causes and define the extent of salinization, a plan can be developed and implemented that will minimise future salt accumulation and direct actions to remove salt from currently affected paddies. A methodical approach based on a sound understanding of the processes will minimise the reclamation costs while maximising the chance of success.

Introduction

The cultivation and widespread cropping in the medium rainfall (500-800 mm/yr) zone of Australia is very recent in Asian terms. It is only in the last 150 years that the native vegetation has been cleared and cereal and other crops planted over large areas. The change of land use changes the equilibrium in terms of water use. Even though Australia is a dry continent, one of the largest threats to sustainable agricultural production is too much water 'leaking' below the root zone. The water that infiltrates into the soil but does not evaporate or is not used by plants reaches the water table. The accumulation of this water and the decreasing depth to the water table is now posing a threat to continued production.

Australian soils are old and many have large accumulated salts on the surface and within the soil profile. In the relatively dry and highly variable climate the deep-rooted native vegetation adapted to survive dry conditions explored the soil to depths of several metres

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to extract water and nutrients. By drying the soil to depth the native vegetation created a large soil reservoir for water. The continual cycling of water through this zone, with a small volume of leakage to the water table, resulted in the accumulation of salt just below the zone carried there within the small amounts of water that past the roots.

The introduced crops and pastures replaced the native vegetation; they have relatively shallow root systems. The result is that the soil is not dried to depth and does not provide the reservoir it did under the native species. During wet periods larger quantities of water pass below the root zone causing the water table to rise. The rising water table brings with it salt (mainly sodium chloride from the accumulated store), killing vegetation further exacerbating the problem.

Sodium chloride is very soluble and mobile in water. This mobility is often the cause of the problem, but it is also the basis for the rehabilitation. In solution the sodium and chloride ions move with the water. The problem is, they do not move with the water when it evaporates or in any great quantity when it is used by plants. Where the saline water table brings water to within 2 m of the surface the water evaporates leaving behind salt. Even where the salt concentration in the water is not high the continual evaporation can result in toxic saline conditions on the soil surface. When salt starts to accumulate and reaches levels sufficient to reduce plants' ability to extract water, the volume of soil explored by the roots decreases, compounding the problem. The result, more water lost by evaporation and more salt accumulated.

In Australia salinity is generally classified as irrigation salinity or dryland salinity. Irrigation salinity is limited to the relatively small irrigation areas. Dryland salinity is more extensive. The National Dryland Salinity Program Management Plan 1998-2003 (LWRRDC, 1998) states that at least 2.5 million ha (5 percent of cultivated land) is currently affected by dryland salinity. It has been estimated that this could rise to 12 million ha (22 percent of cultivated land) before equilibrium is reached.

Current agricultural costs of dryland salinity are estimated to exceed A$130 million annually. Added to this are the cost impact on infrastructure (roads, water supplies, buildings) and the potential impact on surface waters. Many streams have rapidly increasing salinity and if the current trend continues within 50 years they will not be suitable for irrigation or other economic use.

In Project TCP/THA/8922 the problem is very different. Saline water brought in from the coast for shrimp culture adds to the already high natural salinity of the marine sediments and reduces yield from associated rice paddies. However, management for rehabilitation is very similar. Basically rehabilitation of saline farmland depends on the understanding of the problem and effective water management to address it, which lead to salt removal and rehabilitation.

Causes of saline soils in relation to rehabilitation

Saline soils are developed when water brings salts to the soil surface; the water evaporates increasing the concentration of the salts on the soil surface and within the soil profile to

Toxic levels. Any factor that causes rising water table close to the soil surface will induce salinity. Australian soils with high levels of accumulated salt below the root zone are particularly prone to salinization.

In irrigation areas poor water use efficiency and poor drainage promote soil salinization. In dryland areas the introduction of shallow-rooted crops and pastures reduces water use and contributes to rising water table. The location of actual outbreaks of salinity is determined by the local hydrogeological systems.

In FAO project TCP/THA/8922 salinity is caused by the importation of salt or saline water to grow shrimps. The water then leaks or is pumped out of the ponds and impacts on the surrounding rice crop.

Reclamation of saline soils, whether irrigated or dryland, or induced by shrimp farming has the same principles:

1. Identify the cause of salt accumulation.
2. Minimise future accumulation.
3. Implement actions to remove salt from the soil.
4. Implement actions to stop further salt accumulation.

I. The first step in rehabilitation is to identify the cause. To do this there is a need to understand the local conditions that induced the problem. When the cause is understood action can be implemented to prevent or reduce actions that accelerate the problem. In the case of irrigation areas in Australia the cause is poor water use efficiency and insufficient drainage. In dryland areas where rising saline water is causing declines in productivity and in some situations farmland to be abandoned, some major projects have been initiated to determine the causes of salinity in individual situations. A scheme has been developed to classify catchments according to their hydrogeologic characteristics (Coram, 1998) and considerable effort is going into identifying links between surface and groundwater. This improved understanding is essential to enable the development of the most effective solutions tailored to individual situations.

In the Central Plain of Thailand salinity is initiated by the importation of saline water and poor water and soil management. The imported salt compounds the problem of saline sediments and underlying saline groundwater. Salt, imported into the ponds for shrimp culture moves by seepage or pumping to impact on the surrounding rice paddies. Without the importation there would not be a major problem. Alternatively there is a need to focus on the reason the salt becomes a problem.

There is therefore a need in Thailand to determine whether the salinity in the rice paddies adjacent to the shrimp ponds is caused by seepage from the ponds or by secondary use of the saline water that is pumped out from the ponds to the irrigation system (to enable dilution of the salt water in the ponds as shrimp mature).

Project TCP/THA/8922 has within the project design the conducting of a major monitoring programme and soil salinity survey around shrimp ponds. The results of this survey when combined with 3-dimensional models of water and solute transport will provide an enhanced understanding of the processes associated with salinization of the soils surrounding the shrimp ponds and consequently enable the design of more effective remedial methods.

II. The second step in rehabilitation is to minimise future accumulation. In irrigation areas in Australia the government and landholders are working together to improve irrigation efficiency and minimise loss from irrigation water distribution systems. In some areas improved irrigation efficiency is combined with the installation of drainage systems that remove water from the profile and transport it to evaporation basins. Improved irrigation efficiency minimises the volume of drainage water and maximises production from the limited volume of water available. In dryland areas future accumulation is being controlled by the planting of deep-rooted crops such as alfalfa, some of the native grasses and particularly by strategic tree planting. Trees, because of their extensive root system, use much more water than herbaceous plants. Located strategically in the landscape to intercept lateral flow they have been demonstrated to be very effective in reducing groundwater accessions in some situations.

In Thailand where shrimp farming is causing a problem with soil salinity future accumulation can be minimised by reducing the importation of saline water and controlling the fate of the water after it is removed from the ponds. The latter would be assisted by separating the drainage and irrigation water distribution systems. Currently the saline water pumped from the ponds to enable dilution as the shrimp mature appears to be added to the irrigation water system. This water, with a high salt content may then be (and appears to be) used by neighbouring farmers to irrigate paddy rice.

To separate the drainage and irrigation water would require the construction of separate drainage channels leading to disposal basins in the lowest part of the landscape. The saline water would be diluted during floods in the rainy season.

The main emphasis should be on restricting the importation of the saline water in the first instance.

III. The third step in rehabilitation is to implement actions to remove salt from the soil. Irrigation areas in Australia rely on effective drainage systems of tile drains, perforated plastic pipe, drainage ditches or simply deep wells to remove saline water from the root zone. The net downward movement of water prevents salt accumulation in the root zone. In Australian dryland areas drains are sometimes used to encourage leaching, however it is more common to rely simply on the natural rainfall and a more efficient extraction by selected deep-rooted plants.

In the areas of interest in Thailand preliminary soil analyses indicate that the soils at the proposed demonstration sites have high levels of exchangeable sodium. Given the high concentration of salt in the irrigation water during the dry season (EC about 3 dS/m) there is a need for adequate leaching to prevent the accumulation of salt in the root zone and at the soil surface. In these clay soils this can be achieved by establishing and maintaining soil permeability or by lateral leaching. Better soil permeability can be achieved by increasing the soil organic matter content, adding gypsum or lime (depending on soil pH) to provide calcium, and deep tillage to break up the existing plough pan. Lateral leaching will be assisted by the design and implementation of an appropriate drainage system that allows the paddies to be drained relatively quickly, and separates the drainage and irrigation systems.

The key to remove salt from the soil is net movement of water away from the site in such a way that it can transport sodium chloride in solution. This can be vertical or horizontal movement.

For vertical movement leaching requirement can be calculated for each site following analyses of the soil and irrigation water.

Leaching requirement = 100 x EC_{IW}/EC_{DW}
Where EC_{IW} = EC of the irrigation water
And EC_{DW}= EC of the drainage water above which there will be a significant impact on rice production, i.e. 5 dS/m

For example at EC_{IW} of 2 dS/m and EC_{DW} of 5 dS/m
Leaching ratio = 100 x 2/5
= 40 percent

Therefore if annual irrigation depth is 500 mm then leaching will require 40 percent or 200 mm.

For horizontal leaching the water needs to be removed from the paddy by pumping out salty water, freshwater added, the surface soil disturbed by ploughing and the water removed again. The number of times this needs to be repeated will depend on the relative salinity of the paddy and the irrigation water and the efficiency of mixing during cultivation. The salinity levels in the soil and water should be measured during this process.

For vertical leaching to work effectively the soil must be sufficiently permeable for water to move through the profile. Permeability is determined by soil texture and soil structure. In the heavy clay soils of Project TCP/THA/8922 soil structure is the main determinant of water movement. Consequently, rehabilitation should focus on organic matter and interaction between the clay and soluble and exchangeable ions. Vertical leaching does have some disadvantages in that it requires a water table that is sufficiently deep to enable water movement below the root zone. It also requires an available supply of water and will require more water to grow a crop. These issues need to be considered when evaluating whether to use vertical or horizontal leaching.

Effective rehabilitation depends on the effective removal of salt. Salt moves readily in solution so any means by which water can be moved through or across the affected paddies will be beneficial to the removal of salt. However there is also a need to ensure that the salt moved from the affected paddies does not contaminate adjacent unaffected paddies.

IV. The fourth step inrehabilitation is to implement actions to stop further salt accumulation. The key to preventing further accumulation of salt is water management.

It does not matter whether the cropland is in Australia or Thailand; there is a need to ensure that water is managed effectively and does not encourage the accumulation of toxic levels of sodium chloride or other salts in the soil profile.

Sodium chloride is very soluble in water, provided sufficient water leaves the affected site it will transport with it the excess sodium salt. Basically further salt accumulation is prevented by ensuring that more salt leaves the affected site than is brought onto the site. This involves the calculation of salt balances to compare different treatments. Within Project TCP/THA/8922 regular site monitoring of sites is required to enable the calculation of salt balances and improve understanding of the rehabilitation process.

Project TCP/THA/8922

Project TCP/THA/8922 has been developed to provide an understanding of the process by which salinity in the shrimp ponds affects the adjacent paddies and to develop and demonstrate appropriate rehabilitation techniques. The main components of the project consist of assessing the size and extent of the problem, development of the demonstration plots based on best practice and monitoring of the impact of the demonstrations.

Project TCP/THA/8922 will determine the extent of the problem, provide a basic understanding of the related processes, develop demonstration plots to educate farmers and extension workers of the best practices to rehabilitate the saline areas and provide a monitoring programme that enables the assessment of future trends.

The extent of the problem is being determined by satellite image interpretation combined with detailed measurements by EM38 and GPS at around 30 representative ponds on a range of soil types. Best management practice, developed in close consultation with the national consultants is being evaluated for the effectiveness of the individual components by including plots that have all the treatments minus one. Farmers and local extension workers have been involved in selection of the sites and will be closely involved with the demonstrations. The monitoring programme will be established to determine trends over the life of the Project.

Conclusion

Rice paddies affected by salt from shrimp ponds can most effectively be reclaimed by manipulating the field soil water regime. By increased understanding of the processes responsible at each site to diagnose the causes and define the extent of salinization, a plan can be developed and implemented that will minimise future salt accumulation and direct actions to remove salt from currently affected paddies. A methodical approach based on a sound understanding of the processes will minimise the reclamation costs while maximising the chance of success.

Country reports

Bangladesh

Summary

Bangladesh is a small South Asian country with an area of 147 570 sq km and located between 20°34' and 26°38' N latitude, 88°01' and 92°41' E longitude. The population is disproportionately large – about 128 million, the population density being more than 800 persons/sq km. Agriculture, accounting for 30-35 percent of the GDP and more than 60 percent of employment, plays an important role in the economy of Bangladesh.

The salt-affected soils (which are known as 'coastal saline soils' due to their existence in the coastal region) constitute the most important, and also the potentially most productive marginal land resource of the country. The total area of the coastal regions of Bangladesh affected by varying degrees of salinity has expanded markedly over the last two decades from 0.83 million ha in 1966-75 to 3.05 million ha. About 25 million people of Bangladesh are variously affected by soil and water salinity in the coastal region.

The problems of salinity and waterlogging have been aggravated by brackish water shrimp farming in the fragile coastal ecosystem in Bangladesh. The shrimp farms have expanded in area from about 50 000 ha in 1980 to 150 000 ha in 2000. Soil, vegetation and animals have been adversely affected by increasing soil salinity resulting from shrimp farming. Trees have died, wildlife is threatened with extinction, and livestock and human health is being affected as salinity spills over into the environment from the shrimp fields. In the Southeast, a whole mangrove forest with an area of 18 000 ha has been totally destroyed. For every 100 ha of land brought under shrimp cultivation, 230 agricultural labourers become jobless. In addition, shrimp cultivation has resulted in undesirable social conflicts between the shrimp entrepreneurs and local farmers.

Research on the effect of shrimp farming on the environment and human lives and livelihoods has been rather small in volume and scope. In order to preserve the natural resource base and ensure sustainable crop and aquaculture enterprises in the coastal zone of Bangladesh research and monitoring of the coastal ecosystem as a whole need to be strengthened. The following issues merit priority consideration:
- Thorough and continuous monitoring of soil and water salinity levels. Precise mapping of the variously affected areas using GIS technology. Development of practically salinity prediction models using soil, water and climatic database.
- Development of salt-tolerant, high-yielding varieties of rice, and screening and selection of other crops suitable for the coastal areas.

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- Formulation and strict implementation of laws to regulate shrimp culture and prevent shrimp enterprises from damaging agricultural land and the environment.
- Effect of shrimp farming on soil and land quality, agricultural productivity of adjacent lands, natural vegetation and wildlife and on human health and livelihood.

1. Introduction

1.1 Bangladesh is a small South Asian country with an area of 147 570 sq km located between 20°34' and 26°38' N latitude, 88°01' and 92°41' E longitude. The population is disproportionately large – almost 128 million, the population density being more than 800 persons per sq km. Agriculture, accounting for 30-35 percent of the GDP and more than 60 percent of employment (BBS, 1999), plays an important role in the economy of Bangladesh. This sector will continue to play a vital role in achieving food security, in reducing rural poverty and in fostering economic development in Bangladesh at least for the foreseeable future.

1.2 The area of cultivable land in Bangladesh is 9.72 million ha, out of which about 17-18 percent are under one crop a year, about 55 percent are double cropped and 20 percent are triple cropped. The average cropping intensity in the country is around 180 percent. However, in marginal lands like the coastal saline lands, the cropping intensity ranges from 50 to 120 percent.

1.3 Rice is the staple food of the Bangladeshis. Now, wheat is gaining popularity as a second cereal. However, in terms of domestic production wheat usually accounts for only about 5-7 percent of the total annual food grain production. Rice is the pivotal crop in the yearly cropping patterns on almost all agricultural lands in the country. The net domestic food grain production in 1984-85 was 14.48 million tonnes, which increased to 16.2-17.5 million tonnes in the mid-1990s, and to 25 million tonnes in 1999-2000 (Figure 1). Bangladesh is now self-sufficient in food grain. This increase in food grain production resulted mainly from the high-yielding varieties (HYVs) of rice and improved production technologies (crop-soil-fertiliser-water management) developed by the Bangladesh Rice Research Institute (BRRI). As in many other developing countries, the problem of ensuring food security for the swelling populace lingers on in Bangladesh, i.e. right of everyone to have access to safe and nutritious food, consistent with the right to adequate food and the fundamental right of everyone to be free from hunger (as envisaged in the Rome Declaration on World Food Security (FAO, 1996)) still remains a far cry due to widespread poverty among the population.

1.4 The population of Bangladesh is growing at the rate of about 2 percent per year. The population projections for the country (Figure 2) show that, by the year 2020 the population may be around 175 million and may further increase to about 200 million by the year 2030. The projected demands for various food items in future are shown in Table 1. Bangladesh will have to produce at least 29 million tonnes of cereals (rice and wheat) just to maintain self-sufficiency in food grains in the near future (2009-2010). That means an annual production increase of around 5 million tonnes over the present level. Such a production boost will not be possible unless harvests from all marginal land resources (which have hitherto remained under-utilised due to agro-ecological and also socioeconomic constraints) are not increased with the help of appropriate technological interventions.

1.5 The major crop production constraints in Bangladesh are:

- Widespread poverty.
- Irregular and uncertain supplies of good quality seeds, fertilisers and other production inputs.
- Recurring natural calamities like floods, cyclonic storms and tidal surges, drought spells.
- Natural and artificial land degradation: soil fertility decline, nutrient deficiency problems, increasing soil salinity, soil erosion, etc.

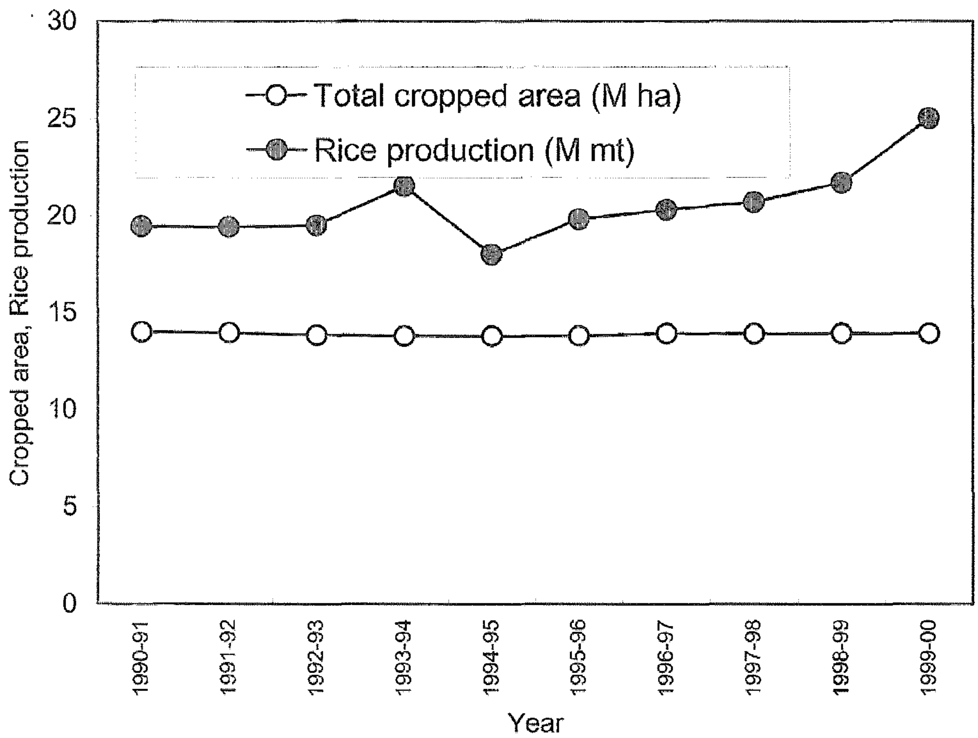

Figure 1. Total cropped area and rice production in Bangladesh, 1990-2000 (BBS, 2000).

1.6 Bangladesh needs substantial increases in crop production to provide its increasing population with food and other very basic necessities of life. However, arable land is no more available. The required additional production has to come mainly from the less favourable ecosystems or the marginal lands. The salt-affected soils, which are known as 'coastal saline soils' in Bangladesh due to their existence in the coastal region, constitute the most important, and also the potentially most productive marginal land resource of the country. With appropriate management practices and, in some cases, with small reclamation inputs, these soils can be cropped to salt-tolerant HYV rice and/or other suitable tolerant crops during the dry season.

2. The salt-affected soils: definitions, causes of salinization and problem identification

2.1. Salt-affected soils in Bangladesh

The salt-affected soils of Bangladesh are essentially in the coastal zone. Inland saline/sodic soils occurring due to aridity as in some arid regions of the world do not exist in Bangladesh. The country has a 710 km coast line along the northern boundary of the Bay of Bengal. The coastline extends from the mouth of the Naaf River in the East to Raimangal in the West within the geographical boundaries of Bangladesh. The coastal zone of Bangladesh covers areas as far as, on average, 50 km inland from the coast line.

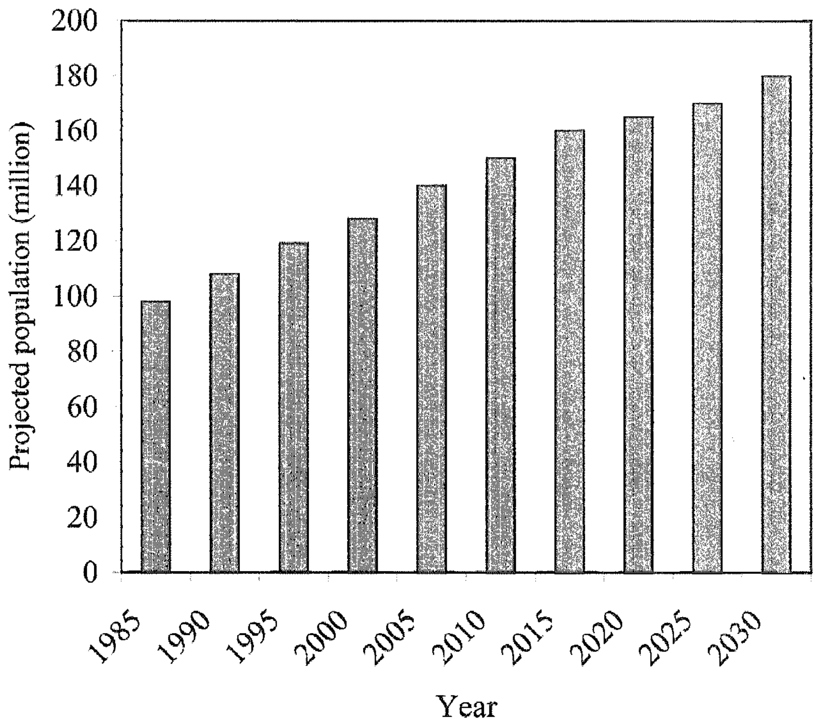

Figure 2. Population projections up to year 2030 for Bangladesh (Karim *et al.*, 1997).

2.2. Extent and distribution

The total area in the coastal regions of Bangladesh affected by varying degrees of salinity was about 0.83 million ha during 1966-75. Over the last two decades the area affected by salinity has expanded markedly to be 3.05 million ha (SRDI, 1997). The soil salinity levels have been arbitrarily classified into five categories: S1 = 2-4 dS/m (ECe of soil during the peak dry period of the year, i.e. March-April), S2 = 4-8 dS/m, S3 = 8-12 dS/m, S4 = 12-16 dS/m and S5 = >16 dS/m. The expansion of the areas under these levels of soil salinity during the period 1987-88 to 1997-98 is shown in Table 2. Presently, slight to strong soil salinity problem exists in 20 districts. The distribution of the saline areas is shown in Figure 3.

Table 1. Projected demands (million tonnes) of various food items for different income growth rate scenarios in Bangladesh.

Food item	**Baseline consumption (1990)**	**Income growth rate (%)**	**Year**			
			2000	**2010**	**2020**	**2030**
Plant origin						
Cereals	19.99	2.0	25.20	31.37	37.42	43.82
		3.0	26.28	33.86	41.78	50.62
Rice		2.0	24.77	29.70	35.00	39.38
		3.0	25.87	32.41	39.95	46.98
Pulses	0.91	2.0	1.48	1.99	2.55	3.22
		3.0	1.59	2.28	3.12	4.19
Sugar/Gur	0.38	2.0	0.55	0.81	1.15	1.64
		3.0	0.62	1.01	1.64	2.68
Tubers	1.58	2.0	2.25	3.08	4.02	5.14
		3.0	2.45	3.59	5.01	6.86
Vegetables	5.28	2.0	7.45	10.17	13.32	16.95
		3.0	8.14	11.68	16.63	22.62
Fruits	0.53	2.0	0.87	1.36	2.05	3.05
		3.0	1.00	1.78	3.07	5.23
Edible oil	0.49	2.0	0.53	0.70	0.89	1.10
		3.0	0.57	0.78	1.04	1.35
Sub-total	29.14	2.0	38.33	49.48	61.40	74.92
		3.0	40.65	54.98	72.29	93.55
Animal origin						
Milk	0.91	2.0	1.35	1.99	2.80	3.84
		3.0	1.52	2.45	3.80	5.73
Meat	0.24	2.0	0.37	0.52	0.70	0.92
		3.0	0.30	0.60	0.87	1.23
Egg	0.23	2.0	0.33	0.45	0.60	0.77
		3.0	0.36	0.53	0.76	1.07
Fish	1.55	2.0	2.13	3.11	4.35	5.90
		3.0	2.38	3.80	5.82	8.65
Sub-total	2.93	2.0	4.18	6.07	8.45	11.43
		3.0	4.65	7.38	11.25	16.68
Grand total	32.07	2.0	42.51	55.55	69.85	88.35
		3.0	45.30	62.36	83.54	110.23

Source: Karim *et al.* (1997).

2.3. Causes of soil salinity

2.3.1 Natural causes:

a. **Tidal flooding.** Vast areas of the coastal zone are subjected to daily tidal flooding during the wet season (June-October). The freshly deposited alluvium from upstream becomes saline as it comes in contact with seawater through the rivers, canals and creeks. Occasionally, tidal surges due to cyclones or exceptionally high tides push the salinity front further inland.

Table 2. Changes in the distribution and extent (1 000 ha) of different categories of dry season soil salinity (ECe) in the coastal and offshore regions of Bangladesh during the period 1985-97.

District	S_1 = 2-4 dS/m		S_2 = 4-8 dS/m		S_3 = 8-12 dS/m		S_4 = 12-15 dS/m		S_5 >15 dS/m		Total	
	1987-88	1997-98	1987-88	1997-98	1987-88	1997-98	1987-88	1997-98	1987-88	1997-98	1987-88	1997-98
Magura	-	70.1	-	-	-	-	-	-	-	-	-	70.1
Faridpur	-	12.6	-	-	-	-	-	-	-	-	-	12.6
Jessore	-	109.5	-	33.1	-	-	-	-	-	-	-	142.6
Nariail	-	75.1	-	19.2	-	-	-	-	-	-	-	94.3
Gopalganj	-	23.5	-	1.2	-	0.3	-	-	-	-	-	25.0
Satkhera	16.5	23.6	85.6	60.1	33.4	49.3	10.9	126.7	-	196.6	146.6	456.3
Khulna	3.9	0.5	92.5	64.2	13.8	144.7	9.8	42.5	-	150.3	120.0	402.2
Bagerhat	28.3	0.1	77.1	43.5	2.6	76.6	-	-	-	329.7	108.0	483.3
Pirojpur	18.4	28.0	1.9	30.9	-	12.6	-	-	-	-	20.3	70.6
Jhalkati	-	12.3	-	2.6	-	-	-	-	-	-	-	14.9
Barisal	-	-	-	32.4	-	-	-	-	-	-	-	32.4
Bhola	9.5	-	30.8	124.0	-	146.0	-	29.4	-	-	40.3	270.0
Patuakhali	68.5	-	46.6	110.1	-	171.4	-	79.7	-	-	115.1	310.9
Barguna	96.4	-	7.2	26.0	-	75.0	-	-	-	-	103.6	180.7
Lauxipur	-	-	-	30.5	-	50.4	-	-	-	-	-	80.9
Noakhali	6.3	-	39.9	88.0	3.4	103.5	-	-	-	31.1	49.6	222.6
Feni	1.6	-	6.7	0.4	0.7	0.6	-	-	-	-	9.0	1.0
Chittagong	18.4	6.1	15.2	37.5	7.0	59.6	5.2	-	-	-	45.8	103.2
Cox's Bazar	7.2	-	16.2	2.3	17.3	8.2	14.0	-	-	69.5	54.7	80.0
Chandpur	1.5	-	-	-	-	-	-	-	-	-	-	1.5
Grand total	275.5	301.4	419.7	705.1	78.2	898.2	39.9	311.7	-	777.2	813.3	3 053.6

Source: SRDI Staff Report (1997).

b. Soil desiccation and capillary rise of saline groundwater. During the dry season (November to May), PET exceeds rainfall resulting in an upward and/or lateral movement of the saline groundwater and an increase in soil salinity. The severity of the problem depends on the level of soil desiccation.

c. Insufficient freshwater recharge of the groundwater. There is quite a high amount of rainfall, but about 80 percent of rainwater in the wet season is lost as surface runoff.

The percolation of rainwater down in the soil profile is low due to poor internal natural drainage conditions of the soils. The groundwater is not adequately recharged and remains saline.

2.3.2 Anthropogenic causes:

a. Withdrawal of water from the Ganges River. A major cause of increasing saline areas in Bangladesh has been the reduced availability of freshwater, drying up of rivers and saline water intrusion from the sea into the Ganges basin area due to the withdrawal of the Ganges river water upstream outside the boundaries of Bangladesh. Following the recently signed Ganges Water Sharing Treaty between Bangladesh and India, the situation is expected to improve.

b. Unplanned shrimp culture. Shrimp culture is a profitable business enterprise, but the shrimp ponds are constructed in an unplanned and indiscriminate manner by business entrepreneurs leasing in land from the poor farmers. Seepage of saline water from the shrimp ponds into adjacent agricultural lands increases soil salinity.

c. Sinking of shallow tube wells. In some areas shallow tubewells (STW) have been sunk for growing 'boro' rice (dry season or winter rice). Although these STWs provide sweet water from isolated pockets for some time, the system is not probably sustainable, and may result in saline water intrusion as the quantity of freshwater in the pocket decreases due to withdrawal for irrigation. Little information is at present available about the short- or long-term consequence use of the STW system.

2.4. Salinity regimes

Soil and water salinity levels vary widely both spatially and temporally. Irrespective of location, the common trend is an increase in salinity with time from November-December to March-April until the on-set of the monsoon rains. The ECs of the soil and water are usually lowest in July-August and highest in March-April. Figures 4-6 show the water salinity in a river, and soil salinity in the wet and dry seasons in five farmers' fields at different locations of the district of Satkhira where BRRI (Bangladesh Rice Research Institute) scientists are evaluating rice varieties for salt tolerance. The salinity monitoring reveals a clear picture of the salinity regimes of the soils identifying the periods of low, medium and high topsoil salinity. July-August is the period of minimum salinity, January-February of intermediate salinity and March-April of maximum salinity corresponding with the peak dry season. The spatial and temporal variations in soil salinity indicate the need for crop production planning separately for the different locations in the coastal areas. No generalisation can be made in this regard.

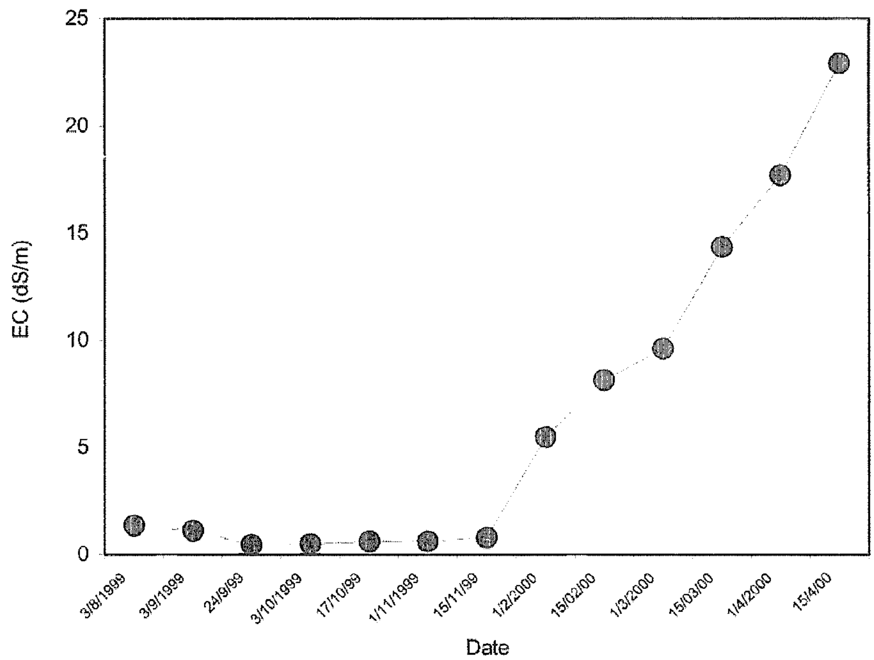

Figure 4. Water salinity levels of Benerpota River in Satkhira in the wet and dry seasons (Panaullah, 2000).

2.5 General constraints to agricultural production in the coastal region

- Soil salinity is the most dominant limiting factor in the region, especially during the dry season. It affects crops at critical stages of growth, which reduces yield, and, in severe cases, the total yield is lost. A substantial area of land is tidally affected by saline water intrusion. Appropriate management practices for crop production in this area are not available.
- The fertility status of most saline soils ranges from low to very low in respect of organic matter content, N, P and micronutrients like Zn and Cu. The crop yields obtained in these soils are also low.
- Scarcity of good quality irrigation water during the dry season limits crop production.
- High year to year variability of rainfall, uncertain dates of onset and recession of seasonal floods and risk of drought restrict the cultivation of rice and other crops. Narrow technological and germplasm bases of salt-tolerant crops limit crop choices. On the other hand, due to extensive cultivation of a particular cultivar of crop year after year, the crop becomes susceptible to insects and diseases. Insects and diseases like hispa, leaf-hopper and tungro virus are prevalent in the region, and extensive damage is caused by these insects and diseases almost every year.
- In the coastal saline belt, the winter season is very short. Therefore, timely sowing/planting of winter crops is essential but this is restricted by late harvest of wet season rice.

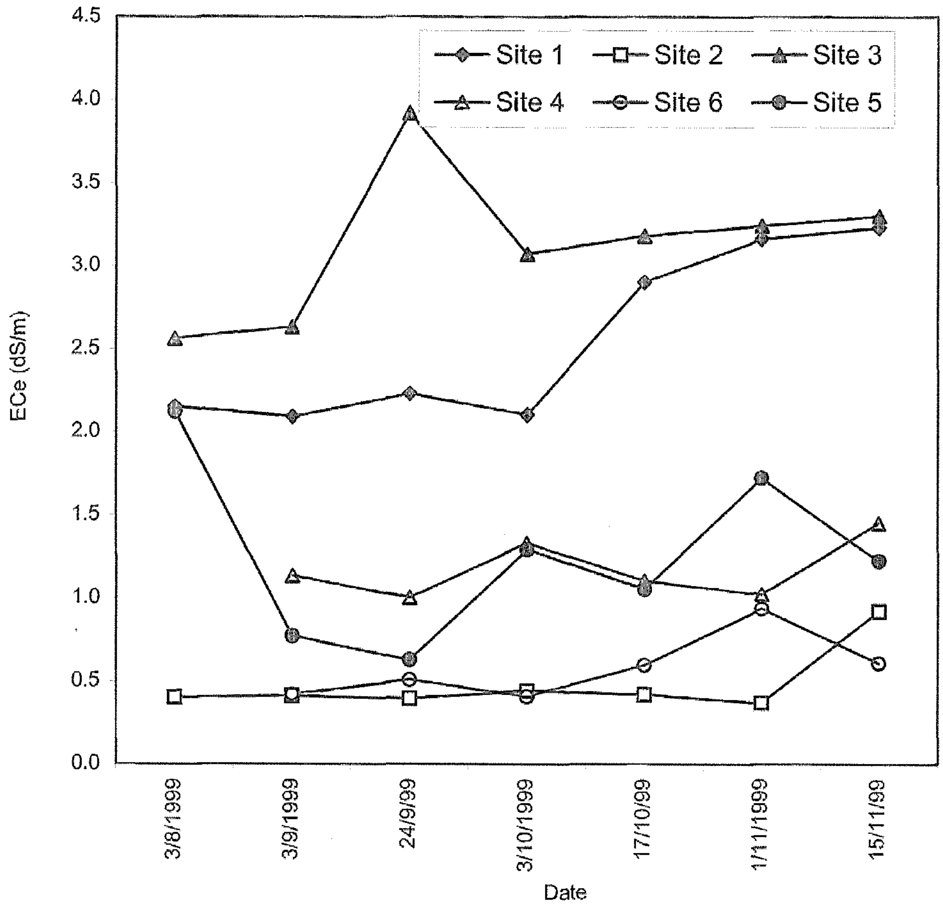

Figure 5. Soil salinity in some farmers' fields in Satkhira during wet season rice, 1999 (Panaullah, 2000).

3. Shrimp farming in Bangladesh

3.1. Shrimp cultivation in Bangladesh

Shrimp cultivation in Bangladesh dates back to the mid-nineteenth century in the Sunderbans mangrove water bodies. (*The Sunderbans, with an area of about 800 sq km, is the world's largest mangrove forest. It is rich in wildlife including the famous Royal Bengal Tiger. Recently, the Sunderbans has been declared a World Heritage by UNESCO.*) With increasing demands and prices of shrimp in the world market since the early 1970s, shrimp cultivation in Bangladesh expanded sharply in acreage and intensity, especially in the coastal districts of Satkhira, Khulna, Bagarhat in the Southwest and Cox's Bazar in the Southeast. Shrimp farms, or 'ghers' as they are locally called, began to be established in large numbers since the early 1980s. Figure 7 shows a typical shrimp gher. The owners of these shrimp ghers are mainly outsiders, business entrepreneurs from the cities who have enough money, political clout and social influence to grab small farmers' lands for just nominal prices or imposed lease deals. Also some rice farmers have switched over to shrimp farming considering the cash benefits. The area under brackish water

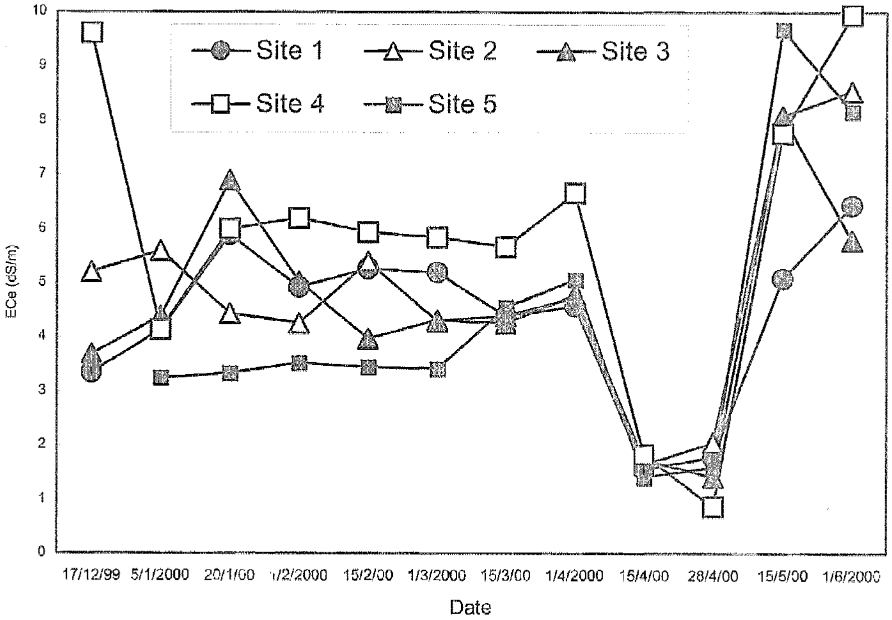

Figure 6. Soil salinity in five farmers' fields, Satkhira, Boro 2000 (winter dry season rice) (Panaullah, 2000).

shrimp was in 1980 around 0.05 million ha and increased recently to more than 0.15 million ha.

3.2. Types of shrimp farming

Four types of shrimp farming are generally practised in Bangladesh (Pal, 1996).

Shrimp-fish-rice
In this shrimp farming system, fries and other fish with saline tidal water (EC<8-10 dS/m) are introduced into the gher. In the relatively low salt situation, shrimp and other fish, such as mullet, are grown. A wetland rice crop is grown, and after harvesting this crop, rice-fish/shrimp dual culture is performed. High levees are constructed to maintain a water depth of 0.5-1.0 m. Sluice gates are set for bringing in and draining out water. Fish is cultured beginning with the onset of winter (December) to the end of summer (June-July). Usually, the shrimp/fish production is 800-1 000 kg/ha.

Salt-shrimp-rice
This is usually practised in the southeastern coastal areas. Seawater is evaporated in bunded fields (evaporation basins) to produce salt and cultivate shrimp in the dry winter season. In the wet season when there is abundant rainfall (around 3 000 mm/year, mostly in June to October), the topsoil becomes a bit free of salts due to leaching, and a rice crop can be grown.

However, the shrimp yield is low due to a short raising time. The rice yield is also low due to a relatively high soil salinity.

Figure 7. A typical shrimp field (gher) established on a former rice land in Satkhira District of the southwestern coastal region of Bangladesh.

Shrimp-fish mixed culture
This has been a traditional fish farming practised for about a century until the late 1970s, but since then this practice is changed fast giving way to cultivating shrimp alone. In this type of farming, the gher is relatively deep (1-2 m), with the water all the year round. Shrimp and other fish fries together are introduced into the gher with tidal water during February to April. The predator fish species are screened out at the sluice gate. Tiger prawn fries may also be procured from elsewhere and raised in the gher. During the high tides at full moon or new moon, tidal water is again and again introduced into the gher. In this system, usually shrimp and mullet are cultured in a 1:2 ratio. The fish feed on the natural fauna, mature in 4-6 months, and are harvested between July and December. The yield of mixed shrimp and mullet is about 2 000 kg/ha.

Shrimp (tiger prawn) only
In this system, only the tiger prawn is grown in a semi-intensive or intensive manner. This type of shrimp farming is expanding speedily due to high profits.

3.3. Impact of shrimp farming

Due to the potential of bringing about windfall profits, especially for the elite businessmen, brackish water shrimp farming in the coastal areas has spread very fast during the last two decades. Local farmers have either willingly leased out their land to the shrimp entrepreneurs on short- or long-term basis or have given in to the muscle power of businessmen from the cities. Due to shrimp farming, saline water from the shrimp ponds seeps to the adjacent agriculture lands. The government and donor agencies like the World Bank have encouraged shrimp farming as it is considered as an economic boost for Bangladesh. Shrimp is exported to developed countries in North America and Europe, and this has contributed substantially to the export earnings, and thus, economic development of Bangladesh. Currently, shrimp accounts for about 6 percent (US$270 million) of the total export earnings of Bangladesh. Thus, shrimp farming is the rich man's 'white gold' in the coastal belt of Bangladesh. If the long-term impacts of this practice on the agriculture, biophysical environment and socioeconomic balance of the fragile coastal ecosystem are considered, benefits from shrimp farming would seem to be only short term. The agricultural production potential, the biodiversity and the lives and livelihoods of a substantial portion of the rural population in the fragile coastal ecosystem are being sacrificed for shrimp farming. Philip Gain, a Bangladeshi journalist, described the woes of a farmer, Bhusan Chandra Roy in a newspaper article 'Attack of the Shrimps' to elucidate the damage resulting from shrimp farming. Excerpts from this news story:

"Bhushan Chandra Roy owns a 7-acre plot of land in the coastal village of Bara Durgapur, 350 km south of Dhaka. Ten years ago he grew enough rice to feed his family of eight – plus a surplus which he sold for extra cash. Now he grows only one-third of that amount. Ten years ago his farm was luxuriant with trees – bananas, betelnut, coconut and date palms. Now the banana trees are gone, the betelnut trees dead, the coconut trees sterile and the date palms are dying. His fields are flooded with brackish salt water, wherein lurk the inheritors of Bhushan's land – shrimps. Reigning over this sunken empire of small fry is one top cat – .... a commissioner of the Khulna City Corporation who has been growing shrimp on a 300-acre farm in Bhushan's area for the last 10 years. Commissioner .... doesn't own any of this land, nor does he live or work on it. He has leased Bhushan's seven acres for $100 a year. Last year Commissioner .... earned nearly six times as much for each acre he controlled, netting a cool $175 000.

"Bhushan can no longer rely on migratory birds to control pests, because the birds no longer come. Fish, which used to be abundantly available, are now exorbitantly expensive because the canals and rivers that were used to be common property are controlled by the shrimp farmers. Some aquatic plants and animal species have become extinct. ... For farmers like Bhushan Chandra Roy the issues are dramatically simple. Ten years ago, before the shrimp farms, he hadn't experienced poverty and hunger. Now he is fighting to keep them at bay."

It took two decades for the agricultural and ecology researchers, sociologists and social workers of Bangladesh to realize the harmful effect of shrimp farming. They are now very much concerned about the impact of shrimp farming on the coastal ecosystem, as the adverse effects began to be quite easily observed within two decades of intensive shrimp farming. Research and assessment of the impact of shrimp farming are very few in Bangladesh. Thus, detailed information and data on the exact magnitude of the damage are lacking. However, based on scientists' hypotheses and findings, results of a few surveys and farmers, the following are own perceptions:

- An increase in soil salinity, not only in the shrimp gher itself, but also in adjacent croplands is the most obvious effect of long-term ponding of saline tidal water for shrimp raising. Over the last decade, due to increasing salinity, the yield of the wet season rice has decreased three-fold in the shrimp areas in the districts of Khulna and Satkhira. In a recent survey (April 1999) conducted by BRRI scientists, agricultural extension officials and NGO workers in two representative villages of the districts of Khulna and Satkhira, the farmers themselves complained about increasing salinity as the main problem affecting crop production.

- Another problem, associated with shrimp farming is waterlogging. In some studies carried out in abandoned shrimp ghers, sharply decreased bearing capacity and destruction of soil structure have been observed in the southwestern coastal region. Prolonged water logging may also bring about drastic chemical changes in the soil. Accumulation of metallic sulphides like FeS_2 may occur which may increase soil acidity when the gher is abandoned, drained and dried. The accumulation of Na_2SO_4 and its subsequent reduction increase soil alkalinity if there is Fe deficiency. Emission of CH_4, CO_2, H_2S, etc. pollute the environment (Bandyopadhyay, 1998).

4. Biophysical, environmental and socioeconomic impacts of salinity

4.1. Biophysical elements, such as, soil, vegetation and animals have been greatly affected by salinity. Many soils became unproductive, poultry and livestock populations in the coastal region decreased sharply due to shrinking grazing lands. The greatest damage to the environment and socioeconomic conditions of the local populace has been inflicted by unregulated shrimp enterprises. About 26 million of the total 128 million people of Bangladesh are seriously affected by soil and water salinity in the coastal belt.

4.2. The adverse effect of increasing salinity in the environment due to indiscriminate shrimp cultivation can be gauged from a case study in the coastal districts where intensive shrimp farming is practised by influential entrepreneurs. Shrimp farming started in Satkhira, a southwestern coastal district, in the 1980s within areas protected by coastal embankments. Shrimp is grown in strongly saline water brought in through illegally dug channels across the embankments. Out of the 170 000 ha of agricultural land in the Satkhira District, almost 61 000 ha are already under shrimp cultivation presently. The fast expansion of shrimp ghers has severely affected the natural vegetation, human and livestock populations. The once green and lively southern part of the Satkhira District now has taken on the look of a 'salt desert'. The natural vegetation has almost vanished, planted fruit trees in hundreds of villages have died away. In the southeastern coastal district of Cox's Bazar, the Chokoria Sunderbans, an 18 000 ha mangrove forest, has been totally destroyed.

Encroachment on government forestland is common. At least 2 million cattle died during the last 15 years due to a drastic shrinkage of the grazing lands. Drinking water sources of the rural population have become polluted with saline water causing diarrhoea and other gastrointestinal diseases which affected 0.8 million human beings over the last 15 years. Thousands of hectares of agricultural land (mostly rice lands) have been abandoned due to saline seepage from the shrimp ghers rendering 0.2 million farmers jobless. Many farmers have been compelled to sell away their lands at nominal prices, the number of landless farmers having increased in the process. According to the gher owners, only two labourers are needed for a 10-ha gher, whereas rice cultivation in a 10-ha farm could employ at least 25 agricultural labourers. Thus, for every 100 ha of land brought under shrimp cultivation, 230 agricultural labourers became jobless. While the individual gher owner may have enjoyed windfall profits, the damage done to the environment and the human populace would run into the billions in financial terms. In addition, shrimp cultivation has resulted in undesirable social conflicts as political influence and muscle power are often used to establish and maintain the ghers. Pal (1996) cited a case study involving a farmer (Mr Chandrakanta Biswas) whose name is mentioned here as a good example of how shrimp cultivation could change the properties and livelihoods of a farm household. Comparisons of the properties and incomes of the Biswas family between 1984 and 1992 are shown in Tables 3 and 4, which clearly show shrimp farming resulted in a substantial loss of agricultural property and decrease in family incomes.

Table 3. Income changes in a typical farm family (1984-1992).

Sources of income	**Income (Taka – according to the prices of 1992)**		**Changes**
	1984	**1992**	
Agriculture	60 000	21 600	-38 400
Coconut + betel nut	44 000	-	-44 000
Cattle and goat	84 000	-	-84 000
Shrimp and other fishes	8 000	46 000	+38 000
Milk, egg and chicken	38 690	7 500	-31 190
Ghee	12 400	-	-12 400
Vegetables	32 000	-	-32 000
Total	**279 090**	**75 100**	**-203 990**

Source: Pal (1996).

5. Main solutions, technologies used to combat salinity

5.1. Increasing agricultural productivity of the coastal saline soils has been one of the major national agricultural development concerns in Bangladesh. Since salinity is the main productivity constraint in the coastal zone, the government, through the Bangladesh Water Development Board, started construction of coastal embankments in the mid-1970s to prevent the intrusion of saline waters into agricultural lands. Until now, 3 700 km of embankments with 900 sluice gates have been constructed at different points of the coastal zone. This project has been partially successful in reducing soil salinity in areas within the embankments, although the embankments with faulty drainage systems have created the problem of waterlogging in several cases. However, thousands of hectares of land still remain saline.

5.2. The development of salt-tolerant high-yielding varieties (HYV) of rice has been one of the major research thrusts of the Bangladesh Rice Research Institute (BRRI) during the last few years, and two varieties, *BRRI Dhan 40* and *BRRI Dhan 41*, have been very recently released for growing in the coastal region during the wet season. These varieties have the potential of giving about 2.0 tonnes/ha higher yield than the local, traditionally cultivated varieties under moderately saline conditions (soil EC_e around 6 dS/m) in the wet season

5.3. In the shrimp ghers, the shrimp yields are declining due to viral diseases. The gher owners are now interested in growing salt-tolerant wet season rice. However, such rice has to be both salt-tolerant and submergence tolerant. No such variety is yet available.

Table 4. Changes in land and other resources in a typical farm family (1984-1992).

List of resources	1984	1992	Comments
Agriculture	3.21 ha	3.61 ha	Some parts of fruit garden has been converted to crop field
Homestead	0.94 ha	0.53 ha	-
Pond	0.45 ha	0.45 ha	Used to cultivate carp fishes, but now they are not grown
Buffalo	18	7	-
Cattle	26	0	There is no grazing land
Duck	50	0	
Chicken	60	10	
Mango tree	4	2	
Coconut tree	28	12	Plants do not bear fruit
Betel nut	100	0	-
Banana, papaya and other fruit tree	Many	0	-
Vegetables	Many	0	No more vegetables

Source: Pal (1996).

6. Other issues

6.1 Land use in Bangladesh does not always remain consistent with the agro-ecological possibilities and potentials. Many other factors including socioeconomic limitations govern the land use patterns. In the coastal areas, land use is further complicated by the presence of fluctuating soil salinity levels on the one hand, and, more recently, by the tendency of profiteering by the shrimp businessmen. Perennial waterlogging due to inadequate drainage facilities restricts the potential land use of the lowlands within the embankments. In these areas, unauthorised digging of channels for the bringing in saline water for shrimp culture creates agronomic problems and also social conflicts and public health hazards. Although badly needed, there are no effective government regulations to rationally look after the conflicting interests of the shrimp entrepreneurs and local farmers.

6.2. Appropriate extension programmes for the diffusion of modern technologies are lacking. Extension personnel trained in saline soil management are inadequate. These retard the adoption of HYV technologies.

6.3. Big land ownership and unfavourable land tenure systems, and dominance of absentee landlords discourage the adoption of modern crop production technologies by the vast majority of small farmers.

6.4. Poor communication and marketing facilities retard agricultural development in the region.

7. Research requirements in the country

Very little research has been conducted in the field shrimp farming in Bangladesh. Research on the following issues is badly needed:

- Changes in the soil and groundwater salinity.
- Effect of brackish water aquaculture on the productivity of adjacent agricultural lands.
- Chemistry and microbiology of the soils under shrimp culture, and accumulation of toxic products.
- Changes in the land use and livelihood pattern of coastal farmers due to large-scale introduction of brackish water aquaculture.
- Continuous monitoring of salinity, and development of models for the prediction of the degree of salinity development. Evaluation of soil and water salinity in the coastal areas is occasionally done by the Soil Resource Development Institute (SRDI) and the Bangladesh Water Development Board (BWDB). SRDI has produced a soil salinity map of Bangladesh using the GIS technique. However, continuous monitoring of soil and water salinity is required given the fluctuating soil and water salinity levels. Development of models for the prediction of year round soil salinity using the available soil and climatic database is badly needed for decision making process in making production plans under fluctuating salinity regimes. Remote sensing and ground truthing techniques need to be applied to sharply delineate the cropped and fallow areas and monitor the changing biophysical environment due to human interventions like shrimp farming and logging in the mangrove areas. The Space Research and Remote Sensing Organization (SPARRSO) of Bangladesh can take the responsibility.
- Improvement of soil physical conditions to facilitate speedy and effective salt leaching during the wet season. The application of organic matter like green manure, crop residues, rice husk, saw dust, animal dung, farmyard manure, etc. will be especially useful as both soil conditioners and plant nutrient sources. However, crop residues, animal dung, etc. are normally used by the small farmers as kitchen fuel, and thus, these are almost never recycled to the soils. There is a need to motivate the farmers to apply organic matter to the soils and look for alternative sources of kitchen fuel. The Department of Agricultural Extension and NGOs working in the rural areas may help farmers realize the benefits of the application of organic matter to their fields. Some strains of blue-green algae (Cyanobacteria) are reported to absorb salts from the soil. These may be used to reduce soil salinity. Research is needed to explore this possibility.
- Proper fertiliser application to maintain an appropriate ionic balance in the soils is important as the concentrations of the nutrient ions in the soils are disproportionate as

far as plant nutrition is concerned. For example, there is a large excess of Na^+ and Mg^{2+} relative to Ca^{2+} and K^+ in the coastal saline soils (Panaullah, 1993). Magnesium has a synergistic effect on the uptake of Na^+, and at the same time an antagonistic effect on the uptake of Ca^{2+} and K^+ by plants. This should be considered in formulating balanced fertiliser doses for crop production in the coastal saline areas. Moreover, the coastal saline soils of Bangladesh are generally moderately to strongly alkaline with high pH values for which micronutrient deficiencies in the soils are common. Appropriate micronutrient doses for different crops need to be determined. Especially research on integrated nutrient management, i.e. appropriate combinations of chemical fertilisers and organic manure for soils with different salinity, sodicity/alkalinity and fertility levels should be extensively researched. Crop research institutes, such as, the Bangladesh Rice Research Institute (BRRI) and the Bangladesh Agricultural Research Institute (BARI) can conduct such research for rice and other crops.

8. Involvement in FAO Network project

The Bangladesh Rice Research Institute, under approval from the Government of Bangladesh will soon start a research and technology validation/dissemination project at two sites in the district of Satkhira (southwestern coast) in collaboration with and sponsored by FAO. The project activities will be:

1. To identify, determine, and characterise coastal salt-affected soils.
2. To apply and test appropriate field demonstration trials on integrated rehabilitation and management techniques.
3. To act as a source of information (as a member of the established FAO Global Network on Integrated Soil Management for Sustainable Use of Salt-Affected Soils) and to participate in the preparation and to contribute to the ongoing newsletter (SPUSH) or suggested Internet system for the exchange of information and experience related to the Network's activities.
4. To disseminate among the farmers the developed integrated soil management technology packages for improving the productivity of coastal salt-affected soils. Preliminary site selection has been done. Work is expected to begin in summer year 2001.

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China

1. Introduction

As a big country in both food production and food consumption, total foodstuff yield in China reached 492.5 billion kg in 1997. The grain yield in the country has exceeded the world's average level. It is recognised that China has successfully fed 22 percent of world population by using only 7 percent of the world's arable land. With the rapid increase of the population, the average consumption level and development of the national economy, the need of food production for China will be continuously enhanced. It is estimated that the total need of food will be 500 billion kg in 2000, 550 billion kg in 2010 and 640 billion kg in 2030. Annual increase in food production for the last half century has been as high as 3.1 percent, while the recent increase (average for 11 years from 1985 to 1995) is only 1.2 percent annually. However, as long as the actual annual food production increase in the country may reach only 1 percent during 1999-2010 and 0.7 percent during 2011-2030, China will be able to achieve the expected food needs. Comparing with the past performance, the expected increase in food production should be realisable. To ensure certain increase in food production, enhancing potentials of unit crops' yield of current arable land and exploiting potentials of reserve land resources, using the available advanced technologies, best utilisation of non-grain food resources and saving in food consumption will be the main practical measures.

Total arable land in China is 137.6 million ha. With more than 1.2 billion of population, however, the average arable land per capita in the country is less than one-third of the world average. Among this 137.6 million ha of arable land, 83 million ha are rainfed, 31.8 million ha are paddy field and 22.8 million ha are irrigated land (Table 1). Groundwater and river water are commonly used as irrigation water resources in China, while drainage water and mixed water are only used in some of arid and semi-arid regions, or for special crops and conditions.

Uneven spatial and temporal distribution of surface runoff can be observed in China, The 62 percent of total national land area in North China, Northeast China and Northwest China regions share only 18 percent of total national runoff. The North China Plain which covers 40 percent of national arable land it only had 6.6 percent of total surface runoff. As the result, groundwater resource is extensively exploited, especially in the northern part of China, for expanding irrigated land. Irrigated land and paddy fields using groundwater for irrigation accounts for about one quarter of total arable land. Sewage effluent is also used in some regions as irrigation water, though the area is rather limited. Re-use of drainage

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water, use of saline water or mixed water irrigation are practised in some arid and semi-arid regions; some of them have been very successful in agricultural production and made the land and water resources better utilised.

Table 1. Area and current utilisation of arable land in China.

Total arable land million ha	Type	Area million ha	% of arable land	Type	Area million ha	% of dry land
137.6	Paddy field	31.8	23.1	-	-	-
	Dry land	105.8	76.9	Irrigated	22.8	21.5
				Rainfed	83.0	78.5

Increasing food needs have induced the stress on land use, and therefore sustainable use of problem soils, such as salt-affected soils, will play a significant role in food production and food security in China. Soil salinity or sodicity, drought, soil erosion, low or unbalanced soil fertility, waterlogging, poor soil structure and texture, and mineral toxicity represent main constraints to agricultural production of land in China, resulting in different land types of low-and-middle yield. Among all of the limitations, salinity and sodicity are very important factors restricting food production. Various types of salt-affected land spread in different regions of China as low-and-middle yield land or reserved land, with high potentials for food production increase (about 37 million ha of land in different regions of China are salt-affected in various degrees).

China covers 55 degrees of latitude from the tropical zone in the South to frigid-temperate zone in the North. As a result, cropping systems vary from only one crop in Northeast China Plain to three crops in South China hill region, while two crops annually is the dominant cropping system in China (Table 2).

Table 2. Crop systems in major plain regions of China.

Region	Annual or biennial crop(s)	Crop system
Northeast China Plain	One crop annually	Maize, soybean, wheat
North China Plain	Two crops annually or three crops biennially	Wheat-summer maize-spring-maize, cotton-wheat, wheat-soybean, wheat-sweet potato
Middle and low reaches of Changjiang River Plain	Two or three crops annually	Wheat (rape)-rice, wheat-rice-rice, rape-rice-rice

2. Definition used to describe salt-affected soils in China

In China, salt-affected soils are defined as a series of soils affected by salinity and sodicity/ alkalinity. Soil falls into the category of salt-affected soils when their soluble salts content exceeds 1-2 g/kg or the exchange sodium percentage (ESP) of its sodic/alkaline horizon exceeds 5 percent, including different types of Solonchak and Solonetz, and salinized and sodic/alkalized soils in various degrees of salinity and sodicity.

According to the traditional soil classification system of China, Solonchak can be further divided into Coastal Solonchak, Meadow Solonchak, Chao Solonchak, Bog Solonchak, Orthic Solonchak, Alkalized Solonchak, Residual Solonchak and Diluvial Solonchak. Solonetz can also be further divided into Meadow Solonetz, Steppe Solonetz, Takyr Solonetz and Magnesium Solonetz. Within the Chinese soil taxonomic classification, a new soil classification system has been established since 1990, although it has not been widely used in classifying salt-affected soils in China. In the system, Halosols order is divided into two suborders of Alkalic Halosols and Orthic Halosols; and Orthic Halosols is subdivided into two groups of Aridic Orthic Halosols and Aquic Orthic Halosols. However, Halosols cannot cover all types of salt-affected soils, owing to the fact that not all such salt-affected soils can meet high salinization intensity required for the Halosols. Therefore, some salt-affected soils have been fallen under the orders of Aridisols, Vertisols, Gleysols or Entisols.

Beside Solonchak and Solonetz, there still exist various types of salinized soils and sodic/alkalized soils with different salinization intensity and large difference on soil chemical composition, by covering different temperature and aridity zones. It is the boundary of salt-affected soils and non-salt-affected soils whether certain amount of salt accumulates in the root zone and whether the salt has restrained the growth of plant, or has harmed normal properties of the soil. From this point of view, salt-affected soils and their grades can be determined by salinity or sodicity/alkalinity levels. Following criteria are suggested for gradation of salinized soils (Table 3) and alkalized soils (Table 4), though some other articles have also been published for gradation of salt-affected soils in particular region, for particular soil type or under particular conditions.

Table 3. Criteria of gradation of soil salinity.

Regions	**Non-salinized**	**Slightly salinized**	**Moderately salinized**	**Severely salinized**	**Solonchak**
	Salt content of soil (g/kg)				
Coastal, semi-humid, semi-arid and arid regions	<1	1-2	2-4	4-6	>6
Semi-desert and desert regions	<2	2-3	3-5	5-10	>10

There exists a special type of soil in the arid and semi-arid regions of China, which is neither saline nor alkaline at present, but may become severely salinized and/or sodic/alkalized under human intervention, especially irrigation. Such soil is defined as potential salt-affected soils, due to its high potential to be salinized or alkalized.

Table 4. Criteria of gradation of soil sodicity/alkalinity (ESP).

Type	North China Plain	Northeast China	North Xinjiang
Non-alkalized	<5	<5	<10
Slightly alkalized	5-10	5-15	10-20
Moderately alkalized	10-20	15-30	20-30
Severely alkalized	20-40	30-45	30-40
Solonetz	>40	>45	>40

3. Problem identification, magnitude, extent and distribution of salt-affected soils

Saline or salinized soils are characterised by a salic or salinized horizon, with high salt content, which results in lower crop yield and even yield loss due to physiological drought and salt toxicity on the crop. Table 5 indicates the impacts of soil salinity on crop growth and yield loss in Xinjiang (Northwest China). The salinity criteria of other regions for similar influence on crop are usually lower than that in arid region of Northwest China, because salt in soil of other regions is more active than in arid region (Table 6).

Sodic/alkaline soil in China is characterised by its high pH and ESP, and by poor physical, chemical, and biological properties. Besides the toxicity of soil sodicity and salinity directly on crop, soil sodicity has also significant influence on agricultural use of land by its low soil fertility, poor permeability, low cation exchange capacity, forming of surface crust, etc. Value of high ESP of sodic soil is highly affecting crop growth (Table 7), while other soil properties due to sodicity are also harmful.

Table 5. Impact of soil salinity on crop growth and yield deduction.

	Very slightly salinized soil	Slightly salinized soil	Moderately salinized soil	Severely salinized soil	Solonchak
Salt content of 0-100 cm soil layer (g/kg)	3.9	3.9-4.9	4.9-6.0	6.0-9.0	>9.0
Ratio of seedling scarcity	<10%	10-33%	33-50%	>50%	Nearly 100%
Crop growth	Normal	Slightly restrained	Moderately restrained	Severe restrained	Mostly dead
Yield reduction	0	10-20%	20-50%	50-80%	100%

Salt-affected soils spread widely in China, especially in the northern part of the country. Such soils can be found almost all over the country, from the tropic in the south to the frigid temperate zones in the north, from the coastal areas in the east to the continental region in the west, and from the plain to the plateau. In China there are 37 million ha salt-

Table 6. Impact of salinity of soil with different chemical composition type on crop growth.

Soil salinity	Yield reduction	Crop growth	Soda type	Chloride type	Sulphate type
			Salt content of 0-60 cm layer (g/kg)	Salt content of 0-100 cm layer (g/kg)	
Non-salinized	0	Normal	<1.0	<1.5	<3.0
Slightly salinized	10-20%	Slightly restrained	1.0-2.0	1.5-3.0	3.0-6.0
Moderately salinized	20-50%	Moderately restrained	2.0-3.0	3.0-5.0	6.0-10.0
Severely salinized	50-80%	Severely restrained	3.0-5.0	5.0-8.0	10.0-20.0
Solonchak	Near 100%	Mostly dead	>5.0	>8.0	>20.0

Table 7. Impact of ESP on wheat.

ESP	Germination ratio (%)	Height of wheat (cm)
0	93.3	14.5
5	100.0	15.3
10	93.3	13.9
20	80.0	13.3
30	67.6	11.6
40	57.6	11.2
50	50.0	9.6

affected lands distributed in different regions of China in various degrees. Besides the coastal salt-affected soil distributed south of the Changjiang River, the aridity of other regions with salt-affected soil is higher than 1. It is the main trend that the higher the ratio of evaporation to precipitation is, the more severe the soil salinization is and the thicker the saline horizon is. According to the change of humidity and temperature conditions of bio-climatic zones of semi-humid, semi-arid, arid and desert from the east to the west, the magnitude of distribution becomes wider and the extent of salinization become more severe (Table 8). The distribution pattern of salt-affected soils changes from spot-like to patch-like and even continuous patch-like. The distribution and regionalisation of salt-affected soils in China is indicated in Figure 1. The development extent of sodic/alkalized soils, however, becomes weaker from the east to the west gradually. Although salt-affected soils are considered as the non-zonal soils, such soils still show certain zonal or regional bio-geochemical features under the influence of bio-climatic conditions. From macro scope point of view, salt-affected soils can be divided into four salinization types, i.e. modern salinization type, residual salinization type, sodic/alkalization type and potential salinization type.

In terms of the results from the last soil survey in China, the figure of salt-affected soil area is slightly different from that indicated in the monograph *Salt Affected Soils of China*. Total area of salt-affected soil is 35 million ha including 14.7 million ha salt-affected soil within arable land (Table 9).

Table 8. Status of soil salinization of meadow saline soil under different E/P ratio.

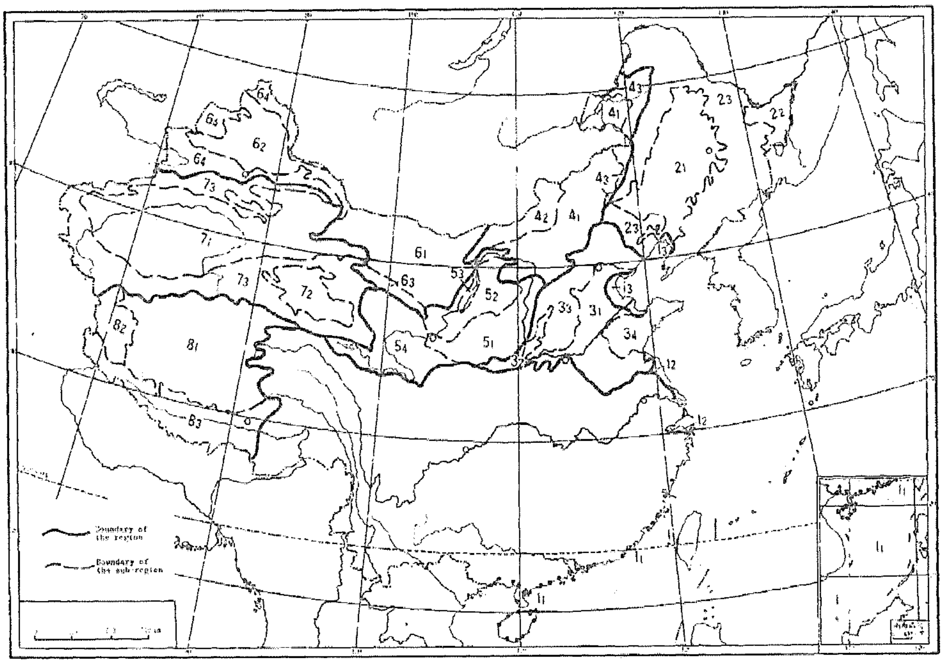
Region	E/P ratio	Ground water salinity (g/litre)	Thickness of surface salification (cm)	Salt content of surface soil (g/kg)	Salt content of bottom soil (g/kg)	Thickness of salt crust (cm)
North China Plain	2-4	1-2	1-3	10-30	1-2	0.1-0.2
Weihe and Fenhe Valley Plain	3-5	1-5	3-10	10-100	1-3	0.1-0.5
Ningxia-Inner Mongolia and Hetao Plain	8-14	5-25	5-20	10-300	3-20	1-2
Qinhai-Xinjiang Basin	6-15	5-30	10-50	100-600	6-40	5-15

Table 9. Area of salt-affected soils in China (million ha).

Salinized soils	16.5
Alkalized soils	1.5
Solonchak	16.1
Solonetz	0.9
Acid sulphate salt-affected soils	0.02
Total area of salt-affected soils	35.0
Area of salt-affected soils in arable land	14.7

Coastal salt-affected soils spread along the coastal area of China, mainly caused by saline parent material and seawater intrusion from both surface and underground. Large-scale water project may have influences on such soil. Fluvo-aquic salt-affected soils and meadow salt-affected soils are widely distributed in the North China Plain, the largest alluvial plain in China, and other northern regions of China. This type of soils is formed under the influences of groundwater, surface water and cultivation. Irrational management (especially the irrigation and drainage management) plays significant roles in formation and evolution of the salt-affected soils. Solonetz and alkalized soils, which are mainly distributed in Inner-Mongolia and Northeast China regions, and are spread as spots in the North China Plain, are formed both under natural and anthropogenic processes. Cultivation and irrigation management has influences on formation of such soils and on alkalization in certain extent. Haplic Solonchak and desert salt-affected soils, mainly spreading in inland region, such as in Northwest China, is caused by strong evaporation of groundwater and strong surface salt accumulation. Coastal acid sulphate Solonchak, distributed along the coastal zone in South China, is mainly formed under natural process. Potential salt-affected soils are mainly distributed in the arid and semi-arid regions of China. Salt-affected paddy soils are mainly distributed in coastal and inland lowland regions where paddy fields occur.

Figure 1. Regional map of salt-affected soils in China (Wang *et al.*).



Index of region code of the map
1 - Coastal humid and semi-humid seawater salinized soil region;
2 - Northeast China semi-humid and semi-arid steppe-meadow salinized soil region;
3 - North China alluvial plain semi-humid and semi-arid meadow salinized soil region;
4 - Inner Mongolian plateau arid and semi-desert steppe salinized soil region;
5 - Middle and upper reaches of the Huanghe River semi-arid and semi-desert salinized soil region;
6 - Gansu and Xinjiang desert salinized soil region;
7 - Qinhai-Xinjiang extremely arid desert salinized soil region;
8 - Tibetan plateau lake-side soda-chloride salinized soil region.

4. Causes and processes of formation of salt-affected soil

In China, salt-affected soils are both caused by natural processes and anthropogenic reasons. The soils in some regions are formed naturally, while human activities influence formation or evolution of such soils in other regions. Formation of salt-affected soils is accompanied with salinization processes, including mainly modern salinization process and sodication/ alkalization process.

Modern salinization is the major cause of salt-affected soils and can be subdivided into several processes of salt accumulation as follows:

a) Salt accumulation process under intrusion of seawater. This kind of process occurs along the coastal areas. The source of salt mainly comes from seawater intrusion. In the manner of tide intrusion, seawater intrusion to the river, groundwater recharge by seawater in coastal region and as a source of salts, seawater still has influences on modern soil salinization or evolution processes. Coastal salt-affected soils cover several bio-climatic zones from Guangxi to Liaoning. In coastal region, salt content of soil in surface layer is either high or not very high, but the content in sub-surface and bottom soil layers is relatively high, because coastal salt-affected soil is developed on saline sediments. Groundwater salinity is commonly high, and the chemical composition of the soil and groundwater is identical to the seawater. In the coastal area of provinces in South China, there also exists salt accumulation process under acid environment and seawater intrusion, where sulphate dominates chemical composition of the soil and acid sulphate salt-affected soil occurs.

b) Salt accumulation process under dual influences of ground- and surface water. Poor groundwater condition is the main cause of such process, while surface waterlogging aggravates soil salinization. Groundwater table in this area is usually shallow and underground runoff condition is poor. Groundwater is recharged by waterlogging through infiltration, such process raises groundwater table and then causes salinization. On the other hand, surface water can dissolve and transport the salt to the soil surface and to accumulate at the edge water pond or basin, by lateral water movement through soil capillaries. Such type of salt accumulation process can be widely found in the North China alluvial plain, Songhuajiang and Liaohe rivers plain, and Fenhe and Weihe rivers plain and basin. Salinization in flood plain as caused by irrational development has mainly been induced by such kind of salt accumulation. Undulate landform in moderate and small scale also plays certain roles in re-distribution of salt in different landform components and in the formation of salt-affected soils under such processes. Strong surface salt accumulation is often observed in these areas, and salt distribution in soil profile often presents as 'T' sharp.

c) Salt accumulation process under influences of groundwater. Poor groundwater conditions absolutely dominate salt accumulation process under such circumstances, without any participation of seawater intrusion nor surface water side seepage. Usually, salinization is not found in the regions with coarse soil texture, deep groundwater table, free underground runoff and fair groundwater quality. Soils are often salinized under conditions of flat landform, fine soil texture, slow underground runoff, groundwater table being above the critical water table in dry season. Extents of soil salinization are mainly determined by groundwater table and water salinity, and evaporation/precipitation ratio. Salt accumulation rate becomes strong and the critical groundwater depth become small, when groundwater table is shallow, water salinity is high, E/P ratio is high and soil capillary activities are active. This type of salt accumulation process occurs in many regions of the northern part of China, including the North China Plain, Northeast Plain, alluvial plains in Inner Mongolia and Ningxia, and Northwest China. The critical groundwater depth varies in different regions, according to local conditions (Table 10).

d) Salt accumulation process under the influence of surface runoff. Such accumulation occurs in extremely arid regions, such as Xinjiang. When surface runoff of the water from high snow mountain passes through high-salt-containing stratum, the runoff water dissolves salts and transports it to the piedmont area. Under strong evaporation, the salt accumulates on soil surface, and salt-affected soils are formed.

Table 10. Critical groundwater depth in different regions of China.

Region	Critical groundwater depth (cm)
North China Plain (different in term of soil texture and groundwater salinity)	100-260
Songhuajiang and Liaohe rivers plain	200
Valley plain and basin of Shaanxi and Shanxi Provinces	250-300
Alluvial plain of Inner Mongolia and Ningxia in semi-desert and arid-steppe zones	250-300
Northwest China in desert climate	400-

e) Secondary soil salinization process. This is a modern salinization process causing salinization of previous non-salinized soil or enhancing extent of previous salinization, by aggregating hydro-geological condition of a region or a basin and by inducing upwards movement of salts in soil and groundwater through capillary rise, and by rapidly accumulating salt on surface soil, due to inappropriate human activities. Secondary salinization is often accompanied by irrigation or building up of large-scale water resource development projects. The high groundwater table that exceeds the critical depth induced by irrational development and management of irrigation/drainage is the most important reason causing secondary salinization in an irrigation district with potential threat of salinity. It is an example that sharply increased the area of secondary salinization in the North China Plain during late 1950s to early 1960s, due to irrational development of irrigation. Using of surface or ground mineralised water (such as brackish water, alkaline water, mixed water, etc.) often induce salt accumulation in upper soil layer and salinization, without adoption of proper regulation means of salt-water regime, such as salt-leaching or drainage measures. This type of salt accumulation is often found in semi-arid or arid areas of China that have been supplied with poor quality irrigation water or by re-using the drainage water. Poor soil and water management and irrigation mismanagement, such as seepage from canals, insufficient application of irrigation water, low irrigation efficiency, poor land levelling, insufficient drainage, improper cropping rotation, all contribute to secondary salinization in certain regions.

f. Biological salinization process. In the semi-desert and desert regions of China, salt-tolerant plants and halophytes participate in modern salinization process to various extent, by their characters of absorbing and excreting salts. Salt in plant residues then accumulates on the soil surface after the plants die.

Solonetz and alkalized soils widely occur in regions of the northern part of China. Relatively distribution of such soils includes Northeast Inner-Mongolia, Songhuajiang and

Nenjiang alluvial plain of Northeast China, the North China Plain and Northwest China. Alkalized soils often occur as spots or patches within other soil types, especially saline soils, which suggests its close genetic link between the two types of soils.

Formation of sodic/alkalized soils is obviously under the influences of zonal temperature, water and biomass accumulation under local bio-climate conditions. On the other hand, cultivation also has certain impacts on the formation of sodic/alkalized soils, which makes the formation even more complicated. In many regions of the northern part of China, modern sodic/alkalization process is caused under frequent change of evaporation/leaching during the year and under existence of rich sodium and carbonate in parent materials. Owing to the improper development of irrigation or adoption of inappropriate agricultural measures, however, soil can also become secondary sodic/alkalized. Saline soil could become sodic/alkalized. when people reclaim saline soil by washing salt or irrigating, without adoption of other bio-agricultural measures (provide the soil with calcium as a divalent cation). From experiences in the North China Plain, leaching of saline soils could accelerate formation of secondary sodic/alkalized soils under such disadvantageous circumstances. Another cause of secondary sodification/alkalization is due to the irrigation with low-mineralised alkaline or high RSC water. Such process can be found in semi-arid or arid regions without fresh irrigation water.

5. Environmental, socioeconomical and agricultural impacts

The essential problem of salinization is that excessive electrolytes get into soil components or the electrolytes accumulate in a particular layer of soil, deteriorating soil physical, chemical and biological properties. The electrolytes themselves have also certain biological toxicity. Salinization results in not only lowering land quality and utilisation values, but also damaging the environment. Since salt-affected soils occur widely in China, the negative effects of salinization are mainly manifested in the following impacts:

a) Salinization restricting utilisation of land resources for agriculture. Land is the basic resource that agriculture relies on. However, large areas of land could not be used due to high salinity. Xinjiang Autonomous Region is the largest region with severe salinity problems in China. The total area of land in Xinjiang is 165.8 million ha, of which more than 13 million ha are subjected to salinity development. The total amount of potential arable land in Xinjiang is 9.82 million ha, about 60 percent of it are problem lands due to salinity. Even among the cultivated land, only 49 percent are free from salinity problem or with slight salinity limitation. The rest is the land with moderate- or severe salinity limitation, which counts for more than 50 percent of the cultivated land in Xinjiang. Salt-affected soils in the Song-nen Plain of Northeast China amounted to more than 3 million ha, of which only 43.8 percent have currently been used for agriculture. The rest remains abandoned due to salinity hazards.

b) Secondary salinization causing contraction of agricultural land. Human-induced salinization often accompanies development of irrigation and other human activities, making salinization hazards more severe on agriculture. With vast distribution, human-induced salinization often occurs in rich alluvial plains, large river basins and in population concentrated irrigation regions. Therefore, human-induced salinization has strong negative impacts on agriculture and it is one of the most important factors limiting development of sustainable agriculture. Salinization induced by irrational irrigation in Northwest China, in the Great Bend of the Huanghe River, and in the North China Plain are examples of agricultural land contraction owing to salinization. In early 1950s, due to irrational irrigation, more than one million ha of salt-affected land were formed in just a few years. Salt-affected soils occupied only 11-15 percent of the irrigated land in the Hetao irrigation district of Inner Mongolia in 1954. The rate increased to 22, 31.6 and 58 percent in 1963, 1964 and 1973, respectively. Xinjiang has seen the largest land loss in China. A total area of 3.4 million ha of previous wasteland has been exploited during the last forty years. However, only 1.86 million ha remain in agricultural use and 1.54 million ha were abandoned soon after cultivation due to development of secondary salinization.

c) **Influences of salinization on yield of agricultural production.** In slightly and moderately salinized land, agricultural production is still possible. Salinization limitation, however, shows its significant influences on crop yield. It inhibits crop growth, and together with poor fertility level, low yield and poor quality of agricultural product is very common in salinized areas. Salinity restricts uptake of water and nutrients by crops. On the other hand, high concentration of specific ions, such as sodium, chloride, has some particular toxicity to emergence and growth of crops. Crop growth environment with much higher or much lower pH caused by salinity also leads to inhibition of crop growth. All mentioned above are reasons for low crop yield in salt-affectd areas. In the North China Plain, crop yield reduction owing to salinization and sodification/alkalization ranges from 10 to 50 percent. In the Song-nen Plain of Northeast China, yield reduction due to sodification/alkalization is more serious, ranging from 4 to 85 percent. In some grasslands affected by sodification/alkalization in Northeast China, pasture yield is only 750 kg/ha. In Xinjiang, loss of crops due to salinity reaches 200 million kg, and loss of cotton 25 million kg annually. In an irrigation district in Xinjiang, due to secondary salinization, the yield of crops per unit area decreased by 35 percent. Hence, high input associated with low output caused by salinization makes big loss to agriculture and economy.

d) **Influences of salinization on adaptability of crop planting and crop quality.** Salinization makes poor adaptability of crop planting. Salt-affected land is not suitable for many salt-sensitive or moderately sensitive crops such as bean, broadbean, corn, sesame, etc. Under high salinity, crops could die completely, or give very low yield. Though by breeding of salt-tolerant species, planting of crops is possible in salt-affected land. However, usually production suffers losses in quality and yield of crops. Salinization is often associated with poor fertility level of land. Photosynthesis of plants, its efficiency and rate of protein accumulation of crops could be inhibited by low water and low fertiliser availability and specific ion toxicity associated with salinization, which makes poor quality of crops in varying degrees.

e) **Influences of salinization on forestry and animal husbandry.** Salinization has caused forestry and grassland degradation. Inner Mongolia and Northeast China are important pasture areas of the country. Vegetation of the pastureland becomes thinner because of overgrazing. In areas with shallow groundwater table, high salinity of groundwater and low-lying landform, salinization occurs due to high evaporation and active capillary rise. Then, salinization results in more serious pasture land degradation. The degraded grassland is characterised by fewer grass species, poor grass quality and quantity, low grass product, as well as thinner vegetation. In China, the grassland area with serious degradation problems reaches one-third of the total grazable pasture land and is still increasing at a rate of 1.33 million ha annually. Salinization plays a very important role in this process. In the Song-nen Plain there are 17 million ha of arable land, of which one-third is salt-affected in various degrees. On the other hand, more than two-thirds of the pastureland are salt-affected in the Plain. One-third of pastureland is abandoned due to serious salinization in Baicheng region of the Plain. Animal husbandry is hazardous by the loss of pastureland, poor pasture quality and low quantity in these areas.

f) Besides the very significant impacts on agricultural production, salinization also causes environmental and ecological problems. Although impacts of salinization on ecological environment show difference in pattern and extent, the common character is that it leads to lower environmental quality and damage of natural resources directly or indirectly. Some impacts already exist and others show long-term hazards and will appear in the future, including impacts of salinization on soil properties and land resources, on vegetation and climate, on environment of water resources, on tourism resources and on living beings.

g) Furthermore, agricultural sustainability is highly restricted by the hazard of salinization. Besides the instant influences of salinization on agriculture and the environment, salinization has potential hazards to sustainable agricultural development as follows:

- Salinization causes reduction of reserve land resources;
Amelioration of salt-affected soils, especially Solonetz and Solonchak in arid zones is restricted by high investment costs or high difficulties;
- Development of potential salt-affected land is at the risk of secondary salinization;
- Salinity problem influences utilisation of water resources for agriculture; and
- Salinization reduces benefits of water conservancy projects.

6. Main solutions, technologies to combat salinization and success stories

The genetic conditions and the types of soil salinization are varied and complicated all over the country, it is imperative to adopt different amelioration and utilisation measures and methods in light of the local conditions in order to mitigate or reduce the adverse effects of high salinity, sodicity and alkalinity on soil physical, chemical and biological properties, to control degradation of soil fertility, to create a sound ecological environment for normal growth of crops, to provide a reliable guarantee for rational exploitation of the land resources of salt-affected soils and hence to facilitate sustained agricultural development. Therefore, selection of methods for amelioration and utilisation of salt-affected soils in different saline areas should not only depend on the soil physical, chemical and biological properties, but also take into consideration the natural conditions and social economy of the area which might affect the feasibility and success or failure of the reclamation, amelioration and agricultural utilisation of the salt-affected soils. China has obtained long experience and remarkable achievements in controlling soil salinization, it may thus lay down a scientific basis for rational exploitation of the saline soil resources and development of agriculture in light of the local conditions. Main solutions and technologies applied in China for combating salinization and for using salt-affected soils include:

a) Consummation of drainage-irrigation systems. Soil salinization often occurs in areas with poor river hydrological and hydro-geological conditions. In saline areas, drainage is often poor, and drought and waterlogging take place alternately and frequently. Therefore, construction of drainage canals and completing field drainage engineering system are the fundamental conditions for ameliorating and utilising salt-affected soils. In arid and semi-arid areas, soil salinization is quite common and serious. Irrigation is essential to combat drought. Particularly in arid and desert areas, no irrigation means no crops. Irrigation has two functions, one is to meet the demand of crops for water, and the other to leach salts out of the soil. In that case, it is generally required to increase the volume of water diverted through the irrigation system or to flood the field purposely to leach salts out which needs the drainage system to strengthen its drainage capacity and its function to control groundwater table, hence to maintain water balance in the irrigation area. In short, in saline areas, complete and rational drainage-irrigation systems are essential in improving water-salt regime, controlling water-salt movement in soil, preventing volume accumulation of salts in the surface soils, and accelerating steady desalinization of the soil, which in turn facilitate overall amelioration and utilisation of salt-affected land and development of agriculture production.

b) Draining and rice-planting. Draining and rice planting is one of the traditional practices of ameliorating and utilising saline land and an effective measure combining amelioration and utilisation together. In saline areas no matter whether in the coastal regions of Southeast China or in the inland arid regions, as long as there is plenty of guaranteed water source and proper drainage conditions, the rice planting system can be used to ameliorate saline land. This practice usually does not need special leaching. After flooding the field with diverted water, rice can be planted and a yield of 4.5-6.0 tonnes/ha can be expected depending on initial salinity level. During the rice growing period, the field is often flooded, thus accelerating soil desalinization and increasing the desalinization rate. With the succession of rice-planting year, the desalinized soil layer deepens and in areas with better drainage facilities, groundwater is gradually desalted, the desalted water layer thickens and soil desalinization gets stabilised. The land thus becomes suitable for paddy-upland rotation. Research results show that in coastal areas, 3-5 years of drainage and-rice-planting lowered the mineralisation degree of the groundwater to 1-3 g/litre, increased the thickness of the freshwater layer to 1.5 m or more and reduced soil salt content to approximately 0.1 percent. In this case, the land can be cultivated for paddy-upland rotation (or rice-green manure crops). When the measure is adopted in sodic soils, application of organic manure and chemical amendments such as gypsum, phosphogypsum, etc. helped to achieve better results. Planting rice to ameliorate salt-affected soils must be carried out under an integrated planning, and paddy and upland crops must be laid out appropriately to prevent the soil of the surrounding upland fields from secondary salinization.

c) Combination of wells, ditches and canals and comprehensive amelioration of saline land. To combat soil salinization, the measures usually taken are to divert river water through canals and to drain the leaching water mainly through open ditches. However, in some areas, the land topography limits drainage and there is a shortage of freshwater sources, affecting salt leaching, salt draining and soil amelioration. Apart from the coastal saline areas and some closed depressions in inland saline areas with poor hydrogeology and highly mineralised groundwater, most saline areas have fairly rich fresh groundwater resources, shallow or deep. According to China's experience of the last two decades, in saline areas, developing pump wells (20-60 m deep) to make use of groundwater resources for irrigation and setting up irrigation-drainage engineering systems with various forms of combination of wells-ditches-and-canals have contributed greatly to the management of soil salinization. Because of the extensive use of well irrigation, a large volume of groundwater is pumped up for irrigation and salt-leaching, thus greatly lowering the groundwater table, which in fact functions as drainage system. Practices show that in irrigated areas with river water, a complete irrigation-drainage engineering system, consisting of wells, ditches and canals and combining well irrigation with canal irrigation by making use of groundwater, not only increases irrigation water sources and expands irrigated land area but also regulates the groundwater table. Renming Shengli (People's victory) Canal Irrigation Region, using water diverted from the Huanghe River, in Henan Province, China is an example. The construction of the combination of well-canal irrigation got underway in 1964. The ratio of the volume of water used from wells to that from canals and ditches was around 1:6 in the irrigation area. A general well irrigation could lower the groundwater table by 0.39 m, whereas a general canal irrigation raised the water table by 0.48 m. So in normal cases, in irrigated areas, the water table is around 2.5 and 3.5 m, thus effectively preventing secondary salinization and mitigating the damage of waterlogging. In saline areas with brackish groundwater, water from wells and canals maybe combined in the form of mixed water (fresh and brackish) for irrigation or rotation irrigation. This practice not only controls the groundwater table but also gradually desalts the groundwater, provided the area is installed with a good drainage engineering system.

d) Addition of organic manure to improve soil fertility. In ameliorating saline land, there are a huge variety of agro-biological measures, the most important one being to increase the content of organic matter. Application of organic manure helps improve soil physical properties, enhance salt leaching, reduce surface evaporation, and inhibit salt accumulation in the surface soil. Organic matter available for use includes crop stems and straws, green manure, farmyard manure, compost, etc. Long-term application of organic manure not only helps ameliorate the saline land but also will increase the content of organic matter in the soil and accelerate the maturation of the surface soil layer. Experiment in the coastal regions of Jiangsu Province, China shows that the matured surface soil layer has reached 15-20 cm in thickness, with soil organic matter content over 1.5 percent, which contributes significantly to improving soil moisture, physical properties, reducing surface evaporation and inhibiting salt accumulation in the surface soil. In saline areas with a shortage of organic manure, growing of green manure is promoted in light of the local conditions. Besides growing green manure solely in the field, rotation, inter-planting and intercropping of grain crops or cotton with green manure of different varieties can also be adopted to expand green manure sources, which can ameliorate soil, improve soil fertility, inhibit salt accumulation, as well as promote the combination of agriculture with animal husbandry and, hence, make the saline ecological environment develop in the direction of benign circulation.

e) Application of techniques of water-saving agriculture. Adopting water-saving measures and extension of water-saving agricultural techniques are effective in semi-arid and arid regions. These techniques can reduce water needs of agricultural production, which are useful in solving water shortage and uneven distribution of water resources. On the other hand, effective use of irrigation water can help in controlling groundwater table. Therefore, application of these techniques can prevent secondary salinization induced by irrigation under certain circumstances. In practice, application of low-quota irrigation, pipe transferring of irrigation water and other integrated water-saving agricultural measures have successfully increased efficiency of water resources. In addition, selection and planting of water-saving crops, improving soil structure and improving soil retention ability by manuring, means in reducing loss of water during agricultural production. They are also useful in utilising water and salt-affected soils resources, in controlling salinization and in getting higher agricultural profits.

f) Regulation of regional water resources. For better utilisation of water resources, better management, resolving regional outlet of drainage water, and enhancing use of surface water are three very important issues. In some catchments of semi-arid and arid regions, there is no natural outlet of drainage water, which induces difficulty in regional drainage. Therefore, three measures should be adopted to solve the problem. Firstly, clearing drainage ditch and canal and improving regional river water system are helpful in enhancing drainage capacity. Rational planning and construction of drainage water pumping/irrigation station and increasing pumping capacity have shown good results in drainage control on the plain. Secondly, in area with sufficient groundwater, well irrigation should be encouraged and canal irrigation should be under control, to enlarge capacity of groundwater reservoir, to accept more water in flooding season and to improve natural drainage condition. Thirdly, regulating water resources by diverting flooding water to area with water shortage should be considered in some catchments where water transfer is possible.

g) Proper management of brackish water irrigation. Irrigation with saline water has achieved some successful experiences. Main approaches include: (1) direct irrigation with brackish water during certain crop growth stages; (2) alternative irrigation with freshwater and brackish water; and (3) mixed irrigation with freshwater and brackish water. Application of these approaches should be in a way that suit local conditions, so that to get more benefits and to prevent secondary problems such as salinization, sodification and alkalization. In some region with large areas of saline groundwater, improving groundwater quality by pumping saline groundwater and replacing with freshwater is a good way. Results of experiment and extension of such approach in Hebei Province show significant increase of area of non-saline groundwater and contraction of area of brackish water. In the northern part of Henan Province, there exists a serious shortage of water. In theory, large quantities of surface water resources, especially rainfall in rainy season, could be used or stored effectively. Hence, effective use of surface runoff is very important in this area. In conditions of keeping monitoring groundwater table and regional salt-water movement, some reservoirs can be constructed for irrigation, which also have the effect on increasing infiltration of surface runoff, to improve the supply of water in dry season. Also ponds can be used as small reservoir. Under condition of river water irrigation, improving of irrigation facilities, reducing of water loss during water transfer and during irrigation practice are also beneficial to enhance surface water utilisation efficiency. Inter-basin and inner-basin water transfer schemes have been operated in some area of the North China Plain and they have shown benefits on agricultural production. For bringing these water transfer schemes into full play, establishing a complete set of water transfer and irrigation facilities should be paid more attention to increase total quantity of irrigation water and enlarge the irrigation area of benefiting districts. At the same time, groundwater table and salinization in water transfer district should also be monitored and relevant measures adopted to prevent possible secondary salinization.

h) Integrated biological-agronomic management. Proper management of integrated biological-agronomic measures has been useful in the use of salt-affected soils, elimination of salinity hazard and prevention of salinization. In the coastal area of China, development of aquaculture by setting large-scale fresh fish pond or shrimp pond is a good practice on the use of coastal salt-affected land, and is also practical for leaching salt and desalting water bodies (including groundwater). After several years, the salt in bottom soil is leached out and groundwater quality is improved, and then the land is cultivated for rice. Finally, the land is suitable for other crops, such as wheat and maize. Such kind of so called 'step-up utilisation' strategy is successful in Jiangsu and Zhejiang Provinces. Building up of coastal forestry band is also a good way to improve agro-ecological condition in salt-affected regions. Such means may not only reduce evaporation of farmland, but also reduce groundwater table by transpiration of those trees, and the chance for salt accumulation on the upper strata of soil is reduced. Other agronomic management measures, such as soil surface covering with plastic films or crop straw as mulching, can also effectively prevent strong soil evaporation and salt surface accumulation. Crop yield could be greatly increased by such simple means applied in wheat and cotton. Plant nutrition is usually unbalanced on salt-affected soils. Therefore, balanced soil nutrition management on N, P, K and some micronutrients will significantly improve the fertility of salt-affected soil, to obtain a fair yield. In this way, soil organic matter content and soil properties are improved, and salt leaching is enhanced.

i) Introducing and application of salt-tolerant crops. Selecting various salt-tolerant varieties of crops/plants to fit different saline ecological environments and tapping the inherent tolerance of the varieties are important measures to improve the efficiency of the reclamation, amelioration and utilisation of salt-affected soils. Even planting (or protecting) natural halophyte vegetation also contributes to controlling further salinization of the soil. Moreover, some of the salt-tolerant plants can be used as forage for animals and can be taken as a direct economic profit from saline lands. The selection of suitable salt-tolerant crops is subject to local soil properties and the salt content. The tolerance of crops varies significantly with the soil properties (texture, moisture physical properties, salt composition, etc.) and the varieties of the crop. As climatic factors and experimental conditions and methods have certain influence on the results, the experimental results from various sites are not identical. So in areas of different types of salinization, salt-tolerance experiments should be conducted mainly on native plants/crops to attain salt-tolerance data and criteria that suit the local conditions and can serve as a basis for selection of salt-tolerant crop varieties. In reality, large volumes of data have been accumulated in almost every place and are available for reference.

In China, successful projects or programmes include:

a) Integrated amelioration of coastal salt-affected soil by "water, fertiliser, forestry and management" measures in Jiangsu;

b) Amelioration of coastal salt-affected soil by rice planting with irrigation-drainage measures in Liaoning;

c) Integrated prevention of secondary salinization by well-pumping irrigation as the means of drainage in Fengqiu, Henan;

d) Amelioration of waterlogged salt-affected land by land surface covering with river sediments and planting rice in Henan;

e) Integrated management of land with drought, waterlogging and salinity problems by well-pumping irrigation and ditch drainage measures in Shandong;

f) Integrated management of salt-affected land by well-pumping irrigation and ditch drainage; by pumping brackish groundwater and make freshwater discharge to groundwater; and by mixed irrigation of brackish and fresh water in Hebei;

e) Amelioration of sodic soil by optimal water-fertiliser management and planting rice measures in Jilin;

f) Amelioration and utilisation of salt-affected soils by combined canal-ditch-well measures in Xinjiang.

In China, institutions or organizations dealing with salt-affected soils problems and their management mainly include Chinese Academy of Sciences, Chinese Academy of Agricultural Sciences, Academies of Agricultural Sciences and Agricultural Administrations in provinces where salt-affected soils occur, agricultural universities, some research institutes for water conservation. Names of the institutions are as follows:

- Institute of Soil Science, Chinese Academy of Sciences, Nanjing
- Institute of Geography, Chinese Academy of Sciences, Beijing
- Institute of Applied Ecology, Chinese Academy of Sciences, Shengyang
- Institute of Biology and Soil Sciences, Chinese Academy of Sciences, Urumqi
- Institute of Geography, Chinese Academy of Sciences, Changchun
- Institute of Soil and Fertiliser Research, Chinese Academy of Agricultural Sciences, Beijing
- Institutes of Soil and Fertiliser Research, Academy of Agricultural Sciences in provinces of Jiangsu, Zhejiang, Xinjiang, Shandong, Heilongjiang, Liaoning, Ningxia, Henan, Shanxi, Inner-Mongolia, Hebei, Jilin, Gansu, etc.
- Agricultural University of China, Beijing
- Nanjing Agricultural University, Nanjing
- Agricultural College, Zhejiang University, Hangzhou
- Research Institutes for Water Conservancy in provinces of Shangdong, Shanxi, Heilongjiang, Xinjiang, etc.

7. Other issues for controlling salt-affected soils in China

As agricultural significance of amelioration and use of salt-affected soil in China, the government, scientists, extension service, and farmers themselves all play important roles for controlling these soils in China. In regions where salt-affected soils occur, government at different levels (such as provincial government, county government, etc.) are all responsible to the matter, such as how large area of salt-affected land is ameliorated and utilised, how small area of land is abandoned due to salinization. Scientists put forward technologies and measures as well as demonstrate for salinity control, based on experimental results and successful practices. The extension service, or scientists themselves, undertake demonstration in large scale and extend the technologies to the farmers. The governments highly encourage the activities of scientists, extension services and farmers towards the control of salinization.

From macro point of view and at governmental administrative level, regionalisation of integrated management and prevention of salinization is considered as scientific and a practical basis for combating soil salinity problem. Such regionalisation can be conducted on different scales for different purposes. Small-scale regionalisation is often used for administrative macro-scale decision-making of high level government, while moderate-scale regionalisation can be used for references in management and prevention of salinization for certain regions or catchments. Some successful regionalisations have contributed significantly on salinity management and salt-affected soil utilisation, such as regionalisation of Tian-Ran-Wen-Yan Canal Basin in the northern part of Henan. Principles and practices of salinity management in one basin can be used in other basin or region with similar bio-climatic and socioeconomic conditions. In such way, good experiences in one region can be extended to larger area.

Irrigation expansion is an important issue on agricultural development and on salinity evolution. Irrational expansion of irrigation usually results in secondary salinization in semi-arid and arid regions. An example is that of the North China Plain during late 1950s and early 1960s. Agricultural irrigation had been continuously developed since early 1950s in the district, by diverting water from Huanghe River. Area of irrigated land increased rapidly and the figure reached on top in 1960-1961, under poor irrigation and drainage management. In the same period, area of secondary salinized land expanded synchronically with the increase of irrigation area. It is suggested, without adopting proper measures to overcome its potential hazard to the land in some regions, it is possible that irrigation expansion may damage land quality and, subsequently, agricultural production. Decision making on such expansion and planning of irrigation layout should be conducted by taking those negative impacts into account.

Some social and policy aspects have impacts on controlling of salinization and use of salt-affected soils. Coastal salt-affected land is the area where government encourages people to exploit and utilise available land resources. Therefore, some advantageous policy is drawn up for farmers in those areas, such as tax reduction, etc. As a result, coastal regions attract more investment on land exploitation and utilisation, and on management of salt-affected soils, based on which agricultural development is benefited from. In China, the farmland is usually contracted from the local government to the farmer as 'responsible land'. One family often operates farmland less than one hectare. Land tenure varies from 5 to 50 years, though long-term tenure is encouraged recently. Farmer has the right to determine planting and using of their responsible land, under the government's suggestion of layout for agricultural production. Owing to relatively small pieces of land cultivated by individual farmers, on-farm irrigation/drainage facilities are also at relatively small scale and its efficiency is moderate. In some regions, some farmers have recently cooperated to become a large farmer, where on-farm irrigation/drainage facilities will be greatly improved, with higher capability to manage salinization.

Of course, layout of irrigation/drainage in regional and catchment levels should be planned properly by relevant authorities, to ensure better management of soil salinity and sustainable development of agriculture in salt-affected or potential salt-affected regions. Short land tenure is not efficient for long-term investment of land, especially for such problem soils. High costs of investment of on-farm irrigation/drainage facilities and optimal management on salinized soil means longer term of investment recovering. Without longer period of land tenure, land users will not put adequate investment on land for combating salinity, which will be disadvantageous to management of salt-affected soils. Therefore, appropriate land tenure should be longer than ten years in salt-affected regions, and even longer period is recommended. In China, land tenure in some coastal salt-affected regions can be extended up to 50 years, and some positive results have been already indicated. Under small-scale farmland operation, local government or agricultural administrative authority plays important roles in the overall layout of agricultural production. Multi-patched layout of different crops, such as rice and dryland crops, often induces salinity problem, which are the same for multi-patched layout of agricultural lands and aquaculture ponds. Such layout could lead to active salt-water dynamics of soil and enhance salt accumulation in the soil. Optimal layout at macro scale could effectively reduce potential hazard of above-mentioned problems, and some successful stories have been obtained in China. Large-scale water development project is another issue related to social aspect. Due to its economical significance, negative impacts of such project on salinization are usually not considered as decisive factor, though the impacts usually exist in many circumstances. Therefore, during the construction of large-scale water development projects, such as big reservoirs, its impacts on salinity should be evaluated and countermeasures should be worked out and be adopted, so that subsequent damages can be avoided.

Groundwater raise caused by seepage of irrigation water is an important reason of secondary salinization. Besides some technical aspects, the lower efficiency use of irrigation water can also be caused by some social reasons. In some regions, especially river water irrigation districts, irrigation fare is collected according to the land area rather than to accurate water amount consumed by farmer. Therefore, some farmers have not paid enough attention to saving water and so that may prevent the rise of groundwater table on farmland. In the regions where irrigation water fare is collected according to consumed water, it is easier to control the water table, owing to the fact that farmers have enthusiasm both on saving water costs and on maintaining land quality.

8. Research requirement on salt-affected soils in China

The importance of researches on salt-affected soils has been recognised by the society, as visualised from their wide distribution and their influences on agriculture, resources and the environment. The close links between salinity and human activities require the salinity research to be focused on increasing food production, sustaining agricultural development, harmonising production, natural and environment, improving life quality of human being. Being a large country, China is characterised with obvious diversities on natural and socioeconomical conditions, land utilisation and management patterns. Therefore, the research on salt-affected soils in China is suggested to include following aspects:

a) Monitoring, assessment and prediction of soil salinity. This aspect of studies is the basis of other aspects of salt-affected soil research. Salinity monitoring system should be created to suit spatial variance and dynamic change of salinity due to alternations of climate, soil-forming condition and human activities. Middle or large-scale lysimeter study is necessary in applied fundamental research of salt-water dynamics and formation of secondary salinization. The lysimeter study can be conducted in several typical bio-climatic zones and under different land utilisation patterns, and the study sites (stations, laboratories) can be linked as a national network, to cover a wide area with different conditions. Beside lysimeters, some practical, reliable, easy-to-use, rapid techniques on salinity monitoring and survey in wider area should also be developed. Remote sensing and GIS techniques can be used as a tool of middle and long term of monitoring of salinity evolution and even prediction of secondary salinization. Based on information and data collected from survey, monitoring and remote sensing, some practical computer models should be developed for salinity assessment and prediction, by using GIS and by simulating different management activities and under different land utilisation patterns. Middle- and long-term salinity assessment and prediction are both important, since they will form the basis of approach study of salinity management and decision making for salt-affected soils.

b) Optimal model and technique system on salinity management and utilisation of salt-affected soils. Main point of the research is to develop effective techniques on salinity control and management, and to develop practical model sets, to suit various bio-climatic zones and social-economic regions. Some research aspects of techniques study should be emphasised, such as irrigation management of salt-affected or potential salt-affected soils, land management under the use of brackish/saline/sodic water, exploitation of salt-affected land leading to sustainable agricultural utilisation, bio-techniques on salinity management and saline agricultural techniques and countermeasures of secondary salinization. The model should be integrated with as many choices of techniques on salinity management as possible, to be suitably used in different natural conditions, management patterns and agricultural layouts. Efficiency, reliability, cost, practicability of techniques and models should be paid more attention to. In different regions of China, such as coastal salt-affected soil region, the North China Plain irrigated salt-affected soil region, Northwest China continental salt-affected soil region, Northeast China sodic salt-affected soil region, the system of such models and techniques should be developed for the matter of suitability in more details. Development of expert system will be a practical output mode of above-mentioned model study. Based on the scientific experience and information model and computer simulating, such expert system could instantly recommend optimal management measures and practical technique sets on salinity control, by inputting relevant information to the expert system.

c) Multiple-objective decision support system. In fact, the control of salinization and management of salt-affected soils are not only related in natural aspect, but also in social, economic and environmental spheres. In most situations, not all those issues could be arranged to the optima. Therefore, a system should be developed to assess, analyse and compare all advantages and disadvantages of those aspects, and to help on decision-making in optimal manner. The multiple-objective decision support system can be integrated with objectives of current economic benefits, long-term sustainability of development, resources utilisation and management, environmental friendship, etc. Such system is designed to supporting decision-making for various levels and for different purposes.

d) Interaction of salinization and environment. Salinization, especially human-induced salinization has certain impacts on environment and ecology, besides those on agriculture. Large-scale water development projects usually have greater impacts than other, owing to the fact that such kind of project covers a wide area and makes a significant alteration of regional salt-water dynamics. Therefore, alteration of regional salt-water dynamics and their regulation, and countermeasures towards the negative impacts of such project on agriculture and environment, as well as regulation countermeasures should be focused on. Other processes related to salinity, such as seawater intrusion due to sea level rise caused by greenhouse effects or by other human activities, should be also included in this type of research.

e) Fundamental study of solute transport and formation of salinization, sodification and alkalization. Following researches are mainly included in this aspect: mechanism of hydraulic and chemical kinetics of salt-water movement, effects of chemical and physical-chemical reactions on solute transport, effects of biological activities on salt accumulation and transport, and mechanism of alkalization and dealkalization.

9. National agricultural plan for improvement of salt-affected soils and regional coordination

Overall national agricultural planing for improvement of salt-affected soils is one effective way to solve salinity problems nationwide. Such agricultural plan had been practised in China during certain period. However, recently improvement of salt-affected soils is included in the national agricultural plan for improving low-to-medium yield soils (including all problem soils) in China. Such agricultural plan covers all provinces and regions where salt-affected soils and other problem soils are distributed. Scientists in research institutions and agricultural universities play an important role in suggestion and implementation of the plan at national and regional levels.

In China, commission of salt-affected soils of the Soil Science Society of China is involved actively in the improvement of the soils and their planning, by organising workshops, exchanging information and putting forward some project proposals. The commission members come from all provinces and they are actually conducting research or extension works on salt-affected soil management. Hence, the commission could be acting in the role of consultant, executor and regional coordinator of national agricultural plan for improvement of salt-affected soils. Once the funds for such activities are available from some foundation bodies, the commission of salt-affected soils of Soil Science Society of China will play more important role in salinity management.

10. Information about the cooperative project with FAO

Project cooperated with FAO, "Integrated Management and Sustainable Utilisation of Coastal Salt-affected Soils, Case of Jiangsu Province, China", has been conducted by the Institute of Soil Science, Chinese Academy of Sciences since April 1996.

Jiangsu is a province with very high population density and less arable land in China. Currently, agricultural land area in Jiangsu Province counts less than 0.1 ha per capita. Shortage of agricultural land is even worse since large area of arable land has been lost to non-agricultural purposes. On the other hand, the province has 1 000 km of coastline and has about 350 000 ha of tidal land and coastal salt-affected land. Salt-affected soils are believed to be the most important low-to-medium-yield soils in this province. Besides, tidal land in Jiangsu is expanding as great as 1 500 ha every year and becomes a new salt-affected land resource. Among 350 000 ha of coastal salt-affected soils in Jiangsu, about 40 000 ha of salt-affected land have been abandoned and 60 000 ha of tidal land are going to be reclaimed by dyking for agricultural use. Others are large areas of low-to-medium-yield salt-affected land with salinity limitation. Therefore, exploitation, amelioration and utilisation of coastal salt-affected soils will be the effective ways to resolve the conflict between the increase in population and the fast contracting of arable land in the province. In the coastal area of Jiangsu, there exist some problems on management of salt-affected soils, such as poor on-farm drainage and irrigation facilities and unsound management, shortage of freshwater resources and low efficiency of water use, low soil fertility and low organic matter caused by low organic manure application rate, unbalanced nutrients, mono-agricultural structure and irrational crop layout. All abovementioned constraints make use of salt-affected soils less efficient and less productive. Therefore, it is needed to identify sound integrated management procedures and measures of salt-affected soils and create several applicable models for sustainable utilisation of such soils in a way to suit local conditions.

Therefore, the cooperative project is aimed to develop and identify integrated techniques on management of coastal salt-affected soils and create applicable models on sustainable utilisation of such soils in the way to suit local conditions in the province; to extend the techniques and models to the farms in this region; to enhance farmers' productivity and output on salt-affected soils toward sustainable development of agriculture and food production in coastal salt-affected land of Jiangsu. Main works done in the project include:

a) Conducted investigation in coastal area of Ru-dong County, to further identify the features of salt-affected soils and major problems on management and utilisation of such soils in this region, to get information of different coastal zones and various salt-affected soils and potential utilisation types.

b) Analysed and evaluated the type, area, function, quality, agricultural limitation and suitability of utilisation of various salt-affected soils. The data and information collected from the investigation and evaluation was used to select typical sites for field trials and demonstration farms, as well as for modifying and detailing of design of experiments in the region.

c) Carried out field experiments in selected farms, which are located in low-to-medium-yield salt-affected area and newly dyked tidal land area. The main subjects that were studied include:
- Background survey of soil salinity, fertility, land productivity, ground water and irrigation/drainage conditions in the farm and experimental sites.
- Monitoring of salt-water dynamics in salt-affected soils under natural precipitation and varied agricultural management conditions.
- Field trials on amelioration of coastal salt-affected soils with various measures and their combinations, including regulating salt-water dynamics of soil, improving on-farm drainage-irrigation facilities, planting rice, balanced nutrition application, green manure application and soil curing, land surface mulching, agroforestry, etc.
- Strategies on regulation and rational utilisation of groundwater and surface water resources and measures preventing saline water intrusion.
- Identification of sound agricultural structures and crops layout, and development of high-yield crop cultivation techniques.
- Introduction, selection and application of salt-tolerant varieties of crops/plants for better use of saline soils.

d) Created applicable models on sustainable utilisation of salt-affected soils and salinity management, based on analysis of data and information obtained from the field experiments and other sources.

e) Demonstration of the integrated techniques and measures on managing coastal salt-affected soils and created typical applicable models on sustainable utilisation of such soils.

Based on research works of the cooperative project, the improvement practices and technologies gained from the experiment have been demonstrated in the coastal area and good evaluation on agricultural production has been obtained on abovementioned aspects. It is suggested that following practices and techniques can be successfully used in this area to combat salinity problem and to improve agricultural and food production including: monitoring of salt-water dynamics of salt-affected soils under various agricultural management conditions; selection and application of salt-tolerant crop/plant varieties for optimal use of the soil; balanced fertiliser management of salt-affected soils; rice planting for leaching salt; mulching using straw for reducing evaporation and salt accumulation on top soil strata; organic matter application for regulating salt-water dynamics; establishment of optimal crop rotation and agricultural layout, and agroforestry measures. Further activities are required on research, extension, policy making, decision making, farmers' training, information exchange, and national planning, to combat salinization and to make full use of the coastal salt-affected soil resource.

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India

Summary

India has made tremendous progress in agriculture and now has become self sufficient in food grains production. But population continues to grow at a high rate. To feed these teeming millions, the target set for 2025 is about 300 million tonnes of food grains as against the current production of 200 million tonnes. Natural resources, particularly land and water play key role in the food production processes and their degradation due to several processes like secondary salinization of soil and pollution of surface and groundwater resources are major constraints in achieving high growth rate. Salinity problem in India can be basically classified into two categories, viz. inland and coastal. Inland salinity is mainly due to secondary salinity in irrigation commands and has developed due to rise in water table in areas underlain by saline/sodic waters whereas coastal salinity is due to marine influence. In recent years excessive exploitation of groundwater in the fragile coastal zone and unplanned introduction of shrimp farming with brackish water have further aggravated the problem. Taking note of the public outcry, the Supreme Court of India intervened in the matter and passed certain directions for regulation of brackish water shrimp farming in coastal areas. Salinization of production resources not only affected productivity but has also caused environmental hazards like increased incidence of floods, pollution of water supply source and desertification. The socioeconomic implications of extension in salinity have been the loss of employment, migration of labour force from rural to urban areas and overall decline in gross domestic product (GDP).

Technologies for reclaiming different kinds of salt-affected soils have been developed. For sodic soils of Indo-Gangetic Plain, agrochemical technology based on application of amendments has been evolved and applied on a large scale. On a limited scale bio-reclamation based on salt-tolerant crops or a hybrid technology, based on reduced doses of chemical amendments and growing salt-tolerant crops, is also available. For reclaiming waterlogged saline soils of alluvial as well as black soil regions, technology based on sub-surface drainage and leaching has been developed and implemented on pilot project scale in areas ranging from 50 to 10 000 ha. Coastal salinity due to its peculiar problems does not have any general prescription. In coastal areas of the Sunderbans, it is largely cultivation of different rice varieties and rainwater management for ameliorating drainage congestion and providing water for supplemental irrigation partly during monsoon and mostly during post-monsoon period, that holds the key. On a limited scale, rice-fish farming both, under fresh- and brackish water aquaculture is practised. Pokhali cultivation of Kerala is another technique that is used to mitigate the salinity effects in rice farming.

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Acid soils of Kerala that are in polders have a unique system based on management of rain and marginal quality coastal creek with ring-bunded areas (Padsekharans). Community participation is the distinguishing characteristic of the water management technology in these Padsekharans. In the last few years technologies for inducing recharge during monsoon season, largely through construction of check dams, sub-surface dykes, recharge wells and percolation, have been evolved and implemented on the western coast in Gujarat. An improved 'doruvu' technically, which essentially skims freshwater overlying the saline water, has also been evolved and implemented on pilot scale in Andhra Pradesh. Salinity problems arising due to shrimp farming are of recent origin and are localised in few places. Proper design of ponds to reduce seepage, construction of interceptor drains to check saline effluent polluting the groundwater, and construction of vegetative barrier between the shrimp farms and adjoining lands, are being suggested. The intervention of the Supreme Court has laid the directions for the policy and institutional framework. Institutions dealing with the salinity research and management are being strengthened and gradually a national agenda is taking shape.

1. Introduction

India faces an uphill task of ensuring the food and nutritional security of the swelling population that has already reached 1 000 million and will exceed 1 400 million by 2050. The difficulty of the task can be gauged from the fact that the current food production is 200 million tonnes and is going to be raised to about 300 million tonnes by 2020. The scope for expansion of cultivated land being limited, the future requirements have to be met through intensification of agriculture. It is not only the land but the water resources are also going to be scarce as the critical limit of 1 500 cu m per capita is about to be reached and any further decrease will heavily affect the economic development of the country. Besides the large population, poverty and smallholdings also come in the way of quick adoption of modern scientific technologies to boost agricultural production. Also, degradation of natural resources, particularly of land and water, is a serious handicap in attaining the higher productivity. The annual loss of soil due to water erosion varies from 20 to 100 tonnes/ha/yr over an area of 48.9 million ha. Waterlogging affects an area of 11.6 million ha mostly in the eastern states while salinity is spread in an area of 8.6 million ha. The area under salinity is continuously increasing due to secondary salinization of irrigated areas.

The problem of salinity in coastal areas has also been aggravated due to large-scale shrimp farming in the states of Andhra Pradesh, Tamil Nadu, Orissa, West Bengal and Karnataka. Brackish water shrimp farming has been a thrust area since economic liberalisation in 1991. Shrimp is the main, cultured species in brackish water, which is a high value commodity and has ample export potential. It is estimated that more than 1.4 million ha of brackish water area are available for shrimp culture (Table 1). Of the total area available, 47.5 percent are concentrated in West Bengal followed by Andhra Pradesh (17.6 percent) and Maharastra (9.4 percent). Only 17 percent of the available area have been developed for aquaculture. Karnataka and Andhra Pradesh have brought maximum of the potential area under shrimp culture (> 44 percent) followed by Orissa (36 percent) and Kerala (20 percent). At present 47 percent of the shrimp aquaculture area is concentrated in Andhra Pradesh followed by West Bengal (30 percent) and Orissa (8 percent). Brackish water aquaculture till 1980 was largely a subsistence-oriented activity pursued by the fishermen with little or no use of external inputs. The yields, though low, were sustainable. Induced by high returns from shrimp farming coupled with favourable trade policies, the corporate sector entered this enterprise in a big way and this led to intensified aquaculture. In pursuit of high dividends, the conditions of a sustainable production were not created. Use of illegally imported seeds, high stocking densities and inadequate effluent discharge and treatment mechanism led to outbreak of diseases. This started threatening the sustainability of shrimp farming apart from causing adverse effect on ecology and the society. Alagarswami (1995) clearly indicated that except for the traditional and improved traditional methods, the other methods of shrimp culture generated pollution and as such may have adverse impact on environment. As cited by Parthasarthy and Nirmala (2000) the Central Pollution Control Board has estimated that about 2.37 million cu m a day of effluents are generated by the aquaculture farmers on the East Coast which may harm the environment of receiving waters. There have been cases of public interest litigation over the adverse impact of shrimp farming on the environment (NEERI, 1995). Advent and adoption of low-cost tubewell technology in the coastal areas has also led to seawater intrusion in the western coast (Raju, 2000). Similar problems are being encountered in some locations on the eastern coast, particularly in Tamil Nadu.

The climate of eastern and western coasts differs widely and so do the cropping systems followed in these areas. On eastern coast it is largely rice based cropping. Sometimes rice is grown in all the three seasons (if water supply is not scarce). Rice-fish farming, both with fresh and brackish water, is also followed in some areas. Horticulture including coconut, cashew nut and banana are also common in these areas. On the West Coast, particularly in the arid part it is mostly upland crops like maize, groundnut, sorghum and the horticultural crops like date palm and pomegranate. The paper discusses the coastal salinity and its management with emphasis on problems created by shrimp farming and seawater intrusion due to overexploitation of groundwater.

Table 1. Potential brackish water area, area covered, production and yield of shrimp in different states, 1997-98.

State	Potential area (ha)	Area covered (ha)*	% of area utilised	Production (tonnes)	Yield (kg/ha)
Andhra Pradesh	150 000	66 290 (46.82)	44.19	34 075 (50.96)	514.03
Goa	18 500	650 (0.46)	3.51	590 (0.88)	907.69
Gujarat	37 600	997 (0.70)	2.65	235 (0.35)	235.71
Karnataka	8 000	3 540 (2.50)	44.25	2 640 (3.95)	745.76
Kerala	65 000	14 595 (10.31)	22.45	7 290 (10.90)	499.49
Maharashtra	80 000	970 (0.69)	1.21	700 (1.05)	721.65
Orissa	31 600	11 332 (8.00)	35.86	5 000 (7.48)	441.23

Pondicherry	800	22 (0.02)	2.75	20 (0.03)	909.09
Tamil Nadu	56 000	670 (0.47)	1.20	1 197 (1.79)	1 786.57
West Bengal	405 000	42 525 (30.03)	10.50	15 121 (22.61)	355.58
Total	**852 500**	**141 591 (100.00)**	**16.61**	**66 868 (100.00)**	**472.26**

*Figures in parentheses are percent of total.
Source: Handbook on Fisheries Statistics, Ministry of Agriculture, GOI.

2. Nomenclature and definitions

Salt-affected soils are known by a variety of names in India. The most common term used is 'usar', meaning barren soil usually applied to all kinds of saline and alkali soils in northern India. 'Reh' is an equally common term first employed by geologist to designate the saline, earthy efflorescence found in Indo-Gangetic Plain in post-monsoon period. 'Kallar' is also commonly used for alkali soils. 'Thur' is a popular name given to predominantly saline soils with light texture in Haryana and Punjab. If the land becomes waterlogged, it is known as 'sem'. In black cotton soil zone of southern India the soil characterised by impermeability to water, extreme hardness and occasional presence of salt on the surface is known as 'chopan'. 'Soudu' and 'jougu' are also saline-alkali soils occurring in Karnataka with poor drainage often resting on high water table. In Tamil Nadu and Andhra Pradesh general terms like 'palachoudu' and 'karu' for such soils are common. While the soil containing alkali carbonate is called 'choudu', the one wherein sodium chloride dominates is called 'uppu'. The saline soils affected by seawater in tidal areas of the south and elsewhere are called 'khar' lands or 'chars'. In Kerala, such soils are known as 'kari', 'pokhali' or 'kaipad' and are acidic in nature (Agarwal *et al.,* 1982).

Appropriate nomenclature and reliable database on salt lands are essential for devising suitable strategies for their reclamation and management. The US Salinity Laboratory (Richards, 1954) classified salt-affected soils into three categories, viz. saline, alkali and saline alkali. CSSRI (Abrol and Bhumbla, 1978) modified this classification (based upon the nature of plant response to the presence of salt and the management practices required for their improvement) and grouped salt-affected soils of the country into two groups, viz. saline and alkali soils. It was advocated that distinguishable pH for alkali soils should be 8.2 instead of 8.5, and such soils contain soluble bicarbonates and carbonates such that ($Na/Cl+SO_4 > 1$) (Gupta and Abrol, 1989).

Alkali soils

These soils contain excess salts capable of alkaline hydrolysis such as sodium carbonate, sodium bicarbonate and sodium silicate, and sufficient exchangeable sodium to impart poor physical conditions to soils and thus affecting growth of most plants. These soils have saturated paste pH higher than 8.2, exchangeable sodium percentage (ESP) higher than 15 and different levels of ECe. The pH of the calcareous alkali soils is highly related to their

ESP. These soils have poor physical properties due to high sodicity and high pH, resulting in restricted water and air movement. Presence of calcium carbonate concretions at about 1 m depth causes physical impedance for root proliferation. Plant growth on alkali soils generally suffers due to toxicity of sodium carbonate and bicarbonate and the osmotic effect of other salts. Alkali soils do not support any vegetation except some hardy indicator plants that grow during the rainy season. In case of alkali Vertisols, the hydraulic properties of soils depend on the clay mineralogy at the species level, ESP of the soil, electrolyte concentration and the nature of electrolytes in the solution. The Vertisols of western India with an ESP of 15 have very poor physical conditions, making tillage operations extremely difficult.

In saline soils when chlorides and sulphates of Ca and Mg are the predominant salts, the SAR usually remains less than 15. However, predominance of Na invariably results in soil-solution SAR being higher than 15. Such soils are termed saline-sodic. Many saline-sodic soils contain, in addition to soluble carbonates, an excess of neutral salts. Such soils manifest alkaline properties. From management point of view, the saline-sodic soils that do not contain soluble carbonates are grouped with saline soils and the others with alkali soils.

Saline soils

These soils, with white salt encrustation on the surface, have predominantly chlorides and sulphates of Na, Ca and Mg. The soils with neutral soluble salts have saturation paste pH < 8.2. The electrical conductivity of saturation extract, ECe of saline soils, is generally more than 4 dS/m at 25° C. Such soils invariably have sodium adsorption ratio (SAR) of the soil solution > 15. In saline soils the excess of neutral salts restricts normal plant growth. Due to the presence of excess salts, saline soils usually remain flocculated, and their hydraulic conductivity is similar to those of non-saline soils. The main causes of poor plant growth in saline soils are high osmotic pressure of soil solution, causing low physiological availability of water to the plant, direct toxic effects of individual ions and complex interaction between sodium, calcium and magnesium, leading to disturbed equilibrium of these ions in the plant's ability to absorb water and nutrients in required amounts.

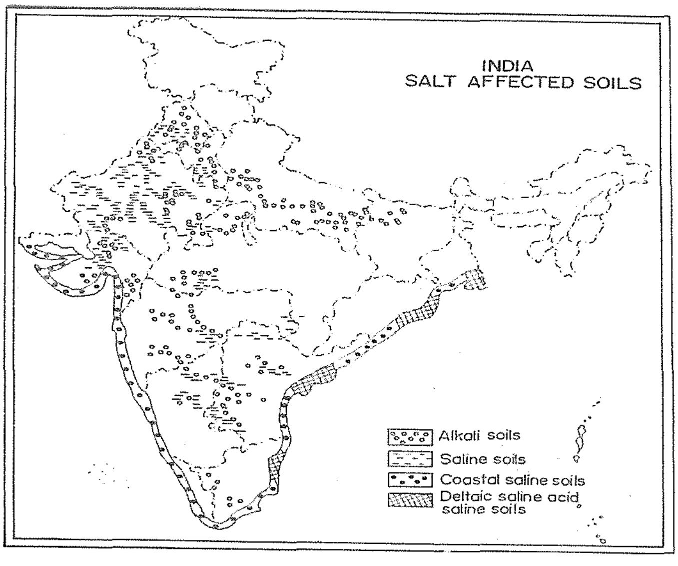

Figure 1. Distribution of salt-affected soils in India.

Table 2. Geoclimatic distribution and characteristics of salt-affected soils in India.

Main characteristics	Rainfall (mm/yr)	Distribution
1. Alkali soils of Indo-Gangetic alluvial plains		
High pH, EC, ESP and preponderance of sodium icarbonate and carbonate	600-1 000	Parts of Punjab, Haryana, UP, Bihar, Rajasthan and Jammu
2. Inland saline soils of arid and semi-arid regions		
Neutral to alkaline pH, high EC and preponderance of chloride and sulphates	< 500	Parts of Haryana, Punjab, Rajasthan, UP and Leh, Pulwama and Patgam Districts of J&K
3. Inland saline soils of sub-humid region		
Neutral to alkaline pH, high EC, preponderance of chlorides and sulphates	1 000-1 400	North Bihar
4. Inland salt-affected deep black soils (Vertisols)		
Neutral to highly alkaline pH, high EC, preponderance of chlorides and suphates with or without bicarbonates, montmorillonitic mineralogy	700-1 000	Parts of Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh, Gujarat and Karnataka
5. Medium to deep black soils of deltaic and coastal semi-arid regions		
Neutral to slightly acid pH, high EC, preponderance of chlorides	700-900	Saurashtra coast in Gujarat and deltas of Godavari and Krishna Rivers in Andhra Pradesh
6. Saline micaceous deltaic alluvium of humid regions		
Neutral to slightly acid pH, high EC, preponderance of chlorides	1 400-1 600	Sunderban Delta in West Bengal and parts of Mahanandi Delta in Orissa
7. Saline humic and acid sulphate soils of humid tropical region		
Acid, pH, high EC, presence of humic (organic) horizon, preponderance of chlorides and sulphates	200-900	Malabar Coast in Kerala State
8. Saline marsh of the Rann of Kutch		
Neutral to slightly alkaline pH, high EC, preponderance of chlorides and sulphates	< 300	Rann of Kutch in Gujarat

Source: Sharma, R.C. (1998).

3. Extent and distribution of salt-affected soils

The area under salt-affected soils was estimated to be 7 million ha by Abrol and Bhumbla (1978). However, during the last decade several agencies have given divergent estimates, e.g. National Commission on Agriculture, 7.16 million ha; National Remote Sensing Agency, 3.9 million ha; National Bureau of Soil Survey and Land Use Planning, 6.2 million ha and Singh (1992), 8.6 million ha. The data from various sources were critically evaluated at the Central Soil Salinity Research Institute, Karnal and the figure has now been modified to 8.6 million ha. The spatial distribution is shown in Figure 1. Apart from the occurrence in arid and semi-arid zones, the salt-affected soils occur in humid and sub-humid zones too. Geo-climatic distribution and characteristics of such soils are also shown in Table 2.

3.1 Extent and nature of coastal salinity

Although there is no sharp demarcation for the coastal land, the marine influence with typical coastal flora and fauna exist approximately up to 50 km inshore. According to Ahmed (1972), 50 m elevation contour may be taken as the inner limit to coastal zone, which runs through variable distances from the shore line at different places from 5 to 100 km. Based upon this criterion, the inner margin of the coastal zone would pass through the head of the Ganga Delta. In the deltaic regions of the Mahanadi, Godavari and Krishna deltas, this line would penetrate much deeper up to 100 km. On the Coromandel Coast the line would normally be 50 km from shoreline, penetrating deeper in the basins of the Cauvery and other larger streams and getting nearer shore in areas of rocky outlines. The coastal zone is narrowest near Cape Comorin, where the 50 m contour is only a few meters from the shore line. On the West Coast the inner margin of the coastal zone is approximately between 15 and 20 km from the shoreline in Kerala and Karnataka, and within 0 and 15 km in Maharashtra. Beyond the Cape the inner limit of the coastal zone is steep and sharp, coinciding with the inner edge of the Western Ghat. Further north in the Cambay region it is about 50 to 60 km from the shoreline. The coastal zone is variable in Kathiwad. On the southeast rocky and cliff area the inner limit varies from 5 to 40 km from the shoreline. From Diu to Dwarka it is about 20 to 30 km inshore. The position is similar for the coast bordering the Gulf of Kutch. India has about 3.1 million ha under coastal salinity. A state-wise breakup of the extent of soil salinity in India is given in Table 3.

The coastal soils may be either saline or acid sulphate in nature. In case of the former, the salinity status of soils varies widely from ECe 0.5 dS/m in monsoon to 50 dS/m in summer. Mostly NaCl followed by Na_2SO_4 are the dominant soluble salts, with abundance of soluble cations in the order Na>Mg>Ca>K, chloride as the pre-dominant anion and bicarbonate in traces. The soils are, in general, free of sodicity problem except in a few pockets in the south and the West Coast. Detailed characterisation of the coastal saline soils is yet to be done, still the soils may broadly be classified as (1) deltaic alluvium, (2)

Table 3. Distribution and extent of Indian coastal area.

SR. No.	States/Union Territories	Area (sq km)
1.	West Bengal	14 152
2.	Orissa	7 900
3.	Andhra Pradesh	35 500
4.	Tamil Nadu	7 424

5.	Kerala	7 719
6.	Karnataka	7 424
7.	Maharashtra	10 000
8.	Goa	220[1]
9.	Gujarat	17 465
10.	Andaman and Nicobar[3]	-
11.	Lakshadweep	26[2]
12.	Pondicherry and Karaikal	3
	Total	**107 833**

1 The width of the coast has been taken as 2 km.
2 Entire area of the island has been included in calculating overall coastal area. Not typical coastal soils.
3 Islands are considered as the ecosystem different from coastal areas. Parts of Andaman and Nicobar islands, however, are characterised by typical coastal soils. It is for this purpose these islands have been included in the overall framework of coastal system.
Source: Yadav *et al.* (1983).

acid sulphate, (3) Vertisols, (4) medium to deep black in deltaic humid and semi-arid regions, (5) Rann of Kutch (Bhargava, 1987).

Besides the saline soils, the other predominant soils in the coastal areas are acid sulphate soils, which occur in low lying tidal flats, having mangrove vegetation amply flushed by saline or brackish tides over several decades in the past. In Kerala these soils have developed on the alluvium, derived mainly from laterite and lateritic soils in lagoons and similar low-lying geomorphic situations. The soils are generally rich in organic matter and contain pyritic clay. The soils have ECe ranging from 3 to 44 dS/m, pH ranging from 3.4 to 7.5, and organic matter from 0.5 to 40.5 percent. Large areas under these soils are also reported from Andaman and Nicobar Islands.

Salt injury to plants may be due to osmotic stress, specific ion effects, ion antagonisms, toxicity caused by ions released through cation exchange, and effects of ionic activities. In flooded soils, salt displaces K^+, Ca^{2+}, Mg^{2+} from the exchange sites into the soil solution. In wet acid sulphate soils, excess water-soluble iron, aluminium, hydrogen sulphide and organic substances, especially fatty acids, are common causes affecting the rice crop.

4. Causes and processes of formation of salt-affected soils in different regions

There are a number of factors that may be geological, climatic and hydrological in nature, which are involved in formation of salt-affected soils. The main causes include (i) weathering of rocks and salt brought down from upstream areas to the plains and their subsequent deposition along with alluvial material that is responsible for primary salinity, (ii) capillary rise from subsoil salt beds or shallow brackish groundwater, (iii) impeded drainage (iv) intrusion of seawater along the coast, and (v) salt-laden sand blown by sea winds. In recent years brackish water aquaculture in the coastal area has also caused salinization of adjoining lands. The marine theory of salt accumulation of Indo-Gangetic Basin, although discounted, postulates that the states of Punjab and Sind of the Indian subcontinent were at one time part of a sea gulf. Sediment coming from Himalayan rivers silted up the gulf. The receding sea left behind saline and the saline material rested on the brackish aquifer. The presence of large quantity of sodium sulphate in the alluvium of Punjab has been attributed to the glacial in origin.

4.1 Inland salinity

Saline soils are in most cases associated with part of arid zone landscapes. The fact that reh (salt efflorescence) development in India occurs in well-marked meteorological areas of Uttar Pradesh, Punjab, Haryana and Rajasthan, was recognised by the earlier workers. Salt accumulation is further increased with certain type of land relief, connected geomorphologically to low lands.

The primary minerals present in the soil of Indo-Gangetic Plain comprises quartz, feldspar, muscovite, biotite, etc. in their sand fraction (Bhargava *et al.*, 1980). Quartz and feldspar occur distinctly in the silt fraction. Sodium bearing mineral like plagioclase feldspar under hydrolytic condition of dissolution releases high amount of sodium. The weathering of alumino-silicate minerals through carbonation yields solution of bicarbonates and carbonates of alkali in addition to silica and alumina. The bicarbonates and carbonates migrate with the subterranean and surface waters and accumulate in undrained areas under arid conditions to form alkali soils (Kovada, 1961). The alkali soils of Indo-Gangetic Plain that occur in micro-depressions seem to have been formed by this process. The relative difference in relief between parts of Plain and Sivalik Hills and within the plains, facilitates runoff during the monsoon, carrying a part of the weathering product to be deposited in micro-basins that creates alkalinity in the region (Sharma, 1998). In the Indo-Gangetic Plain, alkali soils generally exist in the regions with mean annual rainfall ranging from 550 to 1 000 mm. Mainly ustic soil moisture regime exists in the alkali zone of Punjab and Haryana, whereas aquic to para-aquic moisture regime prevails in Uttar Pradesh due to the presence of shallow watertable.

Secondary salinization, which is related to anthropogenic cycles of salt accumulation, results from human activities such as introduction of irrigation resulting in the removal of natural plant cover and flooding with salt rich waters. Soil salinity in major irrigated areas has developed as a result of high water table. Highly saline soils enriched with neutral salts are widespread in Punjab, Haryana and Rajasthan. These soils occur in less than 550 mm rainfall where maximum salt accumulation takes place under excessively desiccating condition. The water table in these areas is shallow and has risen as a result of seepage from canals creating waterlogging conditions. Studies made at different places have led to establishment of the critical water table depth (Ramdas and Malik, 1947; Kulkarni, 1961;

Yadav, 1973). Salinity in areas irrigated through extensive canal system has been due to the rise in water table in the absence of adequate drainage and groundwater development. Groundwater of poor quality, which occurs quite extensively in the states of Haryana, Rajasthan, Gujarat, Andhra Pradesh, has accentuated the problem. These waters, when used for irrigation, have brought extensive areas under salinity in parts of Rajasthan and Andhra Pradesh.

4.2 Coastal salinity

Coastal salinity is distinctly different from inland salinity and is caused due to marine influence during the process of formation itself and subsequently due to periodic inundation with tidal water. In case of lowlands having proximity to the sea, salinity is caused due to high water table with concentration of salts in it. The coastal soils exhibit a great deal of diversity in terms of climate, physiography and physical characteristics. As most of the area concentrated in the confluence of rivers with sea, these areas are frequently flooded and get waterlogged due to lack of easy drainage. Topographically these areas are low lying and are subjected to inundation by tidal waters and inland drainage water almost simultaneously and with great regularity. Major rivers flowing through the coastal saline soils are Hooghly and branches of Ganges, Mahanadi, Godawari, Krishna and Cauveri on the East Coast, and Narmada and Tape on the West Coast. The flat surface of rivers causes silting up of rivers and drain beds and creates outlet problems for local drainage water. The drainage characteristics of some of the coastal soils are summarised in Table 4.

Table 4. Drainage characteristics of different problem areas in India.

Place	Soil characteristics			Drainage properties		Monsoon rainfall (mm)	Depth to water table (m)
	Texture	pH	ECe dS/m	Surface	Sub-surface		
1. Ubharat (Gujarat, Coastal saline soils)	Top 30 cm clay loam, below it clay mixed with sand	7.4	14.5[1]	Good with slopes varying from 0.5 to 1%	Poor 1.8 cm/ day basic infiltration rate	1 400	1.0 to 3.0
2.Ghodbunder (Maharashtra, coastal saline soils)	Top 30-40 cm clay and below it murram	7.3 to 9.5	15.0[1]	Good with slopes varying from 0.5 to 1.2%	Poor 1.2 cm day basic infiltration rate	2 100	0.5 to 2.5

3. Kole and Kuttanad areas (Kerala, acid soils)	Clay to clay loam up to 30 cm	2.1 to 3.9	As high as 30 depends upon season	Flat slopes, surface water stagnation is common	Infiltration rates are good, but water table (poor quality) is high	1 600	1.0
4. Guntur (A.P. heavy soils)	Few cm of sandy soil and below it heavy clay soils	7.8 to 8.9	17 to 35	Surface water stagnation Occurs in rainy season	Poor infiltration rates. Persistency of high poor quality ground-water	800	0.2 to 1.25
5. Ongole (A.P. heavy soils)	Clay soil throughout	7.8	37 to 53	Surface drainage not adequate	Low infiltration rate	800	1.2
6. Canning (W.B. coastal saline soils)	Silty clay loam	6.5	6 to 11	Surface drainage not present	Low infiltration rates. Ground water at shallow depth	1 600	<1.0

[1] EC (1:2)
Source: Bandyopadhyay *et al.* (1988).

5. Biophysical, environmental and socioeconomic effects

Salinity causes several undesirable impacts on land and people. The major casualty is the drastic reduction in the productivity of land. As the degree of salinity increases salt sensitive crops go out of cultivation and are replaced by low value crops. In extreme cases, the soil is hardly able to support dry vegetation and only some kind of bushes and halophytes are able to survive and the land turns into a desert. Increase in incidence of floods in sodicity-affected lands, degradation of surface water quality due to disposal of saline effluents into regional surface drainage system, and displacement of labour and loss of income that causes social tension are the major adverse impacts. The upsurge in shrimp culture activity induced by high profitability is reported to have caused adverse impact on coastal ecosystem and social environment. Studies on the impacts of brackish water aquaculture are scanty but the one conducted by Alagarswami (1995) and NEERI (1995) may be considered pioneering. Alagarswami (1995) identified the adverse impacts on physical and social environment and emphasised the need for adopting eco-friendly technologies. In its report submitted to the Supreme Court NEERI concluded that *ecological and social costs far exceed the benefits that accrue out of coastal shrimp culture.*

The adverse impact of brackish water aquaculture are destruction of mangrove forests that protect the shoreline from erosion and conserve variety of marine fauna, groundwater depletion due to excessive pumping, conversion of fertile wetlands to aquaculture, eutrophication in surrounding water bodies due to indiscriminate release of enriched effluent water, salinization of adjacent fertile areas and drinking water bodies. The seawater intrusion as a result of excessive groundwater pumping also leads to salinization of groundwater and soil on which the pumped water is used. Some important impacts are discussed in more detail below.

5.1 Groundwater depletion and salinization

Brackish water aqua forms draw water either directly from the sea (EC 35-40 dS/m), creeks (EC 20-25 dS/m) or borewells (EC 6-15 dS/m). Since salinity beyond 15-20 dS/m is not congenial for shrimp farming, water drawn from the creek/sea has to be diluted and it has been estimated that about 0.66 ha m of fresh water is needed to maintain salinity at the desired level in 1 ha pond over a period of 4 months, if the source of brackish water is the sea (Mukul, 1994). Therefore, excessive pumping of saline water from borewells dependent farms and fresh water in case of shoreline farms results in the fall of water table. Parthasarthy and Nirmala (2000) inferred from survey in a village in Andhra Pradesh that in about 11 percent of the total water spread of 19 ha, which depended solely on borewells, water table dropped by 0.6-1.2 m within a radius of 500 m. In another location in village Gumpadi of Payakaraopeta Division in Visakhapatnam District (Andhra Pradesh) where all the farms depended on borewell water, farmers complained of acute scarcity during summer. Drawal of groundwater for aquaculture, though prohibited in the Coastal Regulation Zone (CRZ), is being practised unlawfully. On western coast in Kutch and Junagarh Districts, groundwater has been pumped excessively for irrigation purposes. This has also led to drastic reduction in water table resulting in drying up of dug wells and intrusion of seawater into the aquifer.

5.2 Salinization of lands

It has been reported by Alagarswami (1995) that salinization of land was spreading to surrounding lands further away from the seacoast, and that wells have started yielding only saline water. When shrimp farming was taken up, in the initial stages outlet ponds were not constructed resulting in the discharge of pond water into the adjacent field. In many cases the land under brackish water aquaculture was subsequently abandoned. In these lands there could be substantial reduction of microbial population, accumulation of metal sulphides and change in ionic equilibria.

5.3 Increase in flood hazard in alkali-affected area

Due to very poor infiltration rates in alkali-affected watersheds, the monsoon rains that occur in the form of concentrated storms create surface water ponding and large percentage of rainfall is converted into surface runoff. In the studies made at CSSRI (Singh and Tyagi, 1980) it was observed that peak runoff and runoff volume in alkali watershed were higher by 50 and 75 percent respectively as compared to reclaimed watershed.

5.4 Land use change

A very important problem of brackish water aquaculture is the conversion of agricultural lands into shrimp farms. *It has been estimated that gross value of productions in aquaculture per ha is 35 times of paddy.* Attracted by the high returns farmers allowed conversion of highly productive lands, especially in the East and West Godawari and Nellore Districts of Andhra Pradesh. A study conducted in West Godawari District found that 75 percent of the land converted to shrimp farms were paddy lands (Rao, 1995). Such diversion of productive agricultural land may affect the food grain sufficiency in the country.

5.5 Social tensions

Social environment is also affected in several ways due to highly capital intensive shrimp culture. Shrimp farming with modern technology and high profitability attracts rich entrepreneurs and introduces capital from urban areas to rural areas. Though flow of capital to rural areas is welcome but it creates another kind of problem. The small fishermen are deprived of the benefits, and so are the small farmers who cannot adopt the costly technology. Also, when the land is shifted from agriculture to fish farming some displacement of labour takes place. For example, as against the average labour requirement of 183 man-days/ha for paddy, shrimp farming requires only 90 man-days (Selvam and Ramasamy, 2000). Further, due to intensification of shrimp farming there is increasing incidence of landlessness in coastal villages. The entry of corporate sector has activated the land market by inducing the small and marginal farmers to sell their land at lucrative prices. The owner of resource becoming landless proletariat is not desirable in a populous country like India, as it would lead to social tensions (Jayaraman and Selvaraj, 2000).

6. Main solutions and technologies

The technological solutions to salinity problem largely revolve around management of water, be it from rain, groundwater, canals and creeks. Technological innovations and their applications for inland areas are discussed only briefly. As the focus of this workshop is on salinity due to shrimp farming and seawater intrusion, coastal salinity is discussed in greater detail.

6.1 Technologies for reclamation of inland salt-affected soils

Salt-affected soils are largely reclaimed through leaching and drainage. The reclamation of inland salt-affected soils that may be sodic or saline has been attempted through agrochemical, biological and hydraulic technologies that have been adequately described elsewhere (Tyagi, 1999). The agrochemical technology package for sodic soils centres around application of chemical amendments like gypsum or pyrites. The salient components of agrochemical package include recommendations on:

- Pre-reclamation management
- Amendments use
- Choice of crops and cropping sequences
- Nutrient management
- Water management
- Agronomic management

The detailed description of the agrochemical technology can be seen in Tyagi and Minhas (1998) and Tyagi (1999). Adopting this technology package about 0.8 million ha of sodic land have been reclaimed. The technology is user friendly, economically viable and socially acceptable. Saline waterlogged soils are reclaimed through leaching and drainage and the main technology intervention is sub-surface drainage. CSSRI has perfected the sub-surface drainage technology package for reclamation of inland waterlogged soils and has extended it through small, medium and large pilot projects at several locations in the country (Tyagi, 1999). Various components of the technology are given in Table 5. The Government of India has funded special pilot projects in different states for extension of the technology. The third important technology revolves around the use of salt-tolerant crop varieties and trees that can be planted in these lands. Of late, plant based reclamation technologies have picked up, largely because they reduce the cost of reclamation though the returns are lower than the agrochemical technologies. A hybrid technology that involves application of reduced doses of chemical amendments and growing of salt-tolerant crop varieties has also been evolved. This technology is being implemented in sodic soils in the state of Uttar Pradesh.

6.2 Coastal salinity management

East and West Coasts represent two disinstinct agroclimatic zones. On the East itself the Sunderbans and Bay Islands are distinctly different from other coastal areas of Andhra Pradesh and Tamil Nadu, which have better facilities for irrigation from canal and groundwater.

Table 5. Technology for reclamation and management of saline waterlogged soil at a glance.

Sr. No.	Component of the technology	Purpose	What to do
I	Investigations	To characterise the soil problem and assess design parameters	i) Topography, hardpan ii) Physiochemical characteristics of the soil, iii) Water table, its depth and quality; surface and sub-surface drainage coefficient, hydraulic conductivity drainable pore space, etc.
II	Installation of drainage system	To maintain water table	Select appropriate drainage system
III	Levelling and bunding	For effective reclamation and water management	i) Consolidation of land holdings ii) Land smoothening, land levelling iii) Bunding

			iv) Construction of irrigation and drainage channels.
IV	Leaching of soluble salts	To leach down the salts	i) Cultivate the field to loosen the soil ii) Select the depth of layer to be leached iii) 0.5 to 1.0 cm of water need to be applied to leach each cm of the soil layer
V	Crop rotation	To grow crops with optimum yield	i) In the first few years follow pearl millet/ sorghum-wheat crop rotation ii) Cropping pattern could be shifted and more sensitive crops could be grown in later years
VI	Nutrient management	To achieve optimum crop growth	i) Get the soil tested for fertility ii) Add 20-25% more N, P and K iii) Add micronutrients if tests indicate their deficiency
VII	Management	To achieve optimum crop growth	i) Apply shallow and frequent irrigation ii) Select appropriate crop and cultural practices
VIII	Alternate management technology	To reclaim lands under resource constraints	i) Grow salinity tolerant grasses and forest tree
IX	Monitoring	For maintenance of soil health	i) Monitor drainage system frequently, ii) Monitor soil salinization-desalinization iii) Monitor soil fertility status

Source: Singh *et al.* (1998).

6.2.1 Management of coastal salinity in the Sunderbans

The salinity in the Sunderbans is of marine origin. The solution lies in preventing seawater ingress through constructing embankments and cross regulators. Though soils are inherently saline but the effects of salinity are largely manifested during winter and summer. During monsoon period from middle of June to middle of October there is always a sheet of fresh rainwater, with depth varying from a few cm to more than 1 m depending upon the toposequence. The technology aims at managing the high and low salinity cycles in different seasons through proper rainwater management and drainage and introduction of salt-tolerant plant species. The technology package includes:

1. Flushing of salts with water from the initial monsoon rains.
2. Construction of on-farm reservoir to harvest rain for supplementary irrigation during prolonged dry spells in monsoon season and storing freshwater for cultivation of vegetables/fruits/other cash crops during winter/spring season. The ponds also reduce drainage congestion on the farms and provide location where perennial high value horticultural plants like coconut, banana and betel nuts can be raised.
3. Planting of salt-tolerant high yielding rice varieties according to the level of submergence expected at different locations according to the toposequence. CSSRI is engaged in developing rice varieties that are salt tolerant and can be raised at different

levels of submergence. Some of the salt-tolerant varieties that have been developed in 4. India are given in Table 6.
4. Adopting rice-freshwater aquaculture during winter and brackish water aquaculture during spring and summer. Since it uses only creek water and traditional technology, the land can be again used for cultivation of rice during monsoon season.

5. A crop calendar to suit the occurrence of rainfall/water availability and salinity cycle has been developed and is recommended to the farmers to overcome the salinity constraint. The detailed description of coastal salinity management is given in Sen *et al.* (2000).

6.2.2 Technology for minimising groundwater salinity due to over-pumping on the eastern coast

There are large tracts on the eastern coast, particularly in Andhra Pradesh and Tamil Nadu, which are sandy and percolated rain/irrigation water forms a layer of fresh water that floats over saline water. In Andhra Pradesh, out of the total area of 0.82 million ha of sandy soil along the seacoast, nearly 0.17 million ha have shallow water table (0.5-3.0 m). These soils occur in 10 km wide and 972 km long strip in Ichapuram in Srikakulam District in the north to drain into Nellore in the south. The installation of shallow- as well as deep tubewells is constrained by the shallow depth of good quality water and occurrence of clayey soils in deeper layers. Traditionally farms in this region are used to dig shallow pits to skim freshwater, locally called Doruvu. The major drawback of these traditional Doruvu is that they occupy 20 percent of the land, have to be desalted more frequently because of caving of sand and there are chances of upcoming of saline groundwater. In case of shallow tubewells this upcoming is more frequent as there is no control on the drawdown that these structures cause.

Table 6. High yielding varieties of rice, suitable for the varied ecology and stress situations in the coastal ecosystems in India.

State	Nature of problem	Improved rice varieties
West Bengal	Saline areas	CSR 100-1, CSR 2, SR 26B, CSR 2, CSR 3, CSR 4, CSR 7-1, Malta, Canning 7, Canning 7, CSR 6, CSR 10, Hamilton
	Shallow (0-30 cm) water	CR 1009, Pankaj, Mahsuri, CR 1006, SR 26B, CSR 4, CAC 615, Savitri, Salvhana, Moti, Padmini, CR 644
	Intermediate (30-50 cm) water	Gayatri, Utkalprabha, CSR 1014, Dharitri, Tulasi, Kalasree, Suresh, Lunishree, Biraj, Mandira, Jogan, Swarnadhan
	Semi-deep (51-100 cm) water	Jalaj, Janak, Jaladhi-1, Sabita, Panidhan, Dinesh, Nalini, Amulya, Matangini
Orissa	Submergence	Chakrakanda, FR 43A, Ratna
	Saline areas	CSR 10, ORM-89, CR 644, CRM 30, SR 26B, Patnia 23, Pakkali, Nonasail, Nona Bokra, Biradi, Bakari, Lunishree
Andhra	Gall midge	Suraksha, IET-12875

Pradesh	biotype	
	Gall midge	Phalguna, Vibhava, Nagavali, Pushkala, Shaktiman, Rasi
	Endemic areas	Tulasi, Prasanna, Pratibha, Pinakini, Tikkana, Nandi, Vams
	BPH	Krishnaveni, Chitanya, Nagarjurna, IET 12875
	Upland coastal	MTU 9993, Rasi, Pushkala
	Saline soils	Prahash Swarna, Hari
	Winter	Sonasali, IR 64, Ajya, Rasi, Varsha
	Waterlogged	Swarnadhan, Mansarovar, Badavamahsuri
Andaman and Nicobar	Saline areas	CSR 1, CSR 3, CSR 4, B 106
	Upland	Arkavathi, IR 31851-6-3-1, IR 18350-229-3, IR 48
	Medium land	Jaya
	Lowland	CR 1009
Tamil Nadu	Shallow water	Savitri, Ponni, Swarnadhan, Mansarovar, Salivahan, Pavizham
	Saline areas	BR 10, B 11, Patnai 23, SR 26B, PVR 1, Py 1, CSR 1, CSR 4, CO 43, AD 85002, IET 8113
Karnataka	Upland	Amrut, Mukti, Prasanna, Tulasi, Mahaveer, Vikas, Jaldi 1, Jaldi 4, HBC 19, Lata, Jaldi 3
	Medium land	Avinash, Karna, Mahaveer, Prakash, Mukti, Suraksha, Ajya, Sakti, M 06, M 07, M 09, M 001, Sonasali, Abhaya, C) 43
	Lowland	Hemavathi, Netravathi, IET 7191, Abhilash, Avinash, Phalguna, Vikram, Mandyavijaya
	Winter	Jyothi, Mukti, Mahaveer, Prakash, Rasi
Kerala	Lowland areas	Karthita, Aruna, Mokam, Remya, Kanakam, Jayanthi, Kanchana, athira, Pavizham
	Salinity	Vytilla 2, Vytilla 3, Vytilla 4
Maharashtra	Salt tolerance	Bhurarata-4-10, Kalaratal-24, MK 47-22, SR 3-9, Panvel 1, Panvel 2
	Coastal areas	Ratnagiri 3
	Multiple resistance	Suraksha, Saktiman, Lalat, Rasmi, Samalei, Swarnadhan, Nidhi

Source: Siddiq and Kumar (1998).

Recently an improved design on the skimming system has been developed. It has been called sub-surface freshwater skimming system popularly known as improved Doruvu, which works on the principle of rapid phreatic flow in sandy soils under the influence of vertical recharge (Figure2). The lateral flow is collected in a sump, constructed on an impervious layer. The lateral flow is enhanced by providing lateral perforated pipes installed at 3-4 m depth at 0.2-0.3% slope and connecting it to the sump. The radius of influence of lateral is about 50 m. When the sump is pumped the flow towards the sump starts but as soon as the water level drops to level of the lateral pipe, the flow stops. With this system over-exploitation of groundwater beyond the collector depth is not possible. Water so pumped can be used either for diluting the saline water used in shrimp farming, leaching of salts from the soils that have become saline and/or irrigation of crops in the

area. The whole system can irrigate about 3 ha of crops during 'rabi' (winter) using sprinkler and for 4-5 ha of plantation crops with drip system and has been found economically viable (Babu *et al.*, 1999). With several advantages, the technology is becoming very popular with the farmers in the sandy belt of Andhra Pradesh. About 40 improved Doruvus have been installed at different locations as part of an operational pilot project. The details of these locations and the crops being irrigated are given in Table 7.

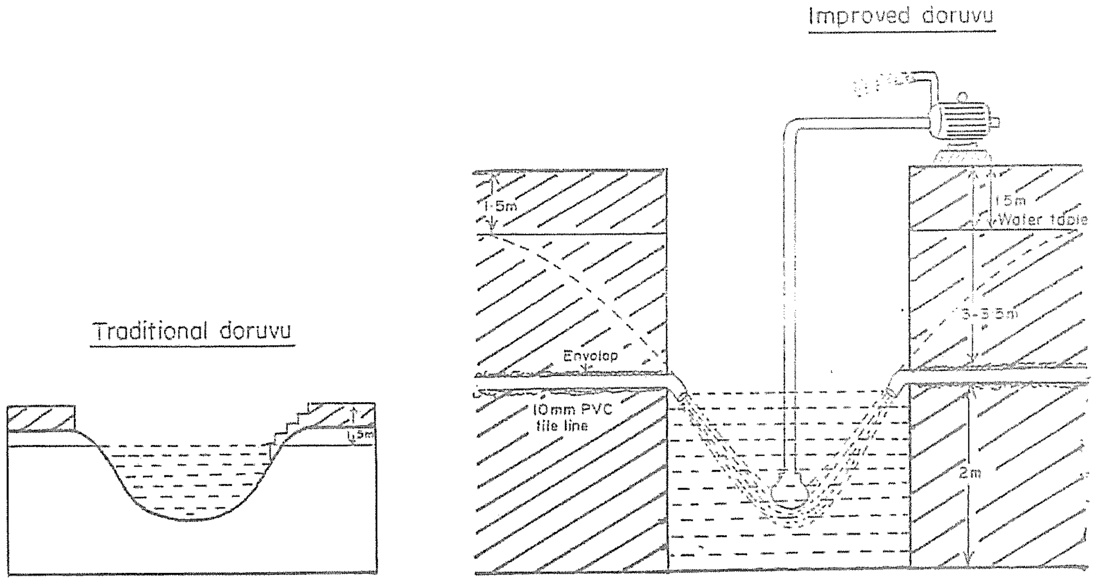

Figure 2. Traditional and improved Doruvu systems of skimming freshwater overlying saline aquifers.

Table 7. Details of sub-surface collector wells (Improved Doruvu) installed in different farmers' fields and other organizations.

Sr. No.	Name of the village	No. of wells	Area covered (ha)	Crops grown
1.	Bapatla	10	25	Paddy nursery, pulses, groundnut (rabi) plantation crops
2.	Vedullapalli	3	4	Rose nursery
3.	Reddy palem	7	21	Oil palm, mango and coconut nursery, paddy nursery, groundnut (rabi) and medicinal plants.
4.	Muthai palem	2	5	Nursery of forest species
5.	Kerthivari palem	1	2	Groundnut (rabi), vegetables and poultry
6.	Kavuru	1	2	Nursery of various crops and vegetables
7.	Bavanamvari palem	1	2	Vegetables and groundnut
8.	Ramabatlavari palem	1	4	Paddy nursery, groundnut (rabi)
9.	Padison peta	9	8	Paddy nursery, vegetables, watermelon and fish-tank
10.	Kajipalem	1	1	Nursery of coconut and mango, vegetables
11.	Dammanavari palem	1	2	Groundnut (rabi), vegetables and paddy nursery
12.	Manubroluvari palem	6	20	Paddy nursery, pulses, plantation crops, cattle and sheep farms
13.	Kothapeta	2	5	Paddy nursery, pulses and plantation crops
14.	Chinamatlapuri	1	1	Paddy nursery, vegetables and groundnut
15.	Akkaya palem	1	2	Vegetables and paddy nursery
	Total	**42**	**104**	

Source: Babu *et al.* (1999).

The economics of improved Doruvu technology is very favourable. The benefit-cost ratio is more than 2.5 and the internal rate of return is about 28 percent. High capital requirement is one of the major drawbacks as the entire system, complete with pump/sprinkler/deep system costs between Rs. 65 000 and 80 000 (US$1 500-1 900). Presently the Government of India is allowing 75 percent subsidies on the total cost of installation on drip- and sprinkler system. If similar subsidies were allowed on the improved Doruvu, the technology would become more popular.

6.2.3 Technology for minimising seawater intrusion on the western coast

The solution for overcoming seawater intrusion problem lies in either reducing the groundwater withdrawal or increasing freshwater recharge into the coastal aquifers. On the western coast the freshwater availability is through rainwater only during the monsoon. The distance between the seacoast and the flood plain being small, the opportunity time for the percolation is low and has to be increased by constructing different kinds of water harvesting structures. The main structures that are relevant to the hydrogeological and morphological conditions are: percolation tanks, recharge wells, tubewells and sub-surface dyke (Raju, 2000).

The purpose of recharge tubewells (Figure 3) is to directly feed the deep aquifers with freshwater. The general design of a recharge tubewell consists of a drilled borehole with a diameter of 50 cm down to the depth of existing borewells, but usually 30 m below the water table. A PVC tube of 15-20 cm diameter is used and the pipe section against the aquifer is slotted. At the top of a recharging well a filter is constructed to prevent the suspended material to enter the aquifer with recharged water. The artificial filter is designed to give high infiltration rate. An air vent is provided to release air during the recharging operation.

Since there is possibility of sub-surface runoff to the sea before the water goes into the sea, sub-surface dyke which is essentially a well in the river bed is constructed with impervious material like polythene sheet on the downstream side. Sub-surface dykes are constructed in wide streams with high flow levels. The dyke is dug along the entire width of the river and the depth is up to the water level or at least 15 m. If the water table is too deep, recharge tubewells are constructed in the dyke section. The entire excavated section of the dyke is filled with good pervious material. In order to intercept the flow, a check dam with the top metre below the land surface is constructed. A typical sub-surface dyke is shown in Figure 4.

6.2.4 Pilot project on recharge of groundwater in Kutch District of Gujarat

Kutch District forms a crescent shaped peninsula bounded in the north and the west by salt deserts known as the Great Raan and Little Raan and in the south and the west by the Gulf of Kutch and the Arabian Sea respectively. With a coastline of 313 km it has a tropical

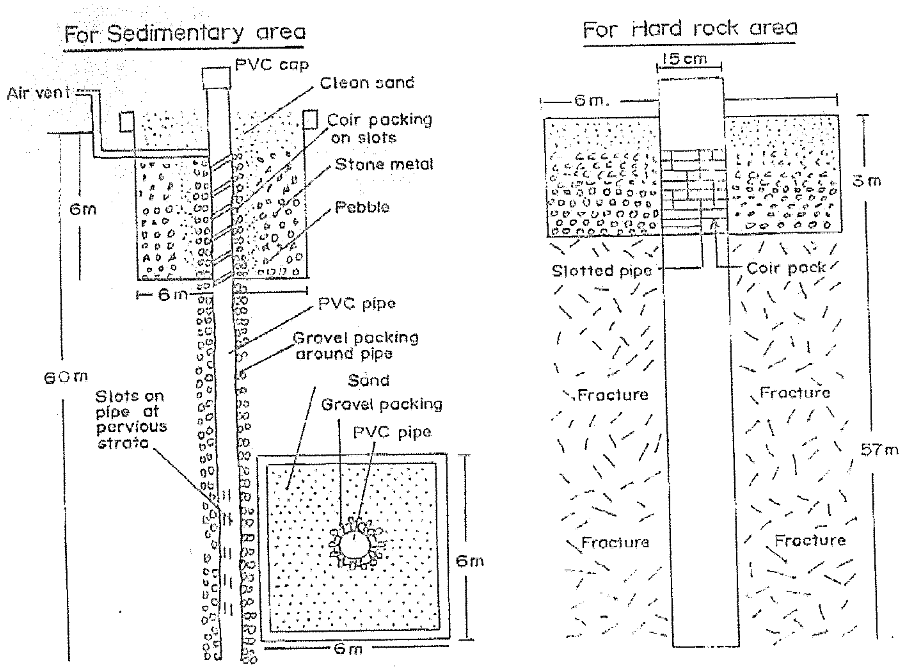

Figure 3. Assembly of recharge well and design for preventing seawater intrusion in coastal Gujarat.

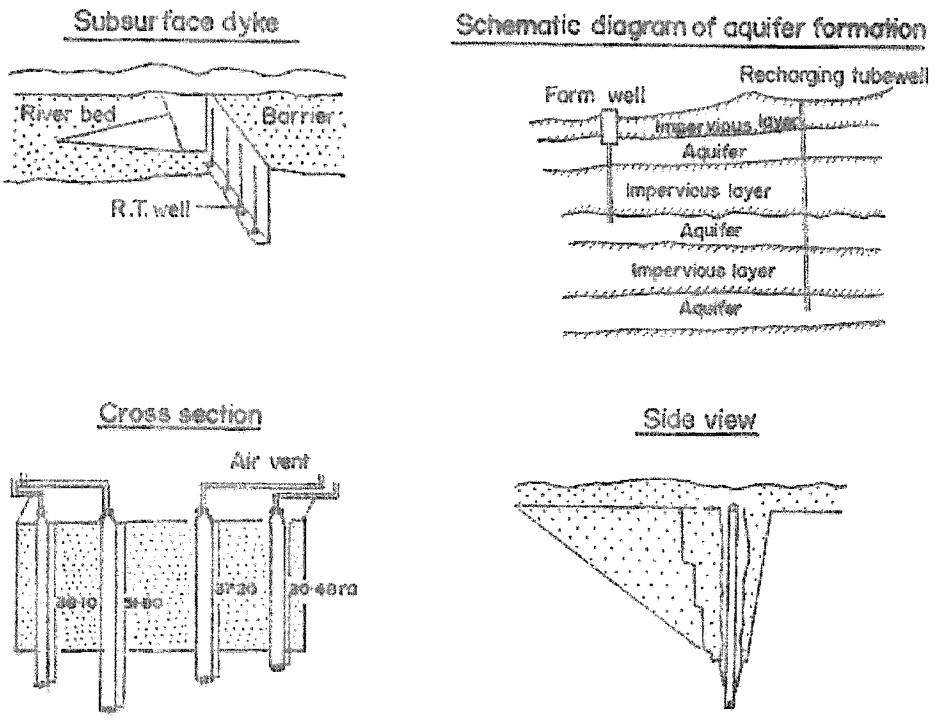

Figure 4. Sub-surface dyke for recharge aquifers designed for Gujarat coast.

monsoon climate with extremes of weather conditions, with temperature reaching 48°C in summer and 1°C during winter. The rainfall in different parts of the district varies between 342 and 451 mm (Table 8) but the coefficient of variation is rather high. The annual evapotranspiration demand varies between 1 750 mm in the coastal area to 1 900 mm in uplands. The area has rolling topography and is characterised by a number of ephemeral streams that carry water only during southwest monsoon. The distances between the hills from where these streams originate and the sea into which they discharge their water are rather short, providing very little opportunity for recharge. The estimated average runoff is 1 183 million cu m. In this area, groundwater occurs under phreatic and confined conditions and has been developed through dug wells, dug-cum-borewells and tubewells. The specific capacity of the tubewells ranges from 0.7 to 1.9 litre/second/m drawdown in Rapar to 0.9 to 7.0 litre/second/m in Bhuj, while in Mundra it is only 0.5-1.8 litre/second/m. The utilisable groundwater in the district has been estimated at 627 million cu m of which 501.6 million cu m can be harnessed for irrigation. It is seen that in some 'Talukas' (sub-districts) there has been an overexploitation of groundwater resulting in the deterioration of its quality (Table 8). In coastal areas of Mandvi, Mundra, Anjar and Nayala seawater intrusion has affected water quality, resulting in the decline of agricultural production in an area of 1 550 ha. According to estimates made by Gujarat Government, as reported by Raju (1998), cropped area declined from 11 812 ha to 7 705 ha. The incidence of mortality in bottle palm/date palm has also been noticed.

Table 8. Groundwater potential and development in Kutch District.

Taluka	Rainfall mm	Potential recharge million cu m/yr	Utilisable GW million cu m/yr	GW Draft million cu m/yr	GW developed (%)
Anjar	343	50.6	40.5	50.6	139.2
Bhuj	342	189.2	151.4	98.5	65.1
Lakpat	338	39.1	31.3	8.6	27.4
Mandvi	402	81.3	65.1	65.6	100.9
Mundra	440	55.3	44.2	39.3	88.9
Nakhatrana	382	70.9	56.7	48.8	86.0
Rapar	365	65.8	52.7	52.8	100.3

Source: Raju (1998).

An innovative technology based on harvesting of floodwaters for recharging the depleted aquifers has been implemented in Kutch District. It is based on the construction of check dams, percolation tanks, recharge tubewells and subsurface dykes for arresting floodwaters that used to go waste. The case of Moti Rayan Project is described in some detail.

6.2.5 Moti Rayan Project

The village Moti Rayan in Mandvi Taluka has 749 ha of agricultural land shared by 200 farmers (Figure 5). There were 84 operational dug wells and many of them have bore holes drilled in them up to a 100 m depth. Due to the application of high SAR water from the wells, the soil has developed infiltration problem and the farmers have to apply gypsum to improve the situation. The Moti Rayan Project had 18 check dams, 3 percolation tanks, 11 recharge tubewells and one sub-surface dyke for harvesting floodwaters. The recharge capacity created was 180 800 cu m and the recharge was monitored from 1989 to 1997. The recharge and the post-monsoon salinity in different years are shown in Table 9.

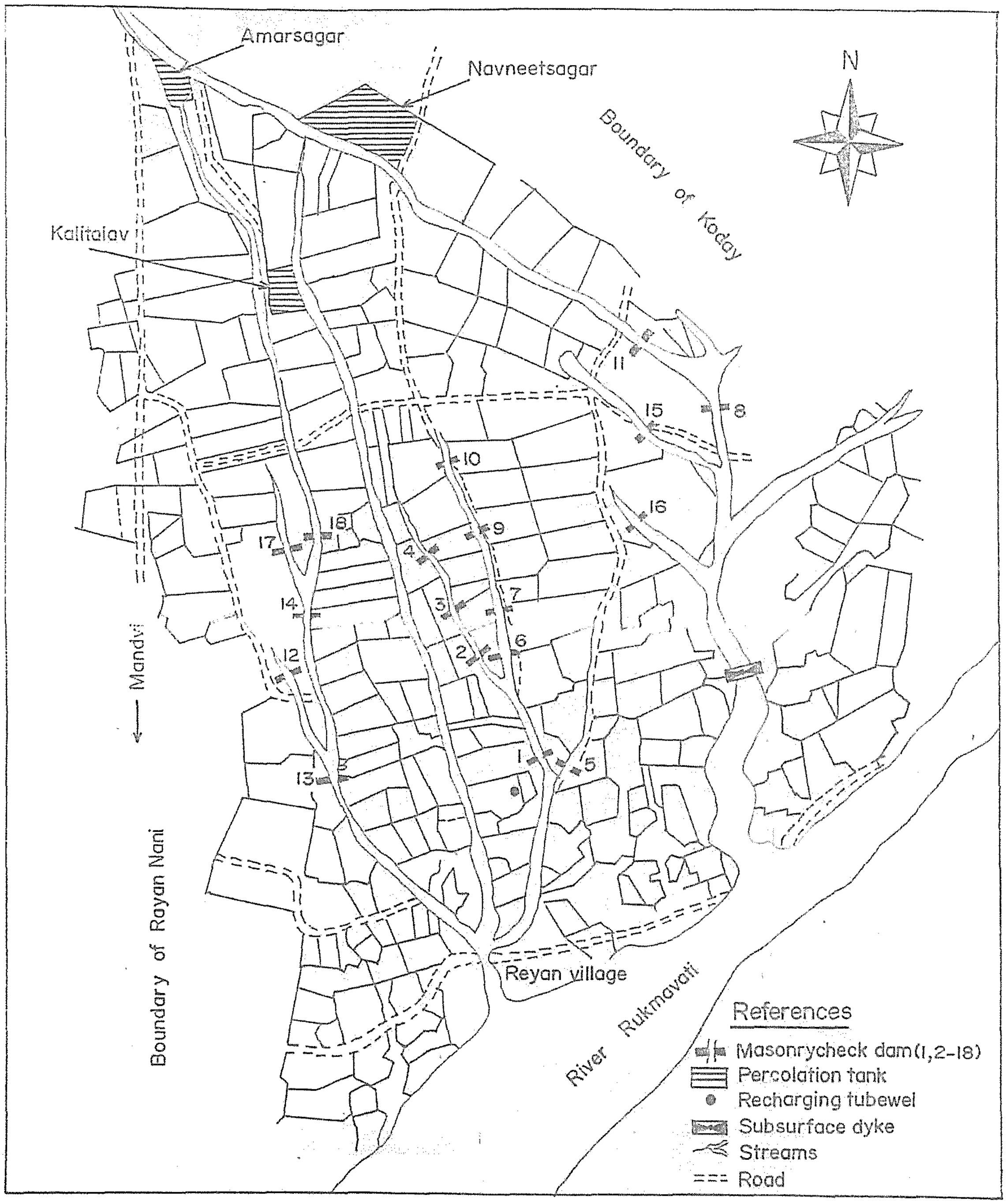

Figure 5. Moli Rayan groundwater recharge project site in Mandvi Taluka, Gujarat.

Table 9. Rainfall, groundwater recharge and post-monsoon salinity during different years after construction of the recharge structures in Moti Rayan Project area.

Year	1989	1990	1991	1992	1994	1997
Rainfall (mm)	310	185	62	791	1 200	611
Recharge (TCM)*	66.4	204.0	89.7	211.8	344.7	406.0
Post-monsoon salinity (ppm)	1 774	1 344	1 185	135	1 136	1 534

There was no runoff during 1993, 1995 and 1996.
*TCM: 1 000 cu m.
Source: Raju (1998).

It is seen that even in low rainfall years there was appreciable recharge. During 1995 and 1996 there was drought so almost no flow took place to the recharge sites but pumping from the tubewells/wells continued. In spite of heavy withdrawals the salinity at the end of the 1997 was lower than that in 1989 and the rising trend in groundwater salinity had been halted.

Salinity ingress prevention measures have been undertaken in the coastal areas of Gujarat in Junagarh District on a large scale and have shown good results. For example, at Maliya (Junagarh) the construction of Vrajmi recharge reservoir has increased the groundwater level from 71.9 m in November 1986 to 65.0 in May 1997 and the salinity decreased from 393 ppm to 243 ppm (4 yearly average). In other words the technology being implemented on the Gujarat Coast is appropriate and has the potential to check the seawater intrusion.

7. Institutions dealing in salinity management

Since salinity is widespread in the country and has implications for food security, a number of public and private institutions are dealing with salinity management in India. The important ones are:

- Research institutes
These include CSSRI, Karnal; Kharland Research Institute, Bhavanagar; Irrigation and Power Research Institute, Amritsar and state agricultural universities in different states. These institutions provide research backstopping to development agencies.

- Land reclamation corporations
States where salinity is a major problem have established corporations to organise land reclamation activities. Such corporation has been established in the states of Uttar Pradesh, Haryana, Punjab and Gujarat.

- Command area development authorities (CADA)
There are more than 100 command area development authorities that have been established in different irrigation project areas. The important CADAs where activities of land

reclamation are being taken include Gandak (Bihar), IGNP (Rajasthan) and Tunga Bhadra (Karnataka).

- Non-government organizations (NGOs)
Many NGOs like AFPRO, Sarvodaya Ashram and VIRTI, etc. are actively participating in salinity management programmes. NGOs are, of late, being encouraged to come forward to organise the reclamation programmes.

- State agriculture and forest departments
The departments undertake afforestation in salt-affected lands.

- Agencies dealing with problems of seawater instruction
There are different agencies dealing with seawater intrusion problems in the country and these vary from state to state. In the state of West Bengal the Sunderbans Development Board is the main agency that deals with seawater intrusion. Also, there are some NGOs like Ram Krishna Mission that extend technologies dealing with coastal salinity. In Gujarat the Sri Vivekanand Research and Training Institute (SVRTI), an NGO, is very actively involved in referring and propagating the technologies dealing with groundwater recharge. Gujarat Government has taken up the salinity ingress prevention project in a large scale on the Kathiawad Coast. In most states the Departments of Agriculture and Water Resources are responsible for large-scale seawater ingress protection programmes.

8. Socioeconomic issues and policies

Salinity, being a countrywide problem with great bearing on economic well being of the country, has become a national issue affecting large sections of the society. Seawater intrusion due to large-scale pumping in fragile aquifers has been known for quite sometime but salinization of soil due to shrimp farming is of recent origin. But in a very short time it has become a burning issue and the public awareness was so much aroused, that a public interest litigation was launched in 1994 seeking court's direction for enforcement of the Coastal Regulation Zone (CRZ) notification that envisaged stoppage of intensive and semi-intensive shrimp farming in ecologically fragile coastal areas and setting up of National Coastal Management Authority. The petition alleged that the coastal states were allowing big business houses to set up prawn farms on a large scale in violation of the Environmental Protection Act 1986, and that the establishment of farms on rural cultivated lands was posing allegedly serious environmental, social and economic problems. The Supreme Court passed a judgement in November 1996 directing the halt of shrimp culture activities and subsequent demolition of ponds within CRZ. Some of the important provisions of the Supreme Court directives are:

- The Central Government is to constitute an 'Authority' under the Environment Protection Act 1986. The Authority is to implement 'precautionary' and 'polluter pays' principles.
- All aquaculture industries (including fish and marine products within the CRZ) except traditional/improved traditional types are prohibited.

- Any industry that causes salinity to soil or drinking water or wells by use of chemicals, and feed for production and increases sedimentation, causing potential health and eco-hazards, is not to be granted approval by the Authority.

In the backdrop of Supreme Court judgement, the Indian Council of Agricultural Research organised a workshop in November 1999 to debate on relevant socioeconomic issues under the auspices of the Central Institute of Brackish Water Aquaculture (CIBA) and the National Centre for Agricultural Economics and Policy Research (NCAP). For the socioeconomic issues and policy directions emerging from the workshop (Krishnan and Birthal, 2000) and similar exercises on seawater intrusion due to overpumping and secondary salinization in irrigation commands, following are considered to be the important issues in salinity management.

8.1 Land holding and tenure

The shrimp culture on intensive scale by corporate houses and big entrepreneurs is undertaken on leased lands. Leasing policy in various states needs a fresh look in view of the emerging market forces and technological change in aquaculture sector. The lease period should be long enough to encourage private investment in modern methods of shrimp farming so as to avoid the 'pollute and leave the land' practice, in vogue at present. Lease duration has a significant effect on land reclamation progress in inland salt-affected lands as well.

The reclamation of land in Punjab and Haryana has been undertaken in two situations by the landowners themselves and by the tenants who took the land on lease for a fixed period of 4-5 years or more. In the second case the investment on development of permanent infrastructure has been less and the productivity has been generally low. In case of smaller holdings, individual farmer was unable to develop his own infrastructure like tubewell, pumping set and other machinery and a cooperative approach was required. The progress of reclamation in such a situation was slow.

Land holding of salt-affected soils varies from state to state. In the northwestern states of Rajasthan, Punjab and Haryana the average land holding of individual farmer is about 3 ha, whereas in Uttar Pradesh, such holdings are in the range of 0.25 to 1.00 ha. In the latter case many of these lands have been allotted to the landless and weaker section of the society in the process of distribution of surplus land surrendered by big landlords.

8.2 Demarcation of shrimp farming zones

The high export and income generating shrimp farming enterprise has to be encouraged, but it should be practised only in areas that are suitable for this purpose. As per CRZ notification by the Government of India in 1991, coastal structures of seas, bays, estuaries, creeks and brackish water that are influenced by the tidal action up to 500 m from High Tide Line (HTL) and Low Tide Line (LTL) come under CRZ, and this area must be kept free from any type of construction. Similar laws also need to be passed for exploiting groundwater in the coastal areas except for drinking purpose of the local people.

8.3 Public institutions

In a developing economy public institutions play major role in promoting land development programmes. Land Reclamation and Development Corporations (LRDC) are the most important institutions created by the state to promote reclamation of salt-affected soils. These corporations do a good job of promoting sodic land reclamation programmes. They lack the technical expertise to undertake reclamation of waterlogged saline lands that require installation of sub-surface drainage system. If in-house expertise is not to be created then, suitable rules/guidelines for hiring experts on contract basis will have to be framed. In certain states, reclamation programmes are executed by CADAs, which have been established in about 150 irrigation projects.

National Bank for Agriculture and Rural Development (NABARD) is another institution that extends credit for land reclamation and has played an important role in facilitating rehabilitation of salt-affected soils. In the state of West Bengal, the Sunderbans Development Board, which is again a state financial institution, is charged with the responsibility of preventing seawater intrusion/ingress. The Indian Council of Agricultural Research (ICAR) plays a major role, not only in the development of technologies but also in their extension through Krishi Vigyan Kendras (KVKs). A result of well-considered strategy, such centres have been established in more than 500 places.

During the first decade (1970-80) of large-scale land reclamation, it was entirely public sector institutions that organised the programme. But gradually several NGOs that were engaged in rural development programmes also got involved in land reclamation activities.

Mention should be made of Sarvodaya Ashram in Hardoi (Uttar Pradesh) and Action for Food Production (AFPRO). Private companies who wanted to establish some agro-based industries also undertook reclamation activities. Hindustan Lever supported alkali land reclamation in Etah and Lupin in Bharatpur. Gradually more NGOs are being set up to facilitate land reclamation. In West Bengal Ram Krishna Mission plays a vital role in assisting the farmers to adopt land reclamation technology. These NGOs essentially get support from the Government and establish rapport with the farmers to facilitate land reclamation.

8.4 Public policies

In view of the experience gained and the Supreme Court directions, institutional measures to regulate the aquaculture activity in ecologically fragile zones are needed. Some regulations already exist but their implementation leaves much to be desired. The regulations also require some modifications so as to give due consideration to system of production and nature of technology to be adopted for avoiding social, economic and ecological problems. The state of Gujarat, where groundwater intrusion is a major problem, has already passed the legislation but its implementation has been kept in abeyance. Other states also need not only to pass these legislation but also to enforce them.

9. Research requirements

9.1 Perspective

India is a vast country in which salinity occurs under varied agro-ecological conditions and resource endowments. Whereas basic principle of salinity management may remain the same, in practice each region needs somewhat different mix of technologies to overcome the problem. The perceptions about salinity management are changing fast due to increased awareness of consequences of salinity and the secondary effects that technological fixes create. Sustainability seems to be the cardinal principle governing the choice of technologies. In our thinking the following factors will decide the research requirements in India or for that matter, even globally:

- Sophisticated scientific tools of investigation like remote sensing and advanced plant integration method will enable prognosis of incipient salinity and its forecast for taking preventive actions.
- Soil salinity and water quality problems are very intimately related. In coming years, salinization due to poor water quality, use/industrial and drainage water reuse is going to be the important issue.
- The emphasis in amelioration of salinity so far has been largely in removal through agro-chemical and hydraulic technologies. Of late biosaline agriculture which is mostly based on living with the situation and taking economic advantage of the plant salinity tolerance is gaining momentum and is opening a new approach to salinity management.
- In spite of the steps initiated to minimise seawater intrusion in arid coastal area the trends indicate that the problem will further aggravate. So will be the presence of arsenic in groundwater in coastal West Bengal.
- Brackish water aquaculture in India has large potential. Presently less than 20 percent of the potential has been realized. Sustainable shrimp culture that can flourish in harmony with agriculture will require due attention to the newly emerging problem of salinization of adjoining lands and groundwater in the coastal areas.

9.2 Research issues

Salinity research has to be seen as a part of the large body of research agenda on environmental research (CSSRI, 1997). The research perspective outlined in the proceeding section deliberated on new paradigms within which research needs to be pursued to develop location specific viable technologies. Some of which are briefly enumerated:

9.2.1 Prognosis of salinity

Salinity being an insidious process does not lend itself to early detection, and attempt in this respect in the past has not been very successful. The recently developed plant integration method (PIM) holds some promise and should be perfected.

92.2 Biosaline agriculture

Amelioration of salinity in some areas in the highly arid regions is difficult to achieve. However, large biodiversity in plant salt tolerance and the newly emerging science of biotechnology can be exploited to develop higher salinity tolerance. The complete agronomic package for practicing biosaline agriculture remains to be developed.

9.2.3 Safe shrimp farming

Brackish water aquaculture, which has high potential in India, has not grown due to the need of appropriate technology. Prevention of salinity ingress from brackish water aquaculture needs interception of percolating saline water before it joins the groundwater or the adjoining land. Drainage system that can meet the requirement of this enterprise has to be studied. Also, research on combination of hydraulic and plant based approaches needs to be pursued.

9.2.4 Rehabilitation of land salinized due to shrimp farming

On account of Supreme Court directives, large area that was hitherto under shrimp farming has been abandoned and it is lying uncultivated due to salinity. Prolonged submergence of land brings about several permanent and semi-permanent changes including accumulation of toxic substance like metal sulphides, depletion of nutrients and reduction in microbial population. Research for developing technology package should be a priority area.

9.2.5 Drainage of coastal areas during monsoon

Coastal areas, particularly in the Sunderbans, suffer from high degree of waterlogging during monsoon but the salinity stress is much less. However, due to continued high level of submergence, the high-yielding rice varieties have not been adopted and fertiliser use is negligible. This is largely due to unsatisfactory surface drainage. Integrated drainage and water management systems based on operation of sluice gates, water level control structures at different locations to provide enough storage in the field to meet the crop water demand and storage in the on-farm reservoirs is needed.

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Indonesia

Summary

Indonesia is an archipelago consisting of 17 435 islands with land area of 192 million ha. Agriculture is the utmost important sector for the population of which around 70 percent depend on. The government has been making efforts to meet self-sufficiency in food supplies and improve the nutrition conditions. Improvement of nutrition is conducted, among other, by intensification of fishery through a programme better known as Gema Protekan 2003 (Movement for increasing fish production and people's protein consumption by year 2003). Indonesia has about 58 000 sq km coastal land, with high potential for the development of coastal aquatic cultures. The highest shrimp production was achieved in 1996 during which, Indonesia produced 151 086 tonnes. Shrimp export in the form of unfrozen, frozen and canned shrimps in that year (100 230 tonnes) was also the highest. Shrimp culture is normally run by large businesses, and only a small portion, for 'bandeng' ponds, is run by smallholders. Coastal ponds in Indonesia are generally developed in inter-tidal areas (areas under the influence of low tides). For these areas the influence of seawater intrusion is very strong during the rainy season and rivers are the source of freshwater. However, in the northern coast of Java, large acreage of shrimp ponds is developed in the super-tidal areas (areas unaffected by seawater intrusion during high tides). Saltwater for the ponds is brought in by pumps while freshwater is taken from wells.

Shrimp productivity in Indonesia is relatively low, being approximately 0.5 tonne/ha; in 1997 the productivity dropped to 0.36 tonne/ha and in 1998 to 0.38 tonne/ha. The main cause of the decline of productivity was the high price of imported feed during the Indonesian economic crises starting in late 1997 until present. Salinization of Indonesian soil is mainly caused by seawater intrusion to the coastal plains. Coastal abrasion occurs especially in areas where clearing of mangrove forest for firewood is intensive. Removal of mangrove is the main cause of saline soil formation in Indonesia. Seawater intrusion affects the growth of lowland rice. Rice plants died as has happened in Pendowahardjo Deta Upang Village, South Sumatra Province. However, seawater intrusion can give benefits if it occurs in the inter-tidal swamp containing pyrite. Improper management of coastal area can bring about contamination of the area, for example, by Pb and Cu contamination in Teluk Pare-Pare, South Sulawesi. The salinization problem could be rectified by water management system of the tidal swamp areas and mangrove planting in abrasion affected lands. Reclamation by the use of amendments and leaching is generally not conducted because high rainfall in most areas causes leaching of salt to the sea naturally.

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1. Introduction

Agriculture plays one of the utmost important roles in Indonesian economy in terms of its contribution to the country's GDP, employment opportunity, as well as the foreign exchange reserve. In the national long-term plan, agricultural sector will become a more dependable sector because it is less affected by the economic and monetary crises. With the population as high as 215 million, Indonesia is very much dependent on agricultural sector to warrant the people's livelihood.

Annual food crop development has shown its historical achievement with the national self-sufficiency in rice in 1984. One of the greatest challenges that remains is, how to keep up with population growth, increase in per capita consumption and increase in per capita income. Efforts in maintaining the sustainability as reflected in the Agricultural Five-Year Development Plan include:

a) To strengthen and sustain food sufficiency that meets nutrition standard.
b) To increase production to suffice domestic as well as export needs.
c) To increase farmers' income and to increase job opportunity.
d) To conserve natural resources.

To bring about the above objectives, efforts to be taken include agricultural intensification, extensification and rehabilitation of agricultural infrastructures. The utmost prominent efforts in this respect are intensification and extensification.

Rice harvest area in the last two decades shows a significant increase from 8.02 million ha in 1968 to 10.5 million ha in the 1990s, corresponding to 1.4 percent annual increase during this period. Meanwhile rice production increased substantially from 11.62 million tonnes in 1968 to 30.66 million tonnes in the 1990s. There is a great disparity in rice production between Java and the outer islands. Java produces 60 percent of the rice national production with an average yield of 4.96 tonnes/ha which is nearly 1.5 times the outer island production (BPS, 1990). This difference is caused by the lower soil fertility in the outer islands and lower level of agricultural recommendation implementation (Ditjentan, 1992).

To attain the nutrition standard, the government during the reformation regime launches an improved and a more productive fishery programme, better known as Gema Protekan 2003 (Movement to attain self sufficiency of fish production by 2003) which includes the promotion of shrimp production. Indonesia owns as large as 58 000 sq km coastal land under the influence of seawater intrusion and these areas could potentially be used for coastal fisheries and ponds (Puslibangkan, 1990). Sukadi and Achmad (1999) projected the national income of US$10 billion from fisheries in which coastal fisheries contribute as high as US$7.3 billion while fishing from other water bodies will generate about US$2.7 billion.

Table 1. Shrimp production (all kinds) in shrimp pond culture by provinces in Indonesia.

Province	Year					
	1993	1994	1995	1996	1997	1998
	Tonne					
D.I. Aceh	19 653	15 538	16 071	15 561	7 310	6 126
North Sumatra	6 788	10 319	14 235	17 434	13 109	14 192
West Sumatra	-	-	-	-	-	-
Riau	83	31	55	46	153	178
Jambi	2	-	3	37	180	251
South Sumatra	108	123	1 250	4 356	4 620	5 210
Bengkulu	2	601	624	643	33	402
Lampung	9 402	14 175	19 638	22 757	26 577	8 976
DKI. Jakarta	2	1	-	-	-	-
West Java	34 746	25 198	24 677	22 764	14 840	17 180
Central Java	17 302	13 853	16 145	12 053	5 528	10 477
D.I. Yogyakarta	-	-	-	-	-	-
East Java	27 964	28 150	28 132	29 347	6 594	25 887
Bali	985	1 548	989	1 701	344	1 081
West Nusa Tenggara	1 512	644	580	1 034	2 237	1 840
East Nusa Tenggara	45	75	45	631	32	42
West Kalimantan	308	542	660	974	502	1 427
Central Kalimantan	-	-	-	-	-	-
South Kalimantan	611	510	710	692	349	1 376
East Kalimantan	1 686	1 870	2 624	3 262	2 610	3 104
North Sulawesi	87	42	47	44	62	47
Central Sulawesi	121	304	145	190	493	367
South Sulawesi	16 932	18 401	18 150	18 808	24 701	17 978
Southeast Sulawesi	207	481	373	295	2 561	2 416
Maluku	2	-	1	125	28	190
Irian Jaya	12	-	1	125	101	190
Indonesia	138 558	132 406	145 216	151 086	112 955	117 847

Shrimp production in Indonesia declined during the period of 1993-98 from 138 558 tonnes/year to 117 847 tonnes/year (Table 1). This decrease in production was caused by economic crisis in Indonesia that has been continuing since late 1997. In addition, the reduction in shrimp production was also caused by the fact that many ponds are not operational for security reasons.

Shrimp pond culture in Indonesia produces three kinds of shrimp, i.e. 'udang windu' (giant tiger prawn), 'udang putih' (banana prawn) and 'udang api-api' (metapenaeus prawn). Giant tiger prawn is the most important shrimp production in Indonesia and contributes to about 74 824 tonnes (63 percent – Table 2) and followed by banana prawn with the production of 22 589 tonnes (19 percent – Table 3) and metapenaeus prawn with the production of 20 434 tonnes (18 percent – Table 4).

Table 2. Production of giant tiger prawn from prawn pond culture by province in Indonesia.

Province	Year					
	1993	1994	1995	1996	1997	1998
	Tonne					
D.I. Aceh	12 785	7 980	7 327	6 295	-	3 386
North Sumatra	5 093	7 449	8 939	12 733	-	10 184
West Sumatra	-	-	-	-	-	-
Riau	62	6	20	16	-	148
Jambi	1	-	-	5	-	45
South Sumatra	108	123	1 250	4 356	-	5 210
Bengkulu	-	601	624	643	-	402
Lampung	9 265	13 672	18 142	21 043	-	8 415
DKI. Jakarta	2	-	-	-	-	-
West Java	9 199	8 948	10 126	8 567	-	6 254
Central Java	11 862	7 778	9 401	4 762	-	4 008
D.I. Yogyakarta	-	-	-	-	-	-
East Java	21 243	17 900	15 486	17 800	-	13 999
Bali	967	916	714	873	-	826
West Nusa Tenggara	1 077	477	385	456	-	746
East Nusa Tenggara	45	71	45	36	-	37
West Kalimantan	-	542	660	974	-	1 427
Central Kalimantan	308	-	-	-	-	-
South Kalimantan	-	336	505	463	-	1 213
East Kalimantan	407	877	726	1 392	-	1 596
North Sulawesi	846	42	47	36	-	42
Central Sulawesi	87	202	112	143	-	306
South Sulawesi	13 657	14 954	14 570	15 266	-	14 919
Southeast Sulawesi	175	319	259	255	-	1 472
Maluku	1	-	-	124	-	189
Irian Jaya	8	-	-	-	-	-
Indonesia	87 285	83 193	89 344	96 237	-	74 824

Table 3. Production of banana prawn from pond culture by province in Indonesia.

Province	Year					
	1993	1994	1995	1996	1997	1998
	Tonne					
D.I. Aceh	3 837	3 612	6 782	5 222	-	1 817
North Sumatra	1 689	2 812	5 188	4 349	-	3 955
West Sumatra	-	-	-	-	-	-
Riau	21	25	35	30	-	30
Jambi	-	-	-	16	-	121
South Sumatra	-	-	-	-	-	-
Bengkulu	2	-	-	-	-	-
Lampung	36	132	394	440	-	561
DKI. Jakarta	-	1	-	-	-	-
West Java	14 874	4 523	3 908	4 007	-	3 606
Central Java	2 961	3 031	3 073	3 609	-	3 289
D.I. Yogyakarta	-	-	-	-	-	-
East Java	3 134	6 226	8 576	7 572	-	6 102
Bali	18	632	275	161	-	255
West Nusa Tenggara	218	81	115	92	-	103
East Nusa Tenggara	-	4	-	-	-	5
West Kalimantan	-	-	-	-	-	-
Central Kalimantan	-	-	-	-	-	-
South Kalimantan	154	174	205	229	-	163
East Kalimantan	790	939	1 898	1 802	-	1 435
North Sulawesi	-	-	-	8	-	5
Central Sulawesi	34	102	33	47	-	61
South Sulawesi	1 362	1 417	1 171	1 236	-	846
Southeast Sulawesi	32	149	22	1	-	234
Maluku	1	-	1	1	-	1
Irian Jaya	4	-	-	-	-	-
Indonesia	29 167	23 860	31 676	28 822	-	22 589

Table 4. Production of giant tiger prawn from pond culture by province in Indonesia.

Province	Year					
	1993	1994	1995	1996	1997	1998
	Tonne					
D.I. Aceh	3 031	3 946	1 962	4 044	-	923
North Sumatra	6	58	108	350	-	53
West Sumatra	-	-	-	-	-	-
Riau	-	-	-	-	-	-
Jambi	1	-	3	16	-	85
South Sumatera	-	-	-	-	-	-
Bengkulu	-	-	-	-	-	-
Lampung	100	371	1 102	1 274	-	-
DKI. Jakarta	-	-	-	-	-	-
West Java	10 672	11 727	10 643	10 190	-	7 320
Central Java	2 479	3 044	3 671	3 682	-	3 180
D.I. Yogyakarta	-	-	-	-	-	-
East Java	3 587	4 024	4 070	3 975	-	5 786
Bali	-	-	-	83	-	-
West Nusa Tenggara	217	86	80	-	-	91
East Nusa Tenggara	-	-	-	83	-	-
West Kalimantan	-	-	-	-	-	-
Central Kalimantan	-	-	-	-	-	-
South Kalimantan	50	-	-	-	-	-
East Kalimantan	50	54	56	-	-	73
North Sulawesi	-	-	-	68	-	-
Central Sulawesi	-	-	-	-	-	-
South Sulawesi	1 913	2 030	2 409	2 306	-	2 213
Southeast Sulawesi	-	13	92	39	-	710
Maluku	-	-	-	-	-	-
Irian Jaya	-	-	-	-	-	-
Indonesia	22 106	25 353	24 196	26 027	-	20 434

Pond fishery, from which Indonesia can export fresh shrimp, frozen shrimp, and canned shrimp (Table 5), is an important source of foreign exchange. During the period of 1994 to 1996 there was an increase in shrimp export from 98 569 tonnes in 1993 to 99 523 tonnes in 1994 and 100 230 tonnes in 1996, while in 1997 it decreased to 93 043 tonnes.

Table 5. Indonesian export of shrimp (tonnes).

Packaging	Year				
	1993	1994	1995	1996	1997
Unfrozen	5 951	6 096	5 317	4 482	2 842
Frozen	91 224	92 401	87 695	94 504	89 529
Canned	1 394	1 026	1 539	1 244	673
Total	**98 569**	**99 523**	**94 551**	**100 230**	**93 043**

2. Extent and distribution of salt-affected soil

The extent of low tidal swamp in Indonesia is about 20.1 million ha (Widjaja Adhi *et al.*, 1992). Parts of these lands have been used for various kinds of economic activities such as annual food crop farming, plantations, fisheries, housing, etc. Data from the Ministry of Environment (Mentri Negara Lingkungan Hidup, 1996) present that mangrove forest extends in about 4.1 million ha of land distributed in Sumatra, Kalimantan, Irian Jaya, and to a lesser extent in Sulawesi. Those mangrove lands have partially been cleared for fisheries, especially for fish and shrimp cultures.

Mangrove has various environmental roles including being the source of nutrients for plankton, harbouring marine biota and protecting terrestrial areas behind it, protecting the coast from abrasion, maintaining the quality of freshwater, and absorbing different sources of contamination such as heavy metals (Cholik *et al.*, 1997).

The Map of Potential Land for Swamp Agriculture (Peta Penentuan Areal Potensial untuk Pengembangan Pertanian Lahan Rawa) with a scale of 1:500 000 (Nugroho *et al.*, 1992) indicates that the low tidal swamp lands under the influence of brackish water distributed in four major islands are as extensive as 2.6 million ha: 0.6 million ha in Sumatra, 1.1 million ha in Kalimantan, 0.3 million ha in Sulawesi, and 0.6 million ha in Irian Jaya. From that distribution Ritung dan Widjaja Adhi (1994) further predicts that land potential for development of brackish water pond culture in the four major islands is about 40 percent or about 1.0 million ha. The rest are not very suitable because of various kinds of soil constraints including high organic matter content, high potential acidity because of sulfate compounds, and coarse texture.

2.1 Typology and extent of coastal lands

In coastal lands, the soils may be classified into: (1) sandy soils, ridges or sand dunes; (2) potential acid sulfate soils with pyritic layer deeper than 0.5 m, previously called potential lands (P); (3) other acid sulphate soils grouped into AS land; and (4) peaty, shallow medium or deep peat soils referred to as G0, G1, G2 or G3 land, respectively. Coastal lands are influenced by brackish/saline water at least during the dry season. Because of that, the typology of coastal land has the symbol of P/S, denoting the effect of brackish/saline water or salt-affected soils.

Table 6. Typology and extent of coastal lands in Indonesia.

Symbol	Typology	Acreage (1 000 ha)				
		Sumatra	Kalimantan	Sulawesi	Irian Jaya	Total
Ridges	Beach ridges/dunes	77	125	54	135	391
P/S	Potential land, brackish/saline	227	17	643	1 205	2 092
AS/S	Acid sulphate land, brackish/saline	1 314	3 311	342	551	5 518
G1/S	Peat land, brackish/saline	103	-	-	-	103
Total	-	1 721	3 453	1·039	1 891	8 104

Source: Nugroho *et al.* (1992).

Land typology can be used as a guide in selecting a wise land utilisation type, in preparing and carrying out a save land development, an in adopting suitable management for farming systems. Constraints that may exist and occur during the period of land development or land management can be assessed if the land typology is known.

The acreage of coastal land typologies in Indonesia is presented in Table 6. The AS/S typology dominates the coastal lands, with a total area of 5.5 million ha and the P/S typology 2.1 million ha. The ridges and G1/S typology is 0.4 and 0.1 million ha respectively.

Some mapping units, interpreted as AS/S typology are actually associated with P/S or G1/S typology. There is no G1/S typology in the coastal lands of Kalimantan, Sulawesi and Irian Jaya because the peat soils are not separated from AS/S. The acreage of P/S typology was also small compared to AS/S, may be because of the same reason. The legend of the maps gives only a wide range of percentage occurrence of the soils, associated in a mapping unit. A re-evaluation is required to have a better proportional composition of land typology for an area.

2.2 Area and productivity of salt-affected soils in Indonesia

The major areas of salt-affected soils being used for pond culture in Indonesia are distributed in the provinces of South Sulawesi, East Java, West Java, Aceh and Central Java (Table 7). The area of salt-affected soils increased as high as 58 421 ha (18 percent) during the period from 1993 to 1997, and then decreased to 32 851 ha (8 percent) in 1998 (Table 8). The increase in salt-affected areas was not corresponding to the increase in shrimp yield and total production (Table 9). Pond productivity tended to decrease with year from 0.53 to 0.38 tonne/ha and shrimp production increased from 138 558 tonnes in 1993 to 151 086 tonnes in 1996. However, the production then decreased to 112 955 tonnes in 1997 and 117 847 tonnes in 1998. The decline in production started in 1997 mainly caused by the decrease in average yield as low as 0.15-0.17 tonne/ha (28-32 percent), although the area of production increased from 8 to 18 percent.

3. Causes and processes of salt-affected soils

Indonesia has more than 1 700 islands with salt-affected soils that are located in the coastal area (Arunin, 1995). The main cause and process of the salt-affected soils in Indonesia are due to seawater intrusion and improper management of the coastal area.

During the high tide, seawater containing sodium chloride floods into the land area and causes a rise in toxicity to plants, especially rice. Large areas of rice fields in tidal land of Java, Sumatra, Kalimantan, Sulawesi are unproductive due to the toxicity of seawater intrusion during dry season. The level of toxicity worsened during the last El Niño period during which large areas of tidal swamp were abandoned because of seawater intrusion. Improper management of coastal land can be caused by many factors such as unawareness of fishery or shrimp pond farmers of the proper management that bring about overexploitation of coastal areas. The government policy may also induce the disturbance of coastal area and lastly in larger salt-affected soils. For example, shrimp farming operation exceeding land carrying capacity in the north coast of West Java resulted in abandonment of areas of salt-affected soil. Salinization process of coastal soils in the Indonesia can be attributed to three major processes:

a) **Tidal saline soils.** These include wetland soils of the tidal plains usually of the estuarine type. Surface seawater intrusion occurs as a result of the fluctuations of tidal waters. Usually these intensify with the loss of mangroves as the natural vegetation and in some cases of marshy type. Shrimp ponds are usually developed in areas previously under mangroves. The tidal saline soils of the Upang Delta (in Sumatra), P. Petak River Basin, and the Barito Tidal Flat in Kalimantan are few of the examples.

b) **Saline wetland soils of the backswamps and lagoons.** These are the wetland soils with sub-surface or seepage as the mode of entry of salinization. The easy seepage of saline water occurs through the sand dunes or sandy natural levees of the backswamps or lagoons. Also narrow rivers facilitate the entrance of sea/brackish water into the lagoons. Shrimp pond is the common land use in this type of soil. The typical examples of this area are the Bima Gulf salt-affected area in East Nusa Tenggara Province and the Banyuasin Delta in South Sumatra.

Table 7. Area of salt-affected land by province in Indonesia.

Province	Year					
	1993	1994	1995	1996	1997	1998
D.I. Aceh	42 604	42 847	42 847	42 847	43 501	40 057
North Sumatra	11 701	6 045	6 071	6 950	22 800	9 104
West Sumatra	-	-	-	-	-	-
Riau	339	339	277	286	349	373
Jambi	34	35	36	100	500	506
South Sumatra	341	501	2 500	3 613	6 009	165
Bengkulu	53	103	170	143	163	454
Lampung	8 148	12 003	14 854	16 200	54 056	51 488
DKI. Jakarta	41	81	-	-	-	-
West Java	52 737	53 107	53 226	54 308	43 022	34 312
Central Java	28 823	28 061	28 409	27 955	29 665	25 982
D.I. Yogyakarta	-	-	-	-	-	-
East Java	61 808	60 611	60 056	60 173	58 873	59 037
Bali	705	6 977	798	678	650	627
West Nusa Tenggara	5 602	744	3 880	7 051	6 055	5 601
East Nusa Tenggara	398	5 800	347	346	434	262
West Kalimantan	-	398	241	557	610	1 367
Central Kalimantan	-	232	300	-	-	-
South Kalimantan	2 071	2 620	2 312	2 363	2 413	4 489
East Kalimantan	11 704	12 007	13 229	15 428	17 990	13 300
North Sulawesi	557	664	667	689	-	701
Central Sulawesi	18 317	5 339	6 067	5 850	6 732	6 279
South Sulawesi	79 373	84 103	84 735	84 832	84 861	90 608
Southeast Sulawesi	6 232	11 038	11 108	13 686	11 290	11 985
Maluku	22	32	32	45	45	497
Irian Jaya	151	163	173	213	164	137
Indonesia	**331 761**	**326 873**	**332 335**	**344 733**	**390 182**	**357 331**

Table 8. Shrimp culture area by province in Indonesia.

Province	Year					
	1993	1994	1995	1996	1997	1998
D.I. Aceh	38 428	37 968	39 398	38 737	38 915	35 816
North Sumatra	1 147	3 404	3 428	4 170	14 464	5 894
West Sumatra	-	-	-	-	-	-
Riau	265	265	213	219	262	288
Jambi	17	17	18	70	400	410
South Sumatra	310	456	1 750	2 529	5 462	159
Bengkulu	45	100	119	119	119	346
Lampung	7 741	11 154	13 496	14 958	20 668	41 177
DKI. Jakarta	40	79	-	-	-	-
West Java	41 160	42 081	43 270	44 310	31 116	26 627
Central Java	24 678	25 431	25 762	25 996	25 899	22 058
D.I. Yogyakarta	-	-	-	-	-	-
East Java	51 847	50 590	51 074	52 216	52 825	56 228
Bali	596	623	685	415	421	451
West Nusa Tenggara	4 865	4 859	3 225	4 936	5 615	4 859
East Nusa Tenggara	350	300	278	286	357	240
West Kalimantan	-	225	228	442	490	1 100
Central Kalimantan	-	-	230	-	-	-
South Kalimantan	1 546	2 081	1 716	1 776	1 939	3 546
East Kalimantan	8 726	8 728	10 489	11 947	13 649	8 939
North Sulawesi	444	654	552	580	-	578
Central Sulawesi	1 422	3 841	4 854	4 833	6 148	5,494
South Sulawesi	73 152	77 458	78 086	74 478	78 599	80 703
Southeast Sulawesi	4 655	8 982	9 162	9 580	9 208	10278
Maluku	20	24	24	34	34	389
Irian Jaya	146	160	171	205	151	119
Indonesia	**261 300**	**279 480**	**288 228**	**292 836**	**306 741**	**305 698**

Table 9. Area of salt-affected soil, water area for shrimp culture, yield and production of shrimp in Indonesia.

Aspects	Year					
	1993	1994	1995	1996	1997	1998
Land area (ha)	331 761	326 873	332 335	344 733	390 182	357 331
Water area (ha)	261 300	279 480	288 228	292 836	306 741	305 698
Production (tonne)	138 558	132 406	145 216	151 086	112 955	117 847
Yield (tonne/ha)	**0.53**	**0.47**	**0.50**	**0.51**	**0.36**	**0.38**

c) Seasonally saline soils. These are the soils of the coastal alluvial plains adjacent to the tidal plains and/or lagoons. Salinization occurs during the dry season when the sea or brackish water back-flow into land through the rivers and subsurface flow or intrusion into the artificial aquifers of the land. Subsequent evaporation process moves the salts to the surface. Pumping of saline water into the rice fields aggravates this process. Salt or sea spray, which results from the breaking of the wave crests, especially during typhoon surges and/or high winds, contributes further to the salinization of the rice lands. Such soils occur in all coastal areas, particularly the ones with tidal flats. In Indonesia this area is very widely distributed in the coastal plain of West Kalimantan, Central Kalimantan, South Kalimantan, West Nusa Tenggara and East Nusa Tenggara.

4. Biophysical, environment impact of seawater intrusion and shrimp farmer practices

4.1 Impact of salinity on rice production

Yields of some crops under farmers' field condition on salt-affected soil at Pendowoharjo, Delta Upang, South Sumatra, have been reported (Table 10). Satsijati *et al.* (1993) reported yield of red pepper, onions and squash/pumpkin with a range of 2.0-3.0, 3.0-5.0 and 6.0-25.0 tonnes/ha, respectively, and yield of banana was 12.4 kg/bunch.

Four best rice lines of 19 tested entries outyielded the recommended lowland rice variety, Cisadane, on salt-affected soils at Delta Upang in 1989/90 wet season (Table 11). The yield of Cisadane was only 3.3 tonnes/ha, IR 6023 was 3.1 tonnes/ha, and other four lines ranged from 3.8 to 5.1 tonnes/ha.

Table 10. Yield of some crops on a saline soil at Pendowoharjo, Delta Upang South Sumatra, 1989/90 WS and 1990 DS.

Crop	Yield	
	Range	Average
Rice, IR42, t/ha	2.4-4.8	3.7
Rice, local Tumbaran, t/ha	1.8-2.5	2.2
Mungbean, kg/ha	325-670	490
Soybean, kg/ha	465-1 150	675
Red pepper, kg/ha	326-455	390
Coconut, nuts/tree/yr	44-98	76

Under good management with sufficiently high rate of N, P and K fertilisers and good pest management, some crops have been reported to produce high yields on salt-affected soils (Ray *et al.,* 1989, unpublished). The yields were almost double of those reported in Table 10. It might be the weather and pest management that played significant roles in determining yield of crops.

Table 11. Yield of five best rice lines of 19 entries tested on a saline soil at Delta Upang, South Sumatra, 1989/90 WS.

Line	Yield (tonne/ha)
B6992-Mr-44-3	5.1
Rice11288-B-B-69-1	4.0
B6996-d-69	3.9
B5332-M	3.8
IR6023	3.1
Cisadane	3.3

Source: Subiksa *et al.* (1991).

4.2 Natural resource management in fish culture areas

Efforts in ecological management to control negative impacts of fishery sector has been initiated by Balitdita (1990) and the results indicated that the sectoral development without integrating the use of coastal land causes environmental damage in Teluk Pare-Pare, South Sulawesi. Wastes from intensively managed ponds contribute to lower environmental quality in this area. Analysis of water samples indicated that there was an increase in heavy metal concentration, i.e. 6.4-32.2 ppm of Pb and 0.23-0.46 ppm of Cu. Bacteriological analysis showed high population of *E. Coli* and Salmonella, and this is also related with the increase in the population of that area.

4.3 The impact of shrimp farming system on supra-tidal area

Areas of supra-tidal swamps are those lands only affected by very high tide, a few times per year (Purnomo, 1990). Most of those areas are used for flooded agriculture, dry land agriculture of corn, vegetables, cassava, sugarcane and coconuts. If pumping could be implemented as a water supply system, the supra-tidal areas are potentially productive for shrimp pond development. Since shrimp is a high economic value commodity, it is believed that the use of this relatively high input technique promises profits. In certain conditions, however, the pumping system may cause intrusion of seawater through highly permeable coastal levee and pond dikes in such a way that it can negatively affect the adjacent agricultural areas (Purnomo, 1990). In controlling pond salinity, the shrimp pond companies often pump up a large quantity of fresh water from deep wells in such a way that it often causes salinization in the wells not only in the fishery area, but also of the surrounding villages.

4.4 The impact of shrimp ponds in inter-tidal areas

The inter-tidal areas, which are normally covered by mangrove vegetation such as Rhizophora, Avicennia, Sonneratia, Bruguiera, Nipa and Lumnitzera, usually contain pyrite the closer the area to the coastal line. The pyrite layer could be overlaid by peat. The soils usually develop high acidity (with a pH of 2.5-5.0) soon after drainage. Acidity could increase after the pyrite undergoes oxidation process following drainage.

The pyrite is formed under the following reaction under anaerobic conditions with the influence of *Desulfovibrio desulfuricans* and *D. maculatum* bacteria:

$2CH_2O + SO_4^{2-} = H_2S + 2HCO_3^-$

Reduced iron (ferro) compounds contained in soil sediment react with sulphide under anaerobic conditions as follow:

$Fe(OH)_2 + H_2S = FeS + 2H_2O$
$FeS + S = FeS_2$ (pyrite)

Pyrite oxidation occurs naturally according to the processes below:

1. $2FeS_2 + 7O_2 + 2H_2O = 2Fe^{2+} + 4SO_4^{2-} + 4H^+$
2. $4Fe^{2+} + O_2 + 4H^+ = 4Fe^{3+} + 2H_2O$
3. $Fe^{3+} + 3H_2O = Fe(OH)_3 + 3H^+$
4. $4FeS_2 + 15O_2 + 14H_2O = 4Fe(OH)_3 + 8SO_4^{2-} + 16H^+$

In this oxidation process *Thiobacillus thiooxidans* and *T. ferrooxidans* play important roles. The $Fe(OH)_3$ is usually found at the bottom of the ponds and along the dike base following the pond drainage. Light yellow colour of jarosite $[K/NaFe(OH)_6(SO_4)_2.H_2O]$ at the dike is an indicator that the pond is constructed on acid sulphate soil. This results in poor quality of the pond water and in turn affects shrimp growth. Rectification of acidification is done through reclamation measures.

5. Technology applied for combating salinization

Reclamation of swamplands is mainly done through water management/drainage systems. Basically, there are three drainage systems used in Indonesia: (1) traditional system, known as 'parit kongsi' (community drainage system) in Riau or 'handil' in South Kalimantan; (2) fork system, designed by the University of Gadjah Mada; and (3) perpendicular drainage system, practised in South Sumatra. Modifications on specification and combination of the last two systems have been practised in several locations in such a way that it is difficult to differentiate their basic features.

To overcome salinization caused by seawater intrusion, flat gate and collector canal are normally used. This system is used, for example, in Karang Agung transmigration area, South Sumatra.

5.1 Delta Upang site, South Sumatra

Brackish/saline water intrusion occurs every dry season, from July to October. The electrical conductivity (EC) increases resembling that of the coastline. At the depth of 60 cm at Pendowohardjo, near the coastline, the measured EC was 6.0 dS/m. Under reductive condition, the soil pH was 5-6, but under oxidisedd condition, the pH fell to less than 3.0. The concentration of Na also increases toward the coast, i.e. at Purwodadi 0.6-0.8 percent, Makartijaya 1.4 percent, and Pendowohardjo 2.7-3.4 percent (Widjaja Adhi, 1996).

Land utilisation type adopted by farmers depends upon the tidal- and soil types. On a potential acid sulphate soil (with pyritic layer deeper than 50 cm), lands of a tidal type are used for 'sawah', lowland rice fields, and of B tidal type for rainfed sawah or 'sorjan', a shrunken raised bed system. The B/C or C tidal type lands are usually transformed into a sorjan system. Actually even the C tidal lands can directly be used for rainfed sawah if stop logs are built to hold water in the tertiary canals. Part of home yards are used for fish ponds, or for planting vegetables, fruit crops, coconuts; and forages, local chicken, ducks, Bali cattle, and goat are promising in the area. The shelter for the poultry is recommended to be built above the fishponds. The system is called 'longyam' for the chicken-fish system, and 'longtik' for the duck-fish system..

5.2 Sebakung site, East Kalimantan

The primary drainage canals are directed to the sea with flap gates that prevent seawater from coming in and let water drain out of the scheme. The drainage system is normally used for this purpose, but consideration should be taken not to let the water level in the canals to be very low or the canal be dried showing cracks at many places, as occurred in the long dry season of 1994.

In this area, pyritic layer is actually deep, more than 50 cm. The overdrained condition oxidisedd the pyrites because the groundwater fell below the pyritic layer. In 1994/95 wet season, the seedlings in nurseries died, especially those in lower parts of the area. The groundwater brought up all toxic substances, produced by the oxidation process of pyrites. This can be prevented by keeping water surface high enough in the drainage canals by constructing overflow dams at the mouth of secondary and even at the primary canals. At the mouth of tertiary canals, stoplogs are required to regulate the water level of sawah or in the soil for upland crops, but the groundwater level should always be kept above the pyritic layer.

5.3 Tabunganen site, South Kalimantan

The scheme is in salt-affected lands. The analyses of salt crusts, carefully collected from surfaces of dikes/farm roads in the dry season, showed very high contents of Al and Mg, and quite high contents of Na, Fe and NH_4 (Table 12). The Ca and K cations were low. The anions were dominated by sulphates and chlorides were only 0.6 me/litre. The analyses were carried out by diluting 1.5 g crusts in 100 ml distilled water, filtering, and the cations and anions were determined using the CSAR's procedure for water analysis.

The analyses of one composite sample from an experimental field at Tabunganen showed exchangeable cations to be dominated by Mg, being as high as 10.7 me/100g, and followed by Ca 4.3, Na 3.9 and K 0.8 me/100 g (Table 13). The soil sample was from a salt-affected land.

Farmers usually plant local varieties of lowland rice once a year, making nurseries in October, 2-3 times transplanting, and harvesting in July-August. The varieties are not only well adaptive, but also 'flexible' to the local conditions. If the field conditions are not suitable for transplanting the seedling, the farmers will postpone the work. Using local varieties, one farmer manages up to 5 ha of land, but they can only afford 0.75 ha if they plant short-duration high-yielding varieties.

Table 12. Analyses of salt crusts, collected from surface of dikes/farm roads in dry season at Tabunganen, South Kalimantan, Indonesia.

Ions	Concentration	
	me/litre	**g/100g**
NH_4	1.32	0.19
K	0.02	0.006
Ca	0.05	0.008
Mg	37.92	3.64
Na	4.23	0.78
Fe	1.43	0.21
Al	78.53	5.66
Mn	0.96	0.21
Total cations	124.46	-
NO_3	0.02	0.10
PO_4	0.07	0.048
SO_4	126.22	48.51
Cl	0.60	0.17
Total anions	126.91	-
pH of solution	3.1	-

Source: Widjaja-Adhi, (1996).

Table 13. Exchangeable cations, cation exchange capacity (CEC) and base saturation of some soils in brackish/saline tidal land.

Items	Tabunganen	Sei Kakap
Exchangeable cations (me/100 g)		
Ca	4.3	3.8
Mg	10.7	8.0
K	0.8	0.4
Na	3.9	3.7
CEC (me/100 g)	25.8	25.1
Base saturation, %	77	66

Source: Widjaja-Adhi, (1996).

5.4 Sei Kakap, West Kalimantan

The scheme is in salt-affected lands (Table 13), with a pyritic layer close to the soil surface, about 20-30 cm. There are two primary canals, one functioning as intake of freshwater from Kapuas River, located at the upper part of the scheme; and the other primarily functioning as drainage canal, located at the lower part of the scheme or closer to the coast. The two primary canals were built to connect the Kapuas and Sei Kakap

Rivers. There are flap gates at every secondary intake on the side of the primary intake, and sluice structures on the side of the primary drainage. The secondary drainage seems to be the adjustment of natural creeks or small rivers in the scheme. It is now hard to say which one is drainage or irrigation canal.

Farmers want to have canals in front of their homestead full with freshwater, whether filled by rainwater or by brackish/saline water. Redesigning and functioning works need to be carried out to meet the requirements of the people and the integrated farming system.

5.5 Pulau Nyiur site, Riau

The island is surrounded by brackish/saline rivers in a delta system of Indragiri River. The island's area is about 18 000 ha, and was previously one of the coconut producing centres. During the last several years, most of the coconut trees have not been giving promising yields. The island is often inundated by high tides of saline water. Many farmers have left their farms to work at other places.

A polder system will be constructed to control water and its salinity in order to develop the island for extensification and intensification of rice and 'palawija', especially maize and soybean. The development will be implemented in two phases: (1) a pilot project of 2 500 ha has been started as the first phase, and (2) the second phase of at least 10 000 ha will follow.

Rainwater will be kept as much as possible inside the polder by closing all outflows from the island and overflow structures at every mouth of natural creeks and canals for irrigation and drainage. To run the system might require pumps to irrigate as well as to drain. Through the process of water management, it is expected that there will be no salinity and acidity problems, since pyrite oxidation will not occur.

6. Research needs

There has not been any inventory of area and distribution of land affected by seawater intrusion. These figures deem necessary for regional planning. Observation through satellite imagery is expected to delineate land affected by salt. In addition, it is also necessary to inventory area of ponds in the inter-tidal and supra-tidal areas such that the management system could accordingly be determined. Integrated soil management research for increasing the productivity of saline soil is equally important. Furthermore, research for the selection of salt-tolerant and high-yielding rice varieties is still limited and regarded as necessary. For shrimp culture management, research on the control of pests and diseases are needed, especially for protozoa-type parasites (*Zoothanium, Epistylis, Acineta, Vorticella*), and bacteria (*Aeromonas* sp., *Vibrio sp.* and filamentous bacteria). These deseases are usually found in shrimp and prawn in Bali, East Java, West Java and South Sulawesi.

Attacks of protozoa are relatively high in ponds of Karawang, West Java. This is attributed to poor condition of ponds as indicated by organic matter accumulation derived from leftover shrimp feed and metabolism wastes especially around the feed spreading spots.

MBV (*Monodan baculo* virus) and IHHN (Infection Hypodermal and Hematopoietic Nerosis) are also found in the ponds in Karawang, West Java. IHHN is also found in the ponds of Kamal, Jakarta.

7. National agricultural plans and programme for the improvement of salt-affected soils

Currently salt-affected soils have been utilised for various economic purposes including housing, food crop agriculture, plantation, fishing, aquaculture, mining, transportation, tourism, manufacturing industries, and for defence and security. Because of this range of use, the areas are often disorderly and overly used. Coastal areas are often affected by the development in the upstream areas as well as by activities taken place in the sea. In other parts, isolation of the coastal areas and lack of infrastructures cause the people to be less developed socioeconomically. With the various uses of coastal areas, its development must integrate all of interacting sectors.

7.1 Integrated management of coastal areas

Integrated coastal area management is the one that integrates approaches of multidiscipline and multistakeholders in judicious use of scarce natural resources among beneficiaries and stakeholders by minimising the negative impacts of development. For judicious integrated management information on the ecological conditions, carrying capacity, motivation, and incentives for land users, economic setting, and strategies for creating social coherence are necessary. Research and development are needed, not only to gather information, but also to develop technical innovations (Cholik *et al.*, 1997).

Vertical integration within each sub-sector is also important. Research should take into account every aspect of agribusiness, starting from recognition of agricultural resources, production processes, post-harvest management, distribution, marketing and consumers' preferences. The vertical integration must be reflected in the multidisciplinary and multi-institutional assessment team working on common pieces of land. Expertise required in the integrated coastal area development include natural resource economics, ecology and environment, fish biology, oceanography, aquaculture, sociology, forestry and farming systems. All of these disciplines must integrate the development and utilisation of coastal line and aim at increasing the income and prosperity of the people, especially of the local inhabitants.

7.2 Ecological development of coastal areas

Eco-regional development of coastal areas is an integral part of the overall integrated coastal area management. In many cases, coordination has been weak in data gathering and analysis, planning, implementation and upscaling.

Around 65 percent of Indonesian population live in the coastal areas (Dahuri, 1996). Biodiversity of the coastal areas is very high because of variable ecosystems including supra-tidal, inter-tidal, mangrove, estuarine and delta, lagoon, marsh, coral reeves and isles. With the increasing population (215 million people in 2001) and the rapid development, natural resources in the coastal areas become increasingly important for economic sustainability. Following the eco-regional development concept, the Indonesian Agency for Agricultural Research and Development launched various farming system projects at proper economic scales with the objectives to:

a) Utilise natural resources by taking into consideration the biophysical, socioeconomic and institutional aspects.
b) Increase the income of local/traditional fishermen.
c) Accommodate the interests of various stakeholders.

These projects take into account:

a) Integrated and holistic use of coastal natural resources.
b) Characteristics of natural resources and socioeconomic conditions.
c) Site specific technology development.
d) Development of implementation modulation.
e) Development of institutions involving agribusiness.
f) Monitoring and evaluation.
g) Feed back mechanism of super-imposed research.

8. Information on the cooperative project with FAO

The purpose of the collaborative project between the FAO and the Center for Soil and Agroclimate Research (CSAR)/Agency for Agricultural Research and Development (AARD) was to carry out field trials on management practices to increase the productivity of coastal saline tidal lands (salt-affected soils) in Indonesia. The study included management techniques, land suitability for selected vegetables and fruit trees, chemical amendments, integrated plant nutrients, including organic manure, leaching requirements, land preparation, tillage practices, and planting procedures. In addition, this research studied the management of lowland soil (sawah) that is affected by the intrusion of brackish/saline water. The research was conducted in 1992-93.

Many sawah in the northeast coastal area of Java are affected by the intrusion of brackish/saline water through creeks/small rivers, especially during the dry season. The influence of brackish/saline water was studied in the delta region of Indramayu, which belongs to two districts, viz. Subang and Indramayu, of West Java.

Experiments on chemical soil amendments were conducted at two villages, namely Sukahaji and Lelea, in Indramayu District. The objective of the experiments was to find out agronomic techniques for increasing the productivity of salt-affected soils. For these experiments, the focus was to evaluate the kind and rate of soil amendment suitable for the regions. Some data are as follows:

8.1 Survey for evaluating soil salinity

A survey has been conducted in evaluating the salinity condition of soil in the northern coast of West Java, covering the coastal plains of Subang and Indramayu Districts in late

1992. The soil samples were taken from rice fields and water samples from groundwater, irrigation canal and shallow well.

8.2 Soil characteristics

The exchangeable Ca and Mg in the area are rated high and the exchangeable Na is low (Table 14). At some locations, i.e. Tegal Taman, Pasekan, Lelea, Lombang and Pusakanegara, the exchangeable Na is rather high compared to that of other locations. The increase of the exchangeable Na and Mg in the second layer of most locations showed that intrusion of seawater into the region did happen. The pH of the soil was generally close to neutral with high cation exchange capacity. The exchangeable sodium percentage was low, because exchangeable Ca and Mg were high and exchangeable Na was low in the soils. The EC also showed low values.

Table 14. Soil chemical analyses of northern part of Indramayu District, West Java.

Location	Soil depth (cm)	Sand	Silt	Clay	PH H_2O 1:2.5	EC (mmhos/cm)	CEC (me/100g)	Exchangeable cations (NH_4OAC 1N) Ca	Mg	K	Na
		%						(me/100g)			
Lombang	0-20	2	25	73	6.4	0.10	47.59	22.22	14.08	0.48	1.49
	20-40	2	24	74	7.0	0.17	49.41	23.93	14.48	0.41	2.45
Juntinyuat	0-20	3	28	69	6.4	0.13	46.94	22.87	12.69	0.58	0.69
	20-40	3	27	70	6.7	0.14	47.84	24.55	14.15	0.66	0.86
Krangkeng	0-20	3	19	78	6.7	0.14	47.84	24.55	14.15	0.66	0.86
	20-40	2	20	78	7.0	0.39	52.97	26.42	17.56	0.72	0.93
Tanjakan	0-20	3	29	68	6.6	0.21	47.29	25.26	12.42	0.35	0.93
	20-40	3	28	69	7.0	0.12	46.71	24.96	13.71	0.37	1.33
Tegal Taman	0-20	1	27	72	6.6	0.21	45.71	18.97	15.46	0.54	4.23
	20-40	0	25	75	6.8	0.39	46.13	15.89	17.42	0.66	6.47
Sukahaji	0-20	1	16	83	5.4	0.18	50.42	25.42	11.27	0.60	0.86
	20-40	0	20	80	6.3	0.32	51.38	25.37	12.47	0.59	1.52
Lelea	0-20	3	27	70	6.5	0.19	46.10	25.25	12.48	0.43	1.93
	20-40	9	29	62	7.0	0.47	43.99	23.22	12.22	0.42	2.13
Pasekan	0-20	4	34	62	6.6	0.32	46.39	211.92	12.78	0.41	1.96
	20-40	4	33	63	7.1	0.56	45.22	23.42	13.05	0.41	3.44
Pusakanegara	0-20	3	15	62	5.3	0.56	51.25	24.40	11.81	0.63	1.17
	20-40	1	17	82	5.9	0.41	50.23	24.89	14.06	0.63	1.37
Sukasari	0-20	6	22	72	5.0	0.20	42.16	19.00	8.02	0.52	0.67
	20-40	5	28	67	6.0	0.10	44.29	22.28	9.05	0.35	0.99

8.3 Water quality.

The quality of water at Kerangkeng and Tanjakan was classified as having high salinity (Table 15), under which yields of many crops are low. The salinity of irrigation water of Lelea is negligible.

Table 15. Water chemical analyses of Indramayu District, West Java.

Kind of analysis	Krangkeng[1]	Tanjakan[1]	Lelea
EC (mmhos/cm at 25° C)	5.8	6.2	1.1
PH	7.5	7.6	7.0
Cations (me/litre)			
NH_4^+	0.15	0.15	0.10
K^+	0.58	0.49	0.17
Ca^{2+}	5.75	8.09	3.62
Mg^{2+}	10.00	12.92	2.88
Na^+	41.38	41.38	4.65
Al^{3+}	0.01	0.01	0.01
Total for cations	57.87	63.06	11.43
Anions (me/litre)			
NO_3^-	0.03	0.07	0.06
PO_4^{3-}	0.00	0.01	0.01
SO_4^{2-}	13.50	9.45	7.16
Cl^-	33.50	43.80	2.00
HCO_3^-	11.08	8.88	2.72
Total for anions	58.11	62.21	11.95

[1] Groundwater

8.4 Response of rice to soil amendments

Kinds and rates of the chemical amendments did not show any significant effect to the lowland rice yields, especially in the wet season at Lelea village (Table 16). During 1993 dry season at Lelea, there were significant differences among the treatments, but no amendment treatment showed significant difference with the partial control. It means that only the blanket fertilisers of N, P and K gave different reactions and yields. The soil and water analyses indicated that there was no salinity problem at these two locations.

Table 16. Mean rice yield (t/ha) at Sukahaji and Lelea, Indramayu District, West Java.

Rate of applied amendment	Sukahaji		Lelea	
	1994 DS	1994/95 WS	1994 DS	1994/95 WS
Complete control	5.9	4.8	1.6	5.8
Partial control (PC)	5.5	4.8	3.4	5.8
PC + OM	5.3	4.5	2.8	6.2
G1	6.1	4.8	3.0	6.4
G2	6.4	5.9	3.6	6.2
G3	5.8	5.5	3.6	6.2
S1 + L1	6.2	4.5	3.6	6.7
S2 + L2	6.3	5.4	3.6	6.3
S3 + L3	5.8	5.1	2.6	6.6
AS + L1	6.1	5.2	3.6	6.4
AS + L2	6.4	6.0	3.6	6.2
AS + L3	6.1	4.5	3.6	6.4

[1] G= gypsum; S= sulphur; As = ammonium sulphate; L= lime; OM= organic matter/rice straw.

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Malaysia

Summary

Malaysia's rapidly growing population will require increasing amounts of food in the future. Although the production of certain types of food such as vegetables and fruit is expected to increase in the next ten years through an expansion in cultivated area, many other food types are being imported. The food import bill is high. To reduce food imports, steps are being taken to produce more food locally. The per capita consumption of fish is also expected to rise due to changing lifestyles. A large proportion of fish and shrimp production in the next ten years is expected to come from aquaculture.

Most of the 1.16 million ha of saline soils occur in the coastal areas. These flat, low-lying areas are ideal for the cultivation of rice and other crops if salinity can be tackled. The main cause of soil salinization is seawater intrusion, although there are examples of salinity development in areas cultivated with high-value crops using excess fertiliser under rain shelters. Shrimp culture is confined to the coastal belt where the soils are already saline, especially in the tidal zone of riverine systems. The major concern with shrimp culture is the destruction of mangrove forests, major breeding grounds of a large number of marine species. The authorities have acknowledged the importance of mangrove forests and government policy favours the conservation of the ecosystem. Although aquaculture is encouraged, its development will be strictly supervised and regulated. However, saline soils are seen as an important resource and reclamation efforts have been undertaken. Besides rice, the potential crops are coconut, oil palm and coffee, although shallow-rooted crops are not ruled out. The construction of bunds, check gates and drains is an essential feature of saline soil reclamation. For oil palm, water table control is crucial. Coconut is slightly more tolerant of seawater than oil palm. The effects of seawater intrusion in rice fields can be tackled by repeated flushing with freshwater under controlled field conditions. With this approach, the salinity level in the cultivated soil layer can be reduced considerably, increasing the yield of transplanted rice. In areas with underlying saline soils, simple flooding and flushing with freshwater helped to increase rice yields. However, in areas that are inundated for long periods, no rice crop was obtained even when lime and gypsum were added. Leaching procedures have also been developed to reduce salinity levels in soils used for the production of high-value crops under rain shelters. These procedures emphasise controlled leaching in accordance to the severity of the salinity problem.

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1. Introduction

The demand for food in Malaysia is expected to increase significantly in the next ten years, mainly because of the expected increase in population, whose annual growth rate is 2.3 percent. However, the demand for certain protein food items such as beef and fish is expected to be higher than that for carbohydrate-rich food items such as rice. These are reflected in the trends of per capita consumption of food commodities (Table 1).

Table 1. Per capita consumption of food commodities (kg/yr) (Ministry of Agriculture, Malaysia, 1999).

	1985	1990	1995	2000	2005	2010
Rice	102.2	89.8	86.9	85.7	82.8	80.4
Vegetables	42.4	45.5	48.5	52.0	57.5	63.6
Fruits	39.7	44.3	49.9	53.5	58.9	65.1
Beef	2.4	3.2	4.3	5.3	6.7	8.4
Mutton	0.4	0.4	0.6	0.6	0.7	0.7
Poultry	14.6	19.0	30.0	35.3	35.9	36.8
Pork	10.1	12.0	13.2	8.1	9.3	9.2
Eggs	11.4	15.7	16.4	16.8	17.2	17.3
Milk[1]	37.2	37.7	51.5	53.0	56.0	60.6
Fish	33.4	34.8	39.1	49.0	53.0	56.0

[1]million litres/yr.

The food import bill is rather high and is a burden to the country (Table 2). The rising trends in food imports are also reflected in the value of rice imports up to the year 2010 (Table 3). Therefore plans are being made to reduce the import of food items and increase national production. Some of the measures that are likely to be taken include the provision of cheap credit for food production enterprises, identification of food production zones in all states, consolidation of small-scale farms into large units and encouragement of research and development in fields related to food production.

The production of major food items is set to increase through both expansion in cultivated area and intensification. For example, the areas for fruit and vegetable cultivation are expected to increase by 7.1 percent and 3.0 percent per year to reach 345 126 ha and 42 100 ha, respectively, in 2000 (Government of Malaysia, 1996). In the near future, greater affluence and health consciousness will lead to higher consumption of fish.

The forecast for the production of major food commodities, 1995-2000 (Table 4), shows high growth rates for aquaculture, poultry and eggs. Future fishery products will increasingly depend on aquaculture farms rather than the sea because production from marine resources is rapidly approaching the sustainable yield limit. From 2000 to 2010, production from marine resources will grow by only 19 percent much lower than the growth rate for aquaculture production, which is 136 percent (Table 4).

Table 2. Malaysia's food import bill (Government of Malaysia, 1996).

Year	Value of food import (RM million)
1989	4 614
1994	6 667
1995	9 000

Table 3. The rice trade in Malaysia (Government of Malaysia, 1996).

Year	Local production (1,000 t)	Import (1,000 t)	Value of import (RM million)
1990	1 144	329.5	273.5
1991	1 228	404.3	361.9
1992	1 268	452.2	360.4
1993	1 274	395.9	296.0
1994	1 287	343.5	302.1

Table 4. Forecast of production of major food commodities, 1995-2010 (1 000 tonnes) (Ministry of Agriculture, Malaysia, 1999).

Item	1995	2000	2005	2010
Crops	3 110.6	3 599.1	4 353.1	5 457.8
Rice	1 372.6	1 456.8	1 512.9	1 608.8
Fruits	1 019.9	1 234.9	1 660.4	2 232.5
Vegetables	718.1	907.4	1 179.8	1 616.5
Livestock	1 400.1	1 706.3	1 979.5	2 266.8
Beef	16.9	25.5	38.7	58.6
Mutton	0.7	0.9	1.2	1.6
Poultry	687.4	1 040.0	1 166.1	1 340.5
Pork	283.4	150.0	210.0	220.0
Eggs	374.9	440.4	498.7	560.0
Milk[1]	36.8	49.5	64.8	86.1
Fish	764.5	1 012.0	1 228.2	1 500.4
Marine	631.8	756.8	825.0	899.0
Aquaculture	132.7	255.2	403.2	601.4
Total	**5 275.2**	**6 317.4**	**7 560.8**	**9 225.0**

[1]million litres

The future role of aquaculture in meeting the nation's food requirements has been discussed in the 7th Malaysia Plan (7MP – Government of Malaysia, 1996), 3rd National Agriculture Policy (3NAP – Ministry of Agriculture, 1999) and other official documents. However, there are important issues associated with aquaculture, and these mainly relate to the environment and socioeconomics. Non-governmental organizations (NGOs), academics and others have discussed socioeconomic and environmental issues. Mangrove forest destruction, pollution through discharge of pond sludge and chemicals, and the adverse effects of these on the livelihood of traditional fisherman have been voiced out.

However, not much attention has been given to soil salinization resulting from the use of seawater in aquaculture ponds, either by NGOs, people involved in the fisheries sector or soil scientists. In Malaysia, the culture of marine shrimps in freshwater areas is generally not practised nor encouraged (Liong Pit Chong, Fisheries Department, Malaysia, pers. com., 2000). But salt-affected soils, especially along the coastal areas, do exist. Shrimp ponds are mainly located in these coastal areas where the soils are already saline. Some studies related to desalinization and management of the soils have been conducted, especially in relation to crop production. The objectives of this paper are to discuss some of the issues mentioned above and highlight methods used to combat soil salinization.

2. Extent and distribution of saline soils

Along the flat coastal tracts of land throughout Malaysia, the soils are affected by seawater intrusion. Although the flat terrain and strategic location are regarded as desirable for agricultural production, especially of shallow-rooted crops, the twin problems of soil salinity and poor water quality have to be tackled first.

A large percentage of the saline soils of Malaysia occur in coastal areas close to population centres. Estimates of the extent of such soils vary according to the map used. For example, Yeop *et al.* (1982) estimated that there are 225 790 ha of saline soils in Peninsular Malaysia, and Zahari *et al.* (1987), quoting Tie and Lai (unpublished), estimated 229 440 ha of saline soils in Sarawak. A more recent exercise based on the calculation of areas of saline soils on a map showing soil distribution at the series level, yielded a total area of 1.116 million ha for the whole of Malaysia (Lim Jit Sai, Department of Agriculture, per. com., 2000). The breakdown for the different geographical regions is given in Table 5. Examples of soil series with saline properties are the Kranji series in Peninsular Malaysia, and the Belat, Pandak, Paloh, Rajang and Semera series in Sarawak. Some properties of a Kranji series soil are given in Table 6. A soil is considered saline if the electrical conductivity of the soil extract exceeds 4 dS/m, when the growth of some crops will be restricted. As electrical conductivity increases further, the range of crops whose growth is restricted widens.

Coastal saline soils are mainly associated with mangrove vegetation, although some saline soils in Sarawak are associated with Nipah palm (*Nipah fruticans*). In view of the large extent of mangrove forests in Sabah, it is no coincidence that the area of saline soils there is substantial. Many of the saline soils in Malaysia are also potential acid sulphate soils.

Table 5. Extent of saline soils in Malaysia (Lim Jit Sai, 2000, per. com.).

Region	**Area (ha)**
Peninsular Malaysia	186 523.4
Sarawak	571 078.0
Sabah	358 434.0
Total	**1 116 035.4**

Table 6. Some chemical properties of a Kranji series soil in Tanjong Piandang (Krian Plain) (after Zahari *et al.*, 1987).

Soil horizon	AC	C1	C2
Depth (cm)	0-22	22-63	63+
Clay (%)	84.4	61.7	93.7
Silt (%)	11.2	36.3	2.4
Conductivity (dS/m)	8	10	12
Sulphate (%)	0.48	0.73	0.96
Chloride (%)	1.50	2.00	2.35
Cation exchange capacity (cmol/kg)	35.8	29.6	28.68
Base saturation (%)	240	324	379

In Peninsular Malaysia, a large percentage of saline soils occur on the West Coast, whilst in Sarawak, most are found in the deltaic and estuarine areas of the Sarawak and Rajang, two of the largest river systems in the state. These soils develop saline properties due to underground intrusion of seawater and/or frequent inundation.

In Peninsular Malaysia, significant areas of saline soils occur in four major rice granary areas, namely the Muda Plain in Kedah (northwest Peninsular Malaysia), the Krian Plain in Perak (west), the Tanjung Karang Plain in Selangor (west) and the Kemubu Plain in Kelantan (northeast) (Figure 1).

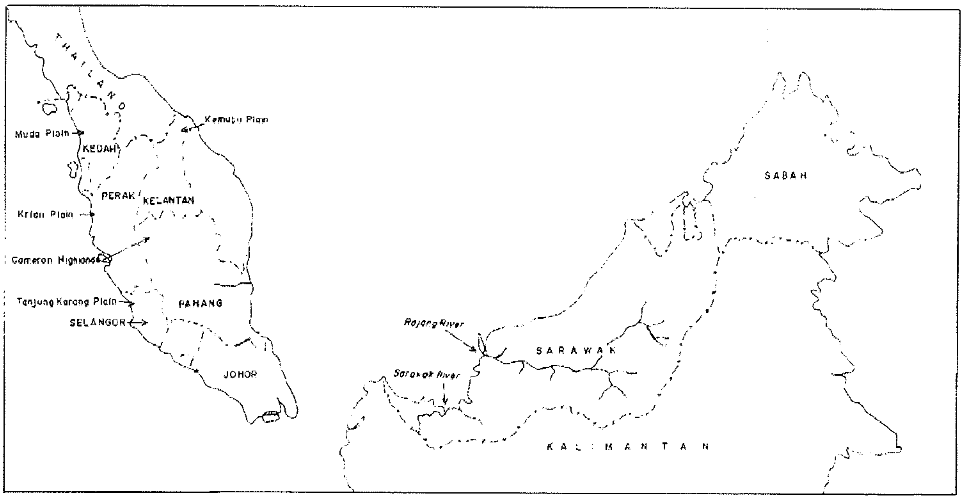

Figure 1. Map of Malaysia showing states and rice growing areas.

Underground seawater intrusion occurs in areas close to the sandy beach ridges in the East Coast. The seawater introduces chloride and other ions in the groundwater. Mohammud *et al.* (1992) found that the chloride content in the groundwater exceeded 15 ppm, the acceptable limit for the production of good quality tobacco. As the rate of groundwater extraction increases over time, soil salinity problems are anticipated to spread over a larger area.

In Cameron Highlands, in the central part of the peninsula, an increasing number of plastic 'rain-shelters' are being built for the production of high-value flowers and vegetables, with inputs of inorganic and organic fertilisers in excess of crop needs. Several years of such practices caused excessive salt accumulation in the soil, leading to the development of saline soils and adversely affecting crop performance. Similar structures are now also becoming popular among vegetable farmers in Johore and other states. Since shrimp culture in Malaysia is confined to the coastal areas where the influence of seawater is already prevalent, the problem of soil salinity associated with it appears to be largely within those areas.

3. Causes and processes of formation of saline soils

Most of the saline soils are derived from marine deposits located in low-lying areas where they are subjected to underground seawater intrusion and inundation. Being recent deposits, they show little or no profile development. The texture is uniformly clayey, though pockets of sand may be present if the soil is located near a river mouth or near a sandy beach ridge in the East Coast of the peninsula. Large amounts of decomposed and semi-decomposed organic matter, derived from mangrove roots and twigs, are present in the lower parts of the soil profile. The influence of seawater gives grey colours to the surface layers that vary in thickness from 1 to 10 cm. In Sarawak, the river basins of the Sarawak and Rajang are almost entirely subjected to periodic seawater intrusion. On drying, salinity increases at all depths of the soil profile, the degree of salinity being greater in the deeper layers.

Some of the rice-growing areas on the West Coast of the Peninsula are very close to the sea and the drainage density in several localities is lower than the recommended density of 25 m/ha. Saline soil conditions easily develop in these places.

On the East Coast, most of the tobacco farms on the sandy beach soils depend on groundwater irrigation. The extraction of groundwater, using shallow wells or tubewells, encouraged seawater intrusion into the low-lying soils.

In the intensive flower and vegetable production systems under plastic rain-shelters, saline soils developed due to prolonged exclusion of natural rainfall. Very little natural leaching occurs and therefore the excessive amounts of organic and inorganic fertilisers added accumulate in the soil.

4. Biophysical, environment impact of seawater intrusion and shrimp farmer practices

4.1 Impacts on mangrove ecosystems

One of the major concerns associated with shrimp culture (and aquaculture in general) in Malaysia is the disturbance and destruction of mangrove forests. The total area of mangrove forests in Malaysia is 641 000 ha, more than half of which are in eastern Sabah. The rest are mainly found in the West Coast of Peninsular Malaysia and in northern and southeastern Sarawak (Chew, 1997).

Reports by NGOs suggest that, by the mid-1990s, 30 percent of Malaysia's mangrove forests have been destroyed, mainly due to the expansion of shrimp culture. Many feared that more such forests will be destroyed in future because the 7th Malaysia Plan (Government of Malaysia, 1996) and the 3rd National Agriculture Policy (Ministry of Agriculture, 1999) suggest that fish (including shrimp) production in future will increasingly be in the form of aquaculture.

Mangrove forests are known for their high biodiversity. The estuaries associated with these forests and the surrounding areas are extremely rich fishing grounds. They are the natural nurseries of many species of shrimp, fish, shellfish and other marine life forms. The organic matter from the mangrove trees is an important source of food for many of these species. In Peninsular Malaysia, the significance of the mangroves is illustrated by the fact that 50 percent more fish and 90 percent more shrimp are caught on the West Coast, with 107 000 ha of mangrove forests, than on the East Coast, where the area of mangrove forests is only 4 000 ha. Fortunately, the Malaysian government has recognised the importance of the mangrove ecosystem. Statements have been made to the effect that all new development in mangrove areas is banned.

4.2 Socioeconomic impacts

The proponents of shrimp culture point to the huge potential of the industry to meet local food needs and export markets. However, there are others who think that shrimp culture ponds can only be sustained for a few years, after which self-pollution from the poor management of pond sludge will cause the business to fail.

The main socioeconomic impacts that have been documented relate to the adverse effects of aquaculture farms replacing mangrove forests. In many areas, the destruction of mangrove forests has drastically affected the breeding of fish, shrimp and other marine species, thus reducing the catch of local fishermen. For example, in the Kuala Muda area in Kedah (northwest Peninsular Malaysia), large-scale removal of mangroves resulted in a decline in fishermen's income from RM 30/day/person previously to RM 5/day/person (Raman, 1997). Some of the affected fishermen who turned to arable farming had to rent land. Rahman also reported a similar situation in a village near Sabak Bernam, Selangor (west Peninsular Malaysia). *The conversion of part of a mangrove forest near Sabak Bernam into shrimp ponds has resulted in a decline in the amounts of fish and shrimp* *caught from the sea and thus a drastic drop in the incomes of fishermen.* In Kerpan, Kedah, where about 405 ha of rice land were acquired by the government and turned into shrimp farms, farmers were unconvinced of the sustainability of the project and opposed it (Raman, 1997). It was also reported that there are cases where large shrimp farms were abandoned due to attacks by the *Manodon bacula* virus.

Other socioeconomic problems include exposure of villages to strong winds, and the effect of clearing of mangrove forests on wildlife (Raman, 1997). The clearing of mangrove forests by large aquaculture companies resulted in one village, Kampong Pengkalan, in the Kuala Muda area, being exposed to strong winds that the village houses on stilts may not be able to withstand. The loss of habitat due to forest clearing caused monkeys to 'invade' and become a nuisance to neighbouring villages.

Another negative aspect of aquaculture farms is that each farm provides jobs to only about 15 people. However, this argument ignores the fact that the aquaculture industry spawns many spin-off industries that provide business opportunities to a large number of people.

Ting *et al.* (1992) discussed the initial failure of one large-scale project that attempted to reclaim coastal saline soils for rice production. The area concerned is a 1 000 ha mangrove swamp in the Merbok estuary in the Muda Plain, where the soils are mainly potential acid sulphate soils. Construction of a bund to prevent seawater intrusion lowered the water table and thus exposed the sulphidic soil horizon to oxidation, leading to severe acidic conditions. Rice yields fell to about 1.2 to 1.4 tonnes/ha, causing many farmers to abandon their fields.

5. Reclamation of saline soils

The first step in reclamation of salt-affected is usually to construct a bund to prevent further flooding by saline or brackish water. Then, either hasten the leaching of soluble salts with good quality irrigation water, or allow leaching to take place naturally by rainwater for a few years (Ahmad, 1986). When natural leaching is allowed to take place, progressive changes in vegetation indicate the degrees of desalinization. However, the progress of leaching can also be monitored by soil analysis. In the early years after reclamation, only certain salt-tolerant rice varieties, such as those selected by WARDA (West African Rice Development Association), can be successfully grown (Ahmad, 1986).

Saline soils along the coasts of Malaysia have been reclaimed for the cultivation of rice, coconut, coffee and oil palm, with mixed success. The yield of coconut, for example, varied from nil to several hundred nuts/ha/year. It was observed that yields increased with drainage, although care must be taken not to expose pyrite (sulphidic) soil layers in the case of potential acid sulphate soils.

5.1 An approach in managing saline soils for oil palm production

Besides bunds, reclamation also involves the construction of check gates at 100 to 200 m intervals and main drains every 1.25 km. For oil palm as well as coconut production, the usual practice is to leave the land idle for one or two years before planting. During the early stages after planting, the water table is maintained almost at the surface, with frequent flushing during rainy seasons and controlled flushing during dry seasons. As the crop grows, the water table is gradually lowered. For immature oil palm, the water table is maintained at 50 cm, while for mature oil palm the water table is lowered to within the range of 75 to 100 cm depth. In Peninsular Malaysia, the primary drainage density is 1.24 m/ha while the secondary drainage density is 14.71 m/ha (Drainage and Irrigation Dept., unpublished, cited by Zahari *et al.*, 1987). Farm drains at 200 m intervals are also required to flush salts out of the soil. The bunds that act as buffers against seawater intrusion, are constructed from earth obtained when digging the drains.

5.2 Management of saline soils for coconut production by small-scale farmers

Coconut appears to be slightly more tolerant to soil salinity than oil palm. An observation by MARDI (Zahari *et al.* 1987) on saline potential acid sulphate soils at Rengit and Batu Pahat, on the west coast of Johore showed that reasonable yields of small-sized coconut, but with poor quality copra, were obtained. The farmers constructed their own system of bunds, drainage channels and small water control gates, which prevented flooding except at the highest tides. Seawater was allowed to enter the channels at high tide but restricted to a level 40 cm below the surface.

5.3 Locally developed technology to overcome soil salinity

Research involving laboratory and field experimentation has been conducted to lower the salinity level in salt-affected soils. Several techniques that have been scientifically proven, pertaining to coastal rice soils, are described below:

5.3.1 Management of saline soil in rice fields in the Muda Plain in northwestern Peninsular Malaysia (Sani Kimi, 1991).

The experiment was carried out in an area of 1.5 ha in Kuala Jerlun, Kedah. Rice was grown over four cropping seasons, viz. 1985 off-season (A), 1985-86 main season (B), 1986 off-season (C) and 1986-87 main season (D). Field preparation, pest and disease management, fertiliser application etc. were the same during all four seasons. No treatment to control salinity was given during A, B and D. But, during C, the following treatment was carried out: water was drained from the field. A week later, the field was levelled and disc-ploughed to a depth of 30 cm with a 4-wheeled tractor. A second ploughing was carried out three days later perpendicular to the direction of the first ploughing. Irrigation and drainage channels were improved. The level of drains was 15 cm lower than the field to ensure efficient drainage. A bund, 30 cm high enclosed the field. To prepare for the entry of water, two irrigation channels were kept open while drains were closed. Water was released into the field to a depth of 15-30 cm and allowed to stand for two to three days. Then it was drained. When the soil water content was at field capacity, water was again released into the field to a depth of 3-5 cm. The water used for the treatment had a salinity of 0.07 dS/m. The water level was maintained at the 5 cm depth during transplanting. Later, when plants were well established the water level was maintained at the 20-30 cm depth.

The rice varieties used were MR71 for A and B and MR84 for C and D.

The positive effects of this treatment were reflected in reduced soil salinity of the cultivated soil layer and increased rice yields. The soil salinity of the 0-30 cm layer was 6.55 and 4.30 dS/m during A and B before the treatment. During C, when the treatment was implemented, the salinity decreased to 1.85 dS/m, and rose to 3.10 dS/m in the following season (D). Salinity in the soil extract was 6.41, 4.08, 1.81 and 2.97 dS/m for A, B, C and D, respectively, again showing the reduced salinity as a result of the treatment during C (Table 7). The rice yields were 3.45, 3.88, 6.10 and 3.20 tonnes/ha for A, B, C and D respectively (Table 8), showing the positive effects of the desalinization treatment during C.

Table 7. Soil electrical conductivity at different planting seasons (after Kimi, 1991).

Cropping season	Electrical Conductivity (dS/m)		
	0-30 cm	31-60 cm	61-90 cm
A. 1985 off-season (no desalinization)	6.55	8.23	12.65
B. 1985-86 main season (no desalinization)	4.30	8.25	12.80
C. 1986 off-season (desalinization carried out)	1.85	8.10	12.60
D. 1986-87 main season (no desalinization)	3.10	8.20	12.80

The salinity of the soil layers below 30 cm remained high throughout the four seasons, being >8.1 dS/m at 31-60 cm and >12.6 dS/m at 61-90 cm.

Table 8. Changes in electrical conductivity of soil and water and in rice yield (after Kimi, 1991).

Cropping Season	Water depth (cm)	Conductivity (dS/m)		Rice (MR84) yield (t/ha)		Harvest index
		Water	Soil extract	Treatment plot	Comparison plot	
1985 off-season	10.3	2.34	6.41	3.45	3.45	0.35
1985-86 main season	10.9	1.15	4.08	3.73	3.88	0.21
1986 off-season (desalinization carried out)	20.7	0.76	1.81	4.20	6.10	0.43
1986-87 main season	11.4	0.86	2.97	4.00	3.20	0.49
Average	**13.32**	**1.28**	**3.82**	**3.85**	**4.16**	**0.39**

5.3.2 Reclamation of saline soils in three different situations (Sani and Daham, 1993).

(i) Salinization due to seawater intrusion: method of reclamation and its results.

Seawater that flowed into the Padang Garam area in the Muda Plain, Northwest Peninsular Malaysia, had EC values of 32.6-44.0 dS/m. Flushing was carried out without any land tillage to avoid salt movement into deeper layers. Field perimeter bunds were kept in good condition to ensure field water retention. It took two days to fill the 15 ha field with freshwater. The water was allowed to stay for three days, after which it was immediately drained to remove standing water and soluble salts. Three flushing cycles were carried out.

At transplanting lime was applied at 2 tonnes/ha. For comparison purposes, both transplanting and direct seeding were adopted. During plant growth, the water level was maintained at 5 cm and drying was avoided until harvesting time.

This exercise succeeded in flushing seawater from the affected areas, without much seepage into deeper soil layers. After three cycles of flushing, the water EC was reduced from 2.13 to 0.25 dS/m, and the EC of the soil saturation extract dropped from 8.02 to 3.67 dS/m. As a result of reduced salinity, the yield of transplanted rice increased from zero in the previous season to 3.87 tonnes/ha.

Direct seeding is not suitable because the soil had to be drained. Drainage led to increased salinity, adversely affecting seed germination. However, subsequent crops fared better than the first crop because of decreased salinity. The addition of lime resulted in healthier-looking crops.

(ii) Salinization associated with underlying saline soil: method and results of reclamation.

The soil at Kepala Tanjung in the Muda Plain has saturation extract EC values of 6.55 dS/m at the 30 cm depth to 15.10 dS/m at the 150 cm depth. The soil was prepared for planting in a dry condition. Lime was applied at the rate of 1.0 tonne/ha. Perimeter bunds were maintained at the 30 cm height. After field preparation, freshwater was brought in to flood the field for two days, after which the field was drained. Transplanting and direct seeding were carried out in different parts of the field. During the growth period, standing water was maintained at the depth of 5 cm. The field was later drained to facilitate harvesting.

Simple flooding and flushing managed to reduce surface soil salinity, from 6.41 dS/m (soil extract) in the first planting season to 2.81 dS/m in the third. The EC of the water dropped from 2.34 dS/m in the first season to 0.76 dS/m in the third. Rice yield increased from 3.4 tonnes/ha in the first season to 6.10 tonnes/ha in the third. These contrast with the yields from control plots that were 3.45 tonnes/ha in the first season and 4.2 tonnes/ha in the third.

Lime-treated plots produced healthier and greener plants. Lime also reduced the incidences of waterlogging, probably due to increased soil aggregation with the introduction of calcium ions. After reclamation, transplanted crops performed better than direct-seeded ones. Direct seeding became more acceptable after the salinity level has been reduced to a safe range.

(iii) Salinization due to seawater-logging: method and results of reclamation

This salinity problem occurred at Sungai Baru, in the Krian District, Perak, on the West Coast of Peninsular Malaysia. The environment is extremely saline with EC of the 0-30 cm soil layer >9 dS/m. The drainage was poor, and the fields were prepared manually since mechanisation was impossible due to the high water table and low elevation. Lime and gypsum ($Ca\ SO_4$) were added at 1.0 t one/ha each to promote flocculation and increase soil strength. Field water depth was maintained at 5 cm during plant growth. Both transplanting and direct seeding were evaluated for crop establishment. For direct seeding, the field was sufficiently drained to facilitate seed broadcasting.

Soil salinity remained high, with EC>9 dS/m in the 0-30 cm layer and >10 dS/m in the 30-60 cm layer, even after three years of rice cultivation. The crop yields were low. Soil aggregation could not be achieved in this saline environment although sufficient organic matter was present.

5.4 Desalinization of soils under plastic rain shelter (Wong *et al.*, 1999)

(i) Flood leaching

The soil was levelled and enclosed with plastic sheets. Flooding was carried out using 300 ml of water in three equal applications.

This method is very effective in removing excess salts, even at 50 percent water-to-soil volume ratio. Increasing the leaching volume to 75 percent and 100 percent ratios further reduced salinity. The desalinization characteristics assumed a quadratic profile with an initial steep decline and flattening towards the end. Salt removal was greatest in the first application of water, as most of the 'free' salt constituents were easily leached. The second and third applications removed the salts from exchange sites. The quadratic functions can be used to determine the amount of floodwater required to reduce the EC of a moderately saline soil to a targeted salinity level.

(ii) Sprinkler irrigation leaching

The entire method consisted of 24 discreet applications. Each application delivered either 13.1 or 6.5 mm of water, depending on the actual field moisture content. When the soil was saturated and runoff was high, the irrigation input was halved.

This method applies small amounts of water over an extended period. It allows more time for salt constituents to come into contact with water. The salts are gradually removed in successive waves of leaching water. The rate of salt removal was described by quadratic equations, indicating an initial rapid removal followed by diminishing rates. Increasing the leaching ratio from 50 percent to 75 percent further increased the rate of salinity reduction. But excessive removal of salts may adversely affect soil fertility. As with flood leaching, the quadratic functions can be used as a planning tool. The rate and frequency of sprinkler irrigation required to achieve a desired salinity level can be determined from the function.

6. Government policies, regulatory bodies and legislation

Agricultural development strategies, food production policies, land use and management issues and other related subjects are spelled out in successive 5-year plans, the latest being the 7th Malaysia Plan covering the period 1996-2000. Other supporting documents include the 3rd National Agriculture Policy that forecasts an increase in demand for fish (including shrimp) as a result of population growth, increasing personal incomes and greater health consciousness. The policy document also states that suitable land and water bodies exist to support further development of the aquaculture industry. It is anticipated that the contribution of aquaculture production to total national fish (including shrimp) supply will increase from 11 percent in 1995 to >30 percent in 2010. One of the strategic directions is to conserve and sustainably manage and utilise fishery resources. To rationalise resource use, identified aquaculture development areas will be zoned and provided with the necessary infrastructure and support facilities. Hopefully, this will lead to the adoption of good aquaculture practices and better water quality management. The policy also states that guidelines, regulations and codes of practice will be introduced and enforced to ensure sustainable practices. The Authorities involved are:

- Department of Fisheries is responsible for the development and management of the fishery sector. Its mission is to transform the sector into a commercial, modern and progressive industry and ensure adequate supply of fishery products to meet the nation's needs. Its scope of activities includes regulation, development, extension, research and training.

- Within the Department of Agriculture, the Soil Management Division is involved, among other functions, in soil survey, classification, reclamation and conservation. It carries out both development and extension.

- The Malaysian Agricultural Research and Development Institute (MARDI) carries out research and development on a wide range of topics including soil management, reclamation and conservation. Collaborative research involving different disciplines within the institute and with other local and international agencies is encouraged. The institute has successfully carried out collaborative research projects on soil-related topics with a number of international research organizations.

- Another important government body is the Department of Environment, which, among other functions, enforces legislation related to environmental protection. One of the important pieces of legislation is the Environmental Quality Act 1974. The Act stipulates that land-based aquaculture projects accompanied by the clearing of mangrove forests of 50 ha or more must be subjected to an EIA (environmental impact assessment). However, various parties have pointed out several loopholes in the Act. One is that the '50 ha limit' will encourage the clearing of 49 ha or less initially, with a view to an expansion in the future. The emphasis on 'land' and 'mangrove forests' may be taken to mean that inland aquaculture projects do not require EIAs.

A common problem in the enforcement of legislation pertaining to the use of land is the fact that state governments have full control over land matters. Legislation concerning land matters, passed by the Federal Parliament, will need to be adopted by the State Legislative Assembly before it can be implemented in a particular state. Furthermore, conflicts may arise over the different jurisdictions of federal and state departments.

7. Proposals for future work

In most countries of the region there are substantial areas of salt-affected soils strategically located near population centres and where topography does not pose a hindrance to agricultural production. Besides being close to markets, good communication networks can be easily established. It is logical that concerted efforts are made to find ways of productively utilising these soils. Initial focus should be on identification and management of the soils as well as on conservation of affected ecosystems. Other factors that should be looked into are:

- Location of shrimp ponds vis-à-vis mangrove forests.
- Sustainable management of shrimp ponds.
- Properties and potential uses of shrimp pond sludge.
- Management of salt-affected soils to improve rice production.
- Sustainable production of shallow-rooted crops such as vegetables in salt-affected soils.
- Selection of tolerant crops/varieties.
- Reclamation processes including leaching and bio-drainage.
- Irrigation management under saline conditions.
- Social, economic and environmental implications of reclamation.

Conclusion

Salt-affected soils occupy a sizable area and can be considered as a potential resource for food production. Their reclamation and management are important issues and merit more research and development.

The future will see more aquaculture farms. Sustainable development and management of these farms, as well as conservation of mangrove forests, are factors that need to be carefully considered to ensure sustained long-term production of fish and shrimps.

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Pakistan

Summary

Pakistan covers about 88 million ha of land area containing six different physiographic units: the northern high mountains (ranges of Karakoram, Hindu Kush and the Himalayas); the Potowar Plateau; the Salt Range; the Balochistan Plateau; the Indus Plains; and the desert area of Thal and Cholistan. The climate of the country can be classified as arid to semi-arid with low and highly variable rainfall over most of the country.

About 22 million ha land area are currently under crops, one-fifth of which is rainfed. Except for the plateaus and mountainous areas, groundwater is used only as supplemental source of irrigation water either directly or after mixing with canal water. Use of mostly untreated sewerage water for crop production is limited to areas around big cities for growing vegetables. Inadequate supply of irrigation water at critical times of growth, lack of drainage, saline and saline-sodic soils, low quality seeds, antiquated farm implements, imbalances in farm inputs, unsatisfactory agricultural and irrigation practices are some of the problems affecting yields. Since the introduction of canal irrigation, waterlogging and soil salinity have become the number one problems impeding agricultural growth.

The very severely, severely, moderately and slightly salt-affected soils are respectively spread over about 2.0, 2.4, 1.2 and 0.6 million ha. These include gypsiferous and non-gypsiferous soils. Surface salinity in the irrigated areas has been observed to spread over about 4.2 million ha. Secondary salinity due to human-induced causes is related to excessive seepage from canals resulting in water table build-up, lack of drainage, use and reuse of poor quality groundwater for irrigation, insufficient leaching and poor land management practices. Besides reduced crop yields, desertification and land going out of production, the impact on local population due to salinization has been observed to be poor living conditions, health problems, crumbling mud and brick houses, reduced life expectancy in females, and difficulties in transport and communications.

Despite the large extent of salt-affected soils and availability of poor quality groundwater in the inland and coastal areas, shrimp farming is currently not practised anywhere in arable lands. With a long coastline of about 1 000 km, shrimp farming on a large scale is considered economically feasible according to studies done by the National Institute of Oceanography (NIO). However, its technical and economic viability/feasibility in the arable areas has not been studied.

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Approaches tried in Pakistan to control and arrest salinity problems are: i) commissioning of large salinity control and reclamation projects (covering about 8 million ha); ii) leaching of salts by applying increased water, chemical amendments, organic wastes and plants (small local level interventions); and iii) promoting saline agriculture without reclamation. The sustainability of the first approach used since early 1960s is becoming highly questionable. The saline agriculture and promotion of salt-tolerant varieties for crops, grasses, bushes, trees, etc. has proved very successful and is now being further tested on larger scales.

The R&D infrastructure in the country for salinity and waterlogging includes the Drainage Research Center at Tandojam (Sind), the International Waterlogging and Salinity Research Institute, the Punjab Directorate of Land Reclamation and the Mona Reclamation Experimental Station. For studying the feasibility of shrimp farming on a large scale the National Institute of Oceanography has done some pioneering work. It has been estimated that, through appropriate farming techniques, the export earnings from shrimp can be increased to US$20 million per year.

1. Introduction

The Islamic Republic of Pakistan is situated in South Asia between longitudes 61° and 76° E and latitudes 24° and 37° N. The geographical area of the country is about 88 million ha including the Federally Administered Northern Areas (FANA). The country is bounded by the People's Republic of China on the north, India on the east and southeast, Afghanistan on the northwest, Iran on the southwest, and the Arabian Sea on the south. It comprises the provinces of the Punjab, Sindh, Balochistan and the North West Frontier Province (NWFP). The coastline of Pakistan on the Arabian Sea is about 1 000 km long.

Physiographically, the country can be divided into six major units: the northern high mountains (ranges of Karakoram, Hindu Kush and the Himalayas), the Potowar Plateau, the Salt Range, the Balochistan Plateau, the Indus Plains, and the desert area of Thal and Cholistan (Figure 1). There are three main hydrological units, viz. the Indus Basin, the closed basin of Kharan Desert in Balochistan and the Makran Coastal Basin. The irrigated areas of the country fall in the vast plains of the Indus Basin, which are formed of river-deposited alluvium.

The climate of Pakistan can be generally classified as arid to semi-arid. It, however, is highly variable and is characterised by large spatial, seasonal and diurnal fluctuations in both temperature and precipitation. The precipitation in the lowlands mostly occurs in the monsoon months of July-September and varies from less than 100 mm in the south to over 1 000 mm in the north. A distinct feature of the monsoon torrential rains is that it may produce one-third of the annual rain in a single day. The characteristic features of the tropical coastal areas are high humidity, medium temperatures, and low rains throughout the year.

2. Population and food security

The recorded current population of the country according to the 1998 census is 130.6 million (population density 164 persons/sq km) with about 68 percent of people living in the rural areas. Table 1 gives the province-wise details of the population growth in Pakistan. The high population growth rate of 2.61 percent per annum since 1981 has led to an increase in food demands and has thus put greater pressures on the agriculture sector to produce more.

The pattern of rural life in Pakistan has changed considerably since 1947. The number of non-farm families including livestock holders in the country has increased considerably and mechanized farming has gradually replaced animal driven power for cultivation. The latter change has been responsible, to some extent, for displacing tenants and agricultural workers. However, the change has been offset by the growing diversified rural sector offering more opportunities for off-farm works.

Table 1. Population details by provinces.

Province/ area	Population (million)		Annual Growth rate (%)	Male/female ratio		Density per km^2		Urban population (%)	
	1981	1998		1981	1998	1981	1998	1981	1998
Punjab	47.29	72.59	2.55	111	107	230	354	27.6	31.3
Sind	19.03	29.99	2.71	111	112	135	213	43.3	48.6
NWFP	11.06	17.56	2.76	109	104	148	236	15.1	16.9
Balochistan	4.33	6.51	2.43	112	115	12	19	15.6	23.3
FATA*	2.20	3.14	2.11	108	109	81	115	-	2.7
Islamabad	0.34	0.80	5.16	119	116	376	882	60.0	65.6
Pakistan	**84.25**	**130.59**	**2.61**	**111**	**108**	**106**	**164**	**28.3**	**32.5**

Source: Population Census Organization, 1998.
* Federally Administered Tribal Areas

Table 2 gives the production and domestic demand for 1993 and the projections for the year 2000 as estimated by the National Commission on Agriculture. These estimates were based on the assumption that the population growth rate would reduce to 2.5 percent by the year 2000, which, apparently, now appears to be justified as at that time a growth rate of 3 percent was generally taken as representative. The estimates indicated increasing shortfalls in production of sugar, maize, edible oil, meat and pulses to meet the national demands.

Table 2. Projected domestic demand and production of agricultural commodities (million tonnes).

Crop	1993			2000		
	Production	**Domestic demand**	**Excess/ shortfall**	**Production**	**Domestic demand**	**Excess/ shortfall**
Wheat	16.38	14.70	+1.68	20.48	18.20	+2.28
Rice (Basmati)	1.29	0.74	+0.55	2.05	1.03	+1.02
Rice (other varieties)	2.93	1.67	+1.26	3.32	1.78	+1.54
Cotton	1.65	0.88	+0.77	2.07	1.22	+0.85
Sugar (refined)	2.05	2.30	-0.25	2.87	3.19	-0.32
Edible oil	0.66	1.46	-0.80	1.02	1.94	-0.92
Maize	1.47	1.62	-0.15	1.98	2.18	-0.20
Millet/sorghum	0.70	0.70	-	1.10	1.10	-
Pulses	0.65	0.90	-0.25	0.71	1.05	-0.34
Meat	1.43	1.70	-0.27	2.18	2.63	-0.45
Milk	16.60	16.47	+0.13	23.00	23.00	-
Fruit	5.00	4.83	+0.17	7.80	7.46	+0.34
Vegetables	4.67	4.57	+0.10	8.00	7.76	+0.24

Source: National Commission on Agriculture, Ministry of food and Agriculture, Government of Pakistan.

Agricultural productivity and total production had been showing a marked increase during the two decades of 1960s and 1970s. This was made possible due primarily to the increase in availability of water at the farm gate, introduction to high-yielding variety (HYV) technology, increase in cropped area, and the consistently increasing use of agricultural inputs like improved seeds, fertilisers and pesticides. The construction of Mangla and Tarbela dams, some of the largest earth-fill dams in the world, and groundwater pumping increased water availability by about 40 billion cu m from 1960 to 1975. The cropped area under canal irrigation also increased by about 8 million ha in the same period. However, the trend of increased agricultural productivity attained cannot be maintained, as the chances of further increases in irrigation water are limited. Thus, it will not be possible for crop production to keep pace with the population growth in the future. Despite current surplus in wheat, rice, cotton, fruit and vegetables, it is feared that without a drastic and revolutionary change in the current system of water management to increase production per unit of water used, the country may face severe food shortages in the next couple of decades.

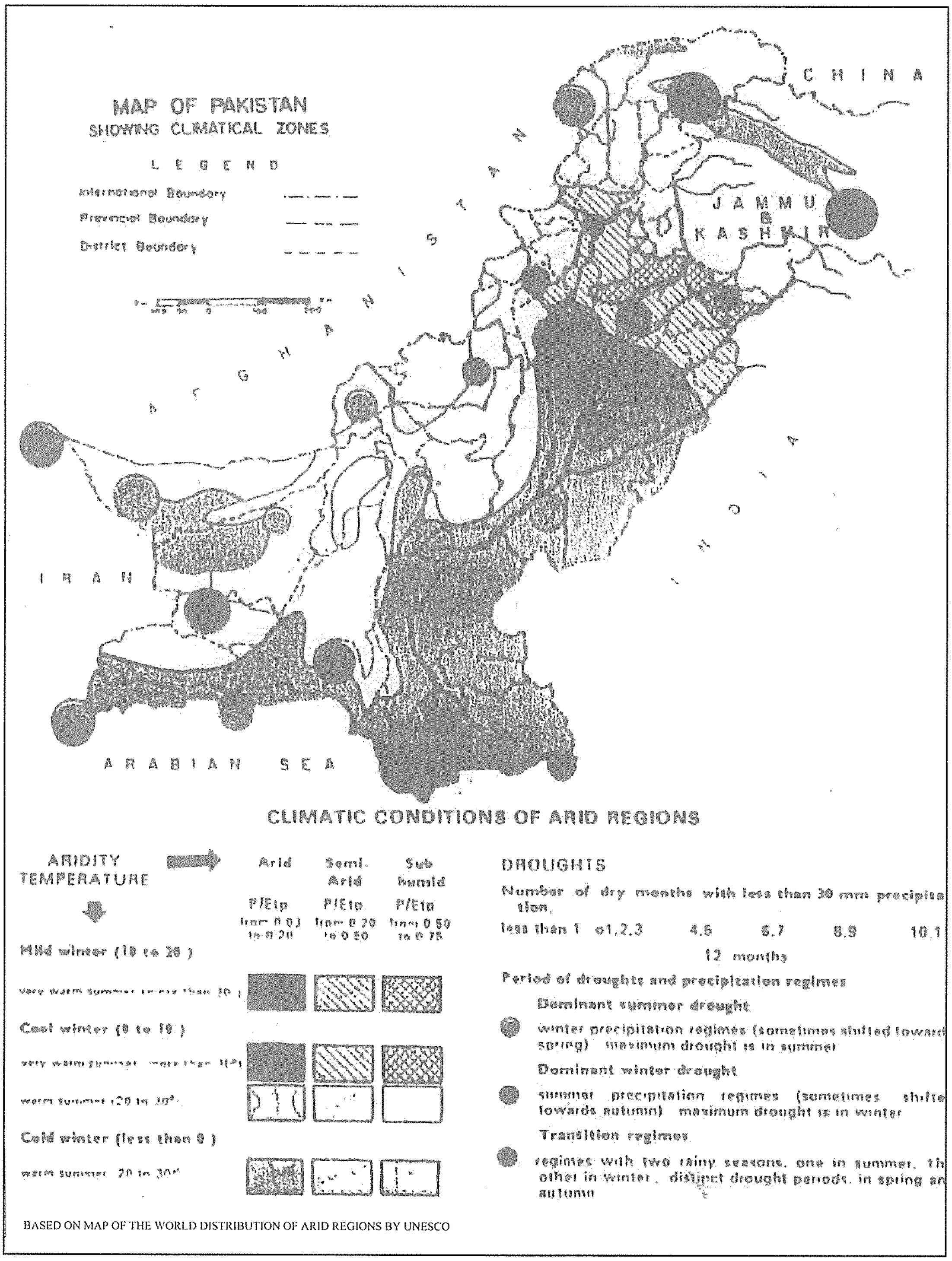

Figure 1. Climatic zones of Pakistan.

2.1 Soils

The Soil Survey Project of Pakistan has surveyed over 80 percent of the total area of the country and has established about 400 different soil series. Of these, some occupy extensive areas whereas others are of limited extent. The texture of majority of the soils is medium to fine with illite as the dominant clay material. The CEC of the soils ranges from 5 to 20 meq/100g. The pH in the bulk of the soils varies from 7.8 to 8.4 though values of 5.0 and 10.5 have also been recorded. The soils are characteristically deficient in nitrogen, organic matter and available phosphorus. Almost 2.2 million ha of cultivated land (mostly sandy soils) suffer from nutrient deficit.

Table 3. Land capability classification in Pakistan (1989).

Class	Description	Area (million ha)	Soil limitation	Production potential
I	Very good agricultural land	5.2	No problems for general agriculture. Highly permeable.	Very high for general agriculture. Moderate for rice cultivation.
II	Good agricultural land	7.0	Minor problems of erosion, surface relief, patches of salinity etc.	High for general agriculture. Moderate for rice cultivation.
III	Moderate agricultural land	4.8	Moderate problems of erosion, waterlogging, flooding, salinity and sodicity, erosion and texture.	Moderate for general crops. Moderate to high for rice cultivation.
IV	Poor/marginal agricultural land	3.0	Severe problems of aeration, salinity and sodicity, erosion and texture.	Low for a few crops only.
V	Good forest or rangeland	0.2	None/minor problems for rangeland development.	High for forestry or range development.
VI	Moderate forest or rangeland	1.3	Moderate problems of erosion, relief, texture, etc. for rangeland development.	Moderate for forestry or range development.
VII	Poor forest or rangeland	15.4	Moderate to severe problems of erosion, soil depths, aeration, salinity and sodicity, etc.	Low for forestry or range development.
VIII	Non agricultural land	23.2	Severe problems of erosion, marshes, soil depth, salinity and sodicity, snow/ice cover, etc.	None for any type of economic agriculture use.
VIII	Unclassified	1.8		
Total area surveyed		61.9		
Area not surveyed		26.3		Mainly barren or land not accessible
Grand total		**88.2**		

Source: Mian and Javed (1989).

2.2 Land use capability

According to the most recent soil survey covering about 72 million ha of total land area of Pakistan, about 20 million ha are classified as cultivable. This includes 18 million ha of irrigated and 4 million ha of rainfed areas. The survey has enabled integration of the data on soils with climatic, biophysical and hydrological information. As a result, about 750 different soils have been grouped into eight land capability classes with respect to potential for agricultural production (Table 3). The proportion of cultivable land is not anticipated to increase much as the unsurveyed area of 26.4 million ha consists mostly of barren and inaccessible mountains and deserts. Much of the land suffers from water erosion (11.2 million ha), wind erosion (4.8 million ha), and by salinity and sodicity (5.3 million ha). The area affected by waterlogging (water table being within 1.5 m), on the average, is estimated at 2.1 million ha. The organic matter content of most of the arable soils is low.

2.3 Agriculture

Keeping in line with growing economies of the world and structural changes in the national economy, the share of agriculture has been showing a decreasing trend. From a share of 35 percent (employing 57 percent of labour force) in the Gross Domestic Product (GDP) in 1962, it is now estimated to be about 25 percent (employing < 50 percent of labour force). Despite this decrease in share, agriculture is still the single largest sector of Pakistan's economy. With 70 percent of export earnings, this sector remains to be the single major earner of foreign exchange for the country.

An increase in output and production aiming at self-sufficiency in food with agriculture output growing at a rate of about 4 percent has been observed since mid-1960s. However, while per hectare yields continue to remain among the lowest in the world, the overall increase in production has been made possible by the increase in area under cultivation and the increased intensity of resource use. The major factors responsible for low yields are waterlogging, salinity and sodicity in irrigated areas, unscientific irrigation and agricultural practices followed by the farming community, and low level of agricultural inputs.

In the irrigated areas of the country particularly in the Indus plains, two main cropping seasons are followed. These are the 'kharif' – the summer season from April to October and the 'rabi' – the winter season from October to April. Important crops sown in summer are cotton, rice, maize and sugarcane. In winter, the major crops are wheat, gram, barley, tobacco and oilseeds. The extent of irrigated areas (perennial and non-perennial) is estimated at 18 million ha.

In other areas like in the uplands of Balochistan, the climate is highly suited to production of high value deciduous fruits like apples, cherries, pomegranates, peaches, plums, apricots and almonds. Dates and coconuts are the major produce of the coastal and some inland areas where climate is suited for the purpose.

The active flood plains of the Indus River and its major tributaries total about 2 million ha. Within this area, about 1.2 million ha are under crops. Agriculture is practised in rabi season and is dependent on residual soil moisture and high water table after flooding. In some more elevated areas, Persian wheels and tubewells are utilised for using groundwater as a source of irrigation. The water pumped is generally sweet and suitable for irrigation.

The hill torrents are a serious problem in D.G. Khan, D.I. Khan, Kachhi Plain, Makran coastal areas and in the Potowar Plateau. The use of this water for agriculture is often not practised, as the flows are flashy, uncertain and highly variable in space. The total area under crops using hill torrent flow is estimated to be around one million ha.

The rainfed areas of the country with agricultural potential are estimated to be about 5 million ha. Currently almost all the area is being cultivated with varying degrees of success. Problems of soil erosion, fragmented and small landholdings and use of traditional technology have prevented the full exploitation of the available potential for agricultural production in these areas. As a result of several projects, the area under cultivation has increased by 100 percent since 1977. Erosion has been controlled to a large extent besides reclamation of much of eroded area and agricultural extension and credit facilities have been strengthened.

Urban sewerage effluents are mainly used for vegetable production on limited area near large cities; however, the effluents used are raw and in untreated form creating serious health hazards. There are no estimates of the area under such irrigation practices, but except for the health-related issues its impact on national economy is considered insignificant.

2.4 Irrigation system

The irrigation system of Pakistan – the largest contiguous network in the world – serves almost 18 million ha of land area. The system is fed by the Indus River, its tributaries and the deep groundwater aquifer underlying the alluvial deposits. The irrigated area has considerably increased (from 10 to 18 million ha) since 1960 due to the construction of big reservoirs, expansion of the canal irrigation system, and increased exploitation of groundwater. Table 4a shows the province-wise expansion in irrigated area of Pakistan since 1960-61. Most of the increase from 1960 to 1975 is attributed to the commissioning of the multipurpose Mangla and Tarbela dams, making more water available at the farm gate. The expansion since 1975 is due to exploitation of groundwater. The extent of irrigated area under different sources of irrigation is given Table 4b.

On the average, the total riverwater available for exploitation in the Indus Basin is estimated to be 165-173 billion cu m (bcm) per year out of which about 15 bcm is lost in the river system by evaporation and conveyance. The system, consisting of 3 major reservoirs, 19 barrages, 12 inter-river link canals, and 43 independent irrigation canal commands, diverts about 130 bcm of water annually. After accounting for about 12 bcm that must continue to flow into the sea to maintain the ecosystem in the Indus Delta and other conveyance and field application losses, exploitation of the remaining 8-16 bcm of water, which is mostly monsoon run-off, would need construction of additional reservoirs.

Table 4. Growth in irrigated areas and sources of irrigation (million ha).

a) Growth in irrigated areas.

Year	Punjab	Sind	NWFP	Balochistan	Total (Pakistan)
1960-61	-	-	-	-	10.40
1970-71	-	-	-	-	11.48
1980-81	10.50	3.07	0.74	0.53	14.84
1985-86	11.41	3.05	0.82	0.51	15.79
1990-91	12.63	2.64	0.84	0.64	16.75
1995-96	13.56	2.29	0.88	0.85	17.58
1997-98	13.66	2.56	0.94	0.84	18.00

b) Extent of irrigated area under different sources of irrigation (1997-98).

Province	Canal	Tubewell	Wells	Others	Total
Punjab	4.08	9.27	0.24	0.07	13.66
Sind	2.43	0.13	-	-	2.56
NWFP	0.78	0.09	0.04	0.03	0.94
Balochistan	0.50	0.25	0.01	0.08	0.84
Total Pakistan					**18.00**

There are some inherent problems in the irrigation system such as constant inflexible flow, lack of drainage network, excessive system losses, and poor operation and maintenance. A significant portion (25 percent or 32 bcm) of the diverted water is lost in the conveyance system from the canal head works to the fields due to seepage. The losses in the field (farmer maintained water channels and application losses) due to poor farm layouts, unlevelled fields and wasteful irrigation practices are estimated at 45 percent or 43 bcm. Part of the losses is however recouped by private and public tubewells.

2.5 Coastal and marine resources

With a long coastline, Pakistan's coastal resources are abundant but under-utilised. The fresh water zone of the Indus Delta abounds in aquatic vegetation (mangroves), while algae and seagrass dominate areas further down the sea. Salt-tolerant xerophytic species are prevalent in the coastal lands affected by salinity. The mangroves provide a good breeding habitat for the complex community of invertebrates, fish, birds and reptiles. However, little emphasis is placed on the conservation and management of mangrove habitats.

2.6 Fisheries and shrimp farming

The contribution of fisheries sector to the national economy is small and accounts for about 0.8 percent of the GDP. Its contribution to the export earnings is, however, significant (3-5 percent or 80 percent of the total earnings from the sector) due mainly to the strong international demand for shrimp, which is the major export commodity in the sector. Despite the importance of the shrimp market and the earnings it can make through exports, shrimp have been harvested without consideration of the life cycle stages needed in order to maintain their sustainable yields. This resulted in the catch of large and medium sized shrimps to collapse during 1980. However, since then the government has been making efforts to ameliorate the situation through pilot projects and experimental stations.

Despite huge potential it offers for export earnings, shrimp farming is not practised in Pakistan, either in the coastal or inland areas on a commercial scale. The industry is limited to the catch of wild shrimp only. According to estimates, the total wild catch of shrimp (15 different species of marine shrimp) is about 30 000 tonnes/year, which are not likely to increase in the future. It is pointed out that the best species *(Penaeus monsoon)* for shrimp farming is not commonly available in Pakistani waters.

There are several distinct areas along the southern coastline, which are suitable for shrimp farming. The National Institute of Oceanography (NIO) has identified these areas as the Indus Delta, Miani Hor and Kalmat Khor. Inland fish farming is becoming a roaring business in the waterlogged areas near rivers, with over 4 000 fish farms covering estimated 6 000 ha of land.

Shrimp culture on small scale was first started in Pakistan in 1982 when the Fisheries Department of the Government of Sind started a shrimp farming pilot scheme on Richal Creek, Garo as part of the Asian Development Bank (ADB) financed aquaculture development project. The NIO is focussing attention on shrimp farming in the coastal areas to increase exports and boost the national economy. Private investors also have been trying to develop shrimp culture on a small scale. Prominent among these are Lipton Farm (12 ha), Baluch Farm (5 ha), and Mansur Sharif Farm (20 ha). The Lipton Farm, in particular, has demonstrated technical viability of aquaculture in Pakistan. Its continued successful operation has demonstrated the technical and commercial feasibility based on local materials and expertise.

The NIO conducted some experiments to gain knowledge on rearing shrimp, larval growth, and the favourable conditions required for maximum growth. Studies were mainly concentrated on the technical problems that might be encountered in shrimp culture in ponds within the final reaches in the Indus Delta.

2.7 Production constraints

The major constraints in achieving potential production from agricultural lands in Pakistan are as follows:

Waterlogged, saline and saline-sodic soils. The extent of the problem is described in detail in subsequent sections.

Lack of proper drainage facilities. The irrigated areas are without complementary drainage systems in most parts. This creates problems with respect to salt build-up in the root zone and makes leaching difficult.

Inadequate (in general and at critical time of growth in particular) and unequal distribution of water. In the existing rotational system of irrigation called *warabandi*, the tail water users receive less than their due share of water because of huge conveyance losses in the system.

Inadequate and low quality agricultural inputs like seeds, fertilisers, and plant protection practices.

Unsatisfactory, primitive and run-of-the-mill agricultural and irrigation practices.

Erosion of productive lands due to wind and water.

Lack of basic shrimp farming technology, lack of shrimp hatcheries and feedings and the adverse climatic factors prevailing in the coastal waters.

3. Extent and distribution of waterlogging and salinity

Waterlogging and salinity have been haunting irrigated agriculture in Pakistan for over last four decades. Waterlogged soils in irrigated areas have resulted from excessive seepage from the canal system and field application losses. In addition, cultural practices like growing improper crop selection have also contributed to the build-up of the water table.

Salinity and sodicity affect a considerable part of the cultivated areas of the country. The problems are both of primary (due to natural processes) or secondary (due to man-made interventions). It has been observed that though primary salinity has been quite widespread, secondary salinity, which is responsible for rendering considerable fertile areas to go out of production, was brought about due to the absence of enough water for leaching salts from the root zone.

3.1 Extent of waterlogging

The water table in the irrigated areas follows an annual cycle of rise and fall. The lowest water table is just prior to the monsoon season (June) and rises after the monsoon season is over (October). Though transitory in nature, high water table conditions after October interfere with the rabi cropping season, as the water table recedes only slowly. It is estimated that about 8 million ha of land area are affected by waterlogging (water table within 3 m of soil surface) throughout the year (Table 5a). The disaster area (water table within 1.5 m) is estimated around 2 million ha (Table 5b). In October, the extent of waterlogged area rises to about 9 million ha (water table within 3 m) and 5 million ha (water table within 1.5 m).

Table 5. Province-wise extent of waterlogging for the years 1990-1994 (million ha).

a. Water table within 3 m.

Province	1990		1991		1992		1993		1994	
	June	**Oct.**	**June**	**Oct.**	**June**	**Oct.**	**June**	**Oct.**	**June**	**Oct.**
Punjab	3.10	N.A.	3.51	3.55	3.16	4.05	3.23	3.74	2.84	3.71
Sind	4.78	N.A.	4.79	N.A.	4.91	5.25	5.02	5.05	4.76	5.22
NWFP	0.18	N.A.	0.20	0.21	0.20	0.21	0.20	0.21	0.20	0.21
Balochistan	0.17	N.A.	0.18	N.A.	0.21	0.20	0.20	0.19	0.19	0.24
Total Pakistan	**8.23**	**N.A.**	**8.68**	**N.A.**	**8.48**	**9.71**	**8.65**	**9.19**	**7.99**	**9.38**

Water table within 1.5 m.

Province	1990		1991		1992		1993		1994	
	June	**Oct.**	**June**	**Oct.**	**June**	**Oct.**	**June**	**Oct.**	**June**	**Oct.**
Punjab	0.71	N.A.	0.77	0.97	0.64	1.25	0.64	1.12	0.58	0.98
Sind	1.35	N.A.	1.27	N.A.	2.23	4.08	1.94	3.63	1.30	4.06
NWFP	0.05	N.A.	0.05	0.07	0.05	0.06	0.04	0.06	0.04	0.06
Balochistan	0.09	N.A.	0.08	N.A.	0.14	0.14	0.09	0.12	0.07	0.15
Total Pakistan	**2.20**	**N.A.**	**2.17**	**N.A.**	**3.06**	**5.53**	**2.71**	**4.93**	**1.99**	**5.25**

Source: SCARP Monitoring Organization, WAPDA.

3.2 Extent of salt-affected soils

A reconnaissance soil survey on about 69 million ha of land done by the Soil Survey of Pakistan, some three decades back, classifies Pakistani soils into different categories with respect to salinity and sodicity problems. Table 6 gives the province-wise extent of saline/saline-sodic soils in Pakistan as established by this survey. It can be seen from the table that about 2.8 million ha cultivated area is affected by salinity and sodicity to varying degrees.

Table 6. Province-wise extent of saline/sodic soils* (million ha).

Province and status of area	Slightly saline/ saline-sodic[1]	Moderately saline/ saline-sodic[2]		Severely saline/saline-sodic[3]		Very severely saline-sodic		Total affected area
		Gypsi-ferrous	Non gypsi-ferrous	Gypsi-ferrous	Non gypsi-ferrous	Gypsi-ferrous	Non gypsi-ferro us	
Punjab								
Cultivated	0.472	0.010	0.791	0.138	0.097	-	-	1.512
Uncultivated	-	-	-	0.003	0.501	0.122	0.530	1.156
Total	0.472	0.010	0.791	0.141	0.598	0.122	0.530	2.668
Sind								
Cultivated	0.118	0.068	0.257	0.676	0.033	-	-	1.151
Uncultivated	-	-	-	0.315	0.150	0.114	0.380	0.959
Total	0.118	0.068	0.257	0.991	0.183	0.114	0.380	2.110
NWFP & FATA								
Cultivated	0.005	-	0.026	-	0.001	-	-	0.032
Uncultivated	-	-	-	-	0.008	-	0.009	0.017
Total	0.005	-	0.026	-	0.009	-	0.009	0.049
Balochistan								
Cultivated	0.003	0.050	0.029	0.031	-	-	-	0.109
Uncultivated	-	-	-	0.069	0.364	0.091	0.715	1.348
Total	0.003	0.050	0.029	0.100	0.364	0.091	0.715	1.239
Pakistan Total								
Cultivated	0.598	0.128	1.103	0.845	0.130	-	-	2.804
Uncultivated	-	-	-	0.387	1.023	0.327	1.633	3.370
Total	0.598	0.128	1.103	1.232	1.153	0.327	1.633	6.174

*Estimated through the reconnaissance soil survey by WAPDA over an area of about 20.6 million ha in the Punjab, 9.2 million ha in Sind, 9.1 million ha in NWFP & FATA, and 30.5 million ha in Balochistan.

[1]Includes soils having mainly patchy or surface salinity/sodicity.

[2]For cultivated areas, the figures include currently uncultivated area which is likely to be brought under the plow.

[3]The cultivated areas reported have relatively low discernable salinity but the soils are dense with severe sodicity problem.

The Pakistan Water and Power Development Authority (WAPDA) also conducted a detailed profile and surface salinity survey of the irrigated areas (16.7 million ha) of the country in 1993. Table 7 gives the province-wise extent of the problem as concluded from this survey.

Table 7. Province wise extent of surface salinity and profile salinity/sodicity (million ha).

Province	Area covered	Surface salinity		Profile salinity		
		Slightly saline	Moderately to strongly saline	Saline	Saline-sodic	Sodic
Punjab	12.6	0.71	0.73	0.89	1.76	0.63
Sind	2.6	1.04	1.57	0.44	1.09	0.05
NWFP	0.8	0.05	0.02	0.09	0.06	0.02
Balochistan	0.7	0.06	0.03	0.19	0.27	0.01
Pakistan total	**16.7**	**1.86**	**2.35**	**1.61**	**3.18**	**0.71**

3.3 Classification of salt-affected soils

Salt-affected soils in Pakistan are broadly classified according to their salinity, sodicity or drainage properties determined on the basis of the following parameters:

- Electric conductivity (EC_e) of the soil saturation extract.
- Sodium adsorption ratio (SAR) of the soil saturation extract.
- Depth to water table – a measure of the drainage conditions of the soil.

Details of the classification are given in Table 8a.

Table 8. Classification of soils and irrigation waters.

a. Classification of soils with respect to salinity, sodicity and drainage capability.

Classes of soil salinity		Classes of soil sodicity		Classes of drainage capability	
Salinity class	EC_e (dS/m)	Sodicity class	SAR	Drainage class	WT depth (m)
Salt-free (Non saline)	<4	Non-Sodic	<13	Very poorly drained	0.0 – 0.9
Slightly saline	4 – 8	Slightly Sodic	13 – 25	Poorly drained	0.9 – 1.8
Moderately saline	8 – 15	Moderately Sodic	25 –45	Moderately drained	1.8 – 3.3
trongly saline	>15	Strongly Sodic	> 45	Well drained	> 3.0

Source: Saline Agriculture for Irrigated land in Pakistan: A handbook (Qureshi and Barrett-Lennard, 1997.)

b. Classification of irrigation waters.

Classification	EC_W (dS/m)	SAR	*RSC
Useable water	< 1.5	< 10.0	< 2.5
Marginal water (Use of chemical amendments is recommended)	1.3 – 3.0	10 – 18	2.5 – 5.0
Hazardous water	> 3.0	> 18.0	> 5.0

3.3.1 Classification of salt-affected soils:

For agricultural and irrigation purposes, salt-affected soils are classified into the following three categories:

- **Saline soils:** Locally called 'thur', the salt concentration in such soils increases to a limit where the crop growth begins to be adversely affected due to development of high osmotic potential. The soil structure remains intact with no effect on permeability. The reclamation of such soils is relatively easy. The EC_e of these soils is greater than 4 dS/m, the pH is usually between 7.5 and 8.5 and SAR is less than 13.
- **Sodic soils:** Locally known as 'bara' soils, they exhibit high exchangeable sodium concentration, which dissolves in the soil and gives it a dark brown or black colour. Poor soil structure in these soils affects permeability and impedes root growth. Reclamation of such soils is difficult. The EC_e of these soils is less than 4 dS/m, pH is greater than 8.5 and SAR is greater than 13.
- **Saline-sodic soils:** Locally known as 'thur bara' soils, they are the most common soils naturally found in Pakistan. They have characteristics of both saline and sodic soils. Their EC_e is greater than 4 dS/m, pH is usually less than 8.5 and SAR value is greater than 13. The soils initially show good permeability but lose structure if leached without using amendments.

Another classification of salt-affected soils used in Pakistan by the Soil Survey of Pakistan in their description of Pakistani soils is as follows:

- **Slightly saline-sodic or saline-gypsiferous soils:** These have slight salinity-sodicity problems, which occur in patches (covering 20 percent of the area) in the cultivated fields. The problem is affecting about 3.5 million ha of agricultural lands.
- **Porous saline-sodic or saline-gypsiferous soils:** These soils extend over an area of about 1.9 million ha. They are saline-sodic or saline gypsiferous soils throughout the root zone but are porous and pervious to water flow. They are loamy to clayey in texture. They are very receptive to reclamation efforts because of their good physical properties and drainage capabilities.
- **Severely saline-sodic and saline-gypsiferous soils:** They are spread over an area of about 1.1 million ha. They are severely saline-sodic or saline-gypsiferous, loamy to clayey in texture, are dense and nearly impervious to water. Reclamation efforts are difficult in these soils and may need special treatments, which are often uneconomical.
- **Soils irrigated by sodic tubewell water:** These soils extend over 2.3 million ha and are formed in areas where irrigation is done with groundwater having high concentrations of carbonates and bicarbonates. These soils become problematic after some time due to sodicity build-up in the profile. About 70 percent of the tubewells installed in the Indus Plains pump sodic water.

3.3.2 Classification of irrigation water

Table 8b gives the classification of irrigation waters used in Pakistan for agricultural purposes. The classification is based on chemical parameters like EC, SAR and RSC (residual sodium carbonate). Though RSC is no longer used as a parameter for evaluating irrigation water internationally, this criterion is still being used in Pakistan for determining the suitability of water for irrigation.

4. Causes of formation of salt-affected soils

4.1 Primary salinity

Primary salinity in Pakistan is quite widespread and is the result of long-term natural processes, which occur in several parts of the Indus Plains. Major role in the salinization and sodification processes has been played by the calcareous parent material of most soils, the physiographic and hydrologic interaction (e.g. levees affected by long-term ponding in adjoining areas, lateral seepage from streams/basins affected by high water table, and collected water runoff) occurring in a landform, and the micro-relief of a site. Climatic features also play an active role. The extent of salinity has been found to be least extensive in the northern sub-humid parts and is dominated by carbonates. It is most extensive in the arid southern parts where it is dominated by sulphates and chlorides. In between, in the semi-arid areas, carbonates and sulphates dominate.

Primary salinity in the coastal areas is very common because of the proximity to the sea. The deeper layers are often very saline and seawater intrusion has been observed to be a serious threat to freshwater aquifers turning into saline aquifers. In the Indus Delta, this could become a potential hazard if most of the flood and river flow is stored upstream. A certain minimum flow (estimated at 12.5 bcm) therefore has to be allowed to flow into the Arabian Sea to minimize problems of maintenance of the coastal ecosystem and seawater intrusion into inland areas and fresh water aquifer systems.

4.2 Secondary salinity

Secondary salinity mainly occurs in the irrigated areas of the Indus Plains and is because of the irrigation activity being practised for more than 100 years. There are four major causes of this salinization.

Aridity of climate: The climate of the Indus Plains where most of the irrigation activity is going on is arid to semi-arid with evaporation exceeding precipitation by a factor of over 6. Plant growth without irrigation is therefore out of question. This creates ideal conditions for spread of salinity because the saline groundwater tends to move up in the root zone bringing up the salts, which are left behind as water gets evaporated or transpired by plants.

Seepage losses from canals: The huge amount of seepage losses from the irrigation system has caused disturbance of the natural equilibrium of the aquifer. This water leaches the salts from the upper layers to lower layers. In the absence of drainage facilities, the salts are added in the aquifer systems.

Use of poor quality water for irrigation and over pumping: The continued use and re-use of relatively poor quality groundwater in the irrigated areas for supplemental irrigation causes deterioration of the aquifer water quality. Moreover, in areas where over-pumping is done, the lower saline water mixes with the upper freshwater layer to cause upcoming of saltwater into freshwater.

Inadequate drainage facilities: In high water table areas, leaching cannot be practised without providing adequate and proper drainage facilities. The average annual salinity of the river water is estimated at 130 mg/litre at the rim stations while at the outflow near Kotri in Sind it is estimated at 250 mg/litre. With the assumption that the inflows are 173 bcm and outflows are 12 bcm, the salts retained in the Basin are around 20 million tonnes per year. This much salt needs to be drained out to the sea to maintain the salt balance.

Lack of extension facilities: The extension services in the problem areas are rather weak and farmers do not have access to appropriate soil and water management technologies under waterlogged and saline conditions. However, this aspect is now receiving increasing attention from the government extension and research agencies/departments.

5. Impacts of salinization

Salinization of lands is known to have the following adverse impacts in Pakistan:

- **Effect on productivity:** The major effect of soil salinization is the loss in land productivity, a universal phenomenon. In addition of toxic effects on plants which may vary from species to species, as salt concentration in the soil increases plant roots have to exert more to take up water from the root zone due to increased osmotic potential in the soil water. This lower and reduced availability of water to the plants causes lower transpiration and thus the productivity is reduced. Salinity is also known to affect the root permeability. In Pakistan extensive yield reductions have been reported due to salinization and in many places entire areas have gone out of production.

- **Effect on soil properties:** Increased concentration of carbonates and sodium ions in soil solution may result in sodicity, which destroys the soil structure particularly if clay content is high. Therefore the soils in Sind Province, which have finer materials, are more prone to such effects than soils in the Punjab where they are coarser.

- **Effect on crop quality and pattern:** Salinization has been observed to change cropping patterns as people are forced to change over from salt-sensitive to salt-tolerant species due to reduced yields and quality. The shift-over generally has a negative effect on the income levels.

- **Effect on health and socioeconomic aspects:** Poor health and hygiene problems become very common with humans, livestock and other domestic and wild animals living in salinized areas. Groundwater being brackish, people are forced to use rainwater collected in ponds for drinking purposes, which is unsafe for human and animal health. Epidemic outbreaks of malaria, typhoid, and cholera have often been reported from such areas, as ponds start to appear with stagnant water, excellent breeding places for mosquitoes and other bacteria.

Studies in salt-affected areas of Pakistan have indicated that the life expectancy of female population in these areas is rather low. Statistics for the Punjab Province showed that the ratio of female to male was 0.68 in a highly salt-affected area, while the ratio was 0.88 in a slightly salt-affected area. The overall ratio for the whole of Pakistan is 0.96. The studies are, however, not conclusive due to limitation of data.

- **Socioeconomic Effect**: Waterlogging and salinization make an adverse socioeconomic impact on the local communities. The problems have resulted in increasingly poor living conditions in the affected areas with land either going out of production or diminishing its productive potential. Because of poor economic conditions in such areas, the literacy rates have also been observed to drop considerably. The literacy rate for male and female population was 44 and 9 percent respectively in a highly salt-affected area as against the national average of 49 and 23 percent. This is obvious as the lower income forces people to work more to maintain their income levels, thus finding less time for education, which becomes a lower priority.

- **Effect on urbanization and civil structures:** Because of the reduced incomes in salt-affected areas, the affected communities are forced to migrate to other more productive areas or urban centres in search of better living, thus creating social problems. In the affected areas waterlogged and saline conditions have been observed to have a very degenerative effect on mud as well as brick-cement-mortar houses. Most of the houses start to crumble and collapse as the area becomes waterlogged and the level of salinity increases.

6. Management techniques for salt-affected soils

Pakistan has long been confronted with the problems of managing waterlogged and salt-affected soils and has tried to tackle the problems through the following four approaches:

6.1 Water management

Seepage from canals, watercourses and poor irrigation practices amounting to over 75 bcm, has contributed to the rise of water table in the irrigated areas and consequent increase in salt-affected soils. Efforts have been made in the past to prevent the losses and increase irrigation efficiencies by lining canals on a limited scale. Extensive use of the lining option could not be done because of its prohibitive cost. Under the On-Farm Water Management Project, funded by the World Bank and the Japan International Cooperation Agency (JICA), farmer-maintained watercourses and government-owned tertiary canals are being lined and cleaned. An essential element of the project is participation of farmers in the activity by organizing themselves into Water Users Associations (WUAs) and meeting 30 to 50 percent of the total cost of lining. The project also provides assistance in land levelling to reduce losses on the field by increasing application efficiency.

A direct beneficial outcome of the project has been that the farmers are becoming aware of the advantages of the project and are willingly participating in the venture. Till 1994, over 94 000 WUAs had been formed with over 800 000 farmers as registered members. Over 900 000 km of earthen channels had been improved and 20 000 km of unlined water channels had been lined. The impact of the project is 30 percent increase in delivery efficiency, 42 percent reduction in water losses, 12 percent increase in cropping intensity, 16 percent increase in crop yields and 9 percent increase in cropped area. However, data on how much the project has helped reduce salt-affected soils are not available.

6.2 Drainage

Drainage in various forms is the most widely used practice in Pakistan to reclaim salinized lands and to control the problems of waterlogging and salinity. The method involves installing a network of tubewells (vertical drainage) or tile and surface drains (horizontal drainage). The drainage effluent is either reused for crop production, if within acceptable standards, directly or in conjunction with fresh water, or is pumped back into the rivers or disposed of into the sea.

An estimated 8 million ha land area have been treated with this approach. The approach involved sinking of numerous tubewells under large-scale vertical drainage projects commonly known as Salinity Control and Reclamation Projects (SCARP) and laying surface and sub-surface drains. Under the SCARP projects, initially, large capacity (60-100 litres per second – lps) tubewells were installed in the public sector to control waterlogging by pumping out groundwater. This also provided water for supplementary irrigation and for leaching of salts. Later, however, greater emphasis was placed on installing smaller capacity (15-30 lps) tubewells in the private sector and laying horizontal drainage (tile drainage) systems. The estimated number of public tubewells in the SCARP areas is 19 000 while privately owned tubewells number about 250 000.

The monitoring of the SCARP has revealed that the project has increased cropping intensities from 84 to 117 percent, increased salt-free area from 49 to 74 percent and decreased areas with severe waterlogging from 16 to 6 percent. Despite these monitoring results, the projects have been the centre of severe criticism due to some critical deficiencies, which are:

- Very high maintenance cost of SCARP projects raising questions about their sustainability due to their sheer magnitude. Under a SCARP transition programme, the government has transferred the operation and maintenance of large capacity SCARP tubewells in the fresh groundwater area to the farmers. However, the tubewells in the saline groundwater areas are still under the public sector.
- Deterioration in groundwater quality due to extensive pumping and reuse of water. In places soils became sodic due to addition of high amounts of sodium and bicarbonates.
- Most of the salt-affected soils are not treatable with simple drainage and leaching, as was initially assumed. These soils are saline-sodic and sodic soils.

In areas underlain with saline waters, surface and tile drainage systems have been laid. These include irrigated areas of East Khairpur, Swabi, Mardan, Chashma, Khushab and Samundri.

A major problem faced by the country is the disposal of saline effluents from drainage sites. Various techniques like disposal into rivers, lakes and in evaporation ponds have been tried. However, all are causing environmental problems of one kind or another. The biggest project to dispose of the saline drainage effluent is the construction of Left Bank Outfall Drain located in the Lower Indus Region. The drain is expected to carry drainage effluent of about 0.6 million ha of land pumped out by saline tubewells and tile drainage systems into the sea. The drain, on completion, will export 25 to 30 million tonnes of salts each year.

The World Bank in 1994 proposed a shift in management of the irrigation systems from public to private sector. It also identified waterlogging and salinity, low irrigation efficiencies, over-exploitation of groundwater, inequitable distribution of irrigation waters, insufficient and poor cost recovery from irrigation projects as the main problems faced by irrigated agriculture in Pakistan. The Bank is now financing the National Drainage Programme under which all the above problems would be tackled in an integrated approach. Various components of the programme include the rehabilitation of saline groundwater tubewells; laying surface, tile and interceptor drains; and transition from public to private sector of the irrigation system and freshwater tubewells.

6.3 Reclamation

As against the drainage approach, the reclamation of salt-affected soils, using different methods, has been practised in Pakistan on a limited scale at the local level only. The following methods have been tried:

Leaching: Leaching of salts has been found to be very beneficial for well-drained saline soils in which the soil structure is not destroyed and either a drainage system exists or the water table is deep enough. In sodic soils with low permeability, it has been found beneficial to first apply brackish water, and when the permeability improves apply fresh water to leach out the salts. It is further helpful if the final application with freshwater is complemented with doses of gypsum.

Using soil amendments: Chemical amendments like gypsum and hydrochloric acid have been used in Pakistan to ameliorate sodic conditions. Gypsum, the cheapest source in Pakistan as compared to other chemical amendments, has been very widely used to improve the physical condition of saline-sodic and sodic soils. Use of hydrochloric acid, as a soil amendment, has been limited to research stations and trial fields of research organizations.

Physical methods: Deep plowing, surface scraping and chiselling have been tried by many farmers in soils that have developed hard pans or have low permeability. Surface scraping is also practised in areas where salinity is visible on the soil surface. However, it generally has only short-term benefits as the topsoil nutrients are also taken away during the process, thus reducing productivity. Moreover, salts may leach out of the heaps of scraped material to make the nearby soils saline. Deep plowing and chiselling has short-term benefits as the soil hardens again after wetting and drying cycle due to the presence of carbonates.

Biological methods: These consist of using salt-tolerant plants. The methods are more suited to sodic and saline-sodic soils, as the plants add organic matter to the soil and have an acidic effect, which makes soluble calcium available to improve the permeability. An excellent example of this in Pakistan is growing 'kallar' grass (*Leptochloa fusca*) followed by 'dhancha' (*Sestina bispinosa*) to act as green manure in saline-sodic soils. It has been observed that this improves soil structure considerably to allow growing of normal crops possible.

Agricultural and other wastes: Highly sodic and saline-sodic soils have been found to respond positively to farmyard manure and pressmud. The use of such materials has been quite popular with the farming community though for a separate purpose of fertiliser. Farmyard manure has been found to help improve the structure and nutrient level of the soils. Pressmud from sugar mills provides necessary organic matter for improving soil structure. The high sulphur content in pressmud also helps acidification of sodic soils.

It is pointed out that the best strategy would remain to be using the combination of various methods based on the properties of soil, farmer's financial status, and access to and availability of supplemental irrigation water. For example, the efficiency and cost effectiveness is improved considerably if biological methods are tried after physical and chemical methods and before the land is used for normal growth of crops.

6.4 Saline agriculture

There is growing realisation in Pakistan that we have to live with salinity, as the menace cannot be done away with. Saline agriculture is the economic utilisation of the salt-affected lands without reclamation, though some improvement in soil condition may be obtained indirectly. The approach so far neglected by farmers is now gaining popularity in Pakistan due to its many advantages such as:

Cost effectiveness in terms of initial investment.
Increased production from the currently 2-3 million ha of salt-affected wastelands.
Improved drainage conditions of soils due to the addition of organic matter in the soil and the lowering of water table.
Improved shading of land, reduced evaporation and production of forage and wood.
Improved environment due to the increased vegetation and the conservation of wildlife.
Improved socioeconomic conditions of the local communities.

There are three major types of plant species, which are salt tolerant or can grow in salt-affected soils. These are:

Halophytes: These are highly salt-tolerant plants and have increased growth at low salt concentrations when compared to non-saline conditions. However, they have decreased the growth at higher concentrations. River saltbush (*Atriplex amnicola*) is a typical example of such a plant. The plant has been observed to achieve a 10 percent increase in growth at salinity levels of 5 dS/m, 50 percent decrease in growth at 40 dS/m, and survives at 75 dS/m. Other plants in this group include quailbrush (*A. lentiformis*), *Suaeda fruticosa* and *Salicornia bigelovii*.

Salt-tolerant non-halophytes: They are able to maintain normal growth at low salt concentrations but have decreased growth at higher salt concentrations. Cotton (*Gossypium hirsutum*) is a typical example of such plants. It can grow normally at low concentrations of under 4 dS/m but its growth is found to be 50 percent less at salinity levels of 17 dS/m. Other plants in this group are sugar beet, barley, date palm, Bermuda grass and olives.

Salt-sensitive non-halophytes: These plants are sensitive to even low levels of salt concentrations. Beans exhibit 50 percent reduction if grown at salinity of 3.6 dS/m. Other plants in this group are rice (moderately salt tolerant), carrots, almonds, grapefruits, okra, onions, black berries, peaches, oranges, plums, etc.

Out of a total of over 1 500 salt-tolerant plant species in the world, some 150 agriculturally important species have been ranked by world literature for practicing saline agriculture. However, they have little or partial value for Pakistan conditions, as they do not take into account the problem of waterlogging. Less than 1 percent of the salt-tolerant species have been tried in Pakistan. The important food and cash crops that have been grown on 3.5 million ha of land with patches of salinity (covering 20 percent of land area) are wheat, cotton, rice and rapeseed. These crops have been observed to give poor yields, which are a cause of great concern to planners as such poor yields have serious economic impacts at the national level.

Following is a list of various important crops, grasses and trees that have been tried in Pakistan towards promoting saline agriculture:

Crops: Rice, wheat, cotton, rapeseed, sugarcane and barley are the most commonly grown crops in salt-affected soils. Table 9 gives the recommended cultural practices that are generally followed for three major crops (rice, wheat and cotton) in salt-affected soils. Barley is considered to be very salt tolerant but its survival under waterlogged conditions has not been tested.

Grasses: A number of forage grasses have shown promising results when grown under saline conditions in Pakistan. The most popular grass is kallar grass *(Leptochloa fusca* or *Diplachne fusca*). This perennial summer growing grass imported from Australia is now cultivated in many parts of Pakistan. A very effective biological reclamation agent for saline or saline-sodic soils with structural problems, the grass is suitable for feeding cattle, buffaloes, sheep and goats. Its use for methane production and ethanol (biogas) has been found very promising. The Rhoades grass (*Chloris gayana*) is perennial, attains a height of almost 1 m and is tolerant to salinity and high alkalinity. The tall wheat grass (*Agropyron elongatum*) is a perennial grass and adapts well to poorly drained and moderately saline and alkaline soils. The grass has been successfully grown on sand dunes for sand dune fixation in Balochistan from seeds and transplanted plants. A number of other grasses have been cultivated on experimental basis in Pakistan. These include Bermuda grass (*Cynodon dactylon*), 'maddal' (*Eleusine coracana*), Japanese millet (*Echinochloa crus-galli*), Puccinellia (*Puccinellia ciliata*) and coastal salt grass (*Distichlis spicata*). Preliminary results show good potential for their use as reclamation agents for salt-affected soils.

Trees and shrubs: There are a number of different types of trees and shrubs, which are found to be suitable for growing in salt-affected soils because of their tolerance to salinity. Table 10 gives profile of some popular varieties in Pakistan. In addition to these trees/shrubs, salt-tolerant fruit trees of 'falsa' (*Grewia asiatica*), 'chiku' (*Manikara* *zapota*), 'khajoor' or 'khajji' (*Phoenix dactylifera*), 'amrood' (*Psidium guajava*), 'ber' (*Ziziphus mauritiana*) and 'jaman' (*Syzygium cumini*) are also very common in desert and waterlogged and saline areas.

Table 9. Crops for saline agriculture and recommended agricultural practices.

Crop	Recommended agricultural practices
Rice – Recommended for moderately salt-affected soils	Use older (40-45 days) than normal seedlings. Use high density planting (4 seedlings per hill) against usual planting of 2 seedlings per hill. Use poor quality water only at the establishment and vegetative growth stage. Use nitrogen (urea at 100-150 kg/ha), phosphorous (superphosphate at 44 kg/ha), calcium (50% of gypsum requirements), zinc ($ZnSO_4$ at 10-20 kg/ha), and boron (boric acid at 1.5 kg/ha on alternate years) as fertilisers.
Wheat – Recommended for moderately salt-affected soils. Highly salt tolerant and waterlogging tolerant species being developed.	In freely draining soils, sowing in dry soil followed by heavy irrigation to leach salts. Next irrigation at crop establishment. In poorly draining soils prepare land in the form of raised beds (100 cm wide and 30 cm high) separated by irrigation channels. Sow seeds 15 cm apart after giving a heavy soaking dose of irrigation water and add first dose of nitrogen and phosphorous. Use nitrogen (Urea at 160 kg/ha N), phosphorous (superphosphate at 35 kg/ha), calcium (10-20% of gypsum requirements), zinc (as for rice but not required if applied for rice phase), boron (apply as for rice but not required if applied for rice phase)
Cotton – Recommended for saline soils. Sodic soils may considerably reduce emergence and yield. Waterlogging may seriously affect growth.	After cultivating the soil, apply gypsum. Use a bedding plow to construct the furrow and raised beds as for wheat. Plant seeds on either side of ridges or raised beds in clumps of 3 or 4 seeds together. Seedlings can be later thinned after 45 days when the plants are 15-20 cm high. Use phosphate (di-ammonium phosphate at 55 kg/ha), nitrogen (urea and di-ammonium phosphate N at 200 kg/ha) Apply fertiliser one week after first irrigation water has been applied. Application may be split into several applications but should be complete within 60 days of sowing. Apply plant hormone growth regulator (Pix at 247 ml/ha) at four periods of growth: 40, 55, 70 and 90 days after sowing).

Saltbushes: Most common saltbushes in Pakistan are different varieties of *Atriplex amnicola, A. lentiformis, A. cineraria, A. undulata* (all suited to saline waterlogged lands), *A. bunburyana, A. vesicaria, A. stocksii, Marieana brevifolia, M. polytergia, M. aphylla* and *M. amoena*. There are two major disadvantages of the use of saltbush leaves as forage; they are high in salt content and they have low digestibility. The major advantage is that they are rich in nitrogen, which is good for animals.

Table 10. Popular salt-tolerant trees in Pakistan.

Tree	Properties, Extent and Uses
'Kikar' or 'babul' (*Acacia nilotica* or *Acacia arabica*)	Evergreen with thorns. Attains a height of 10-20 m. Can tolerate moderate saline and sodic conditions. Relatively tolerant to waterlogging (well-established tree can withstand a 3-month inundation). It is native to Pakistan and occurs at altitudes of up to 600 m. Can also tolerate light frost. Used for fuel, timber, tanning, lac, medicines, fodder and gum.
'Shirin' or 'siris' (*Albizia lebbeck*)	Fast growing large deciduous ornamental tree with feathery foliage. Tolerates light frost, moderate salinity, sodicity and high pH. Grown in plain areas of the Punjab and Sind. Native to sub-Himalayan area. Used for wood, timber, fuel, forage, honey, erosion control, and ornamental plant.
'Jila bush' (*Acacia amplicep*). Also known as salt wattle	Fast growing shrub or small tree. Attains a height of 2-8 m. Can tolerate high salinity and sodicity. Sensitive to waterlogging. Native to Australia, it has recently been introduced in Pakistan with promising results. Used for windbreaks, soil conservation, sand dune stabilization, fodder, fuel, poles and posts.
'Jangli saru' (*Casuarina litoria* or *Casuarina equisetifolia*). Also known as Australian pine or whistling pine	Large erect evergreen tree. Attains a height of 10-40 m. Grows on sea coasts in warm sub-humid zone with precipitation exceeding 1 000 mm. Can tolerate moderate salinity and sodicity but is sensitive to waterlogging. Used for fuel, poles, fences, sand dune stabilization, wind breaks, as fertiliser.
'Suphaida' or 'ratta suphaida' (*Euclyptus camaldulensis*). Also known as red gum	Medium to tall tree with thick trunk. Attains a height of 20-45 m. Grows in semi-arid subtropical climate. Native to Australia but grows well in Pakistan in plains and hills. Tolerates slight salinity and waterlogging. Transpires a lot of water and thus can act as waterlogging control agent. Used for fuel wood, timber, plywood, chipboard, furniture, pulp for paper, nectar and pollen, and revegetation in salt affected wastelands.
'Iple-iple' or 'subabul' or 'American shirin' (*Leucaena leucocephala*)	Fast-growing evergreen small tree with feathery foliage. Attains a height of 20 m. Grows well on deep fertile soils with summer precipitation. Prefers moist tropical climate. Tolerates slight salinity and is sensitive to waterlogging. Used for wood and forage, fodder and alley farming.
'Vilayati kikar' (*Parkinsonia aculeata*). Also known as Jerusalem thorn.	Small evergreen tree with broad crown. Attains a height of 5-9 m. Native to America, it grows well in Pakistan on plains at elevations of up to 1 300 m in low rainfall areas (200-1 000 mm). Tolerant to high levels of salinity but is sensitive to waterlogged conditions. Used for avenues and as ornamental tree in salt-affected areas.
'Jand', 'kandi' or 'lhau' (*Prosopis cineraria*).	Small tree or large shrub with open and spreading crown. Attains a height of 10-12 m, is thorny and evergreen. Tolerant to high levels of salinity and alkalinity. Important feature of the landscape of desert areas of Pakistan. Sensitive to frost. Well liked by grazing animals. Used for agroforestry, timber, fuel and fodder.
'Pahari kikar' or 'Jangli kikar'(*Prosopis juliflora*). Also known as mesquite.	Small evergreen thorny tree. Attains a height of 12-15 m. Can tolerate moderate to high salinity and sodicity, high alkalinity and intermittent flooding. Excellent for lowering water tables. Mainly used for sand dune stabilization in Pakistan in some very difficult sites of arid wastelands. Excellent source of fuel wood, timber, forage and nectar.

'Dhancha' (*Sesbania bispinosa*)	Erect annual or bi-annual legume. Attains a height of 3 m. Adapts to a variety of soil conditions, varying from waterlogged to saline and from sands to clays. Native to Pakistan, it grows in plains and foothills. Used as reclamation agent, green manure, fodder, fuel wood, and roofing of mud houses.
'Jantar' (*Sesbania sesban*)	Small to medium evergreen leguminous tree. Very fast growing attaining a height of 6-8 m. Can tolerate waterlogging, salinity and alkalinity. Planted extensively in Pakistan in semi-arid areas. Used for fodder, fuel wood, pulp, stakes for vegetables, windbreaks, and nitrogen fixing.
'Frash' or 'Pharwan' (*Tamarix aphylla*)	Small tree of large shrub. Attains a height of 10-15 m. Grows well on drained sandy soils. Native to Pakistan. Tolerates high levels of salinity and acts as a common tree for salt-affected wastelands. Used for fuel wood, timber, erosion control, and shelter.

7. Institutional arrangements

There are numerous organizations in Pakistan responsible for undertaking development, monitoring, research and extension services for the control of waterlogging and salinity.

7.1 Development and monitoring

The main agency responsible for developing and executing major projects in waterlogging and salinity control is the Water and Power Development Authority (WAPDA). The Authority also maintains an excellent monitoring network for collecting data on water resources, groundwater depths and salinity. Besides water resources development, the Authority has completed some major projects in drainage like vertical and horizontal drainage SCARPs and Left Bank Outfall Drain (LBOD). Other projects like the Right Bank Outfall Drain and extension of the LBOD are in hand. The monitoring of the completed projects is also done by the Authority through their monitoring organizations like the SCARP Monitoring Organization and the Dam Monitoring Organization. The completed projects are generally handed over to the provincial irrigation departments for operation and maintenance.

7.2 Data collection

Considerable ground truth data such as topography, rainfall, geology, soils, vegetation, etc. are available from various departments. These include the Geological Survey of Pakistan (GSP), Soil Survey of Pakistan (SSOP), Pakistan Meteorological Department (PMD), Survey of Pakistan (SOP), the Space and Upper Atmosphere Research Committee (SUPARCO), Pakistan Forest Institute (PFI), provincial forest departments and WAPDA.

7.3 Research and extension

- The Drainage Research Centre (DRC) previously known as the Drainage and Reclamation Institute of Pakistan (DRIP), established by the Pakistan Council of Research in Water Resources (PCRWR), introduced the first ever tile drainage project in Pakistan by completing work over a pilot area of about 400 ha. It has established some small collaborative tile drainage projects on individual farmers' lands. It is also conducting field experiments on irrigation practices, consumptive use, and reclamation of salt-affected soils.

- The International Waterlogging and Salinity Research Institute (IWASRI) was established by WAPDA to manage and coordinate research activities in waterlogging and salinity and to collect and document necessary relevant data and information. Besides conducting collaborative research with other national and provincial research organizations, the Institute has sponsored numerous research studies on drainage and reclamation of salt-affected soils.

- The Nuclear Institute for Agriculture and Biology (NIAB) and the National Institute of Biology and Genetic Engineering (NIBGE) have developed crop varieties and cultivars suited to local conditions including waterlogged and saline soils using nuclear and other techniques.

- The Agriculture and Engineering Universities of Faisalabad, Lahore and Tandojam are doing research work in drainage and reclamation. The Agricultural Universities have developed many crop varieties and cultivars that are tolerant to drought and salinity.

- The provincial irrigation and agricultural departments and research institutes conduct research studies and provide extension services to farmers in drainage, reclamation and saline agriculture.

- Mona Reclamation Experimental Project started by WAPDA conducts research studies on seepage losses, reclamation techniques and water management.

7.4 Efficiency and output

The efficiency and output of almost all the public sector organizations involved in development, data collection, research or extension services have been observed to be deteriorating over the years. The major reasons are:

Overstaffing with imbalance in technical and managerial staff. The ratio is highly tilted in favour of managerial staff.
Increased costs of project completion due to poor planning, delayed receipt of funds and frequent changes in time schedules of project completion and top management.
Poor employment/management systems.

7.5 Potential for aquaculture

The coastline of Pakistan offers tremendous potential for undertaking aquaculture on large commercial scale. For successful shrimp farming, the delta areas of Miani Hor and Kalmat Khor have already been identified as potential areas for shrimp culture with semi-intensive and intensive techniques. It has been estimated that, through appropriate shrimp farming techniques, the Indus Delta alone can produce US$2 million worth of shrimp crop per year. There is also sufficient potential in inland areas where highly saline water is available for commercial scale production of shrimps; however, its negative impact on local environment needs to be carefully assessed before any activity is to be undertaken. The experience of Thailand in shrimp culture in rice areas can be used before planning of activities.

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The Philippines

Summary

Rice production in the Philippines for the year 1997 was 7.325 million tonnes with food consumption of 7.214 million tonnes. In the year 2000 the population is 76 601 349 people with the growth rate of 2.3 percent. With the rapidly growing population, sustained food crop production is crucial for the stability of the nation. It is in this context that the salt-affected soils in the coastal areas are of prime importance as the expansion area to increase production. About 400 000 ha are classified as saline soils in the Philippines, of which 175 000 ha are used for fish/shrimp ponds, 100 000 ha are mangrove forest and the remaining 129 000 ha are idle lands.

The salt-affected soils in the Philippines are grouped into three groups based on the process or mode of salinization. These soils are the tidal saline soils, the saline wetland soils of the backswamps and lagoons, and the seasonally saline soils. The tidal saline soils and the soils of the backswamps and lagoons are being used for shrimp ponds, while the seasonally saline soils are being used for rice cultivation. Due to salinity as a constraint to crop production the yield of rice is 50 percent less as compared to normal soil and becomes worse with higher level of salinization. Shrimp production in the saline-affected soils had been booming until 1995 when the outbreak of the environmentally related "luminous vibriosis bacterial disease" caused the collapsed of the industry.

With the concerted efforts of the government and the private sector some techniques were developed to remedy the disease. These are the Tilapia water introduction into the prawn system, low salinity technique, crop rotation, and the polyculture with finfish (Bangus and Tilapia). The acidic shrimp ponds are being remedied with the use of rock lime.

Constraints to crop productivity are the high salinity, lack of irrigation water to leach the salts, and lack of salt-tolerant varieties. Research needs are the establishment of the database of salt-affected soils, techniques in assessing and predicting salinity development, integrated soil management to increase productivity, salt-tolerant rice varieties and research on the eradication and control of disease(s) for sustained production of shrimp.

The national agricultural plans and programmes for the improvement of salt-affected soils are: the Agrikulturang Makamasa Rice Program, the Oplan Sagip-Sugpo Task Force and the Mangrove Protection and Utilization Regulations.

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The FAO TCP/PHI/6712 Project entitled "Integrated Management for Salt-Affected Coastal Soils in the Philippines" started May 1998 and ended in June 2000. The objective of the project is to assist the Philippine government to demonstrate the integrated management techniques for the improvement of the salt-affected soils in support to food security. Results showed that the treatments introduced by the project, i.e. the use of the mixture of organic and inorganic fertilisers, could increase the yield to more than 5.0 tonnes/ha as compared to farmers' yields of 1.5-3.0 tonnes/ha.

1. Introduction

In 1997 the rice production in the Philippines was 7 325 034 tonnes. The food consumption by 71 549 851 Filipinos was 7 214 233 tonnes with 187 319 tonnes used as seeds and 476 128 tonnes as feeds/wastes, with a total utilisation of 7 877 676 tonnes. A deficit of 552 642 tonnes (Table 1) was remedied with rice importation from Thailand and Vietnam. In the year 2000 the population of the Philippines was 76 601 349 with a growth rate of 2.3 percent.

Table 1. Rice production and use estimates, Philippines.

Year	Production utilization				Total use (tonnes)	Production	Surplus (deficit)	Population (No. of persons)
	Food use Total	Per capita (kg)	Seeds	Feeds and wastes				
1970	3 013 546	81.77	142 070	211 021	3 366 636	3 246 475	(120 161)	36 852 392
1975	3 832 641	90.69	170 199	259 246	4 262 086	3 988 400	(273 686)	42 258 849
1980	4 452 944	92.16	169 197	323 080	4 945 220	4 970 457	25 237	48 317 444
1985	5 156 027	95.03	162 190	374 344	5 692 561	5 759 122	66 561	54 256 999
1990	5 948 574	97.66	162 569	396 175	6 507 318	6 095 051	(412 267)	60 909 732
1995	6 553 254	95.88	183 244	445 357	7 181 855	6 851 616	(330 239)	68 349 474
1996	7 195 270	102.86	192 628	476 743	7 864 641	7 334 528	(530 113)	69 951 865
1997	7 214 233	100.83	187 319	476 128	7 877 676	7 325 034	(552 642)	71 549 851

With the rapidly growing population, food security and self-sufficiency is vital to ensure stability of the nation and the health of the people. Sustained food crop production is the key to attain food security and self-sufficiency. It is in this context that the salt-affected soils in the coastal areas are of prime importance as the expansion area to increase production. Even rice is one of the crops being grown in these areas, productivity is low (< 1 tonne/ha) due to salinity and/or submergence.

Shrimp is another crop that is suitable in wet salt-affected coastal soils. It is a lucrative enterprise/high income generating activity for the farmers in the coastal areas. Prawn or black tiger shrimp is one of the big cash earners for the country from 1987 to 1997 (Table

2). However, the drop in production was felt in 1995-96 due to the outbreak of the environmentally related disease 'luminous bacteria'.

Table 2. The Philippine prawn export.

Year	Quantity Tonnes	Value US$million
1987	14 935	154.50
1988	24 288	251.80
1989	26 052	233.60
1990	24 146	222.60
1991	31 156	272.60
1992	23 003	207.90
1993	22 206	221.70
1994	21 518	239.30
1995	12 095	149.07
1996	13 514	-
1997	10 532	108.14

2. Problem identification, magnitude, extent and distribution of salt-affected soils in the Philippines

The Philippines is an archipelagic country consisting mainly of three major groups of islands, viz. Luzon, Visayas, and Mindanao. Its geographic setting makes the country one of those having the longest coastline in the world (Figure 1).

About 1.3 percent or 400 000 ha of the total land area of the Philippines are classified as saline soils (Gonzales, 1977). Of these, 175 000 ha are used for fishponds, 100 000 ha are mangrove forest while the remaining 129 000 ha are idle land (Guerero, 1997). The distribution of these soils mostly associates with coastal landscape and they are geographically situated among the three major groups of islands as follows: Luzon, 124 000 ha, Visayas, 175 000 ha, and Mindanao, 108 000 ha.

Some of the topsoil characteristics of Philippine coastal saline soils are: soil pH: 2.3-7.8; ECe: 4-34 dS/m; OC: 0.6-8 percent; Olsen P: 2.5-14.0 ppm or more; exchangeable K: 0.4-2.05 me/100 g; CEC: 7-38 me/100 g; exch. Al: 0.01-230 ppm; avail. Zn: 0.5-2.2 ppm; avail. B: 2.3-4.9 ppm or more; active Fe: 0.2-2.0% (Gregorio, 1977). Filipino farmers, on the other hand, identify the following indicators of salinity: presence of shiny-rusty color on the soil crust; reddening, stunted growth and less tillering of the plant (Figure 2); appearance of white deposits of salt on the soil crust when dry (Figure 3); occurrence of salty water in the field; and eventual death of the young plants.

3. Causes and processes of salt-affected soils in the Philippines

Salinization process of coastal soils in the Philippines can be attributed to three major processes as follows:

3.1 Tidal saline soils

These are the wetland soils of the tidal flats usually of the estuarine type. Surface seawater intrusion occurs as a result of the diurnal fluctuations of tidal waters. Usually these are with mangroves as the natural vegetation and in some cases of marshy type. Shrimp pond is the land use in this soil when mangroves are cleared. The tidal saline soils of the Pampanga Delta, Bicol River Basin, and the Butuan tidal flat are the examples of this (Figure 4).

3.2 Saline wetland soils of the backswamps and lagoons

These are the wetland soils with sub-surface or seepage as the mode of entry of salinization. The easy seepage of saline water occurs through the sand dunes or sandy natural levees of the backswamps or lagoons. Also narrow rivers facilitate the entrance of sea/brackish water into the lagoons. Shrimp pond is the common land use in this type of soil. The typical examples of this are the Aparri salt-affected area and the Pangasinan Dagupan Delta.

3.3 Seasonally saline soils

These are the soils of the coastal-alluvial plains adjacent to the tidal flats and/or lagoons. Salinization occurs during dry season when the sea or brackish water backflows inland through the rivers and subsurface flow or intrusion into the artificial aquifers of the land. The subsequent evaporation process moves the salts to the surface. This is being aggregated by the pumping of saline water into the rice fields. Salt or sea spray which results from the breaking of the wave crests, especially during typhoon surges and/or high winds contributes further to the salinization of the rice lands. These soils occur in all of the coastal areas, particularly the ones with tidal flats.

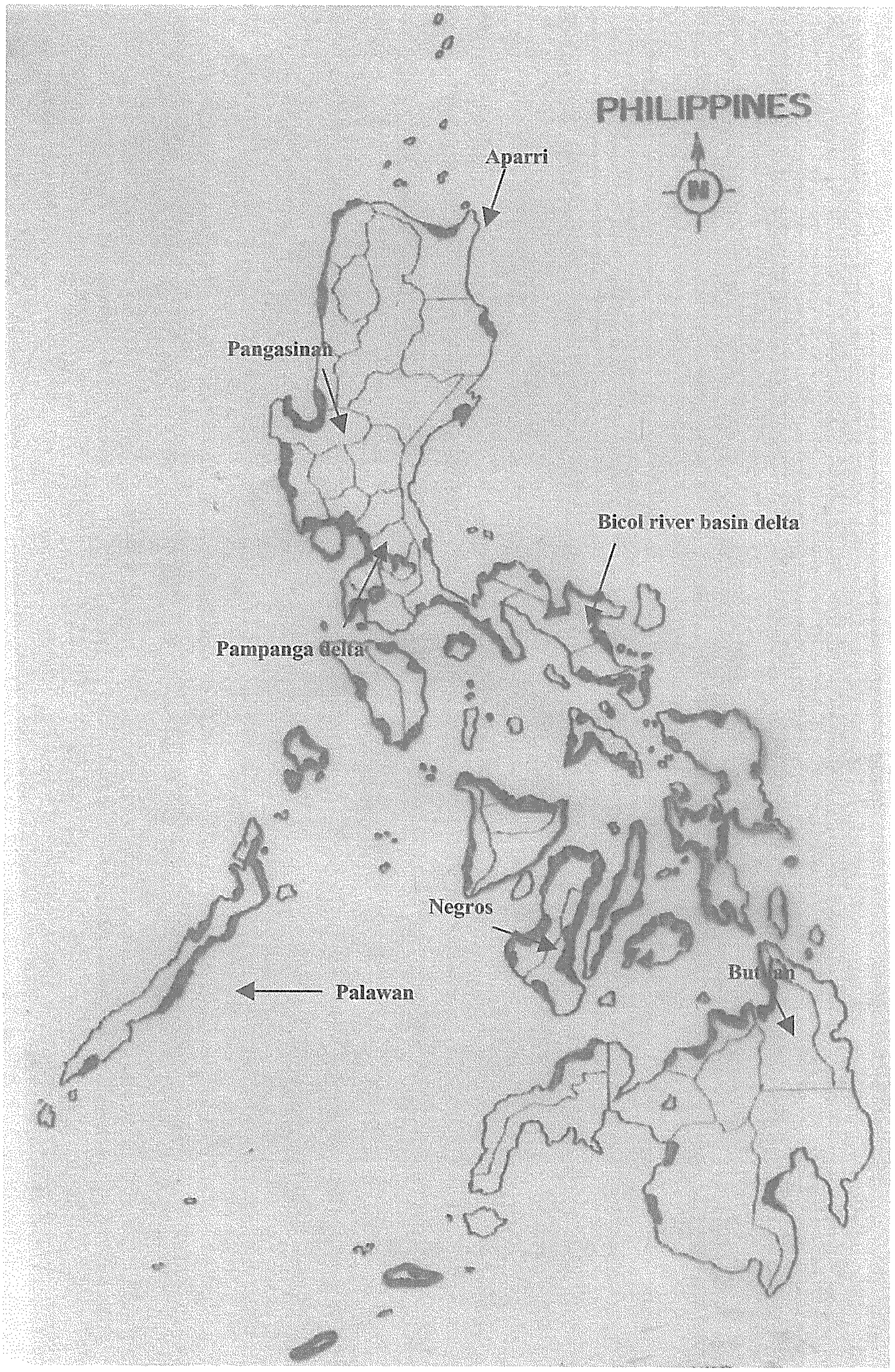

Figure 1. Coastal saline soils of the Philippines.

Figure 2. Stunted growth of rice with less tillering due to salinity.

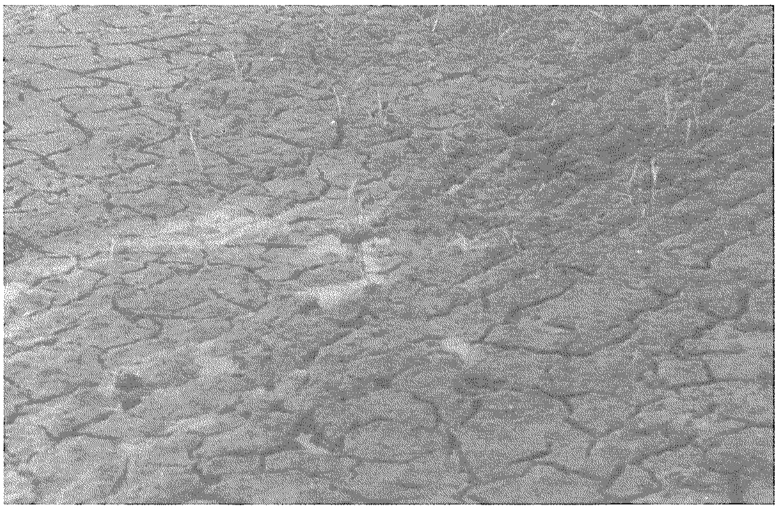

Figure 3. Salt crust on the surface.

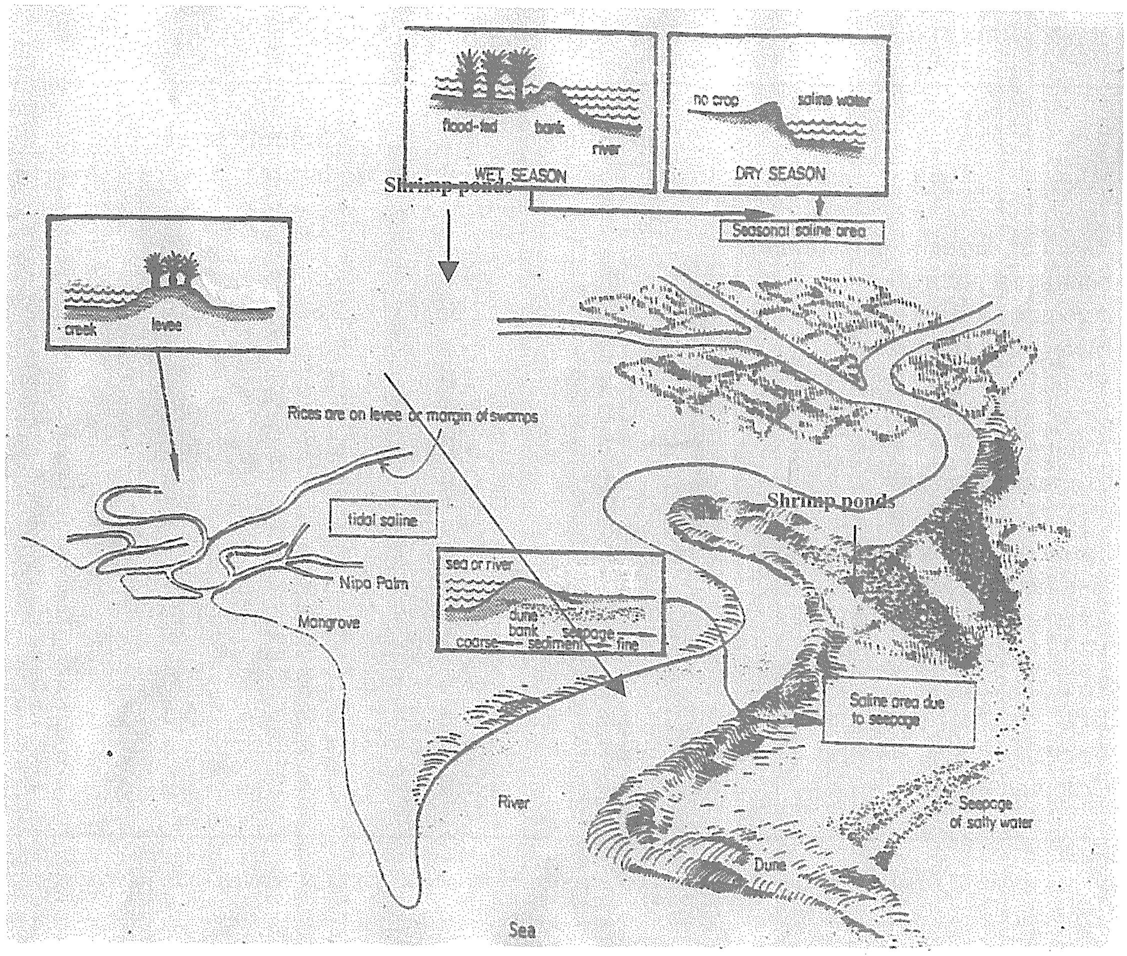

Figure 4. Three types of coastal saline soils in the Philippines.

4. Biophysical, environment and socioeconomic impacts of seawater intrusion and shrimp farming practices

4.1 Impact of salinity to agronomic crop / rice production

Salinity restricts crop growth and productivity. In Aparri, Cagayan, the rice yield shows a declining trend as salinity worsens (Table 3). Non-saline farms produced 3.64 and 2.1 tonnes/ha for wet season, respectively while saline-affected farms got half of the non-saline farms.

Table 3. Average farm size, mean yield and cropping intensity for rice grown in non-saline and saline affected areas, Cagayan, Philippines, 1998-99.

Item	Non-saline	Salinity level			
		Slight	Moderate	Severe	Average
A. Based on farmers' perception					
Number reporting	5	16	25	11	
Average farm size (ha)	1.88	2.35	2.83	2.07	2.52
Mean yield (tonne/ha)					
Wet	3.6	2.0	1.3	*	1.1
Dry	2.0	2.0	1.0	0.9	1.2
Annual	3.0	4.0	2.3	0.9	2.3
Cropping intensity	2.0	2.0	1.4	1.0	1.6
B. Based on technical assessment					
Number classified	23	3	18	2	
Average farm size (ha)	2.84	1.38	1.78	1.25	1.68
Yield (tonne/ha)					
Wet	2.1	1.6	1.5	1.0	1.5
Dry	1.6	1.6	1.3	0.4	1.2
Annual	3.7	3.2	2.8	1.4	2.7
Cropping intensity	1.9	2.0	1.3	1.3	1.4

* flooded
Note: The number of farmers classified and the number reported by farmers do not tally because some interviews do not have soil analysis.

4.2 Conversion of mangrove into shrimp ponds

Clearing of mangrove for shrimp pond development will deprive this very important ecosystem the countless benefits that it gives to both nature and human beings. They are as follows:

- It serves as shelterbelts that protect the coastline from the onslaught of tidal waves and typhoons.
- It traps sediments coming from the uplands; and
- It serves as rich spawning grounds for fishes and as habitats for important wildlife species.

The positive socioeconomic impacts are as follows:

- Since shrimp command high price (₱400/kg), the economic conditions of the farmers will be uplifted.
- Shrimp pond development and operation needs more manpower; this will create employment for people living in the coastal areas.

4.3 Conversion of sugarcane fields/rice fields

During the late 1980s when the shrimp industry was booming, many sugarcane farmers with farms along the main rivers in Negros Occidental excavated their fields for shrimp farming. The established shrimp ponds caused salinization of the adjacent sugarcane fields. Conversion of sugarcane fields to shrimp ponds is an irreversible process. With the collapse of the shrimp industry due to the outbreak of the environmentally related luminous bacterial diseases, these ponds were abandoned up to the present.

4.4 Acidic shrimp ponds

Some shrimp ponds developed on tidal flats with mangrove are acidic; they are saline acid sulphate soils. This occurs when the ingredients for its formation are complete (i.e. with high organic matter content, high Fe and high sulphate, which is natural in seawater or brackish water). Acidity affects the growth of shrimp or even mortalities occur at extremely acidic condition (Evangelista, 1985). This condition has been observed in Aparri, Cagayan, Iloilo in Panay and Negros Occidental.

4.5 Water and soil pollution

The long abuse and overuse of the natural resources mainly led to the collapse of the prawn industry. As prawn ponds mushroomed in the countryside and huge returns were reaped, prawn growers lost touch of the reality that ecological requirements must be met to make the industry sustainable. True enough, less than a decade after the initial project, the exploitation of the environment took its toll and confiscated the industry of an essential component: good supply of water and soil.

The most telling sign of ecological breakdown is the influx of environmentallyrelated diseases. These attack the soil and water and ultimately, the stock animal, thereby reducing production. Research endeavours for the past years were generally concentrated on 'luminous vibriosis,' believed to be the causative bacterial agent in the widespread mortalities of cultured prawns in almost all farms worldwide, including the Philippines.

Shrimps were affected at five weeks post-stocking. Clinical signs included decreased feeding, surfacing of the stock and gathering of the stock towards the pond dikes.

Mortalities of about 10-20 percent occurred within five days from the onset of the clinical signs. Dead shrimps were found on the pond bottom below the paddle wheels and near the central drain. At night, affected shrimp, especially the heads, displayed luminescence.

5. Main solutions, technologies and institutions involved

5.1 Improvement of saline acid sulphate soils for shrimp farming

A technique was developed by the Bureau of Soils and Water Management (BSWM) to increase the profit of prawn/shrimp farming in saline acid sulphate soils. The technique was the placement of gravel-size rock lime to a depth of 15 to 30 cm below the soil surface to serve as a buffer layer that will arrest the upward movement of acidic solution that originated from the acid sulphate horizons underneath the pond bottom. Results showed that the soil pH above the layer of rock lime became stable at about 7.4 (Tables 4 and 5).

Table 4. Soil chemical analysis of acid sulphate soils before reclamation, Montelibano Farm, Cadiz City, Negros Occidental.

Depth (cm)	**pH**		**OC %**	**OM %**	**EC mmhos**	**Sulphate ppm**
	H_2O	$CaCl_2$				
0-20	3.8	4.0	4.0	6.88	10.0	14 000
20-55	3.0	3.2	2.83	4.87	10.0	12 000
55-80	3.8	3.9	2.75	4.73	10.0	
80	4.2	4.5	1.85	3.18	10.0	

Table 5. Soil chemical analysis of acid sulphate soils after reclamation Montelibano Farm, Cadiz City, Negros Occidental.

Depth (cm)	**pH**		**OM %**	**ppm**	**Hot K ppm**
	H_2O	$CaCl_2$			
0-8	7.1	6.7	5.25	3.7	710
8-21	6.6	6.2	5.35	4.7	710
21-42	2.9	2.6	5.52	4.9	830
42-75	2.9	2.6	5.52	3.7	930

The technique could eliminate the frequent application of lime and reduce the cost of a series of washing and draining the pond (Table 6).

Table 6. Production cost reclamation technique of saline acid sulphate soils.

	First cropping					Second cropping				
	Price (PhP)	Requirements//ha		Total expenses/ha		Price (PhP)	Requirements/ha		Total expenses/ha	
		Farmers' practice	BSWM recomm.	Farmers' practice	BSWM recomm.		Farmers' practice	BSWM recomm.	Farmers' practice	BSWM recomm.
I. Material Inputs										
Agricultural lime	10/30kg	8-10 t/ha	500 kg/ha	3 333	166	10/30kg	8-10 t/ha	500 kg/ha	3 333	166
Rock lime (unprocessed)	250/t	-	18 t/ha		4 500	250/t	-	-	-	-
			Sub-total	3 333	4 666			Sub-total	3 333	166
II. Labor and Service										
1. Scrapping of organic matter	50/MD	15 MD	15 MD	750	750	50/MD	15 MD	15 MD	750	750
2. Shallow cultivation	85/MD	7 MAD	7 MAD	595	595	85/MD	7 MAD	7 MAD	595	595
3. Series of washing and drying	50/MD	15 MD	15 MD	750	750	50/MD	15 MD	6 MD	750	300
4. Deep cultivation	85/MD	-	8 MAD	-	680	85/MD	-	-	-	-
5. Liming										
Broadcast	50/MD	0.5 MD	-	25	-	50/MD	0.5 MD	0.5 MD	25	25
Furrow base placement	50/MD	-	4 MD	-	200	-	-	-	-	-
c. Covering	85/MD	-	2 MAD	-	170	-	-	-	-	-
			Sub-total	2 120	3 145			Sub-total	2 120	1 670
Grand total				5 453	7 811				5 453	1 836

As an answer to the soil and water pollution induced disease 'luminous vibriosis', techniques were developed to revive the collapsed shrimp industry through the concerted effort of the Negros Prawn Producers Marketing Cooperative, Inc. (private sector) and the Bureau of Fisheries and Aquatic Resources of the Department of Agriculture, as follows:

5.1.1 Tilapia water introduction into prawn system (Greenwater system)

The 'Greenwater' concept was conceived in 1995 as an offshoot of a multi-disciplinary monitoring of the water from Tilapia finfish (*Tilapia mosambicus*) in the Little Sur Development Corporation farm in Saravia, Negros Occidental. Results of the 12 months monitoring of seven Tilapia ponds at different stages and species revealed that Tilapia water is suitable for use in shrimp ponds. At 3.0 tonnes biomass, the level of luminous bacteria is very low (oftentimes non-detectable at 10^1), total Vibrio count within tolerable range (majority of which are yellow colonies), the physico-chemical parameters are all within optimum range and plankton composition favourable for shrimp culture. Several trial runs using Tilapia water for prawn culture had been experimented. Others employed the original method, while some used a modified scheme. At present, after two years, no technology was established. It is noteworthy that the results in the past experiments conducted at LSDC farm were utilised for the trials in FSD and FEVE farms. Naturally, some modifications were introduced and methods were devised in order to come up with more worth effective strategies and management schemes. The Santa Clara shrimp farm improved the technique by combining this Greenwater system with low salinity. The cost and return analysis is shown in Table 7.

Table 7. Cost and return analysis of Sta Clara Prawn Farm, Negros Occidental, Philippines.

Cost and return analysis	Pond 3	%	Pond 4	%
Land preparation	24 288.99	3.54	22 912.92	3.55
Fertilisers	423.94	0.06	383.35	0.06
Probiotic	32 210.50	4.69	31 442.00	4.88
Salaries and wages	85 084.48	12.40	85 084.48	13.20
Security services	9 629.66	1.40	9 153.66	1.42
Fry	53 893.62	7.85	50 133.60	7.78
Feeds	191 401.80	13.29	172 087.00	26.69
Supplementary feeds	69 858.05	10.18	62 765.00	9.73
Electricity	170 607.03	24.87	161 935.50	25.12
Chemicals	8 656.00	1.26	8 364.00	1.30
Laboratory analysis	38 197.20	5.57	38 197.20	5.92
Pond maintenance	844.00	0.12	844.00	0.13
Repairs and maintenance	350.00	0.05	350.00	0.05
Harvest expense	2 081.75	0.30	1 846.00	0.29
Administrative expense	22 869.57	3.33	22 168.56	3.44
Total production cost	687 107.60		644 754.35	
Biomass				
Gross sales	4 163.50		3 741.00	
Direct cost/kg	1 440 686.57		1 250 835.00	
	164.79		172.35	

5.1.2 Improved low salinity and greenwater system technique

ABW = 28.18 g	ABW = 27.24 g
DOC = 136 (9/6/00)	DOC = 137 (9/7/00)
Sar percent = 88 percent	Sar percent = 89 percent
Biomass = 4 163.5	Biomass = 3 741.0
FCR = 1.17	FCR = 1.12/FCR = 1.40 (with golden snail)
Total feeds = 4 874.6	Total feeds = 4 149.3
Area = 0.5261 ha	Area = 0.4914 ha
Stock	Stock = 151 920 (Cebu)
SD = $31.0/m^2$	SD = $30.0\ m^2$
Stocking date = 4/24/00	Stocking date = 4/24/00

This technology, which employs routine laboratory analysis, was a breakthrough in Negros Occidental after several crop losses. This is already validated in the FSD and FEVE sites for four crop cycles. The performance of this culture technique is now being verified in other areas in the province.

The many insights learned from the foregoing trials led to the eventual development of successful finfish-based biological control technology in the FSD and FEVE farms, Negros Occidental.

The practices observed by the above-mentioned farms attributed to the success of the operation are:

- The ponds were used for Tilapia culture from 1995 to 1996. Tilapia culture may have reduced the level of luminous bacteria in the pond soil.
- For every pond, there were at least two reservoirs with 'greenwater' that supply the water requirement.

This ratio ensures that there is ample supply of good water from the reservoirs, especially during emergency situation such as phytoplankton die-off:

- A biomass of 3 000-3 500 kg of Tilapia is maintained in each reservoir.
- Tilapia are installed in the centre of the pond stocked with prawns. The cages are placed in such a way that the water circulation is not hampered.
- A biomass of the range 400 to 1 200 kg Tilapia was maintained at the shrimp pond.
- Farm management decisions were based not only on visual observations but also on results of laboratory analyses, soil and water.

The rationale of this technology is that luminous vibriosis is usually caused by *Vibrio harveyi*. Although *V. harveyi* has been considered a part of a normal microflora of shrimp and its environment, certain strain(s) may be more pathogenic than the others. When these pathogenic strains are plentiful, they can overwhelm the immune system of shrimp, thus allowing disease to develop.

The Tilapia serves to minimise if not eliminate the incidence of *V. harveyi* in the ponds. Tilapia has been known as an effective bio-filter that cleanses the water of vibrios to a very significant extent.

5.1.3 Low salinity pond culture technique

The rationale behind this genius idea is the realisation that luminous bacteria thrives in marine water, hence will not survive in low-saline water, a habitat greatly dissimilar to its own. Figure 5 shows this relationship.

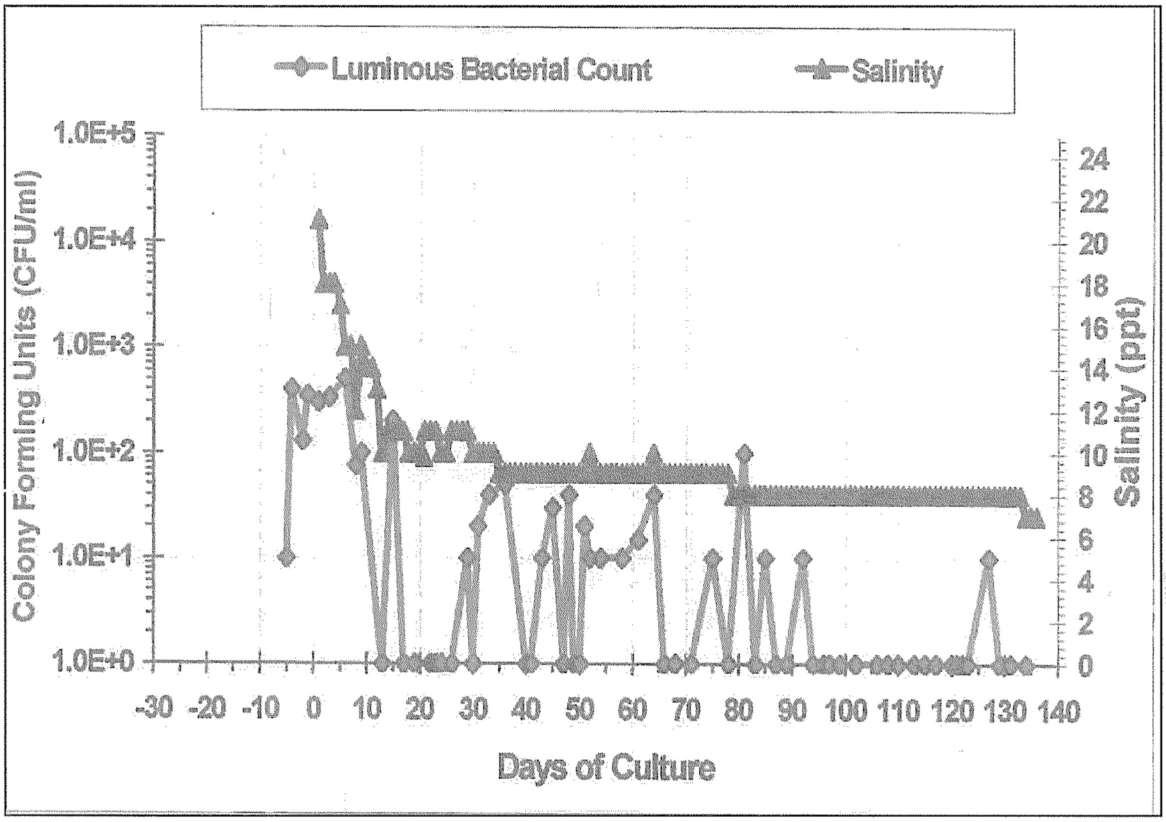

Figure 5. Salinity vs. water bacterial profile, Sta Clara shrimp farm, Negros Occidental.

To complement the low-saline technology, pro-biotic is used in the water as deterrence to bacteria that might have managed to infest the stocked animal.

It is certain that this fresh idea has struck a hopeful note in the prawn industry. Emphasis, however, must be made that this technology is site-specific. Meaning, it works in certain ponds with certain parameters but fails in others with dissimilar peculiarities.

5.1.4 Crop rotation

The principle behind the crop rotation as a disease control in shrimp culture has been explained by Paclibare *et al.* in 1998. The continuous monoculture of the shrimp over the past few years may have caused the increase in the shrimp pathogenic *V. harveyi* in the culture environment.

Although many farms employ thorough pond preparation techniques, these bacteria may be carried over into succeeding culture as they may be protected in bacterial bio-films. Bacterial bio-films are composed of populations or communities of microorganisms adhering to environmental surfaces. Bio-films may be found on essentially any environmental surface in which sufficient moisture is present. Bio-films are notably resistant to drying and disinfection. The role of bio-films in the development of bacterial diseases in shrimp ponds has not been investigated yet. However, the finding of Karunasagar *et al.* (1996) may have some relevance to shrimp ponds. They reported mass mortality of *P. monodon* larvae due to an antibiotic-resistant *V. harveyi* infection and suggested that antibiotic-resistant, virulent strains of *V. harveyi* were colonizing larval tanks.

Since shrimp and finfish, such as Tilapia and milkfish (Bangus) belong to different orders within the animal kingdom, they are considered good candidates for crop rotation. It has been proven that the culture of Tilapia favours the proliferation of bacteria other than *V. harveyi*.

5.1.5 Polyculture of Bangus and shrimp

This technique combines prawns and milkfish (*Chanos chanos*) in one culture. It uses the ratio of fewer than 3 pieces of prawn to 1 piece of milkfish per sq m. This technology averts heavy losses where there is extremely low market price of milkfish, specifically in the months of June to July 1998. This technique was the trend in areas where milkfish culture alone could not generate enough income to a sustainable level. With the harvest of prawns that can be marketed at a higher price, the grower has a fallback position.

5.2 Institutions involved

The institutions involved in the development of technologies to combat salinization and to improve productivity of shrimp and rice farming in coastal lands are as follows:

- Bureau of Soils and Water Management (BSWM)
- Bureau of Fisheries and Aquatic Resources (BFAR)
- Philippine Rice Research Institute (PHILRICE)
- Negros Prawn Producers Marketing Cooperative, Inc. (private sector)
- University of the Philippines in the Visayas
- Philippine Council for Aquatic and Marine Research and Development (PCAMRD)
- Southeast Asian Fisheries Development Centre (SEAFDEC)

6. Other issues for controlling salt-affected soils in the Philippines

Salinity is the main constraint to crop growth and productivity especially when salinity is high. This condition exists for rice crop during dry season. For shrimp, experiences showed that high salinity in pond water gives a favourable condition for the existence of the luminous bacterial disease that caused the downfall of the shrimp industry in the Philippines. Main constraints to the efforts for controlling the development of salt-affected soils are:

- Lack of irrigation facilities to leach the salts from the root zone
- Lack of high-yielding salt-tolerant varieties

7. Research requirement

- Establishment of database for salt-affected soils with the use of remote sensing/GIS.
- Development of appropriate techniques for monitoring/assessing and predicting salinity development of a certain area.
- Integrated soil management for increasing productivity of salt-affected soils.
- High yielding salt tolerant rice varieties.
- Researches on the eradication or control of disease(s) for the sustained production of shrimp in the salt-affected soils.

8. National agricultural plans and programmes for the improvement of salt-affected soils

8.1 Agrikulturang Makamasa Rice Program (National Rice Production Programme of the Philippine Department of Agriculture)

This flagship programme of the Department of Agriculture is being implemented nationwide, with organic-based fertilisation, good high-yielding seed varieties, adequate irrigation, and Integrated Pest Management (IPM) as the components.

The organic-based fertilisation is site specific and a mixture of organic and inorganic fertilisers. A specific fertiliser recommendation group is for salt-affected soils (Table 8). This fertiliser recommendation was used as one of the treatments in recently concluded FAO TCP Project on salt-affected soils that gave a yield of more than 5 tonnes/ha.

8.2 Oplan Sagip-Sugpo Task Force (Task Force for Saving the Shrimp Industry)

This task force was created by a Special Order issued by the Secretary of the Philippine Department of Agriculture Salvador H. Escudero dated September 16, 1996. The objectives of the task force are to hasten the rehabilitation of the shrimp culture industry and to set the R&D direction of shrimp health management and production aspects. The task force has a wide representation of agencies including the private sector.

8.3 Mangrove protection and utilisation regulations

The regulations related to mangrove protection and utilisation are covered by the Department of Environment and Natural Resources Administrative Orders (DAO). The establishment of Buffer Zones in the coastal and estuarine mangrove areas is covered by DAO 76 series of 1987. The regulations concerning the conversion of mangrove areas into fishponds is covered by DAO 15 series of 1990.

9. Information on the cooperative project with FAO, TCP/PHI/6712

Project Title:	Integrated Management for Salt-Affected Coastal Soils in the Philippines
Effective Date:	January 1998
Project Date Started:	May 1998
Closing Date:	June 2000

Recently, the demand for food and space of the increasing population resulted in the extensive exploitation of coastal areas across the Philippines. The country has one of the longest coastlines in the world comprising approximately 500 000 ha of arable land. These lands, in general, are an integral component of the agricultural food production synergies; otherwise known as Strategic Agriculture and Fishery Development Zones (SAFDZ) as recently identified by the Department of Agriculture in the Philippines.

Table 8. Reformulated BFS fertilizer recommendations for saline-intruded, flood-prone areas, Group 7. (> pH 7.5; EC > 2 but < 8)

MIXED ORGANIC-INORGANIC FERTILIZER GROUP 7						
Region	**Municipalities/Provinces**	**Recommendation (bags/ha)**	**Wet season**		**Dry season**	
			Heavy/medium	**Light**	**Heavy/medium**	**Light**
1	Currimao, Ilocos Norte	*Basal application*				
	Sta. Catalina, Ilocos Sur	Commercial organic	5	5	6	6
	Sta. Maria, Ilocos Sur	1. 14-14-14	3	3	2	2
	Binmaley, Pangasinan	2. 16-20-0 or (20-20-0)	0	0	1 or (1)	1 or (1)
	Lingayen, Pangasinan	3. Urea	0.5	0.5	1.5	1.5
	Sual, Pangasinan	4. $MgSO_4$	1	1	2	2
3	Sexmoan, Pampanga	5. $ZnSO_4$	10 kg	10 kg	10 kg	10 kg
	Macabebe, Pampanga	*Topdress*				
	Masantol, Pampanga	Urea	1.5	2.5	1.5	2.5
		Total fertilizer mix				
2	Aparri, Cagayan	Organic fertilizers	5	5	6	6
	Buguey, Cagayan	Inorganic fertilizers	6	7	8 (8)	9 (8)
	Abulog, Cagayan	plus 10 kg $ZnSO_4$				
3	Paombong, Bulacan	*Basal application*				
	Hagonoy, Bulacan	1. Commercial organic	5	5	6	6
	Bulacan, Bulacan	2. 14-14-14	2	2	0	1
	Obando, Bulacan	3. 16-20-0 or (20-20-0)	1 or (1)	1 or (1)	3 or (3)	4 or (4)
	Malolos, Bulacan	4. Urea	1	1	1	1
5	Calabanga, Camarines Sur	5. $MgSO_4$	1	1	2	2
	Bonbon, Camarines Sur	6. $ZnSO_4$	5 kg	5 kg	5 kg	5 kg
	Cabusao, Camarines Sur	*Topdress*				
	Libmanan, Camarines Sur	Urea	2	2	2	2
	Canaman, Camarines Sur					
	Minalabac, Camarines Sur	**Total fertilizer mix**				
	Milaor, Camarines Sur	Organic fertilizers	5	5	6	6
6	Oton, Iloilo	Inorganic fertilizers	7 (7)	7 (7)	8 (8)	10 (10)
	Tigbauan, Iloilo					
	Pan-ay, Capiz	plus 5 kg $ZnSO_4$				
8	Borongan, Eastern Samar	*Basal application*				
11	Mati, Davao Oriental	1. Commercial organic	5	5	6	6
		2. 14-14-14	2	3	0	0
10	Butuan, Agusan del Norte	3. 16-20-0 or (20-20-0)	1 or (1)	1 or (1)	3 or (3)	3 or (3)
	Nasipit, Agusan del Norte	4. Urea	1	1	1	1.5
	Buenavista, Agusan del Norte	5. $MgSO_4$	1	1	2	2
		6. $ZnSO_4$	10 kg	10 kg	10 kg	10 kg
Note:	The towns indicated showed that their respective wetland areas grown to rice are presumed to be saline-intruded, being within the coastal areas. Degree of salinity subject to laboratory analyses; for pH and EC. Areas with EC of >8 mS/cm during dry season will be subjected to critical review and or possible rejection.	*Topdress*				
		Urea	2	2	2	2.5
		Total fertilizer mix				
		Organic fertilizers	5	5	6	6
		Inorganic fertilizers	7 (7)	8 (7)	8 (8)	9 (8)
		plus 10 kg $ZnSO_4$				
		Topdressing and possible addition of N fertilizer should be guided by leaf color chart.				

These areas, which are coastal alluvial plains and broad alluvial flood plains basically drained by the fringing mountains, are traditionally being cultivated for the production of rice and other food grains. However, soil productivity of these areas in terms of the agronomic yield of rice and other food grains is below the Philippine's national average. A major factor causing this low productivity is the combined effect of adverse soil

conditions, primarily salinity and/or sodicity, and the cyclic occurrences of climatic disturbances, which can cause severe damage to the agricultural crops being grown in these areas.

Salinity or sodicity of agricultural lands in the Philippines was derived as a consequence of primary salinization resulting from surface and sub-surface saline water intrusion into the soils, due to diurnal tidal fluctuations of the nearby body of seawater and typhoon surges. Salt-affected soils interspersed with non-salt affected soils within the coastal areas across the Philippine archipelago, thus it is difficult for the rice farmers to farm these areas. Under these conditions only 50 to 60 cavans/ha of rough rice could be harvested. (One cavan = 50 kg)

The Bureau of Soils and Water Management (BSWM) carried-out a small-scale experimentation in collaboration with the FAO Global Network on Integrated Soil Management for Sustainable Use of Salt-affected Soils. Through these research activities a number of low-cost, low-risk techniques have been identified for the conditions prevailing in the Philippines. However, management of salt-affected soils requires a combination of methods developed from a detailed characterisation and comprehensive investigation of the targeted salinization processes. These integrated management techniques should then be field-tested and adapted in pilot demonstration farms to local conditions. Extrapolations for larger-scale rehabilitation/management recommendations can be based on results of studies from such demonstration farms.

These coastal and/or basin areas, presently being affected by salinization processes have been planned to be part of the economic growth areas, thus, both foreign and local investors are being encouraged to invest in agricultural development programmes such as among others, the Agrikulturang Makamasa for rice, corn and high value commercial crops programme of the Government.

In order to gain an in-depth understanding of the hazards and demonstrate appropriate technologies to improve salt-affected soils, technical assistance from FAO was requested to assist the government in the introduction and consequent development of appropriate integrated low-cost, low-risk management techniques. This was done through the establishment of experimental farms in the three main islands of the Philippines, designed to address the needs of small-scale farmers. It is expected that results of this project would be integrated into the agro-technology transfer activities and policy decision process of the Department of Agriculture, regarding agricultural investment in coastal areas.

The primary objective of the project was to assist the Government of the Philippines in the demonstration of the integrated management techniques for the improvement of salt-affected coastal lands in support for food security programme in the country.

Upon completion of the project the following were accomplished:

1. Guidelines on integrated low-cost, low-risk technique for the management of salt-affected soils under local conditions.
2. Appropriate integrated methods for the management of salt-affected soils in three demonstration sites.
3. Training of trainers/national staff as focal points of carrying out agricultural programmes and projects in salt-affected soils.
4. Training of farmers in each demonstration farm as innovators/leaders on soil management of salt-affected soils.
5. Extension pamphlets, curriculum and material published and disseminated to small-scale farmers in coastal salt-affected areas.
6. Proceedings of the workshop on integrated management for sustainable use of salt-affected soils.
7. Socioeconomic evaluation of the demonstrated management techniques including the socioeconomic viability of introducing aquaculture components into the system.
8. Technical documents on project activities and achievements, the economic uses and appropriate management techniques for increasing crop production in coastal salt-affected soils as a basic reference for large-scale national agricultural development projects in coastal salt-affected areas in the country.

9.1 Project activities

The project was implemented in three pilot demonstration farms situated in coastal areas in the northernmost island of Luzon in Aparri, Cagayan, the Southern island of Luzon in Bicol Region, Sta Teresita, Camarines Sur and the coastal area of Mindanao island in Butuan City. The criterion used in the selection of the pilot farms was based on the extent of saline areas and the type of climate was also considered. The biophysical and socioeconomic profile for each site was also described. Activities implemented by the project included:

9.1.1 Training

To increase the participation of the field technicians and farmers themselves, to make them fully aware of the problems and to increase the possibility of adaptation of whatever technology that can be developed from the project, series of training were conducted.

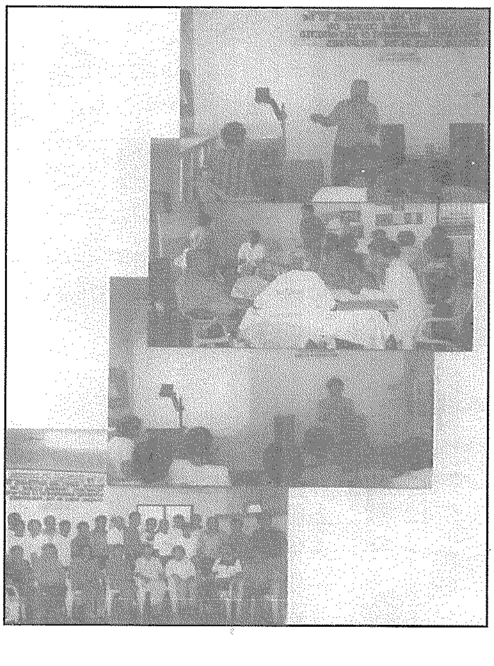

Figure 6. First training involving the agricultural technicians of Appari, Cagayan

Figure 7. Awarding of certificates to participants after the training for agricultural technicians held November 23-24. 2000

Figure 8. Group picture of participants with the consultants and FAO project coordinator

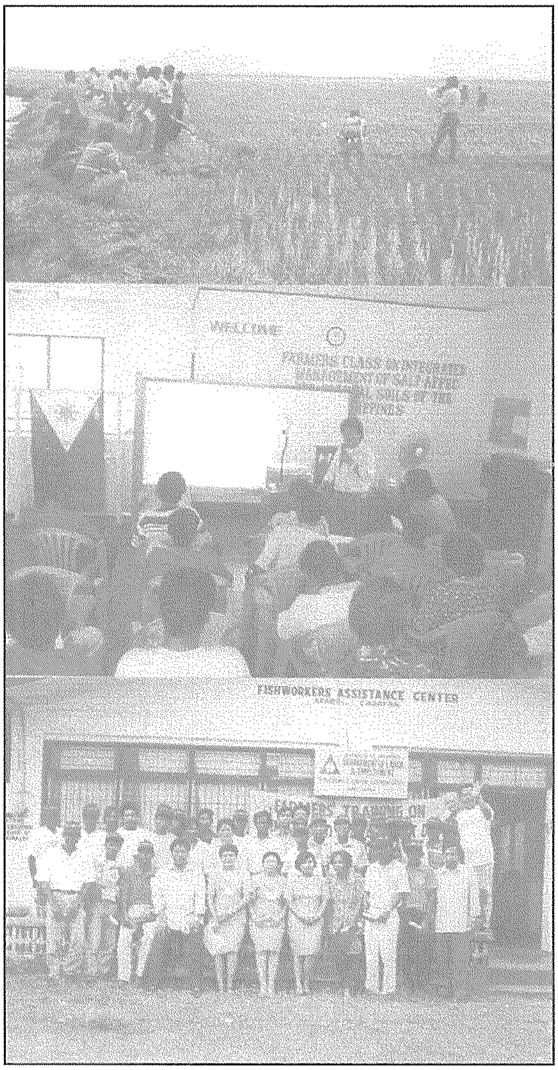

Figure 9. Second training component involving the rice farmers at Aparri, Cagayan

Figure 10. Group picture of participants

9.1.2 Knowledge, attitudes and practices

A strategically planned, problem solving and participatory oriented extension programme was done aiming at increasing awareness/knowledge level of identified target beneficiaries and altering their attitudes and/or behaviour towards favourable adoption of a given idea or technology, using specifically designed messages, cost-effective extension methods and materials to support its information education/training and communications intervention activities.

9.1.3 Technologies and treatments applied

The research design considered the interaction effect of local and salt-tolerant varieties, water management (flushing and pumping out of irrigation water during high salinity intrusion) and application of inorganic and organic fertilisers (rice straw and commercial organic). Treatments used are as follows:

T_1 - $V_1F_1W_1$	T_5 - $V_2F_1W_1$
T_2 - $V_1F_1W_2$	T_6 - $V_2F_1W_2$
T_3 - $V_1F_2W_1$	T_7 - $V_2F_2W_1$
T_4 - $V_1F_2W_2$	T_8 - $V_2F_2W_2$

Where:

V = Variety
V_1 = Traditional variety
V_2 = Salt-tolerant variety (PSB RC 50)

F = Fertiliser
F_1 = 2 T rice straw + Rec. inorganic fertiliser of fertility group 7 BFS
F_2 = 6 bags commercial organic + Rec. inorganic fertiliser of fertility group 7 BFS

W = Water management
W_1 = flushing
W_2 = Pumping of water

The local crop variety frequently was used by the farmer cooperator (V_1); the other variety (V2) was the recommended variety of PhilRice.

9.1.4 Installation of piezometers

a) Different micro-topographic sites

Piezometer or sampling tubes (5 cm in diameter, 1.5 m long) was installed at various micro-topographical areas. This was done to determine the location and extent of degree of salinity, which are related to tidal river flooding caused by typhoon, impedance of natural drainage by tidal fluctuation and subterranean saltwater intrusion.

b) Experimental site
For the techno-demo site, two piezometers (top left corner and bottom right corner of the harvest area) were installed in each plot (experimental unit) to monitor the water quality/characteristics of the different plots. Water was sampled at depths 0-30 cm and 30-60 cm for every phonological stage of the rice crop (i.e. 0, 30, 60, 80 DATS and harvesting).

9.2 Results of the techno-demo trials

a) Aparri, Cagayan
Data collected indicates that the soil of the experimental site both surface and sub-surface are very strongly acidic with pH 4.6-5.0. This suggests that the site is in a potential acid sulphate area. The ECe of surface and sub-surface was both moderately saline at 4-8 dS/m.

Only Aparri site succeeded in obtaining the crop yield and results showed that all plots treated with organic fertilisers combined with inorganic inputs produced > 5.0 tonnes/ha. All other plots produced between 4.0 and 5.0 tonnes/ha, as compared to the previous yield of farmers at 30-60 cavans/ha.

b) Camarines Sur, Bicol Region
Data collected indicates salinity level at slight to moderate with ECe of 3-8 dS/m. The pH values of both soils and water are near neutral (pH 6.5-7.8).

c) Butuan City, Surigao del Norte
Based on the results of the soils and water analyses pH values are near neutral at 6.5-7.2 and ECe analysis showed moderate to high salinity level at 2-4 dS/m.

9.3 Conclusion and recommendations

There is a promising results obtained based from the experiment in Aparri, Cagayan. Rice planted in slightly saline affected area and fertilised with inorganic inputs coupled with application of zinc sulphate and magnesium sulphate (BFS fertiliser group 7) produced a yield of > 4 tonnes/ha. The yield could further be increased with the application of commercial organic fertiliser (300 kg/ha).

Good yield was obtained (4-6 tonnes/ha) due to good timing of planting where critical stage did not coincide with higher salinity level. During that time low salinity (< 4 dS/m) was experienced as an effect of heavy rains causing dilution of salt in the area. Unlike that of the techno-demo trials in Camarines Sur and Butuan City where the rice crops were washed out by the flood due to heavy rain. Crop could not be grown unless proper timing is followed.

Based on the results it is suggested that there is a need to continue the project on the same sites using similar treatments, or include other treatments such as with varying levels of zinc and magnesium sulphate.

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Thailand

Summary

Land degradation, particularly related to soil salinity, is the oldest problem of mankind in agricultural production since ancient time. Soil salinity is a major factor that has turned high quality lands to be low quality ones, becoming a major constraint to agricultural production.

Salt-affected soils in Thailand occur naturally and cover an approximate area of 3.5 million ha. They are divided broadly into two groups, i.e. (1) inland saline soils, and (2) coastal saline soils. In addition to the natural causes, human activities are causing anthropogenic soil salinization, e.g. deforestation, salt production, irrigation and construction of reservoirs, and shrimp farming. The countermeasures on salt-affected soils are applied by using two methods, i.e. prevention, and improvement and reclamation.

The saline soil particularly caused by humans, such as shrimp farming, is a very important issue, which has substantially impact on soil and water resources and environment as a whole. The government has been concerned on these problems so it has banned shrimp farming in freshwater areas throughout the country since July 1998. At the same time it announced the plan to reclaim the land affected by shrimp farming to be used for agricultural purpose.

1. Introduction

Thailand is an agricultural country and is well known in food production, with large amounts of farm products for export each year. Total agricultural area of the country is approximately 21 million ha, which are used for paddy land, field crops, fruit trees and tree crops, vegetables and flowers, livestock farms etc. in an area of 11.0, 5.2, 3.4, 0.15 and 1.3 million ha respectively. Out of 21 million ha of agricultural land, 4.64 million ha are irrigated area, 45 percent of which are located in the Central Plain.

Global demand in food consumption by rapidly increasing world population continues to increase. Also with the economic growth and the better return from farming activities, this has led to the diverse use of land for many purposes, including shrimp farming, which has greatly affected soil and water resources, especially in the form of soil salinization, in arable land.

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Shrimp farming has been practised in the coastal area of Thailand during the last 70 years. Within the last five years, there has been a rapid expansion of shrimp farming into freshwater area of the Central Plain, which is considered the rice bowl of the country, producing one-third of total rice production. This expansion was caused by both the shrimp disease outbreak in the coastal area and the lucrative market of such commodity. It is estimated that the total area of shrimp farms is approximately 72 000 ha in the coastal area, while 22 400 ha are located in 23 Central Plain provinces.

Concerning the food security programme, Thai Government has been implementing several agricultural development projects that have also increased irrigated areas in the country. Although Thailand is at present not a food deficit country, in the long term carelessness in using land resources may result in large area being degraded and will eventually affect future food production. This paper provides an overview of the issues mentioned above and the management of salt-affected soils in Thailand.

2. Extent and distribution of salt-affected soils

Soils are considered to be saline by the presence of a salinized horizon with a high content of soluble salts that affect the growth of plants. This is used in connection with the electrical conductivity of the saturation extract from a soil sample (ECe): i.e. soil is named saline when the ECe is higher than 2 dS/m at 25°C. The levels of salinity hazard on cropping are different, depending on salt composition in the soil, climatic conditions and crop types and varieties.

Salt-affected soils in Thailand cover an area of approximately 3.5 million ha. Salt in these soils is composed mostly of sodium chloride. These are divided broadly into two groups, i.e. inland saline soils and coastal saline soils.

Inland saline soils cover an area of 2.9 million ha, which is distributed in 18 northeastern provinces, i.e. Nakhon Ratchasima, Roi-et, Chaiyaphum, Khon Kaen, Loei, Mahasarakam, Ubon Ratchathani, Srisaket, Udon Thani, Sakon Nakhon, Buriram, Yasothon, Nakhon Panom, Kalasin, Mookdaharn and Amnart Chareon.

Coastal saline soils are found along 2 600 km of the coastal belt in 24 provinces (Bangkok, Samut Sakhon, Samut Songkhram, Samut Prakan, Petchaburi, Prachuab Kiri Khan, Chumporn, Surat Thani, Nakhon Si Thammarat, Songkhla, Pattani, Narathiwat, Pattalung, Krabi, Phuket, Trang, Pang-nga, Satun, Ranong, Chacheongsao, Chon Buri, Chantaburi Rayong and Trad, covering an area of 0.58 million ha.

Beside natural saline soils, soil salinization has occurred since a few decades ago in many places due to certain human activities, including shrimp farming, which resulted in anthropogenic saline soil. Shrimp farming is so far the activity that might have caused the most serious damage, as it has induced salinity to large areas of arable land. However, the Royal Thai Government has realized this problem and has thus banned the shrimp farming in the freshwater areas throughout the country since July 1998.

3. Causes and processes of the formation of salt-affected soils in different regions

In Thailand, soil salinization is caused both by natural and anthropogenic processes. Saline soils are usually formed naturally, but human activities also cause such soils to be developed. The causes and processes of formation of salt-affected soils can be divided into the following processes of salt accumulation:

3.1 Inland saline soils. The phenomenon of this type of salt-affected soil exists in Korat and Sakon Nakhon Basins, through the weathering of salt-bearing rocks and rock salt under the ground of Khok Kruat and Mahasarakham formations.

3.2 Coastal saline soils. These soils are formed from marine and brackish water deposits, and are generally covered by salt-tolerant mangrove vegetation under tidal condition. However, the coastal saline soils can be divided into two kinds, i.e. active tidal flat areas and former tidal flat areas, depending on various physical circumstances.

In fact, active tidal flat areas are affected directly by seawater or brackish water. The areas are mostly flooded at spring tide, but some low-lying areas are flooded daily at high tide. They are very saline with heavy clay or silty clay texture and are very young with little or no profile development. The former tidal flat areas, on the other hand, are formed from brackish water and marine sediment, with high clay and salt contents. The use of such land is mostly for paddy rice and salt-tolerant fruit trees after reclamation.

Also, human activities have been responsible for anthropogenic salinization, which can be described as follows:

- Deforestation with replacing the forests with shallow-rooted crops causes the consumptive use of rainwater to be much less, allowing excess water to percolate down to the water table. The change of ground hydrology has resulted in the movement of the groundwater and its salinity level. This caused high water table and the movement of the solved salts upward by capillary rise and the evaporation processes and accumulation of salts on the soil surface.

- Salt making has usually been found in the very strongly saline soil areas of the northeastern region. The process is that the producers pump the shallow concentrated saline groundwater to get evaporated on the earth pans to obtain salt afterward. This results in the seepage of saline water to adjacent area, particularly arable land.

- The occurrence of saline soil due to the construction of reservoirs is usually related to its proximity to the sources of salt or in the area where saline groundwater is shallow. In that case water in the reservoirs attain high salinity level within a few years.

- Shrimp farming is a big problem that has caused anthropogenic soil salinization. In the process shrimp farmers transfer concentrated brine (and occasionally applied with salt granules) to the ponds and dilute it with freshwater to suit a salinity level (3-10 ppt) for shrimp before their release into it. The intensive use of chemicals and antibiotics has severely affected the environment. Discharge of sludge, excess feeds and saline water into nearby irrigation canals, including seepage of saline water to adjacent agricultural areas and underground water has led to a significant build-up of toxicity and salinity. In some severe cases large rice fields have gone out of production. Moreover, the increasing number of farms has resulted in the exploitation of large tracts of agricultural land that have been converted to shrimp ponds.

4. Biophysical, environment and socioeconomic impacts

At present, major problems of inappropriate land use have increased widely in the country, particularly shrimp farming that has caused soil salinization. Salinization processes including accumulation of excess salts within the soil profile resulted in the deterioration of soil chemical, physical and biological properties. Salinity also caused toxicity to certain biological processes.

When the soil becomes saline the land's quality becomes lower and results in the decrease in agricultural production, as well as damaging the environment. Although an inappropriate land use such as shrimp farming will give farmers much higher profit, the damage caused to the land and adjacent arable areas may be very serious. Since shrimp farming has boomed quickly in Thailand, the damaging effect of salinization on agricultural production, particularly in the southern region and the Central Plain, is quite obvious. The damaging effects include the reduced capacity of the land to provide long-term economic value, increased investment cost and problem of soil and water management.

5. Main solutions, technologies applied in the country to combat each type of salinization

There are two categories of measures being used to combat each type of salt-affected areas: (1) prevention, and (2) improvement and reclamation.

The improvement measures are usually applied in slightly and moderately saline areas. They combine appropriate required technologies as packages, e.g. using salt-tolerant plant varieties, compost, organic matter, green manure, and soil amendments to improve soil properties and increase crop yields.

Prevention and reclamation measures are used in strongly saline areas. Along the seacoasts where land is subjected to seawater or brackish water intrusion during high tide, construction of dyke or polder is recommended to prevent such intrusion. At the same time, the process will allow salt to be leached from the root zone with rainwater or slightly brackish water. Beyond the sea coast where strongly salt-affected inland soils occur, biological measures such as reforestation that include screening of suitable salt-tolerant plant varieties with deeper rooting system and high consumptive use of water are recommended to prevent the spread of salinity. These types of vegetation will be planted in recharge areas to reduce the amount of water that percolates to the water table in the discharge low land areas. This will lower the saline groundwater table to the depth that the capillary rise will not bring saline water up to the soil surface.

6. Other issues for controlling salt-affected soils

Monitoring the salinization of lands is one major practice that has been conducted using satellite imagery together with ground verification. As soil salinization is dynamic, its monitoring needs some sophisticated techniques that must be pursued continuously. This will be useful in conducting research, in drawing soil map, particularly with purpose to control soil salinity.

The degraded soils, particularly salt-affected soils, can be solved by presently available technologies. There are some cases that have occurred by human activities such as salt making and shrimp farming, resulting in the distribution of salinity in very large areas of arable lands. These activities can easily earn high profit in a short time, which has led farmers to continuously conduct these businesses.

The government has been much concerned of issues such as the problems on the deterioration of land quality, caused by anthropogenic soil salinization, may gravely affect the quality of soil and water resources and sustainable land use, as well as the food security programme of the country. Its policy thus enhances sustainable use of natural resources and good care of the environment.

Nevertheless, the improvement of land by technologies still could not stop the problems because farmers still want to continue such profit-making activities. Therefore a legislation measure has to be sought. This measure has been used by the government to protect cultivated areas from those harmful activities. For example, the measure was used in a critical case in 1989 when the government prohibited illegal salt production in the northeastern region. Then in 1998 this legislation measure was used to ban shrimp farming in freshwater areas throughout the country.

7. National agricultural plan for the improvement of salt-affected soils

Shrimp farming on arable land causes salinization and has shown negative effects on soil and water resources and the environment in large areas of the country. The technologies for improvement and rehabilitation of these areas are required and need to be urgently implemented for sustainable land use. The government strongly intends to reclaim and improve salt-affected lands to be used for sustainable agricultural purposes.

Land Development Department has launched a land reclamation and improvement project to subsidize the farmers by changing land use from shrimp ponds to crop cultivation in the system of agricultural freshwater farming, including fish pond and/or livestock raising.

To reclaim abandoned shrimp ponds and resultant salt-affected areas, the land will be reconstructed to suit certain agricultural purposes as well as the need of farmers. After that the desalinization or removal of accumulated salt in the soil by rainwater or water of lower salt concentration is to be done. In some area lime or gypsum is required to replace exchangeable sodium. Salt-tolerant plants are selected for cultivating by farmers' choices. In 1998, selected farms have been developed, covering in an area of 153 ha in 8 provinces in the Central Plain. The reclamation will be continued every year within the target of 160 ha per year.

According to the 8th National Economic and Social Development Plan (1997-2001), the Land Development Department has planned for the improvement of salt-affected soils as follows:

1. To increase crop yields and income of farmers in slightly and moderately salt-affected areas.
2. To prevent the distribution of salinity in cultivated areas.
3. To reclaim the strongly saline areas to suit crop cultivation.
4. To enhance and protect the environment in salt-affected areas.

The policy on shrimp farming is that, the arable land should be conserved for sustainable agricultural use. The Land Development Department has introduced a land use map, indicating the appropriate zones for crop cultivation and shrimp farming. The zones are drawn according to the natural availability and the use of freshwater and brackish water. As such, the shrimp culture will be located essentially in coastal areas. This zoning of land use will also be enforced by legislative measures.

8. Information on the cooperative project with FAO

The shrimp culture has extended significantly in large areas, causing lands to deteriorate and become unsuitable for cultivation. The government of Thailand has considered that there will be a long-term effect on land utilization and consequently the food security programme of the country.

Due to the extent of the problem, the technical assistance from FAO was urgently requested to assist the government in introducing and developing various appropriate improvement and reclamation techniques. The project title is "Impact of Shrimp Farming on Arable Land and Rehabilitation of Resultant Salt-affected Soils, FAO Project TCP/THA/ 8922". The project has been operated since November 1999 and it supports a national programme within the Land Development Department. The objectives of the project are: (1) to assist the Government of Thailand to study the impact of shrimp farming in freshwater arable land, (2) to demonstrate appropriate integrated techniques for rehabilitation of abandoned shrimp farms and improvement of resultant salt-affected lands, and (3) to support the food security programme in the country. The project is currently conducted in three provinces, i.e. Prachin Buri, Suphan Buri and Nakhon Si Thammarat. More details are given in the next paper for Thailand.

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Thailand

Project TCP/THA/8922 Impact of Shrimp Farming on Arable Land and Rehabilitation of Resultant Salt-affected Soils in Thailand

1. Introduction

Cultivation of brackish water shrimp has been practised in the coastal areas of Thailand for the last 70 years. Due to high world market demand and high profits earned, the number of farms has rapidly proliferated in recent decade. It is estimated that 72 000 ha have been used for shrimp culture in the coastal area. Because of inappropriate farming, disease outbreak and environmental problems, including shortage of freshwater required in diluting the salinity in shrimp ponds, have occurred. Shrimp farms have extended significantly from the coastal areas to the freshwater areas of arable land in the Central Plain. In early 1998, 22 455 ha in 23 Central Plain provinces had been converted to black tiger shrimp ponds. Shrimp farmers in this region transported salt or concentrated brine from salt-making fields near the coast to increase salinity in the ponds.

The increasing number of intensive shrimp farms has resulted in the destruction of mangrove forest and enlargement in the area of agricultural land converted for shrimp culture. Discharge of saline water, sludge and excess feed into nearby irrigation canal's as well as seepage of saline water to adjacent agricultural areas and to underground has led to a significant build-up of toxicity and salinity. Even though shrimp farming produces a higher income than traditional agricultural practices, it is not sustainable in the long term. The practice is similar to shifting cultivation as farmers will move to other areas when diseases and pollution problems developed.

In addition to the adverse effects on soil and water properties, shrimp farming practice has turned the good quality land to be unfit for rice cultivation. Within two to three years after introducing shrimp farming, production from surrounding paddies decreased. In some severe cases, rice paddies that were directly affected by increased salinity of soil and water have gone out of production. Conflicts have occurred between rice and shrimp farmers.

In July 1998, the government, with a grave concern with such problems, has announced for the total ban on shrimp farming in freshwater area throughout the country and at the same time planned for the reclamation of the resulted salt-affected land.

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Due to the extent of the problem, technical assistance from FAO was urgently requested to assist the Royal Thai Government in the introduction and subsequent development, of appropriate integrated low cost, low-risk rehabilitation techniques. The assistance, which started in 1999, has supported the Land Development Department to assess the extent of land affected by shrimp farming, develop a monitoring programme, develop and implement demonstration of land rehabilitation and an associated extension programme.

2. Objective

The objective of the project is to assist the Government of Thailand to study the impacts of shrimp farming in fresh water arable land and in the introduction and demonstration of appropriate integrated techniques for rehabilitation of abandoned shrimp farms and for the improvement of salt-affected lands resultant from sea water intrusion and shrimp farming practices in arable lands, in support of food security programmes in the country.

3. Field programme

The field programme is being carried out in three provinces: Suphan Buri, Prachin Buri and Nakhon Si Thammarat. In each province, one abandoned shrimp farm and one adjacent salt-affected rice field were selected. The study focuses on the introduction and demonstration of integrated rehabilitation technologies in both salt-affected farms.

The soil in the study area in Suphan Buri Province is Sing Buri series, very fine, mixed, semi-active, isohyperthermic (Aeric) Ustic Endoaquerts and poorly drained. Relief is level to nearly level. Land is mostly used for rice production.

The soil in Prachin Buri Province is Chachoengsao series, fine, mixed, semi-active, isohyperthermic Ustic Endoaquerts, poorly drained. Relief is level to nearly level. Rice is common in this area.

In Nakhon Si Thammarat, soil is Bangkok series, very fine, smectitic, isohyperthermic, Typic Tropaquepts, poorly drained. Relief is level. Land is mostly used for rice.

These demonstration plots have two major treatments: Best Management Practice (BMP) and Traditional Farming Practice. The best management practice comprises drainage, addition of organic matter and lime/gypsum requirements according to the pH values with fertiliser uniformly across the plots. Other small plots are used to compare the effect of different treatments quantitatively and have been designed to assess the incremental value of individual best practice components.

The treatments applied in the demonstration plots are as follows:

1. T1 Best Management Practice (BMP).
2. T2 BMP – drainage
3. T3 BMP – organic matter
4. T4 BMP – lime/gypsum
5. T5 Control (traditional farming practice)

Rice is being used for demonstration in the wet season while corn may be considered as cash crop in the dry season. Preferably, the farmers select the rice varieties to be used in the demonstration plots. Transplanting is to be done when the seedlings are 30 days old.

Organic matter was applied at the rate of 3 tonnes/rai (6.25 rai = 1 ha). Application of lime/gypsum requirements was according to soil pH values. Lateral leaching has been facilitated to allow the demonstration farms to drain quickly.

The processes of the implementation of field programme are as follow:

- Select the demonstration areas.
- Obtain farmer participation and agreement to implement the treatments in cooperation with LDD staff. Financial incentives were provided where necessary.
- Collect basic data from abandoned shrimp farm and salt-affected rice field before the ponds are filled in and levelled. Collect soil samples from the shrimp ponds before getting filled and from the salt-affected rice field. Use GPS to record the location of all existing bores.
- Fill in shrimp ponds and construct drain in both demonstration farms in each of the three
  sites (provinces). Collect soil samples to analyse EC, pH, CEC, OM, exchangeable Na, Ca, Mg, K, available P, Soluble Na, Ca, Mg, Cl, NO_3, HCO_3 and CO_3. Use GPS to record the location of soil sampling. (Tables 1 and 2 show data from the demonstration farms in Suphan Buri and Prachin Buri provinces. Data from the third selected site in Nakhon Si Thammarat province are not yet available)

- Establish seedbed.
- Apply the treatments 'organic matter', and 'gypsum/lime'.
- Transplant when the seedlings are 30 days old, six per hill at 20 x 20 cm spacing.
- Seven days after transplanting apply fertiliser at the same rate to all plots (30 kg/rai of 16:20:0 mixed fertiliser).
- Measurement and determination of texture, hydraulic conductivity and other physical and chemical soil properties.
- Collect water samples from demonstration plots.
- Manage the plots as normal crop.
- Harvest 3 areas of 3 m x 5 m from each treatment.

4. Selected Sites

a) Suphan Buri Province

The demonstration plot is located at Banpho Village, Muang District, Suphan Buri Province with the area of 2.72 ha. Farmers are Mrs Chamlong Cheavnurus and Mrs Sanranya Mukayaprasert (Figure 1).

b) Prachin Buri Province

The demonstration plot is located at Thayang Village, Bangnampreo District, Prachin Buri Province with an area of 4.16 ha. Farmers are Mr Choa Thaingtae and Mrs Chom Sapprasert (Figure2.)

c) Nakhon Si Thammarat Province

In Nakhon Si Thammarat Province, the demonstration plots are located at Ban Thonglamchiak Village, Chianyai District with an area of 2.72 ha. Farmers are Mr Somya Shimmi and Mrs Chinda Thongkao (Figure 3.)

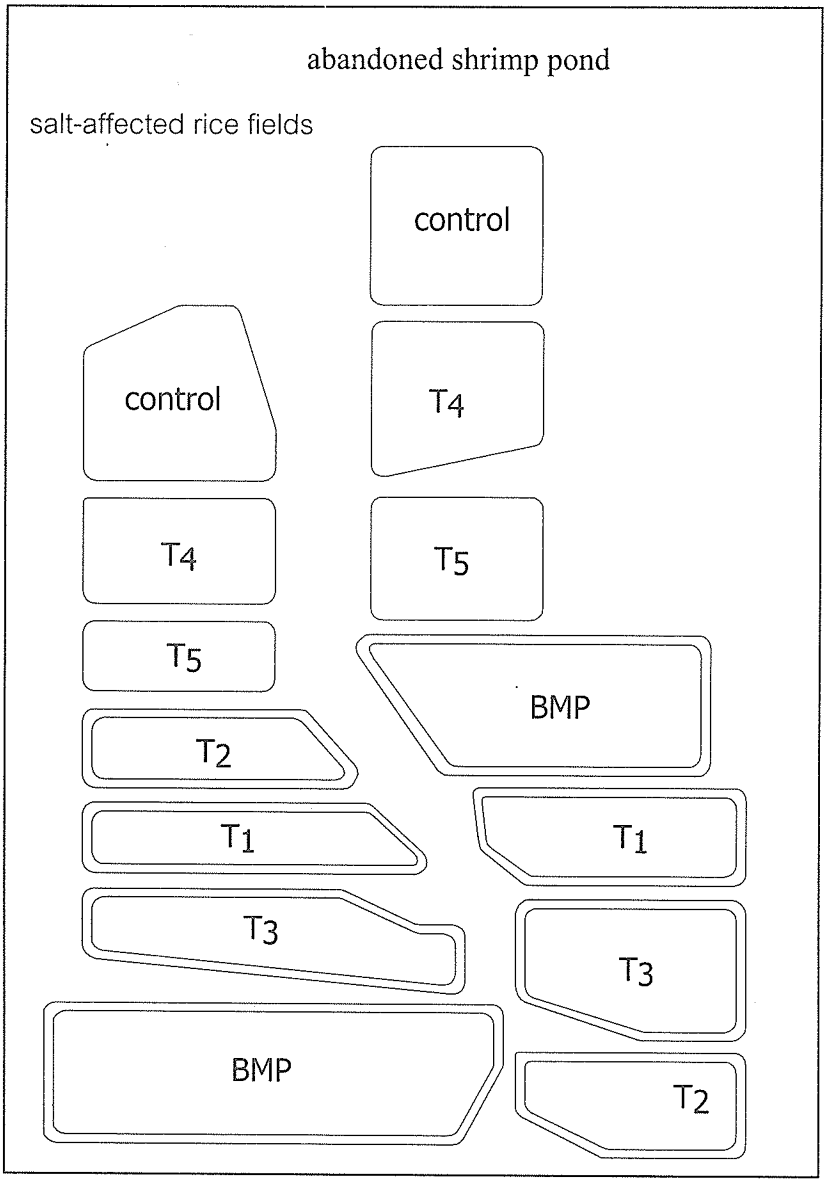

Figure 1. Demonstration plot at Suphan Buri Province.

Table 1. Chemical analysis of soil sample from Suphan Buri Province.

Parameter	Rice field			Shrimp pond			
	0-30 cm	30-60 cm	60-150 cm	0-25 cm	25-50 cm	50-75 cm	75-100 cm
EC (dS/m)	2.16	2.38	1.20	7.86	6.85	5.26	4.86
pH (1:1 H_2O)	6.0	5.5	6.1	6.6	6.7	7.0	7.1
Saturation percentage	107.43	104.28	70.23	67.28	59.48	54.61	54.00
Organic matter, %	1.86	1.50	0.37	0.71	0.60	0.07	0.15
Exch. cations, cmol (+)/kg							
Na	3.05	3.05	0.90	-	-	-	-
Ca	18.63	18.68	10.64	-	-	-	-
Mg	1.94	2.02	1.26	-	-	-	-
K	0.27	0.25	0.14	-	-	-	-
Extractable cations (mg/kg)							
P (Bray II, W/V = 1:10)	<1	<1	<1	4	2	<1	<1
Na	765	714	250	1 122	918	735	735
Ca	3 949	4 282	3 091	2 848	2 616	2 303	2 252
Mg	689	676	428	750	550	420	410
K	101	96	53	72	48	38	41
Sol. cations & anions (me/litre)							
Na	10.00	11.05	4.21	63.67	46.11	48.30	43.91
Ca	5.11	6.41	2.61	35.71	23.69	27.42	15.67
Mg	2.38	2.96	1.34	17.86	11.44	13.19	7.76
K	0.06	0.05	0.03	-	-	-	-
Cl	13.74	16.43	9.61	50.94	49.51	35.58	29.00
NO_3 (ppm)	0.04	0.00	0.27	-	-	-	-
HCO_3	3.44	4.57	1.64	2.72	1.37	0.92	1.01
CO_3	0.00	0.00	0.00	0.26	0.00	0.00	0.00
SO_4 (me/litre)	3.71	4.24	2.09	31.99	22.75	9.84	10.04

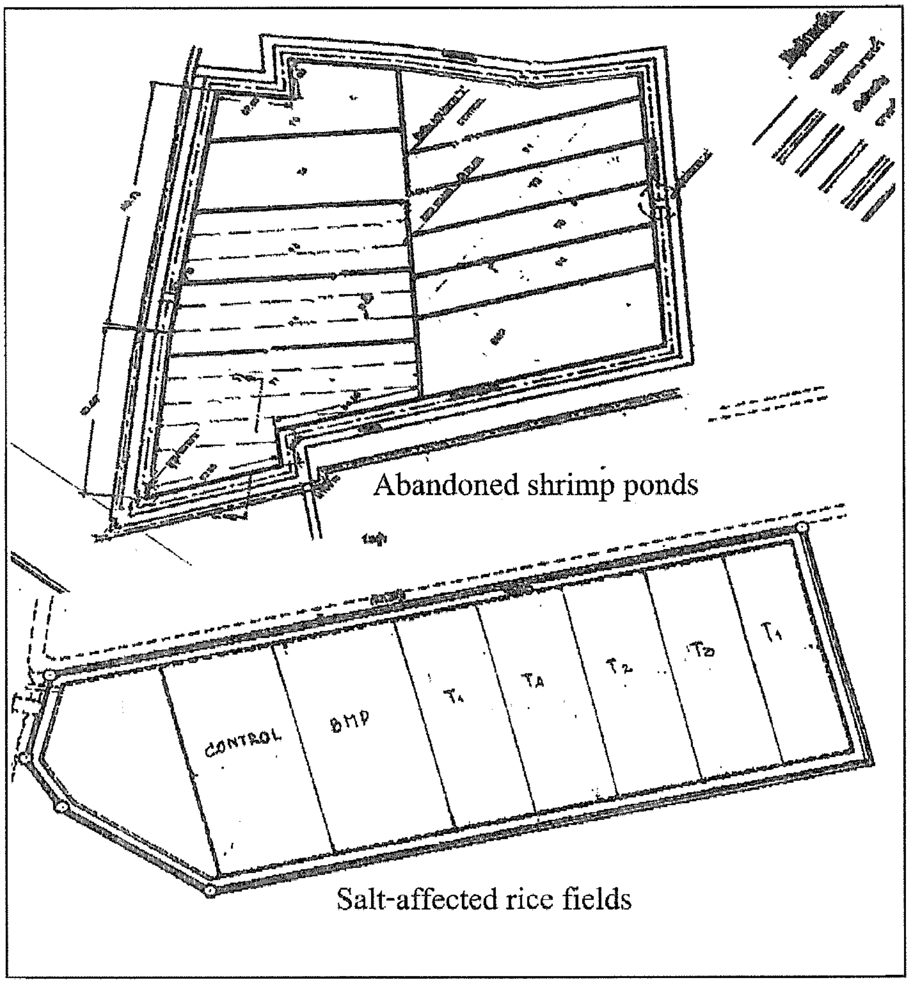

Figure 2. Demonstration plot at Prachin Buri Province.

Table 2. Chemical analysis of soil sample from Prachin Buri Province.

Parameter	Rice field				Shrimp pond		
	0-30 cm	**30-60 cm**	**60-150 cm**	**0-25 cm**	**25-50 cm**	**50-75 cm**	**75-100 cm**
EC (dS/m)	5.87	3.12	3.94	4.95	3.76	4.47	4.69
PH (1:1 H_2O)	4.40	5.00	4.60				
Saturation percentage	96.94	112.22	90.93	88.34	109.14	100.86	86.14
Organic matter, %	2.26	0.67	0.38	3.09	0.86	0.94	1.47
Exch. Cations, cmol (+)/kg							
Na	6.89	5.61	4.88				
Ca	25.75	12.78	9.62				
Mg	4.47	7.08	4.64				
K	0.83	0.76	0.33				
Extractable cations (mg/kg)							
P(Bray II,W /V = 1:10)	22	5	36	109	3	1	2
Na	1 683	1 377	1 071	1 275	1 377	1 224	1 020
Ca	4 222	2 464	2 273	5 242	1 848	1 757	1 929
Mg	1 245	1 666	2 040	1 580	1 583	1 350	1 638
K	330	286	220	470	200	170	170
Soluble cations & anions (me/litre)							
Na	31.09	14.92	19.90	41.72	28.54	32.93	31.18
Ca	11.29	4.83	5.16	15.52	4.64	13.84	9.12
Mg	17.32	8.40	7.60	14.19	5.76	10.02	14.11
K	0.45	0.28	0.31				
Cl	43.94	19.22	35.70	23.66	23.09	31.48	37.11
NO_3 (ppm)							
HCO_3	0.09	0.19	0.72	5.18	0.34	0.30	0.39
CO_3				3.55			
SO_4 (me/litre)	27.77	16.42	5.67	22.27	7.10	6.15	6.34
PO_4				0.0040	0.0014	0.0009	0.0013

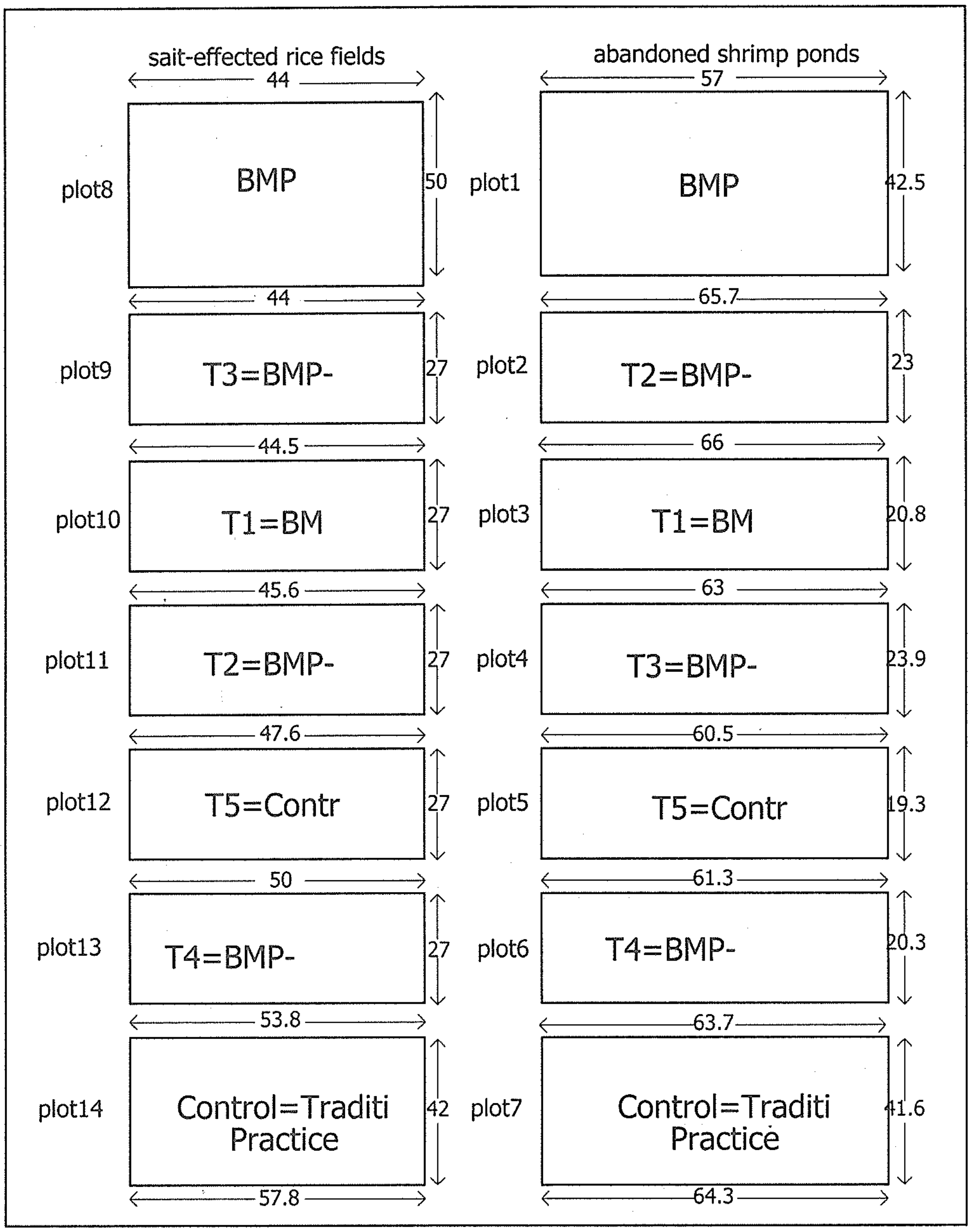

Figure 3. Demonstration plot at Nakhon Si Thammarat Province.

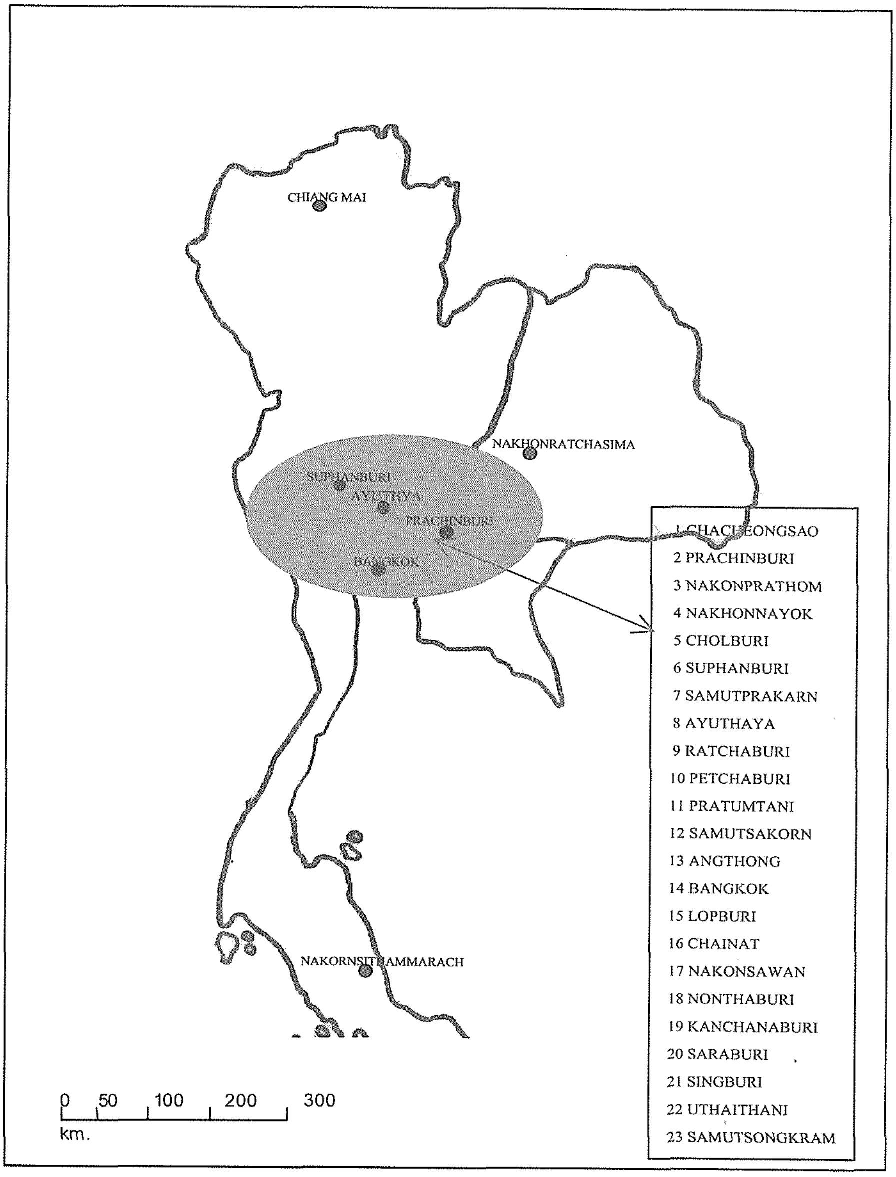

Figure 4. Shrimp farming area on arable land in the Central Plain.

5. Monitoring programme

Land Development Department used Landsat imagery from July 1998 to survey the extent of shrimp farms on arable land in the Central Plain. It was reported that 22 455 ha of arable land in 23 provinces were changed to shrimp ponds (Figure 4 and Table 3.)

Table 3. Shrimp farming area on arable land in 1998.

Province	Area, ha
Ayutthaya	450.56
Angthong	192.80
Bangkok	51.36
Chachoengchao	8 375.36
Chainat	46.40
Chon Buri	1 630.88
Kanchanaburi	19.20
Lopburi	48.00
Nonthaburi	22.24
Nakhon Sawan	44.00
Nakhon Nayok	1 751.52
Nakhon Pathom	2 204.00
Prachin Buri	4 577.28
Pathum Thani	244.00
Petchaburi	321.60
Ratchaburi	349.76
Samut Prakan	518.40
Samut Sakhon	206.08
Samut Songkhram	4.80
Saraburi	15.52
Suphan Buri	1 358.56
Sing Buri	12.48
Uthai Thani	10.08
Total	**22 454.87**

5.1 Monitoring programme in the demonstration plots

- Collect basic data with EM 38 from abandoned shrimp farms and salt-affected rice fields before the ponds were filled and levelled from at least 10-15 locations. Using GPS, record the locations where the collection of soil samples was done. Soil samples were taken at each site at least in two locations of 1 m depth (0-25, 25-50, 50-75 and 75-100 cm).
- Using GPS, carry out an EM 38 survey of each proposed demonstration area. Measurements of EM 38 were recorded from the rice fields and abandoned shrimp farms after the ponds were filled and levelled. Soil samples were taken from each site with at least 14 soil cores, to a depth of 1 m (1- 25, 25-50, 50-75 and 75-100 cm).
- Analyse EC, pH, Na, Ca, Mg, Cl, CO_3 and HCO_3.

5.2 Monitoring of groundwater quality

In order to determine the groundwater quality in study area, it was necessary to install a number of piezometers to detect its movement and salinity distribution. Piezometers have been installed in three provinces, Suphan Buri, Prachin Buri and Nakhon Si Thammarat.

a) Suphan Buri Province

- Piezometers were installed at Ban Pho Village, Muang District. They are located at 10, 20, 50, 100 and 200 m away from the shrimp pond. At each distance, two piezometers were installed at the depths of 3 and 7 m.
- Analyse EC, pH, Na, Ca, Mg, Cl, CO_3 and HCO_3.

b) Prachin Buri Province

- Piezometers were installed at Ban Bangplueng Village, Bansang District. It is located at 10, 20, 50, 100 and 200 m away from the shrimp pond. In each distance, two piezometers were installed at the depth of 3 and 7 m.
- Analyse EC, pH, Na, OM, CEC, exchangeable Na, Ca, Mg, K, soluble Na, Ca, Mg, Cl, CO_3, FCO_3, texture and hydraulic conductivity.

c) Nakhon Si Thammarat

- The piezometers are to be installed at Ban Thonglamchiak Village, Chainyai District. They are to be located at 10, 20, 50, 100 and 200 m away from the shrimp pond. In each distance, two piezometers will be installed at the depth of 3 and 7 m.
- Analyse EC, pH, OM, CEC, exchangeable Na, Ca, Mg, K, soluble Na, Ca, Mg, Cl, CO_3, HCO_3, texture and hydraulic conductivity.

6. Results

- Demonstration of appropriate integrated techniques for rehabilitation of salt-affected soils is being conducted in the plots at Suphan Buri Province and Nakhon Si Thammarat Province. Basic data and soil samples were taken and drainage system was constructed. Treatments were applied in each plot as designed and rice seedlings were transplanted. At Prachin Buri Province site, basic data and soil samples have been taken but the construction of drainage system is not yet complete.
- Monitoring of salt distribution showed a tendency of salinity distribution from shrimp pond to adjacent area. The area of salinized soil near the shrimp ponds is higher than in areas without shrimp ponds. However, data were only from December 1998 when there was an obvious difference in salinity. The dominant kind of ions in the water is sodium. The trend of salt distribution is not homogeneous. This may be due in part to the government ban of shrimp farming and some farmers had already discontinued.

7. Summary

Shrimp farming in Thailand has rapidly proliferated due to strong demand and high profits earned. In recent years, shrimp farms were widespread and encroached an area of 22 455 ha on arable land in the Central Plain.

The increasing number of farms has resulted in an expansion of the area of mangrove forest and agricultural lands converted to shrimp ponds. Discharge of saline water, sludge and excess feed into nearby irrigation canal as well as seepage of saline water to adjacent areas and underground has led to a significant build-up of toxicity and salinity. Shrimp farming is not sustainable in the long term, as the farmers will move to other areas when the diseases and pollution problems are developed

Introduction, demonstration and application of appropriate integrated techniques for rehabilitation of salt-affected soils is being conducted in the three selected provinces. The basic data, soil samples and other necessary data have been collected. The study on salt distribution is being conducted. The result showed that there is a tendency of salinity distribution from shrimp ponds to adjacent areas.

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Viet Nam

Summary

In recent years, the demand of the increasing population for food and space has resulted in the extensive exploitation of coastal areas in Viet Nam. Being a country that is situated right on the beach of the Pacific Ocean, Viet Nam has a coastline of about 3 000 km long. Because of its high population, 80 percent of which are living in rural areas, the land resources are quite limited, especially arable land. Salt-affected soil is one of the problem soils, which should be appropriately used for agriculture production in terms of food crops, forestry and aquaculture. Shrimp culture is an important income for farmers living in coastal salt-affected lands in the country.

There is about one million ha of coastal salt-affected soils; they are concentrated in the Red River Delta in the North and Mekong River Delta in the South. In many coastal areas of Viet Nam, impoundment is used to protect agricultural fields, fish farms and also human habitations from seawater intrusion.

Main reasons for low productivity of shrimp culture are: (1) large ponds: many ponds are so large that the embankment cannot be protected, and water exchange cannot be performed regularly; (2) unsuitable pond location: if the pond is excavated on land only flooded by high tide, it will be difficult to exchange water; (3) unsuitable construction: most of the shrimp ponds in mangrove areas are poorly constructed; (4) reduction of shrimp post larvae: the limitation of food, no measures taken to eliminate predators; (5) conversion of mangroves to agricultural land use; and (6) water pollution.

Main technologies applied in the country to combat salinization are: a strategic plan for water resource exploitation and protection, improvement of drainage-irrigation systems, improving soil fertility by applying organic manure, developing coastal mangrove forests with aquaculture resources, etc.

Some models of land use for aquaculture include: (1) natural aquaculture: dam construction and improved extensive pond, (2) semi-industrial farming, (3) silvofishery model (forest-shrimp), and (4) model of specialized shrimp farming protected by mangrove tree species.

Constraints to high productivity of saline soils include: high salt content, especially during summer causing salt injury; lack of irrigation water to leach salts from the root zone; poor drainage during the rainy season; lack of high-yielding salt-tolerant crop varieties; land tenure system and land use, etc.

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Research needs: -establishment of database of natural resources in coastal salt-affected soils using GIS technology to include: distribution, classification, land use/land capabality, etc.; monitoring, assessment and prediction of soil salinity development; dynamic of salt intrusion along the river systems from estuaries and its control measures; salt-tolerant rice varieties, especially high quality rice; integrated soil management for food and crop production; mangrove forest protection in appropriate combination with fish-shrimp culture; land use policy and environmental protection in salt-affected soil regions.

The Government of Viet Nam is allocating a large part of agricultural land, forestland and barren lands (or unused land according to the Land Law) to people with the aim to the effective use of land, to establish forest and to protect existing natural resources. Government support in combination with farmers and private sector contribution on construction and consolidation of irrigation-drainage systems.

Information about the cooperation project with FAO: The project title: *"Integrated Management and Sustainable Utilisation of Coastal Salt-Affected Soils in Viet Nam"* was started at the beginning of 1997 and has finished in the year 1999. The research site was in Rang Dong Farm, Nam Ha Province in the northern part of Viet Nam. Some activities for the year 2000 are as follows: demonstration sites at the farmer fields with the participation of the farmers in the state farm Rang Dong and in the villages. Agricultural and shrimp farming technologies are recommended in the new settlement areas in Nghia Hung District, Nam Ha Province.

1. Introduction

1.1 Land resources for agriculture in Viet Nam

Total land mass (million ha)	33.3
Lowland area:	8.3
Mekong delta	4.0
Red River delta	1.0
Scattered lowlands	.3
Upland area	25.0
Farmland Area	7.0
Cultivated area	6.9
Cultivated land per capita	0.09
Population:	76 million

Because of its high population of which about 80 percent are living in rural areas, the land is quite limited, especially agricultural land. The population density mostly concentrated in the flat lands, especially in the Red River Delta and Mekong River Delta (Red River Delta 1 142 person/sq km, Northern upland areas 122 persons/sq km, Mekong River Delta 406 persons/sq km, Tay Nguyen Plateau 56 persons/sq km). Salt-affected soils are one of the problem soils that should be appropriately utilised for better agricultural production in terms of food crops, forestry and aquaculture. Shrimp culture is an important income for farmers living in coastal salt-affected soils in the country.

Table 1. Food production (paddy equivalent) over time in Viet Nam.

Year	1 000 tonnes	%
1930	5 480	56
1960	9 879	100
1975	13 493	137
1985	18 200	184
1990	21 408	217
1995	27 571	279
1998	31 854	322
1999	34 000	344

1.2 Food security

From Figure 1 we can see the limited increase of food crop areas, but the area per capita is dropped significantly over years, due to rapidly increased population.

Facing the problem of food security, food production increased over time (Table 1) resulted by the great efforts of farmers and the government, but this will still be a problem if the population continues to increase at the same in the future.

2. Problem identification, magnitude, extent, and distribution of salt affected soils related to shrimp farming practices and seawater intrusion

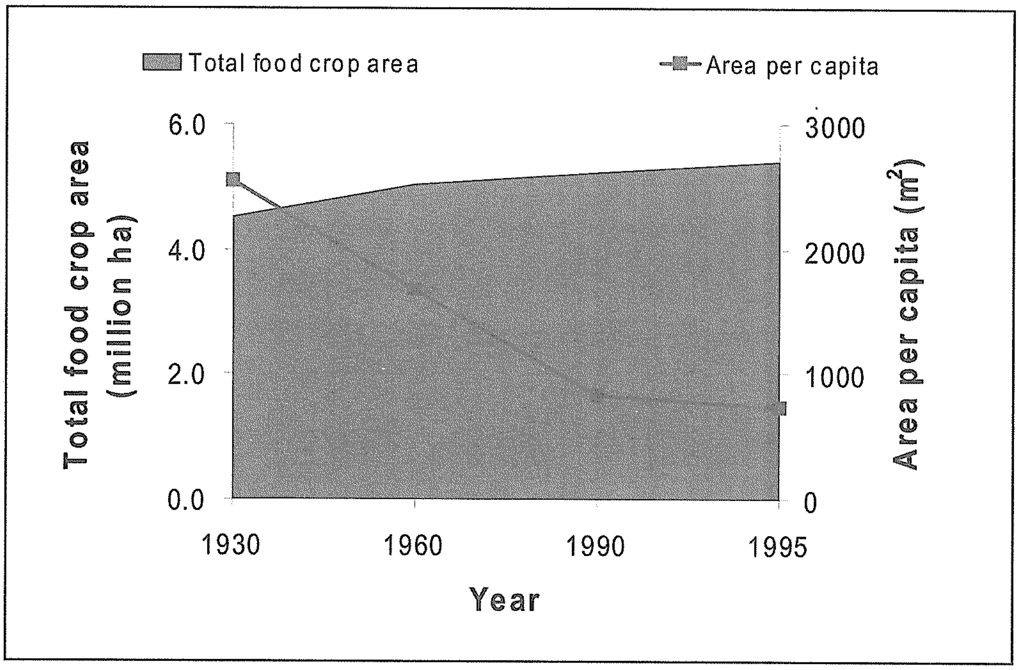

Figure 1. Total food crop area and area per capita.

There is about 1.0 million ha of coastal salt-affected soils that are concentrated in the Red River Delta in the North and Mekong River Delta in the South. By nature, these soils are alluvial soil affected by salt from tidal water or from groundwater. The content of soluble salt in this soil is > 0.25%. In the rainy season, salt is washed out from the topsoil (0-50 cm).

2.1 According to the FAO-UNESCO classification system, saline soils are divided into three soil units:

2.1.1 Gleyi-salic Fluvisols:

Total area is 105 381 ha, distributed mainly in the Mekong River Delta with an area of 56 448 ha, in the Red River Delta 18 807 ha, with the remaining area is in the Narrow Central Plain. The main cause of formation is the intrusion of seawater, which made the soils saturated with NaCl. This type of saline soils is generally used for aquaculture (shrimp culture and others).

2.1.2 Hapli-salic Fluvisols:

Total area is 133 288 ha, distributed mainly in the Mekong River Delta with an area of 102 000 ha, the remaining part occupies in the Narrow Central Plain. The main causes of formation: the intrusion of seawater or saline groundwater, or both. This type has a total soluble salt of more than 1.0 percent, with Cl^- more than 0.25 percent. This type is commonly used for cultivating only one rice crop in the rainy season. The main traditional solution applied to manage and use such soils consists of dyking, washing out salt from the soil, cultivating rice. But this is limited by high total soluble salt contents. In the Red River Delta and the Mekong River Delta, farmers construct beds for growing cash crop, the lower part being used for growing rice or aquaculture.

2.1.3 Molli-salic Fluvisols:

Total area is 732 584 ha, distributed mainly in the Mekong River Delta with an area of 586 422 ha, in the Red River Delta 53 370 ha, in the Narrow Central Plain 73 919 ha and in the eastern part of the South 2 500 ha.

The main cause of formation is rich-salt groundwater. This type has a total soluble salt from 0.25 to 1.0 percent and Cl^- from 0.15 to 0.25 percent. This type of saline soils is mostly used for two rice crops per year. In some regions, where the irrigation and drainage can be controlled, rice yield can be increased.

There are mangrove forest lands up to 494 000 ha, formed in soft mud, submerged in high tide; the earth maturity being very poor, while it continues to form in the process of alluvium deposit. The mangrove areas in Viet Nam are mainly concentrated in the South, with total area of 389 000 ha (or 78.7 percent of the total mangrove area in Viet Nam) of which, the coastal mangrove area in the Mekong River Delta amounts to 306 376 ha (62 percent). The mangrove area in Minh Hai Province of Ca Mau Peninsula amounts to 205 997 ha.

2.2 Soil properties

Physical properties of saline soils are similar to alluvial soils. They have heavy texture with high clay content. Soluble salt is mainly chloride and sulphate, the former being more dominant than the latter. Soil organic matter is high in mangrove saline soils and decreases gradually from the seashore into the inland. Nitrogen content ranges from 0.10 to 0.25 percent, phosphorus content (in P_2O_5) ranges from 0.05 to 0.10 percent. Sum of exchangeable cations is 12-20 meq/100 g of soil, ratio of Ca^{++} and Mg^{++} is less than 1 with the domination of sodium ion (Na^{+}). Saline soils are rich in vermiculite and illite, so they have high content of potassium, ranging from 1.8 to 2.0 percent of K_2O.

3. Causes and processes of formation of salt-affected soils in different regions

3.1. Main irrigation rivers deltas

- Hong (Red) and Cuu Long (Mekong) Rivers are the biggest ones in Viet Nam, their combined volume of flow represents 70 percent of the total flow of all rivers in Viet Nam. In dry season the sediment particles in the water comprise only 0.5 kg/cu m of water, but in flood season the water is very translucent, red in colour, the silt in the water of the river is as high as 3 kg/cu m. According to Pouyanne (1931) the Red River annually transports about 130 million tonnes of alluvial matter to the sea (or 80 million cu m of sediment).

- Mekong River is 4 600 km long, with a watershed area of about 795 000 sq km, and an annual flow of 550-600 billion cu m of water. Mekong River annually transports to the sea about 130 million tonnes fertile alluvial matters (Nguyen Viet Pho, 1978-1984).

- From 1930 to 1950 the Phatdiem-Ninh Binh Region of the Red River Delta extends 10 km to the sea. Therefore, on the average the Red River Delta extended to the sea about 100 m annually (Friland, 1964; Nguyen Vi; Do Dinh Thuan, 1976). The Tien and Hau River estuary regions extend annually 40 m to the sea. The deposited land west of Ngoc Hien District (Minh Hai) Province of the Ca Mau Peninsula from 1930 to 1991 has been increased by 136 ha every year, the speed of extension of the deposited land to the sea is 21.3 m/year (To Quang Thinh, 1990).

- In Viet Nam, saline soils are concentrated in the two large deltas: the Mekong River Delta and the Red River Delta. By the difference of topography, the slope of the Red River Delta is reasonable, the flow of water is high and so the intrusion of seawater is only up to 15 km inland (Table 2). On the other hand, in the Mekong River Delta, seawater flow is 40-50 km inland, even as far as 90 km in 1998, and a big flood in 2000, as the delta is flat and the water flow in the rainy season is smaller than that of the Red River. In the Red River Delta, farmers have built up long dykes, often about 10 m high, to extend the area for agricultural production.

3.2 Impoundments

In many coastal areas of Viet Nam, impoundments are used to protect agricultural fields, fish farms and also human habitations from seawater intrusion. In addition, river systems have been barraged to divert fresh water for irrigation.

The construction of embankments and barrages in the upstream regions for agricultural

Table 2. Salinity intrusion of some rivers in Red River Delta.

River	0.1% L max. (km)	0.1% L min. (km)	0.4% L max. (km)
- Kinh Thay	40	27	12
- Lach Tra	30	22	12
- Van Uc	28	18	8
- Thai Binh	22	15	6
- Diem Dien	12	6	2
- Tra Ly	20	8	3
- Song Hong	14	10	2
- Ninh Co	32	11	10
- Day	40	15	10

Source: Chu Dinh Hoang, 1993

and hydroelectric purposes has led to seawater intrusion in agricultural land. On the other hand, the resultant sealing of fresh water inflow into the mangrove system has resulted in mortality of trees along the seaward belt resulting in erosion of coastline. This problem has been observed in the Can Gio District after the construction of the Tri An hydroelectric station.

The Da River hydropower plant with a reservoir, containing over one billion cu m of water, has reduced the speed of water current and the large amount of alluvium which used to be washed to the estuaries. This results in a very slow growth of mangroves. On the other hand, in the dry season, salt intrusion takes place further and further inland. According to some local research documents, the sea has moved 30 km inland, causing salt intrusion over a large area

4. Biophysical, environment and socioeconomic impacts of seawater intrusion and shrimp farming practices

4.1 Reduction of water flow of the river in dry season

Since most of the water is kept in the reservoirs for agricultural and industrial use and for daily consumption, the water flow in the rivers below the reservoirs is reduced in the dry season. This will result in a shortage of water for areas in the lower reaches of the rivers for daily life. At some river mouths, due to the scanty freshwater flow, tidal water penetrates into the hinterland, damaging the nearby crops. Also, due to the drying up of the rivers, there is not enough freshwater to dilute the wastewater discharged from industrial areas or cities, thus causing pollution of the water resources and accordingly, the loss of important aquatic products, especially in the dry-up river portion.

4.2 Flooding hazards in the rainy season

For the safety of reservoirs, in the rainy season the water flow must be regulated by draining out through spillways. The storing and drainage of water affect the water flow system of the rivers where reservoirs have been built, and may cause long drown-out flood, threatening dams, dykes, and the lowlands. Some localities in the river basin that could drain easily before the dam was erected are now uncultivable, because the water level is always higher than ground level that makes drainage difficult or impossible.

4.3 Adverse effects of irrigation and drainage

Irrigation and drainage have negative effects on the environment. First of all, the reclamation of lowlands, barren lands, and submerged forests has affected natural life there. The digging of canals in the saline and acid sulphate lands makes the neighbouring lands saline and acid too. Especially in the rainy season, floods bring acid water to nearby areas, damaging the crops. The drainage of water in the rainy season also does harm to aquatic life. Many species, found in abundance in the past, have now become almost extinct.

4.4 Mangrove for sea dike protection in Central Viet Nam

- Although Mangrove forests are not abundant in central Viet Nam, they fulfil a very important role in the protection of sea dykes, prevention of coastal abrasion, as buffers against typhoons, as wood reserves and as fishery habitats. After four years of construction and establishment, mangroves already provide a habitat for surrounding fisheries, including species with high economic value. For example, the mangrove density, fish and shellfish output reaches 50 kg/ha/year from year 10 onward and is sold for an average price of US$1/kg.
- Mangroves save the cost of dyke maintenance: Average annual dyke repair costs are 314 350 person-days in Viet Nam for 100 km of sea dykes. Assuming that protective mangrove belts allow savings of 20 percent of annual repair costs, annual savings from preserving/planting mangroves along sea dykes amount to US$62 870 at an average wage of US$1 per person-day.
- Mangroves have an important role for sea dykes protection. The value of preserving mangroves along sea dykes in central Viet Nam is calculated. Analysis reveals the important role of mangroves for sea dyke protection, which is complemented by the support of local fisheries and the production of wood. For 100 km of sea dykes corresponding to 500 ha of mangroves, protective mangrove belts generate economic value of US$533 000 (NPV) calculated over a 30-year period.

4.5 Estimated cost of mangrove destruction in Viet Nam

By 1993, only 38 percent of the mangrove forests that existed in Minh Hai Province ten years earlier, had remained intact from the onslaught of shrimp pond development. Assuming that this ratio applies to mangrove wetlands in the whole Mekong Delta, in the

Red River Delta and in the Northeast, shrimp farm development has led to the destruction of some 148 000 ha of mangrove forests in Viet Nam during the last decade. This implies an economic loss of US$277 million. Even if the loss is attributed to only half of the non-Mekong Delta mangrove areas, because their problem soils are much less, the total economic loss of US$209 million is still substantial.

4.6 Low production of shrimp farms and failure in traditional culture system

4.6.1 Shrimp rearing areas and production

Table 3 shows that the development of shrimp farming in terms of areas and production is very fast because of high income and high benefit for home consumption and exportation. Mostly shrimp culture development is in southern Viet Nam, especially in the Mekong River Delta, which comprise about 80 percent of the area and shrimp production in the whole country. However, the shrimp yield is still low in comparison with their potential.

Table 3. Development of shrimp rearing area and production from 1990 to 1998.

Region	Shrimp rearing areas (ha)				Shrimp production (tonne)			
	1990		1998		1990		1998	
	Area	%	Area	%	Tonne	%	Tonne	%
Whole country	93 544	100	235 498	100	63 765	100	99 359	100
Northern VN	2 406	3	17 347	7	3 335	5	8 829	9
Southern VN (Mekong Delta)	91 138 (85 973)	97 (92)	218 151 (205 901)	93 (87)	60 400 (48 178)	95 (76)	90 530 (77 838)	91 (78)

4.6.2 Main reasons for the poor shrimp yield are as follows:

a) Large ponds: Many ponds are so large that the embankments cannot be protected. Water exchange cannot be performed regularly. This led to increased acidity in the pond water. The results from observing shrimp growth show that shrimp grow slowly even in slightly acid water, growth ceases below pH 5 and mortality occurs at approximately pH 4 (Hamilton and Snedaker, 1984).

Acidification is due to the oxidation of sulphides, which lead to the formation of sulphuric acid. This formation is brought about by an abundant supply of organic matter in the soil at the bottom of the pond. The pH value of the pond water strongly affects the development of microorganisms including bacteria, fungi and protozoa. Acidity also affects the ability of microflora and microfauna to assimilate metabolites. Important chemical processes are also sensitive to changes in pH value. When the pH value decreases, the equilibrium point shifts in the carbonate system and certain toxic heavy metals are released and phosphate ions needed for algal growth are immobilised (Hamilton and Snedaker, 1984).

b) Unsuitable pond location: If the pond is excavated on land only flooded by high tide, it will be difficult to exchange water. If daily exchange water is not possible, there will not be enough seeds and food for shrimps. However if the location is too low, the water will not be released and it will be difficult to screen the entry of potential predators and competitors.

Some examples of the failure of shrimp farm production include: i) The Agriculture Enterprise of the Ben Tre Foreign Trade Service at Thua Duc Commune (1978) felled all the mangrove vegetation surrounding the ponds and used the soil to construct embankments. The construction was not yet complete when the embankment was broken by waves, thus resulting in the waste of a lot of labour and money. ii) The Agriculture Enterprise of Ba Tri District (1979) at Tan Thuy Commune, the shrimp ponds did not have sluice gates, the land dried out after the dike construction and was left fallow and iii) Thanh Phu Agriculture Enterprise at Thanh Phong Commune did not take into consideration the accretion process when constructing their ponds. After building the dykes, tidal water could not enter more than half of the pond area and finally the ponds could no longer be used (Hong, 1982).

c) Unsuitable construction: Most of the shrimp ponds in mangroves are poorly constructed. The pond embankments are not carefully built or regularly maintained and repaired, so they often leak or become damaged. Due to high organic matter content in the soil, holes in the embankments are created when the soil is dry. Fish, shrimp and their predators often find shelter in the holes. Heavy rains often erode the improperly constructed dikes. This was seen in the enterprises in Binh Dai District. The embankments of the shrimp ponds at Duyen Hai Enterprise were broken many times by strong tides. The embankments have collapsed. There is no salt-tolerant grass covering the sides; so when it rains, pyrites in the soil cause the water to become acidic, thus adversely affecting the shrimp. Shrimp can also be affected due to a sudden reduction in salinity or rise in temperature.

Pond beds which are not well constructed cause soil deterioration. There are many striking examples, such as Binh Dai Aquaculture Enterprise, where the water exchange was poor resulting in the death of all *Avicennia ceriops*. The lack of sluice gates in the shrimp farm in the rivulet of Ba Thanh at Ngoc Hien District caused the pond beds to crack. Development of high acidity in pond water impedes the growth of shrimps and cause mortality. Other ponds suffer from the severe situation: the water is too deep and stagnant, containing a large amount of foul smelling hydrogen sulphide. In 1987 the Thanh Phu District had over 20 large shrimp ponds with the largest being more than 200 ha. Because water could not be changed regularly, productivity remained low and the ponds collapsed. In some places the main gully is too shallow or poorly located, and is silted every year.

d) Reduction of shrimp post larvae: During the early 1980s the shrimp ponds were still undeveloped and fishing equipment was inadequate. However, shrimp population in the sea was large and mangrove cover was still extensive. Baby shrimps were still plentiful in the mangrove waterways. After only 30 days or even 15 days of confining shrimp to a pond, people could haul in an enormous catch.

The high export price for shrimp created a widespread movement of shrimp culture, most of which was carried out in mangrove areas. The construction of dikes and the clearance of large areas of mangroves affected both food availability for shrimps and their movement in the mangrove areas.

Over the past three years the availability of large boats and fuel, as well as fishing equipment has quickened the pace of harvesting shrimps. Some fishermen use small-meshed nets to catch baby shrimp in the breeding area, about 10-12 m offshore. This has contributed to the depression of the shrimp population.

Before 1978, the district of Can Gio, which was still separate from Ho Chi Minh City, was poor and underdeveloped. People owned simple fishing tackle, which they used to catch small fish. By mid 1988 they owned 1 124 gape nets of very small mesh size, which could catch the juveniles of lobsters, Penaeus and little fish, accounting for 40 percent of the total yield. With about 400 motor boats and other nets of small mesh size, used during nine months of the year, they take in a haul of 1 500-1 700 tonnes per year of shrimp in shallow sea and estuaries.

e) The limitation of food: Because there is no regular exchange of water, the food in the pond is inadequate. In addition, the water turns acidic, so some insects, algae, soft juveniles of Polychaetas and other creatures, which provide food for shrimp, cannot survive.

f) No measures taken to eliminate predators: One of the problems that face shrimp farming in the mangrove is the large number of predators such as birds, snakes, oysters, frogs, varans, and especially fish among which *Lates calcarifer* is the most dangerous.

This fish preys upon shrimp when they go out for food at night. In large ponds, if the water area is large, it is hard to get rid of *L. calcarifer.*

In Nha Mac pond (Quang Ninh Province), covering over 1 194 ha, with 22 km of surrounding dikes, the highest annual yield reached only 41 tonnes or 34 kg/ha in 1986. The majority of the yield consisted of *Metapenaeus ensis*. In all, 182 tonnes of fish were caught, 5 percent of which were *L. calcarifer,* the largest weighing 12 kg.

4.7 Impact of shrimp farming on mangrove areas

So far, there have been many studies conducted elsewhere on the conversion of mangrove areas into aquaculture and their impact. In Viet Nam, the status is even more serious due to the pressure of economic condition and transmigration. Therefore, the government has promulgated a decision to give a small portion of mangrove areas for shrimp farming and to restore the denuded mangrove forests to maintain ecological equilibrium. Nevertheless, it is very difficult to maintain the forests, because people are only interested in short-term profits. Furthermore, local government agencies in the coastal region sometimes encourage the conversion of mangrove forest areas to shrimp ponds. Shrimp farming in mangrove areas has both positive and negative effects.

4.7.1 Positive socioeconomic impacts:

a) Shrimp pond construction needs a number of workers for clear felling of trees, construction of canal, platforms, embankments and sluice gates. Thus, shrimp pond ventures have provided job opportunities to the dwellers in the mangrove areas.

b) The existence of shrimp ponds also generates income for fishermen and other inhabitants of the surrounding areas, including shrimp pickers, processors and traders, thus improving the livelihood of the people in these areas.

c) Shrimp and crab farming increases national shrimp production and foreign exchange earning.

4.7.2 Negative impacts:

a) Mangroves are recognized as providing important support in maintaining fish resources and as nursery grounds for penaeid shrimp. It is implied that the using mangrove ecosystems for shrimp pond operations will decrease the shrimp production in the adjacent sea.

b) Mangroves are also the habitat of mud crabs *(Scylla serrata)*. Recently the population of mud crabs has decreased due to the overexploitation and the conversion of mangroves to other uses.

c) Mangrove forests create a buffer zone against sea storms and intrusion of saline water. The long, large embankments have blocked the waterways and caused saline water to penetrate inland. In 1991, more than 2 000 ha of rice fields at Can Gio District, Ho Chi Minh City perished due to saline water intrusion.

d) A contagious disease, the mosquito-borne malaria-associated with mountainous and coastal settlements, have been eradicated in the coastal areas. Recently, however, an outbreak of this disease occurred at Can Gio District, Ho Chi Minh City and the coastal area of Ben Tre, Minh Hai Province, caused by clearing mangrove forests for brackish shrimp ponds and rice fields.

4.8 Conversion of mangroves to agricultural land use

The coastal mudflats are abundant in alluvium. Nevertheless, owing to the direct effects of sea tide, they have many characteristics unsuitable for vegetation growth. Pasty mud, insufficiency of air, high salinity and waterlogging due to daily submersion by salty water or by periodical brackish water, are some factors that make it difficult for agricultural crops to grow well on these soils. Only a very limited number of species can grow well in mangrove habitats. Staple crops are very sensitive to unfavourable environmental conditions. Unless a large capital is invested to improve the soil over the year, clearing forests and constructing dykes or building embankments to keep out salty water for agricultural purposes, will have negative effects and can lead to the failure of any land use attempt. This problem has been studied for many years by pedologists in different countries. Population pressure in Viet Nam is the main reason for the conversion of mangroves to agriculture. Without a clear understanding of the characteristics and the dynamics of the changing processes of the soil, people cannot use the land gainfully for any other purpose. The land is quickly deteriorated and after some years has to be left fallow, leading farmers to clear other forest area. The nomadic life and farming practices in coastal areas have thus become a big threat to mangrove areas.

4.9 Pollution

4.9.1 Water pollution:

Due to the rapid increase in population and industries, and lack of treatment facilities for pollutants, the pollution problem has increased rapidly. According to Triet and Thinh (1990), about half a million cu m of water per day is discharged without any treatment into small riverines and canals, which then lead into the Saigon River and the mangrove area at Can Gio District. Under the influence of semi-diurnal tide, pollutants in the wastewater that flows down to a certain distance during ebb tide will flow up during high tide, resulting in that a certain amount of pollutants remains behind in the mangrove area and causes damage.

In Hai Phong City, heavy metals and other hazardous wastes from the cement plant and other factories such as fish canneries and plastic works have had serious impacts on the mangroves at the estuaries of Van Uc, Cam and Lach Tray Rivers. The evergrowing population also discharges sewage pollution to the estuaries with mangroves. Most of the poor people and fishermen living in boats around the mangrove areas live in poor sanitary condition.

4.9.2 Petroleum pollution

Petroleum pollutants, in the form of oil spills, slick and tarballs have become a growing concern in the coast and the seashore. Oil spills are especially dangerous to mangroves because they cut the oxygen supply to pneumatophores. Oil also affects marine creatures and aquatic productivity. Currently, many oil and gas drilling platforms have been put up at the continental shelf in southern Viet Nam. The subsequent increase in oil pollution may become a major threat to the mangrove ecosystem. Coastal dwellers have observed that oil spills have resulted in the death of mollusks and of seedlings. The population of crabs and gastropods in mangrove areas and the wetlands has increased and the death of young Rhizophora and Avicennia has also occurred in these areas.

4.9.3 Pesticides and insecticides

The use of pesticides and insecticides has increased in conjunction with the use of high-yielding rice varieties. The toxic chemicals enter the river systems through runoff and eventually reach the mangrove areas. In urban localities, particularly in coastal cities, solid and liquid wastes poured into the rivers are carried into the mangrove forests by tides. In addition, many agricultural and agro-industrial plants in the suburbs of the coastal cities discharge organic residues into the mangrove waterways. These substances are toxic to plant growth and harzardous to fisheries.

4.10 Coastal mangrove forests with aquaculture resources

In the coastal wet areas, especially at the estuaries where mangrove forests are the places the food sources are abundant and also where live many species of crabs, oysters, fish, etc. About 80 percent of sea aquaproducts of high value concentrates in this zone and from where two-thirds of the raw materials are supplied to the world shrimp and fish processing industry at present, of which there are the processing industries with high profit such as shrimp processing industry (PBUD, FAO, UNESCO, WWF).

The price of shrimp in home market rose high resulting in tens of thousand hectares of mangrove forests being destroyed unplanned for the construction of shrimp rearing squares in extensive shrimp farming method. For example, in Minh Hai Province there were in 1983 only 3 000 ha under shrimp farming, in 1993 the figure was 67 072 ha (Minh Hai Forest Service, 1994). This fact has exerted bad effects on environmental factors such as the pollution of water resources in the region, land degradation and even the changing of the tiding submersion regime and sediment depositing in the region, increased erosion of the seashore due to waves and sea currents as well as the threat of storms to agricultural crops and people's life in the coastal region.

The destruction of mangrove forests for shrimp farming considerably diminishes the aquatic products resource, because the decomposed organic matter of the mangrove forests is an important link in the food chain of shrimp, crabs, oysters, fish, and at the same time mangrove forests are the living and protective habitat of aquatic animals caught offshore.

5. Main solutions and technologies

5.1 A strategic plan for water resource exploitation and protection

The plan must be based on the water resources of each river and the demands in water for agriculture, industry, energy, and daily consumption in the rural as well as in the urban areas. From past experience, measures have been worked out to prevent bad environmental effects on production and daily life. A strategic plan has been worked out for long-term and short-term irrigation development on big rivers and key areas. In saline areas, drainage is often poor, because of low altitude and high seawater level, and drought and waterlogging take place alternatively and frequently. Irrigation is essential to combat salinization to flood the field for leaching salt out, thus, a rational drainage-irrigation system is needed to strengthen its drainage capacity and control groundwater table to keep the water balance in the irrigation areas, preventing accumulation of salts on soil surface.

5.2 Improvement of soil fertility by applying organic manure

Increased input of organic matter is the most important measure. It includes rice straws, crop residues, green manure, farmyard manure, compost, etc. to improve soil fertility.

5.3 Some models of land use in aquaculture

5.3.1 Natural aquaculture

a) Dams. Canals were embanked to have about 1 hectare of water surface where shrimp and fishes coming in at high water looking for food will be kept and harvested once a month with nets and by hands. This farming method is very harmful to the environment because, when harvesting, shrimp and fishes of all sizes in the dammed area are caught, and the seed source is severely lost and the productivity is low as well, from 500 kg to

1000 kg/ha/year in average. At present, the local fishermen tend to turn gradually to improved extensive dams.

b) Improved extensive pond. This kind of pond was started to develop in 1984, and is similar to the above farming pond, but has sluice gates for water running in and out. Those sluice gates have three functions of exchanging water, receiving natural shrimp seeds and controlling the water level in the pond; the main sluice gate is for harvesting. Shrimps are harvested twice a month on fixed dates. After harvesting, a certain quantity of shrimp and fish is kept and water in the pond is always ensured at a certain minimum level.

This method gives higher productivity (from 1 000 to 1 600 kg/ha/year in average) and juvenile shrimp and fishes are not caught.

Both types of ponds are continuously put to work all year round. They are only drained off and their bottoms exposed every year at the beginning of the rainy season for two months in order to be cleaned.

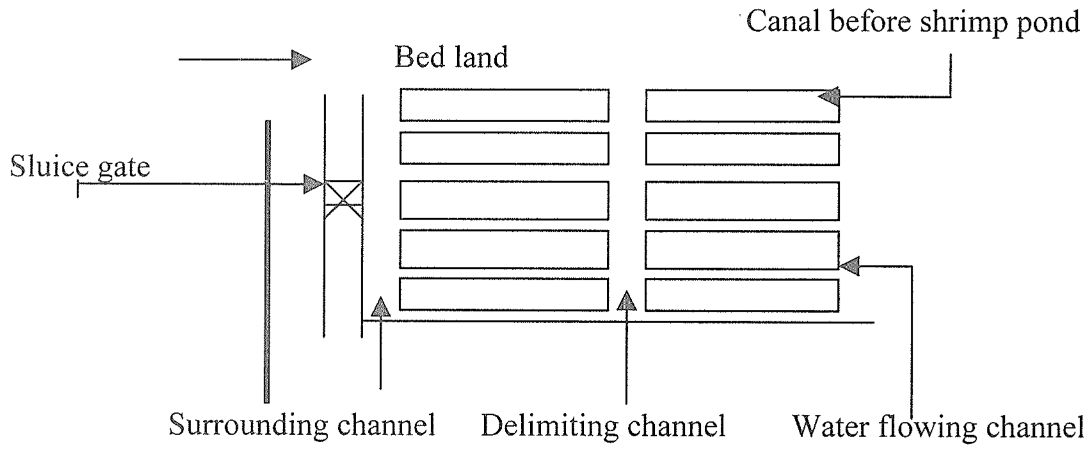

Figure 2. Scheme of a household shrimp pond using natural extensive culture with many channels and beds.
Note: Surrounding channel: 5 m in width, 2 m in depth, with 2 m in width at the bottom
Delimiting channel: 3-4 m in width, 0.5 m in depth
Water flowing channel: 2-3 m in width, 1 m in depth.

c) Semi-industrial farming. This is farming of shrimp, crab and some fish species in ponds or in cages sunk in water. Juvenile stocks were put in the pond at a certain density and food was supplied.

The semi-industrial farming technique brought high productivity and did not do much harm to mangrove forests, but the investment capital was big, therefore many shrimp ponds were abondoned.

Aquaculture in mangrove forests is necessary. In the past, it has succeeded in some localities, but it is developing very slowly, because of the huge investment and low effectiveness and over-dependence on the nature and seed sources.

This is an urgent problem for the management of shrimp farmers. If aquaculture is not developed, local people will become poorer and certainly they will destroy mangrove forests for their daily livelihoods.

5.3.2 Sylvofishery model (forest-shrimp)

Rhizophora apiculata forest planting is usually combined with shrimp farming (*Penaeus indicus*, *P. merguiensis*). In the process, 80 percent of the shrimp and fish rearing areas is planted with mangrove forests comprising *R. mucronata*. Twenty percent of the area is for canals dug for shrimp and fish rearing. Shrimp and fish rearing here is carried out in extensive management: shrimp and fish are all from natural sources. A number of sylvofishery state enterprises are implementing the model of *R. apiculata* forest planting combined with shrimp farming.

5.3.3 Model of specialised shrimp farming protected by mangrove tree species

This system is suitable to specialised shrimp farming is in low-lying or depressed land, the soil maturity is very poor, very wet and wet mud (the mud is still mixed with much seawater). The land is tidally submerged almost everyday (tide submersion more than 20 days a month and the water depth is 40-50 cm or more). Mangrove forest trees are only sparsely planted along the canal banks with the total of 500-1 000 trees/ha of the shrimp square. The tree planting is aimed at ensuring the water temperature in the shrimp square does not rise in intense sunlight season. It usually lies in places convenient for taking in natural shrimp stock and food, therefore extensive shrimp attains high productivity: 500 kg of shrimp/ha/year. The size is normally 2 ha/household. Based on the actual situation and the results of investigation, intensive shrimp rearing must be developed, the following models of shrimp farming practices are recommended:

- Model 1: For areas thickly covered by shrimp squares (> 40 percent): sea product rearing areas (30-40 percent) at the front site; areas for *R. apiculata* plating with density of 4 000-10 000 trees/ha in the rear.

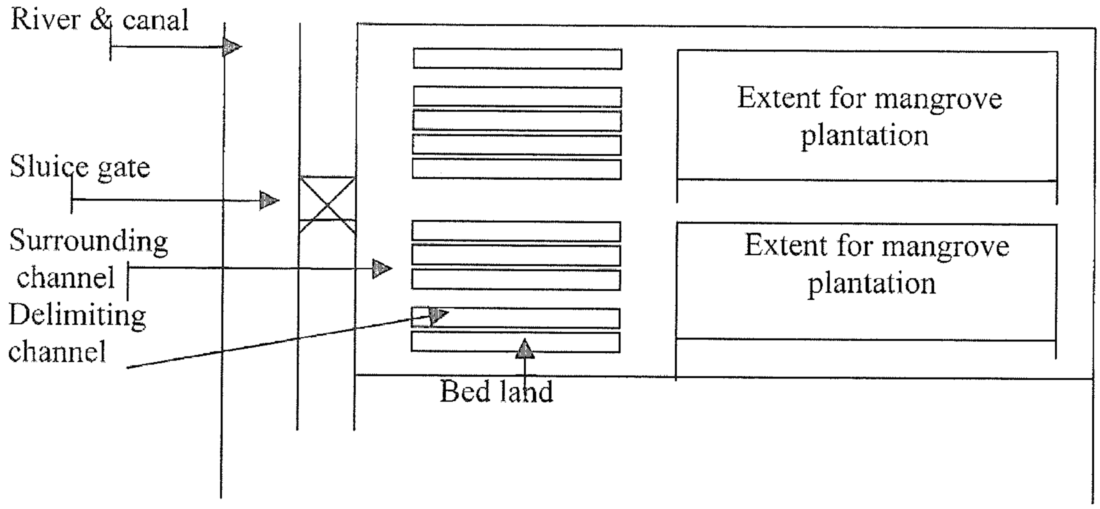

Figure 3. Model of fish-forestry applied for areas thickly covered by shrimp squares (>40 percent).

- Model 2: For areas thinly covered by shrimp squares (<40 percent). Sea product rearing in surrounding and in already available channels, as well as in newly dug ones, according to planning. Plantation of *R. apiculata* with density 4 000-10 000 trees/ha.

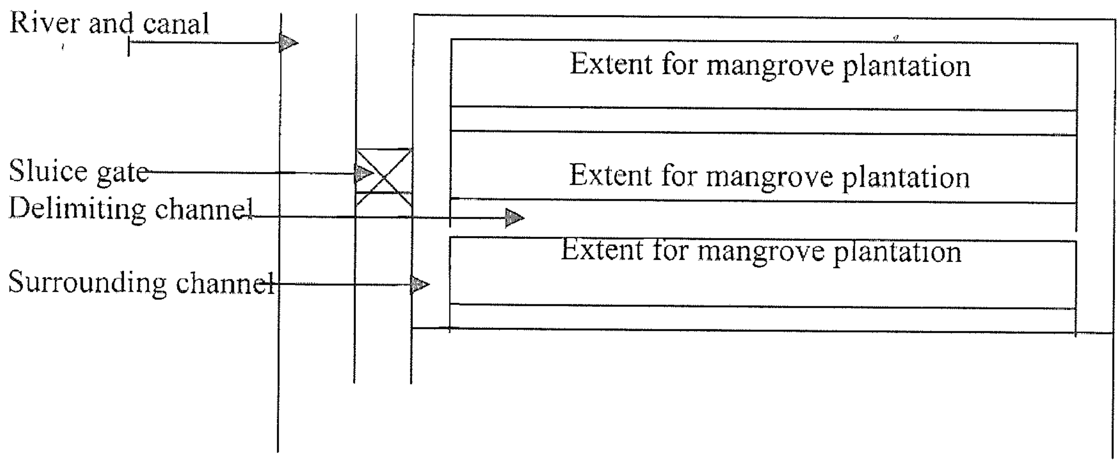

Figure 4. Model of fish-forestry applied for areas thinly covered by shrimp squares (<40 percent).

If these models are widely accepted by the farmers, the contradiction between forest and sea product rearing will be solved.

5.3.4 Model of mangrove forest planting combined with shrimp farming in high elevation land

This high elevation land type has rather good soil maturity. The land is less frequently submerged by tide, less than six days a month or only occasionally in the year, the water is more over shallow: 20 cm or less. This type of shrimp farming produces low yield: 100-150 kg/ha/year. *R. apiculata* forest survival is rather low, enrichment plantings must be done many times and forest growth is also poor. Other mangrove forest types in this land type also have low timber productivity. The soil is quickly degraded when the vegetation cover is lost. The area of mangrove forest cleared for construction of shrimp farming squares and then abandoned as wasteland (because of shrimp productivity was too low in Minh Hai Province in recent years) have amounted to 3 220 ha.

5.4 Management practices of salt-affected soils in agricultural development

Normally cropping patterns on saline soils are as follows:

5.4.1 Tidal rice-shrimp breeding

In the saline soil area situated far from the source of fresh water, people make small dykes surrounding the field with a size of two to four hectares, having valves for controlling seawater (0.7-1.4 m diameter). Rice varieties resisting to salinity has been cultivated in rainy season, Rice yield can reach between 2.5 and 3.0 tonnes/ha. Two harvests of shrimp in dry season with the output of 350-400 kg/ha of shrimp are possible.

5.4.2 One rice crop in rainy season

In the saline area situated far from the source of freshwater or even seawater, people can only wait for rainfall to cultivate one crop of summer rice. In this area, in dry season the surface of the soil cracked, the saline water goes up to surface and is crystallised to become salt flowers. The salinity is rather high at the beginning and decreases at the end of the harvest, the content of chloride and sulphate is respectively from 0.3 percent down to 0.08 percent, and 0.15 percent down to 0.10 percent. Rice yield of 3.0 to 3.5 tonnes/ha can be obtained. This is the traditional rice cultivation.

5.4.3 Two rice crops in rainy season

People can profit from the long duration of rainy season (150-190 days) to cultivate two short-term rice crops by applying dry-broadcasting techniques. This is a new achievement in increasing the crop number in the Mekong Delta. After harvesting summer rice, the land is ploughed to cut off the capillary rise of saline water. When the rainy season is coming, in the land half prepared and readily divided into beds with shallow drains (20 cm), farmers broadcast rice seeds. When it rains, soluble salt is washed of through the drains and rice seeds can germinate.

The second crop is followed in the middle of the rainy season and harvested at the beginning of the dry season.

5.4.4 Making dikes to prevent seawater intrusion

In the Red River Delta, where population density is high, typhoons and floods often happen, small dykes could not resist strong waves and wind in the stormy season, people have to make big and long dikes surrounding the seashore to reclaim the new land. These dikes are 10 m large and cover an area about ten thousand hectares. Along these dykes, big channel digging is necessary for preventing the penetration of seawater into the newly reclaimed area.

In these newly reclaimed areas, salt-tolerant plants like rushes can be grown at the first step in three years. After that local rice varieties can be grown. There is only one rice crop in rainy season, but if freshwater is available in dry season, one more rice crop can be added. After reclamation, the soils often keep in swampy status, machine cannot be used. Incorporation of organic fertiliser, rice straw, rice husk, soluble silicate gives high effect in increasing rice yield up to 5-7 tonnes/ha/year.

6. Other issues for controlling salt-affected soils in the country

6.1 Constraints to high productivity of saline soils

- High salt content, especially during summer causing salt injury. High salinity would be one major constraint to crop production in three kinds of saline soils, especially during the dry season, the electrical conductivity of the wet samples is below the critical level of 4 dS/m. An electrical conductivity of 6.2 dS/m can reduce yields of some intolerent rice varieties by 25 percent. On prolonged drying, low acidity of the subsoil layers could be a problem.
- Lack of irrigation water to leach salts from the root zone. However, there could be a problem in leaching if water table was high.
- Poor drainage during the rainy season.
- Lack of high-yielding salt-tolerant crop varieties.
- Land tenure and land use: land allocation to the farmers are practised, but land use planning for integrated management to protect and improve soil fertility and the environment is not widespread.

6.2 Government policy on land allocation to the farmers

The Government of Viet Nam is allocating a large part of agricultural lands, forestlands and barren lands (or unused land according to the Land Law) to people with the aim for an effective use of land, to plant new forest and to protect existing natural resources.

Land use planning and land allocation in flat land are almost completed for sustainable agricultural development. The farmers in these areas have the right to use their lands for a long time to improve and conserve soil fertility at the same time with effective use of lands to develop crop yields and production. But land use planning and land allocation for forestlands could not be carried out in satisfactory speed due to shortage of fund and of a proper and feasible methodology. Therefore after reaching a simple procedure for Land Use Planning/Forest Land Allocation including salt-affected soil areas, farmers received agricultural land and forestland certificates.

6.3 Government support

In combination with local contribution on construction and consolidation of irrigated-drainage systems, the government pays more attention on the investment for construction of the systems on flat land especially for coastal saline water control by establishing dykes and linking culverts for increasing food production and food security.

7. Suggested measures and research requirement

7.1 Research requirement

- Establishment of database management of natural resources on coastal salt-affected soils using GIS technology: distribution, classification, land use/land capability, etc.
- Monitoring, assessment and prediction of soil salinity. Rapid techniques on salinity monitoring and survey should be developed. Some practical computer model should be developed for salinity assessment and prediction by simulating different management activities under different land use patterns.
- Dynamic of salt intrusion along the river systems from estuaries and its control measures.
- Salt-tolerant rice varieties, especially high quality rice.
- Integrated soil management for food and crop production.
- Mangrove forest protection in appropriate combination with fish-shrimp culture.
- Land use policy and environmental protection in salt-affected soil regions.

7.2 Suggested measures of sustainable use of salt-affected soils focussing on shrimp farming

The following measures are recommended:

- It is urgent and practical to make an overall plan of production on the areas with shrimp farming to conduct investigations and surveys of the exact current status of shrimp farming land, agricultural land, mangrove forest land. Afterwards, planning of the irrigation system, clean water supply for the shrimp ponds and sewage system should be given sufficient concern. Adequate investment from the state and the local authorities is essential.
- Assessment with regards to the economic, resources and environment impacts of some models in the silvofishery enterprises should be carried out in order to evaluate achievements to be replicated and problems to be solved. Some shrimp breeders should be organised to apply improved models in other places.
- Research should be done on the relationship between mangroves and marine products through the amount of nutrition cycled in the shrimp breeding area with different proportion of the extents of forests and, shrimp ponds in order to work out the economic and environmental impacts. Based on that, a specific appropriate proportion of the extents of forests/shrimp ponds will be calculated for localities.

8. The cooperation project with FAO

The project "Integrated Management and Sustainable Utilisation of Coastal Salt-Affected Soils in Viet Nam" was started at the beginning of 1997. The research site is in Rang Dong farm, Nam Ha Province in northern Viet Nam.

The soil type FLsm (moderate and slight saline soils) occupies a large area and because of soil improvement and irrigated condition, can be used for rice growing, especially the local rice varieties with high quality and salt tolerance.

Efforts were made in the selection of salt-tolerant rice varieties, and improvement of soil fertility, step by step to increase the rice yields in the soils with low and medium salinity.

High-yielding rice varieties may uptake large amounts of nutrients from the soils. Freshwater also washes away soil nutrients. These result in the rapid decrease of soil fertility.

8.1 Objectives

- To carry out field trials on management practices for increased productivity of coastal salt-affected soils in Viet Nam, particularly the management techniques, their suitability for selected salt-tolerant rice varieties and field crops, chemical amendments, addition of organic matter, leaching requirements, land preparation, crop residues, planting procedures and tillage methods.
- To collect experimental data and monitor changes in soil, crops and water, and evaluate the results.
- To train national staff and farmers in the project site.

8.2 Activities

8.2.1 Field experimental programmes

a) Field experiments were established and operated at the Rang Dong Farm since 1997. Brief information of the experiment is as follows:
- Rice: Spring rice: Dzau An Do variety, growing time – 185 days.
    Summer rice: Tam Thom variety, growing time – 165 days.
- Soil: medium saline.
- Fertiliser used: three rates:
    Rate 1: Four tonnes of rice straw, kg/ha of N, P_2O_5 and K_2O = 90, 60 and 30.
    Rate 2: Four tonnes of rice straw, 3 tonnes FYM, kg/ha of N, P_2O_5 and K_2O = 120, 90 and 60.
    Rate 3: Four tonnes of rice straw, 6 tonnes FYM, kg/ha of N, P_2O_5 and K_2O = 150, 120 and 90.
    Types of fertilisers: urea, single superphosphate, KCl.
- Spring rice: planting time, 20-22 February; harvesting time, 7-15 June.
- Summer rice: Planting time, 16-20 July; harvesting time, 24-27 November.

b) Treatments: There were 18 treatments as follows:

Treatment	Rice straw (t/ha)	FYM (t/ha)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
T1 (control)	0	0	0	0	0
T2	0	0	90	60	30
T3	4	0	0	60	30
T4	4	0	90	0	30
T5	4	0	90	60	0
T6	4	0	90	60	30
T7	4	3	90	60	30
T8	4	0	120	60	30
T9	4	0	90	90	30
T10	4	0	90	60	60
T11	4	3	120	90	60
T12	4	6	90	60	30
T13	4	0	150	60	30
T14	4	0	90	120	30
T15	4	0	90	60	90
T16	4	6	150	120	90
T17	0	0	120	90	60
T18	0	0	150	120	90

Note: Randomised Complete Block Design.
Replication: 4.
Plot size: 4 m x 5 m = 20 sq m.

c) Results

The results were obtained for two years and the recommendations are as follows:

- The appropriate fertiliser level for spring rice is
Four tonnes of rice straw, 3 tonnes FYM, kg/ha of N, P_2O_5 and K_2O = 120, 120 and 60.
- The appropriate fertiliser level for summer rice is:
Four tonnes of rice straw, 3 tonnes FYM, kg/ha of N, P_2O_5 and K_2O = 90, 60 and 30.

8.2.2 Case studies are conducted in two or three intercepts to clarify the severity of existing salinity.

8.2.3 Field days and training were organised for extensionists, policymakers and farmers in salt-affected areas at the site and some places of the neighbouring provinces.

8.3 Participating institutions

- The National Institute for Soils and Fertilizers (NISF)
- The University of Water Resources
- The Department of Water Resource Management, MARD
- The Forest Science Institute of Viet Nam
- The Agriculture Service of Nam Dinh Province
- The Extension Center of Nam Dinh Province
- The Rang Dong Farm.

8.4 Activities in the year 2000

The project funded by FAO was finished in 1999. Some activities for the year 2000 are as follows:

- Demonstration sites at the farmers' fields with following treatments:

Treatment	Spring rice				Autumn rice			
	Organic manure	N	P_2O_5	K_2O	Organic manure	N	P_2O_5	K_2O
	(t/ha)	*(kg/ha)*	*(kg/ha)*	*(kg/ha)*	*(t/ha)*	*(kg/ha)*	*(kg/ha)*	*(kg/ha)*
1	6	150	112.5	75	0	150	100	50
2	11	150	112.5	75	5	150	100	50
3	11	170	127.5	85	5	170	113.4	56.7
4	Farmer's practice							

- Participants: 15 households.
- Organised by farmers field school in Rang Dong Farm.
- Shrimp farming in the new settlement areas in Nghia Hung District, Nam Ha Province.

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Annex 1

Opening addresses

Opening Address, by Mr Payon Koompai, Director, Ayutthaya Provincial Agriculture and Cooperatives Office

Mr Dong Qingsong, Mr Amin Mashali, Deputy Director General of LDD, Distinguished guests, ladies and gentlemen,

It is my great pleasure to welcome you to Phra Nakhon Si Ayutthaya Province on behalf of the provincial sector and the people of Ayutthaya. It is a great privilege to our province to have been chosen as the venue of the Regional Workshop on "Impact of Shrimp Farming on Arable Land and Rehabilitation of Resultant Salt-affected Soil/Integrated Soil Management for Sustainable Use of Salt-affected Soils."

I am delighted to learn that this workshop includes distinguished participants from 11 countries and it seems that most of you have not been in Ayutthaya before. Although, Ayutthaya Province is rather small but it is an ancient city, lively, friendly and peaceful. Therefore, I sincerely hope that Ayutthaya Province will provide a traditional atmosphere of lively discussions and the outcome will offer the direction for more positive approach towards greatest success in sustainable use of salt-affected soils.

Ladies and gentlemen, I realize that your visit to Ayutthaya this time is only five days and at the same time you will be busy with a number of the work sessions in the meeting room. Therefore, you may not have much opportunity to visit various interesting places in Ayutthaya such as the Grand Palace, the Bang Pa-In Palace, the Royal Folk Arts and Crafts Centre, Wat Yai Chaiyamongkhon and Wihan Phra Mongkhon Bophit. However, I have learned that you will have a 1-day excursion to areas of shrimp farming and resultant salt-affected soils and existing programmes to improve salt-affected soils in Thailand and project TCP/THA/8922 site in Suphan Buri Province. On the way to Suphan Buri province you will have a glimpse of various interesting places from the bus. So please let such an excursion be something like an orientation or an introduction to Ayutthaya and you are welcome to come back to visit us again any time.

Again, on behalf of the provincial sector and the people of Ayutthaya, I would like to express our warm welcome to all of you. I wish you a very happy stay in Ayutthaya and a great success of this workshop.

Thank you.

Opening Address by Mr Chaiyasit Aneecksamphant, Deputy Director General of the Land Development Department

Mr Dong Qingsong, Mr Amin Mashali, distinguished delegates and guests, ladies and gentlemen,

It is my great pleasure to join you in the Regional Workshop on Impact of Shrimp Farming on Arable Land and Rehabilitation of Resultant Salt-affected Soils/Integrated Soil Management for Sustainable Use of Salt-affected Soils, I am delighted that Thailand has been chosen to host this workshop.

On behalf of the Land Development Department, I would like to extend our greetings and warm welcome to all of you, particularly to those who have come from distant parts. I hope your stay will be both fruitful and enjoyable.

Thailand is an agrarian country with the total area of 51.4 million ha. About 41 percent of the total land are suitable for agriculture, which are mostly under paddy rice, followed by field crops, fruit trees, vegetables, flowers and livestock respectively.

As you may know, agriculture plays a predominant role in Thailand's economy. It contributes significantly to the economic growth of the country especially to the Gross Domestic Product (GDP). At present, land resources have been intensively used to increase the production to cope with the increasing demand for food by the country's population, which continues to increase. This leads to the diverse use of land for many purposes including shrimp culture on arable land. Even though shrimp farming makes high profit, but, like shifting cultivation, such activity does not lead to sustainable land use. In recent years, shrimp farming has obviously affected environment, particularly the soil and water resources for agricultural production.

Brackish water shrimp farming has been operated along the coastal belt of Thailand in approximately 72 000 ha, and recently it encroached in freshwater arable land areas totalling 22 455 ha in 23 provinces in the Central Plain. Followed by this activity, arable land areas in the Central Plain became saline, agricultural production decreased and that would eventually affect the food security of the country. To rehabilitate the degraded soil and land for sustainable land use, the Thai Government announced a total ban on inland shrimp farming in freshwater areas nationwide in July 1998.

Ladies and Gentlemen, I believe that the experience and knowledge to be shared among participants of various countries in this workshop would help improve and rehabilitate salinized land and soil caused by brackish water shrimp farming, leading to sustainable land use.

I would like to take this opportunity to express our sincere thanks and appreciation to FAO staff, particularly Dr Mashali, for their active roles and continuous collaboration as well as the generous support for implementing the Impact of Shrimp Farming on Arable Land and Rehabilitation Salt-affected Soils Project.

Ladies and Gentlemen, at this auspicious moment let me declare the Regional Workshop on Impact of Shrimp Farming on Arable Land and Rehabilitation Salt-affected Soils/Integrated Soil Management for Sustainable Use of Salt-affected Soils open. I wish this workshop a full success and for our foreign participants a very pleasant stay in Thailand.

Thank you.

Opening Addresses by Mr Dong Qingsong, Deputy Regional Representative, FAO Regional Office for Asia and the Pacific, Bangkok, Thailand

Mr Chaiyasit Aneksamphant, Deputy Director General, Land Development Department
Mr Thirawat Kullavanijaya, the Governor of Ayudhya
Mr Payon Koompai, Director, Ayutthaya Provincial Agriculture and Cooperatives Office
Dr Amin M. Mashali, FAO Headquarters
Ladies and Gentlemen,

First of all I would like to say that it is my great pleasure to come here for attending this workshop today. Therefore, please allow me to express a warm welcome on behalf of FAO to the participants from abroad and from Thailand attending this workshop, and also to thank the organising officers and working staff of the Land Development Department for their excellent work on the arrangements of the workshop and the implementation of this project.

I would also like to take this opportunity to briefly inform all of you here about the background of this TCP project on the "Impact of Shrimp Farming on Arable Land and Rehabilitation of Resultant Salt-affected Soils".

Early last year, the former Minister of Agriculture and Cooperatives and his staff came to visit our Regional Office. The purpose of this visit was to exchange the views on how to strengthen the FAO/RAP-Thailand collaboration in agriculture in order to secure food security under the impact of Asian economic crisis.

One important issue raised during the meeting was "How FAO could help Thailand to rehabilitate the arable land in the provinces of the Central Plain affected by inland marine-shrimp farming?" I would like to say that this affect would also occur in the countries of the participants in this room who are from outside Thailand.

Therefore, a project proposal of the "Impact of Shrimp Farming on Arable Land and Rehabilitation of Resultant Salt-affected Soils" was jointly and immediately prepared by the Land Development Department in consultation with the technical officers of FAO/RAP and the Headquarters, and was subsequently approved by the FAO Headquarters.

Ladies and Gentlemen,

Here, I would like to emphasise that the objective of this project is to support the initiative of the Ministry of Agriculture and Cooperatives, which are as follows:

Firstly to support the study of the impact of marine shrimp farming in freshwater arable land.

Secondly to support the demonstration of the appropriate integrated techniques *on* rehabilitation of the abandoned shrimp farms in Suphan Buri, Prachin Buri and Nakhon Si Thammarat Provinces, and *on* the improvement of salt-affected lands.

I had a chance to visit the sites of this project with Dr. Rungsun Im-Erb, the Assistant Project Coordinator, in Suphan Buri and Prachin Buri Provinces during 28-30 July this year. These sites are located in the areas of the shrimp farming. I hope that this FAO-TCP assistance would serve the needs of Thailand and countries of all participants.

Therefore, I would like to encourage all participants here to use this workshop for discussion and exchange ideas in order to receive new techniques for efficiently solving the problems of salt-affected soils caused by inland shrimp farming and take it back for using in your home countries.

Ladies and Gentlemen,

Finally, I would like to say that I wish this Regional Workshop on "Impact of Shrimp Farming on Arable Land and Rehabilitation of Resultant Salt-affected Soils" every success, and I am looking forward to seeing its fruitful outcome.

Thank you very much.

Opening address, by Dr Amin Mohamed Mashali, FAO Headquarters

Mr Payon Koompai, Mr Chaiyasit Anecksamphant, Deputy General Director, Land Development Department and National Project Director, Mr Dong Qingsong, Deputy Regional Representative RAP, distinguished participants, ladies and gentlemen,

I feel privileged to address the distinguished participants and guests of this workshop at its opening session, after listening to the wisdom of the preceding speakers.

FAO felt particularly honoured in organising this workshop in cooperation with the Government of Thailand, on one of today's important subject: Integrated Soil Management of Salt-affected Soils. Please allow me to refer to some technical matters that may throw some light on the extent of the problem.

Recent estimates indicate that the global demand for food, fibre and bio-energy products is growing at an annual rate of 2.5 percent and that of developing countries at 3.7 percent. World population has doubled in the past 40 years and may double again in the next century to approach 11 billion by the year 2100. Historical evidence suggests that an annual growth in output is less than one percent can be expected from area increase at global level. Hence, optimisation of the productive potential of land including degraded and problem soils, i.e. fragile ecosystems including salt-affected soils, is considered to be a major contribution to meet the world food demand.

The development of agricultural technologies and a better appreciation of the existing but under-utilised knowledge of resource management will be crucial in meeting the ecological needs and in achieving the anticipated food demands of the growing population in the future. The greatest challenge for the coming decades lies in the fact that the production environments are unstable and degrading. Land degradation is proceeding so fast that unless policies and approaches change, many countries will not be able to achieve sustainable agriculture in the foreseeable future. Soil salinization has been identified as a major process of land degradation. The greatest technical causes of decreasing production on many irrigated projects, particularly in arid and semi-arid areas, or failure of large areas in rainfed agriculture, are waterlogging, salinization and sodication. It was estimated from various available data that the world is losing at least three hectares of arable land every minute because of soil salinity.

Although many countries are using salt-affected soils because of their proximity to water resources and the absence of other environmental constraints, there is a clear need for a sound scientific basis to optimise their use, determine their potential, productivity and suitability for growing different crops, and identify appropriate integrated management practices. Because of this and the increasing awareness of continuing soil salinization and sodication, FAO's Regular Programme is supporting national institutes in countries having problems of salt-affected soils to strengthen their experimental programmes on adapted soil management practices. Since 1990, collaborative projects have been identified to develop management practices for sustainable use of salt-affected soils: experiments and demonstrations on pilot farms have been conducted in 22 countries in different regions – Near East (Egypt, Iran, Syria and Tunisia); Asia and Pacific (Bangladesh, China, Indonesia, Pakistan, Philippines, Thailand and Viet Nam); Latin America and Caribbean (Argentina, Brazil, Cuba and Mexico); Africa (Ghana, Kenya, Nigeria and Tanzania); Europe (Hungary, Romania and Turkey).

Successful experience and initiatives for soil improvement in specific countries or socioeconomic and agro-chemical environments have taken place but their wider dissemination for the benefit of other countries, even in the same region, is rather limited. Therefore, to avoid fragmentation of field oriented research and development efforts in developing countries and to stimulate coordination of work between different international and national organizations on the management of salt-affected soils, a cooperative project was signed in November 1994 between FAO and UNEP, in association with the Subcommission on Salt-affected Soils of IUSS. The project was to establish a Network on Integrated Soil Management for Sustainable Use of Salt-affected Soils. The twenty-two countries involved in the mentioned ongoing FAO collaborative projects are members in the Network, in addition to other "Associated Members" running their country national programmes on management of salt-affected soils (Australia, Canada, Colombia, India, Italy, Spain, Sudan and Uzbekistan)

With the recent emphasis on the FAO priority programme on Special Programme for Food Security (SPFS), issues related to land degradation and problem soils including salt-affected soils and their negative impact on food production, as well as land improvement for enhanced productivity, are receiving special attention. Rectifying soil degradation including salt-affected soils and sustaining crop production through appropriate soil management and conservation are, therefore, important components in the effort towards world food security. Therefore, FAO has been concerned with different activities in the field of soil and water management of salt-affected soils including technical support of several field projects, for example in Egypt, China, Pakistan, the Republic of Korea, Syria, Romania and the Philippines; organization of several training courses and workshops on the subject for example in Egypt, the Republic of Korea, for Near East in Tunisia, for Latin America in Argentina, for Africa in Ethiopia and Nigeria, and for Asia in the Republic of Korea and in the Philippines; and publishing several FAO Soils Bulletin and Irrigation and Drainage Papers and Newsletters on salt-affected soils and their management, water quality for agriculture and water management and the use of saline water for crop production.

The Government of Thailand reflected the deep concern of the country with regard to the conflict that has exploded between rice and shrimp farmers in arable freshwater areas and the extent of salinity problems faced by the small farmers, with negative effect on their income and yearly agricultural production loss, and with the expected negative impact on food security of the country.

In order to effectively implement Section 10 of the National Environment Quality Act to reclaim the affected lands and to gain an in-depth understanding of the impacts and demonstrate appropriate integrated technologies and farm salt-affected areas, technical assistance from FAO was requested to assist the Government in the introduction and consequent development of appropriate integrated low-cost, low-risk rehabilitation techniques. The Government expressed that this be accorded urgently and with highest priority.

Therefore, a 22-month project was approved by the FAO in October 1999, to be implemented by the Land Development Department (LDD), Ministry of Agriculture and Cooperatives, as the Government Executing Agency on "Impact of Shrimp Farming on Arable Land and Rehabilitation of Resultant Salt-affected Soils". The project's objective is to study the impacts of shrimp farming in freshwater arable land and in the demonstration of appropriate integrated techniques for rehabilitation of abandoned shrimp farms and for the improvement of salt-affected lands (resultant from seawater intrusion and shrimp farming practices in arable lands) mainly rice production in support of food security programmes in the country through introduction of appropriate management techniques for optimum production of such soil. The aim is to introduce, test and demonstrate to the farmers sound integrated soil, water and crop management techniques in representative pilot experimental demonstration farms to overcome production constraints in the resulted salt-affected soils under local conditions.

It has been decided that these pilot farms will continue as demonstration farms after project completion to disseminate to the farmers the appropriate integrated low cost, low risk rehabilitation techniques for their salt-affected soils.

The present Workshop is one of the activities of the project to determine the performance of the project and to exchange information and experiences with other collaborating scientists from neighbouring countries and international consultant. The participating countries, in addition to Thailand, are Bangladesh, China, India, Indonesia, Malaysia, Pakistan, the Philippines, Viet Nam and Australia.

The immediate objectives of this workshop are:

Analyse and synthesise available information in the participating countries on the extent and cause of salt-affected soil and its impact with more focus on shrimp farming impacts.
Highlight successful experience(s) on management of salt-affected soils.

Identify priority areas, programmes and follow-up action for enhancing productivity of salt- affected soils in support of food security.

Although technology may be available for rehabilitation and management of salt-affected soils, there is a need for local institutions to conduct applied research to provide the technical backstopping to the field projects. A very important task for a national organization is to guide and coordinate the field work and to provide scientific backstopping for the appropriate integrated soil and water management technologies required, and this regional workshop is a good opportunity for discussions and exchange of views among participants leading to fruitful results. I am sure that the contribution of all participants will make this Regional Workshop a turning point and a success with the appropriate actions.

Thank you for your attention.

Annex 2

Programme

Sunday, 19 Nov. 2000	
14:00-16:00	Registration
Monday, 20 Nov. 2000	
08:00-08:30	Registration (cont.)
08:30-10:00	
Opening Ceremony	**Mr Dong Qingsong**, Deputy Regional Representative FAORAP **Dr Amin M. Mashali**, AGLL, FAO, Rome **Mr Chaiyasit Aneecksamphant**, Deputy Director General, Land Development Department (LDD) and National Project Director TCP/THA/8922 **Mr Payon Koompai**, Director, Ayutthaya Provincial Agriculture and Cooperatives Office, welcomes participants
10:00-10:30	Refreshments
Technical Session I	Chairperson: **Mr Chaiyasit Aneecksamphant**, Deputy Director LDD. Introductory Session Rapporteur: **Mr Mathee Maneewon**
10:30-11:00	FAO Networks on " Soil Management of Problem and Degraded Soils with Focus on Network on Soil Management for Sustainable Use of Salt-affected Soils/ Activities of Project TCP/THA/8922: Impact of Shrimp Farming on Arable Land and Rehabilitation of Resultant Salt-Affected Soils" by **A.M. Mashali**, FAO, Rome
11:00-11:15	Open Forum
11:15-11:45	Monitoring of Salt-affected Soils/Practical Models for Predicting Salinity Development with Reference to Project TCP/THA/8922 by **Robert J. Crouch,** International Consultant, Australia
11:45-12:00	Open Forum
12:00-13:30	Lunch
Technical Session II	Chairperson: **Dr Thai Phien**, National Institute for Soil and Fertilizers, Vietnam. Rapporteur: **Mr Kamron Saifuk**
13:30-14:00	Country paper of Bangladesh: Problems and Soil Management of Salt-affected Soils with Focus on Shrimp Farming Practices/Sea-water Intrusion and Related Salinity

	Development in Bangladesh by **Golam M. Panaullah**, Chief, Soil Scienc Division, Bangladesh Rice Research Institute (BRRI)
14:00-14:15	Open Forum
14:15-14:45	Country paper of China: Problems and Management of Salt-affected Soils with Focus on Shrimp Farming Practices/Sea-water Intrusion and Related Salinity Development in China by **Jingsong Yang**, Chief Department of Salt-affected Soils, Institute of Soil Science, Chinese Academy of Sciences
14:45-15:00	Open Forum
15:00-15:30	Refreshments
Technical Session III	Chairperson: **Dr Jingsong Yang**, Institute of Soil Science, China. Rapporteur: **Mr Pirach Pongwichian**
15:30-16:00	Country paper of Indonesia: Problems and Management of Salt-affected Soils with Focus on Shrimp Farming Practices/Sea-water Intrusion and Related Salinity Development in Indonesia by **Putu I.G. Widjava-Adhi**, Centre for Soil and Agroclimate Research, Indonesia
16:00-16:15	Open Forum
18:00-20:00	Welcome Reception
Tuesday, 21 Nov. 2000	
Technical Session IV	Chairperson: **Dr Jingsong Yang**, Institute of Soil Science, China. Rapporteur: **Mrs Parida Kuneepong**
08:30-09:00	Country paper of Malaysia: Problems and Management of Salt-affected Soils with Focus on Shrimp Farming Practices/Sea-water Intrusion and Related Salinity Development in Malaysia by **Ghulam Mohamed Hashim**, Malaysian Agricultural Research and Development Institute (MARDI)
09:00-09:15	Open Forum
09:15-09:45	Country paper of Pakistan: Problems and Management of Salt-affected Soils with Focus on Shrimp Farming Practices/Sea-water Intrusion and Related Salinity Development in Pakistan by **Abdul Majeed**, Chief (Research) Pakistan Council of Research and Water Resources, Pakistan
09:45-10:00	Open Forum
10:00-10:30	Refreshments
Technical Session V	Chairperson: **Dr Golam M. Panaullah**, Bangladesh Rice Research Institute (BRRI). Rapporteur: **Mr Pramote Yamclee**
10:30-11:00	Country paper of the Philippines: Problems and Management of Salt-affected Soils with Focus on Shrimp

	Farming Practices/Sea-water Intrusion and Related Salinity Development in the Philippines by **Perfecto Evanglista**, Chief, Soil and Water Resources Research Div., Bureau of Soil and Water Management (BSWM), Philippines
11:00-11:15	Open Forum
11:15-11:45	Country paper of Thailand: Problems and Management of Salt-affected Soils with Focus on Shrimp Farming Practices/Sea-water Intrusion and Related Salinity Development in Thailand by **Chaiyasit Anecksamphant**, Deputy Director General LDD and National Project Director TCP/THA/8922
11:45-12:00	Open Forum
12:00-13:30	Lunch
Technical Session VI	Chairperson: **Dr Perfecto Evangelista**, BSWM, Philippines. Rapporteur: **Mrs Waraporn Boonsorn**
14:00-14:30	Country paper of Viet Nam: Problems and Management of Salt-affected Soils with Focus on Shrimp Farming Practices/Sea-water Intrusion and Related Salinity Development in Viet Nam by **Thai Phien**, National Institute for Soil and Fertilizers, Vietnam
14:30-14:45	Open Forum
14:45-15:15	Pilot Experiments/Demonstration sites/ Field Programmes and Results from Project TCP/THA/8922 (Suphanburi, Prachinburi and Nakhon Si Thammarat Provinces)
15:15-15:30	Open Forum
15:30-16:00	Refreshments
16:00-16:30	Monitoring Programmes in the Project sites/Provinces (Piezometers, soil and water sampling) and results from project TCP/THA/8922 (Suphanburi, Prachinburi and Nakhonsrithammarat) by **Rungsun Im-Erb** - LDD, Thailand
16:30-16:45	Open Forum
16:45-17:15	General discussion
Wednesday, 22 Nov. 2000	
	Field trip to areas of shrimp farming and resultant salt-affected soils and existing programmes to improve salt-affected soils in Thailand and project TCP/THA/8922 site in Suphan Buri province (Pilot Experiment/Demonstration site and monitoring programmes).
Thursday, 23 Nov. 2000	
08:30-10:30	**Chairperson: Mr Pitsanu Attaviroj**, National Consultant, Thailand. **Rapporteur:** Mr Rungsun Im-Erb In a participatory manner, discussions on project activities (TCP/THA/8922),

	field programme, suggestions for modification of field pilot areas, future programmes and recommendations.
10:30-10:50	Refreshments
Working Group Session I and preparation of related conclusions and recommendations	**Group 1:** Bangladesh, China, Indonesia, Pakistan Facilitator: **Dr Abdul Majeed**, Chief (Research), Pakistan Council of Research and Water Resources, Pakistan. Rapporteur: **Golam M. Panaullah**
10:50-12:30	**Group 2:** Malaysia, the Philippines, Thailand, Vietnam and Australia Facilitator: **Dr Robert J. Crouch,** International Consultant, Australia Rapporteur: Rungsun Im-Erb In a participatory manner the following issues will be discussed and related conclusions and recommendations will be formulated:

- Major production constraints in the Region particularly as a result of shrimp farming practices, sea-water intrusion and other major causes and related cropping systems.

- Problem identification, magnitude, extent and distribution of salt-affected soils in the Region with focus on Shrimp farming practices and sea-water intrusion

- Causes and processes of formation of salt affected soil with more focus on sea-water intrusion and shrimp farming practices (anthropogenic causes, poor soil and water management, irrigation mismanagement – seepage from canals, insufficient water application, irrigation at low efficiency, insufficient drainage, improper cropping pattern and rotations, etc.)

- Biophysical, environment and socio-economic impacts, etc. with particular references to the impacts of sea-water intrusion and shrimp farming practices.

- Main solutions, technologies applied in the Region to combat each type of resulted salinization or sodication and examples of success stories of projects or programmes that controlled the development of salinity or improved the resulted salt-affected soils due to the shrimp farming practices or sea-water intrusion.

- Other issues for controlling salt-affected soils in the Region with focus on those resulted from sea-water intrusion and shrimp farming practices including legal, economic and social aspects, policy and government responsibilities, land tenure and land use, institution arrangements, the role of private sector, farmer involvement and the role of farmer co-operatives and associations or extension services.

· Researchrequirement: Integrated research for decision-making support with particular attention to applied research and development, monitoring systems, regulation and predicting techniques for salinity development to study the impact of shrimp farming practices and sea-water intrusion and related required management practices used in the Region and to improve the productivity of the resulted salt - affected soils.

- National agricultural plan for improvement of salt- affected soils in the Region and coordination, actions to address program of salt-affected soils in the Region with more focus on salt- affected soils resulted from shrimp farming practices and sea-water intrusion

12:30-14:00	Lunch
Working Group Session II	Chairperson: **Dr Ghulam Mohamed Hashim**, MARDI, Malaysia. Rapporteur: **Dr Buri Boonsompopphan**
14:00-14:30	Presentation of findings, conclusions, recommendations of Working Group I and discussions
14:30-15:00	Refreshments
15:00-17:00	Presentation of findings, conclusions, recommendations of Working Group II and discussions
18:00-21:30	Farewell Party

Friday, 24 Nov. 2000

Working Group Session III	Chairperson: **Dr A.M. Mashali**, Technical Officer, FAO, Rome Rapporteur: **Mrs Nitayaporn Tonmanee**
08:30-10:30	Presentation by **Dr Abdul Majeed**, Chief, Pakistan Council of Research and Water Resources, Pakiatan and **Dr Robert Crouch**, International Consultant, Australia: Summarises of the preparation and publication of FAO Guidelines on Integrated Soil Management for Sustainable Use of Salt-affected Soils, discussions and suggestions for modification or additions.

10:30-11:00	Refreshments
11:00-12:30	In a participatory manner, discussions on the FAO Network on Integrated Soil Management for Sustainable Use of Salt-affected Soils and related conclusions and recommendations will be formulated • Future activities of the Network • Action plan and agreement on priorities • Newsletter/Internet Web Page of the Network • Research and Cooperation between members of the Network • International Workshop on Integrated Soil Management for Sustainable Use of Salt-affected Soils to be held in Spain May 2001
12:30-13:00	**Closing Session**
13:00-14:30	Lunch
15:00	Departure to Bangkok

Annex 3

List of participants

No.	Name	Address
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3.	Dr Thai Phien	National Institute for Soils and Fertilizers Tu Liem, Chem, Hanoi, Vietnam Tel: 844-8385035 Fax: 844-8389924 Email: tphien@netnam.org.vn
4.	Dr Jingsong Yang	Institute of Soil Science, Chinese Academy of Sciences 71 East Beijing Road, P.O. Box 821, Nanjing 210008, China Tel: 86-25-3366413 Fax: 86-25-3353590 Email: jsyang@issas.ac.cn
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6.	Dr Golam Panaullah	Soil Science Division, Bangladesh Rice Research Institute (BRRI) Gazipur 1701, Bangladesh Tel: 880-2-9333098 880-681-57386 Email: brrihq@bdonline.com

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