Food and Agriculture Organization of the United Nations

Technology Assessment and Transfer for Sustainable Agriculture and Rural Development in the Asia-Pacific Region

- A Research Management Perspective

Research and Technology Development Division
Food and Agriculture Organization of the United Nations
Rome, Italy

FOR COPIES WRITE TO:

Senior Agricultural Research Officer
Research Development Centre
Research and Technology Development Division
FAO, Viale delle Terme di Caracalla
00100 Rome, Italy

Printed in September, 1994
(Through FAO RAPA, Bangkok)

Food
and
Agriculture
Organization
of
the
United
Nations

Technology Assessment and Transfer for Sustainable Agriculture and Rural Development in the Asia-Pacific Region

- A Research Management Perspective

Edited by

R. Kwaschik
R.B. Singh
R.S. Paroda

Research and Technology Development Division
Food and Agriculture of the United Nations
ROME, 1994

CONTENTS

Page

Foreword i

Preface iii

I. **KEYNOTE PAPERS:**

1. Technology assessment for sustainable agricultural production systems and rural development in different agro-ecological zones - some conceptual considerations *(R. Kwaschik)* 1
2. Technology transfer for sustainable agriculture and rural development *(R.B. Singh)* 17
3. Indicators for sustainable agriculture in the Asia-Pacific region *(Ann Hamblin)* 47
4. Animal production technologies for integrated small farm systems in the Asia-Pacific region: relevance and assessment of needs for sustainable development *(C. Devendra)* 87
5. Technology assessment and transfer - an Australian perspective *(M. Williams and R. Munro)* 95

II. **COUNTRY SCENARIOS:**

6. Bangladesh *(M.S.U. Chowdhury)* 111
7. China *(W. Lianzheng)* 119
8. India *(V.L. Chopra)* 123
9. Indonesia *(S. Hadiwigeno)* 131
10. Korea, Republic *(Y.H. Shin & J.D. Kim)* 137
11. Laos *(B. Chounthavong)* 139
12. Malaysia *(M. Yusof Hashim)* 145
13. Nepal *(P. Amatya)* 155
14. Philippines *(C.B. Perez, C.A.E. Magboo, B.M. Burgos & A.O. Lapitan)* 159
15. Thailand *(V. Benjasil)* 169
16. Vietnam *(N.H. Nghia & N.T. Dan)* 173
17. South Pacific Island Countries *(M. Umar & A.de S. Liyanage)* 177

III. **CONCLUSIONS AND RECOMMENDATIONS:** 185

FOREWORD

The Asia-Pacific region, despite impressive and commendable achievements in agricultural production and productivity, is facing serious challenges of land pressure and resource degradation. Estimates of future developments indicate that the race between population growth and food production is far from over. Additionally, past and present land use practices, in order to cope with the demand for food and cash crops, have led to serious concerns about future strategies for increased agricultural productivity. Sustainability has become a central issue technological intervention is one of the essential elements to address this issue in a holistic manner.

FAO, together with MARDI of Malaysia, had organized an Expert Consultation covering this complex issue, with participation from 10 countries in the region and several international institutions. The result is a comprehensive framework that hopefully offers the possibility to explore the concepts of technology assessment and transfer for sustainable agriculture in a flexible way. The rationale being that the concepts are highly contextual, no overall solid definition of the concepts is given but rather a user's manual for operationalizing them under location-specific conditions. Instead of offering paternalistic solutions that often fail to relate to users' environments and constraints, it is strongly felt that this approach duly recognizes the need for local capacity building.

This publication addresses two of the major constraints to sustainable agricultural development, particularly in countries with relatively weak technological capacities: the elusiveness of the sustainability concept and the limited ability of some National Agricultural Research Systems (NARS) to assess, acquire, adapt and develop technological options with a view toward sustainability objectives.

The reader is reminded that both keynote and country papers reflect the authors' views and do not claim to be exhaustive in their coverage of the issue. Individual approaches in the countries may differ considerably from the general overviews presented here. It is, however, important to note that this book aims at facilitating practical applications, and views and approaches that depart from its general philosophy. I am sure readers would find it quite interesting.

Drs. Kwaschik, R.B. Singh and R.S. Paroda must be congratulated for their initiatives and efforts in compiling, editing and brining out this most timely and valuable publication.

Mohamed S. Zehni
Director
Research and Technology
Development Division
FAO, Rome

A.Z.M. Obaidullah Khan
Assistant Director-General and
Regional Representative for
Asia and the Pacific

PREFACE

The present publication is intended to be a conceptual contribution to two different but related issues: technology assessment and transfer on the one hand and sustainable agriculture on the other. Those who might feel alienated by either the conceptual tenor or the subject matters at hand shall be reassured: it is well recognized that both issues have already suffered to some extent from much scholarly interpretation to little practical avail, the fate of many a good ideas. This seemingly harsh statement is supported by the fact that, for both concepts, there exists a multitude of interpretations. In such a situation, ideas and concepts tend to get bogged down in academic analysis. Consequently, a certain helplessness prevails among those who are concerned with conceptual applications. It is, therefore, the foremost intention of this book to shed some light on the functionality of the concepts for practical purposes and to suggest ways to put them to use in a context of problem definition and solution for agricultural development. It is the firm belief of the editors that both concepts entail powerful tools and need to be placed in a flexible framework that enables planners and practitioners to make use of existing technologies as well as develop appropriate solutions for well defined technological challenges.

The papers and country scenarios contained in this book mostly stem from an Expert Consultation FAO organized together with Malaysia's MARDI in Kuala Lumpur in December 1992. The first two papers (R. Kwaschik, R.B. Singh) present the main concepts and set the stage for subsequent elaborations of site-specific applications. The third paper (Ann Hamblin) was not presented at the Consultation but included nevertheless as it was felt that indicators are a centre piece of any effort to quantify and monitor sustainability trends, which in turn is an important tool for the streamlining of the technology development and application process toward sustainability objectives. The fourth paper (C. Devendra), with its rather specific thematic emphasis on livestock, is meant to counterbalance the unfortunately frequent neglect of this component of agricultural production systems in the sustainability discussion. It furthermore emphasizes the distinctive features of one of the most predominant production systems in Asia: the mixed small farms with varying levels of livestock/crop integration. Finally, the case of Australia (Meryl Williams and R. Munro) is presented as an example for a considerably elaborated and institutionalized approach to technology assessment and transfer for sustainable agriculture in the region.

Country scenarios reported under Section 2 reflect the substantial differences that exist between countries in the region as regards awareness of and capacities for the application of technology assessment methodologies as well as priorities for sustainability issues. Although the regional emphasis is on the Asia-Pacific area with ample references to the region's unique features, it is hoped that the experiences, conclusions and recommendations reported here are of some use in other regions of the world and will help to facilitate and catalyze similar efforts and approaches elsewhere.

It is the trust of the editors that the present publication would help in bridging the gap that frequently exists between promising concepts and their application at the intended users' level.

R. Kwaschik R.B. Singh R.S. Paroda

Section I

Keynote papers

Section I

CHAPTER 1

TECHNOLOGY ASSESSMENT FOR SUSTAINABLE AGRICULTURAL PRODUCTION SYSTEMS AND RURAL DEVELOPMENT IN DIFFERENT AGRO-ECOLOGICAL ZONES - SOME CONCEPTUAL CONSIDERATIONS

R. Kwaschik [1]

CONTENTS

Abstract 1
I. Introduction 2
II. Definition and determinants of sustainable agriculture 2
III. Agro-ecological zones framework 3
IV. General and specific concepts of technology assessment 3
V. Priority setting for a sustainability agenda 9
VI. Implementation 12
Selected Referenced 13
Acronyms 15

ABSTRACT

Technology assessment for sustainable agricultural production systems and rural development is defined here as a comprehensive approach to examine the potential impact of technology application on certain sustainability issues and to facilitate the development and use of technological interventions according to location-specific constraints and objectives. To render the somewhat elusive concept of sustainability operational, a methodological approach is suggested that builds on the description of agro-ecological zones, production systems, resource endowments and their management, and socio-economic environments with special reference to rural development. The conceptualization, collection and collation of sustainability indicators and critical areas shall eventually lead to definable objectives and technological needs and options. Technology assessment capacities require, besides conceptual inputs, sustainable institutional arrangements and sectoral linkages to effectively translate assessment into technology application. The following issues are considered key factors in the development of technology assessment programmes and relevant, to varying degrees, to most NARS in the Asia-Pacific Region:

- *(i) agro-ecosystems, resource endowment and production systems characterization, and associated socio-economic indicators, e.g. population density, poverty etc. within agro-ecosystems;*
- *(ii) identification of sustainability/unsustainability indicators/parameters and critical areas/sustainability determinants for the AEZs and systems described under (i);*
- *(iii) definition of objectives and technological requirements for sustainable agriculture under the AEZs and systems described under (i);*
- *(iv) identification of technological options (information/management-based and material) for the objectives and requirements under (iii);*
- *(v) choice of qualitative and quantitative criteria (e.g. economic valuation, energy efficiency etc.) and a methodology for decision-making/priority setting for the use of certain technologies for sustainability objectives;*

[1] *Research Officer, Research and Technology Development Division, FAO, Rome, Italy*
Present address: MPC, Eschborn, Germany

(vi) *evaluation of institutional requirements for technology assessment capacity development and their integration with adaptive research and technology transfer for successful technology application; and*

(vii) *integration of various actors through collaborative arrangements between specialized agencies/institutions (FAO, IARCs, universities, private sector), donors, and national/regional programmes, including NGOs, cooperatives etc.*

I. Introduction

The definition of technology assessment should be based on its primary purposes, thus making it meaningful in a demand-driven context: technology assessment is meant to address the widespread lack of capacity in many national agricultural research systems (NARS) to identify and capitalize on available, i.e. on-the-shelf and indigenous technologies for adaptation to location-specific problems and transfer to specified target groups. More specifically, it can serve to examine the impact of technology application from various points of view: resources, costs and returns, nutrition, health, safety etc. for the users of a technology or sections of the society, the country, the region, the environment etc. This is by and large the common concept of technology assessment for all possible areas of technological applications. However, the above definition might be interpreted as technological dependence, particularly as regards countries with rather weak indigenous technology generation capacities. Technology assessment for sustainable agriculture, therefore, should also aim at gearing the technology development process toward perceived needs of agro-ecosystems and farm-households, and the use of technological interventions for the improvement of both rural livelihoods and agro-ecosystems' performance. Technology assessment, thus, is not an end in itself but a first step in focussing the technology acquisition, generation, adaptation, and transfer process on relevant and accessible technological interventions. This, as will be shown later, is largely a function of efficient and effective research management. The development of technology assessment capacities may imply a considerable demand for institution-building and establishment of sectoral linkages in order to make use of technology assessments and to allow for appropriate use of technologies for sustainable development.

The FAO/Netherlands Conference on Agriculture and the Environment has spelled out issues of sustainability for a wide range of aspects and problem areas in agriculture and rural development. The United Nations Conference on Environment and Development (UNCED) subsequently has largely adopted the so-called Den Bosch Declaration as the agriculture programme in its Agenda 21. This is a step toward the operationalization of programmes and FAO, besides other agencies, has been identified as an actor in the follow-up of UNCED and the implementation of strategies for sustainable agriculture and rural development. Agricultural technologies, including newly developed ones, technologies widely used in farmers' fields, and indigenous local technologies need now to be assessed or re-assessed with a view toward their long-term environmental and socio-economic impacts.

II. Definition and determinants of sustainable agriculture

This issue has been dealt with extensively in numerous publications. The definition used for the present assessment concept, however, is the one adopted by the FAO Council in 1988: *"Sustainable development is the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable."*

Determinants of sustainability are listed here rather comprehensively. Obviously, any location-specific assessment will have to apply a more detailed analysis. Sustainability determinants can be divided into physical, biological and socio-economic categories. Physical determinants comprise soil and water, atmosphere, hazardous chemicals and energy. Biological factors relate largely to genetic resources, crop pests and weeds and to animal nutrition and health Socio-economic determinants of sustainability include political commitment, economic policies and price structures, infrastructure and markets, inputs, credit facilities and availability, research, extension, education, tenure, regulations, labour availability, and household survival and capital accumulation strategies.

Departing from this outline, it becomes clear that the measurement or quantification of sustainability trends has to develop generic and specific indicators that relate to multitude of factors and thus will be required to express complex systems' behaviour.

III. Agro-ecological zones framework

There is a number of approaches to the agro-ecological classification of environments, both within and outside the international agricultural research system. Agro-ecological zones are commonly described by a combination of climatic and soils characteristics, with spatial and temporal variability, e.g. specific biotic or abiotic stresses, only partially accounted for. On the other hand, the "recommendation domains" of farming systems research closely define climate, land type and socio-economic conditions.

To distinguish major land use patterns and resource potentials in developing country regions without complicating the concept to an extent that renders it unmanageable, four major agro-ecological zones (AEZs) are suggested here. Based largely FAO's AEZ classification, these include *drylands*, *irrigated lands*, *humid lands*, and *highlands* (Figure 1). Field testing/implementation of an assessment framework will clearly require a more detailed analysis and classification of sites within the major AEZs. The above categorization is, furthermore, largely congruent with the AEZ classification for the IARC's eco-regional approach to agricultural research which is important in the context of technology transfer from IARCs to farmers' fields. The Technical Advisory Committee (TAC), in reviewing the CGIAR priorities and strategies, has identified nine agro-ecological zones or a total of 23 regional agro-ecological zones (four in Subsaharan Africa, three in West-Asia, nine in Latin America and seven in Asia). However, the above is considered sufficiently disaggregated to lend itself to initial planning.

Drylands comprise arid and semi-arid zones with a growing period (GP) of less than 180 days and an annual precipitation of less than 1000 mm. *Humid lands* are further subdivided into *subhumid* (GP 180-270 days, annual precipitation 1000-1500 mm) and *humid* areas (GP >270 days, annual precipitation >1500 mm). *Irrigated lands*, including naturally flooded lowland paddy rice, encompass all areas with active collection or diversion of ground or surface water. They cut across all AEZs and, for the purpose of land use classification, feature as a separate category. The same holds true for *highlands*, which are rather a topographic category and can thus be characterized by elevation and slopes.

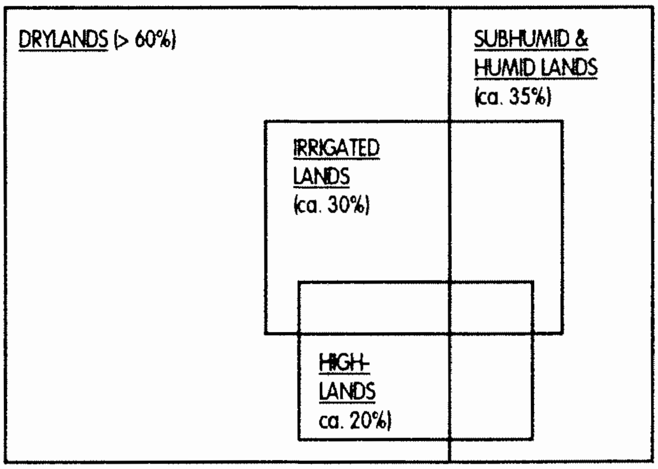

FIGURE 1. SUGGESTED AEZs IN THE ASIA-PACIFIC REGION (% of agricultural land)

IV. General and specific concepts of technology assessment

As a concept, technology assessment does not offer immediate solutions or all-purpose methodologies, but it can provide a framework for the meaningful interpretation of relevant data and the identification of leverage points for concrete interventions with a likelihood of desirable impacts over a range of envisaged targets. This is a complex undertaking and its impact will, eventually, be measured by success or failure of technology transfer: assessment and transfer are complementary.

As an initial step, a three-dimensional matrix can be derived from the above, consisting of the *major agro-ecological zones* (climatic classification: rainfall means and distribution, temperature, GP, topography), *resource endowments* (soil characteristics, bio-diversity, energy, infrastructure, economic and human resources), and *technological options/input levels* (Figure 2).

Figure 2 suggests that there is a whole range of technologies available for irrigated lands, with the balance more on information-based technologies for humid and drylands,

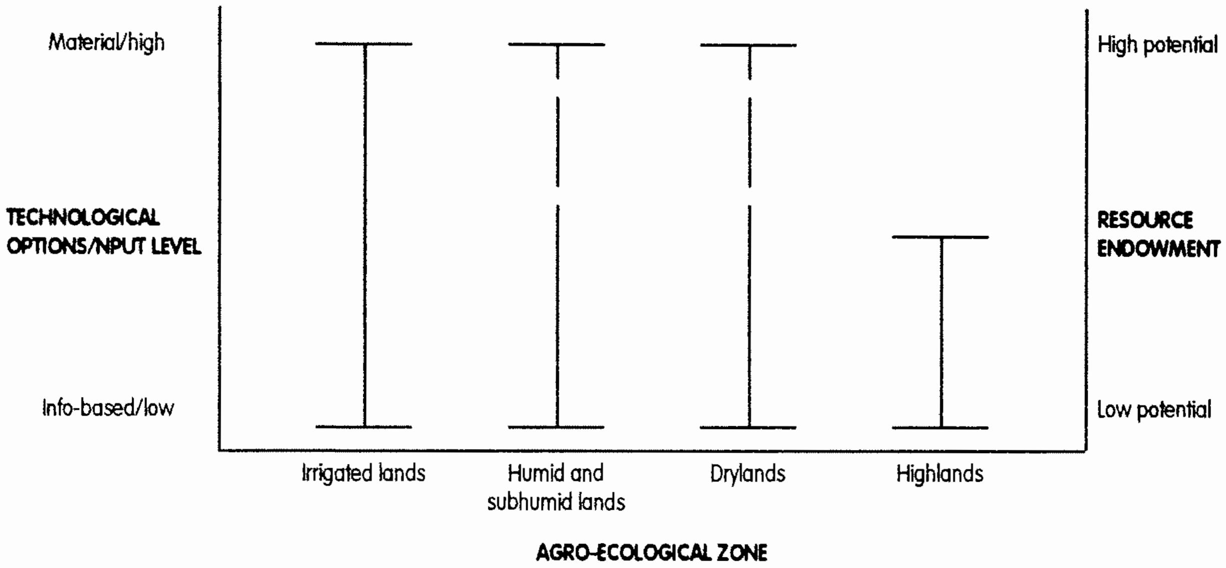

FIGURE 2. THREE-DIMENSIONAL MATRIX FOR TECHNOLOGY ASSESSMENT: TECHNOLOGY LEVEL RELATIVE TO AEZs AND RESOURCE ENDOWMENTS

and material-based options rather ruled out for highlands. This is certainly debatable, e.g. as regards the availability of any proven technology for the highly variable dryland farming systems. There are, though, indigenous solutions to problems of sustainability in drylands, e.g. soil and water conservation, that do not seem to receive due attention as to their replicability in different locations.

The distinction between AEZs and resource endowment is to make allowance for the variation of production potentials, due to a number of factors, within the same AEZ. There appears to be a positive correlation between the level of resource endowments and the potential for the use of high-input technologies. Such a general concept shall serve as a first orientation from which specific concepts can be derived.

For any specific spatial context, the concept needs to be extended to accomodate existing production systems and to include likely mechanisms and sectoral linkages for effective technology transfer (Figure 3).

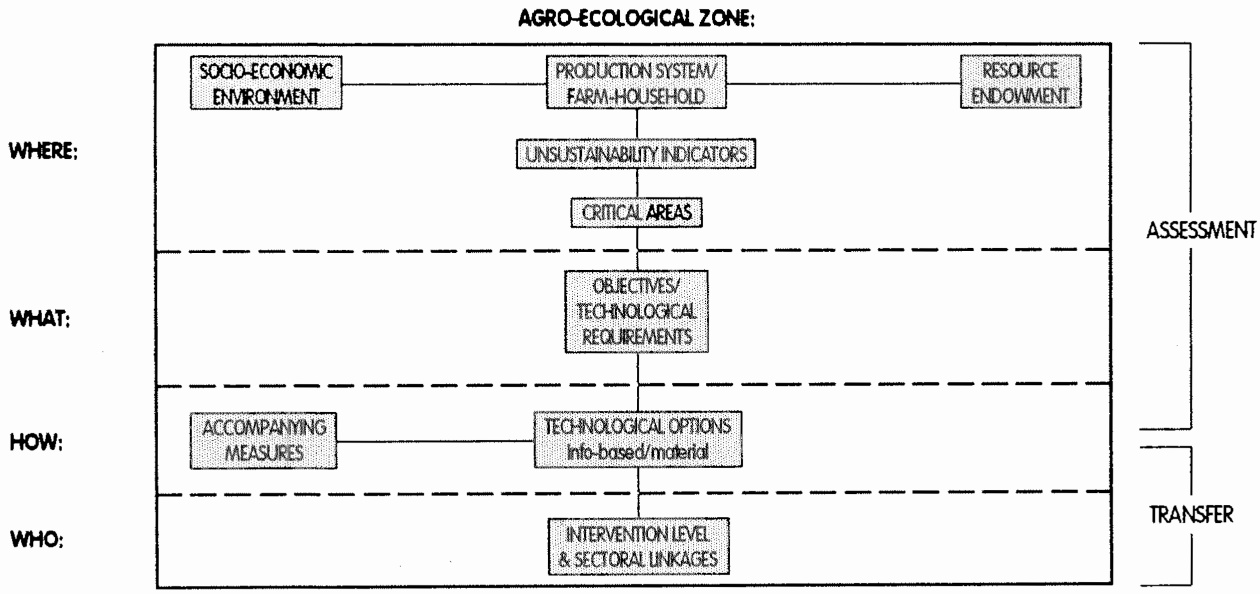

FIGURE 3. LOCATION-SPECIFIC ASSESSMENT CONCEPT

The presentation of location-specific technology assessment as a logical hierarchy features the management aspect of technology assessment: *where* are we (socio-economic environment, resource endowment, production system, farm-household, unsustainability indicators, critical areas), *what* do we want to achieve (objectives), and *how* do we get there (technological options, accompanying measures). The concept also indicates *who* will be the responsible parties for technological interventions (intervention level & sectoral linkages). A crucial point is, evidently, the decision-making process (=*what*) that follows the inventory (=*where*). Data, analysis, and informed judgement have to culminate in recommendations (=*how*). Choices have to be made among several objectives and technological options. This is commonly refered to as priority setting and shall be further elaborated in Chapter 5.

For practical applications of a sustainability assessment concept it is suggested to translate the hierarchy into a matrix or framework of two dimensions (Figure 4). Points of reference to which location-specific technology assessment should relate are production systems within a given agro-ecological zone. Production systems or possibly farm-households are an appropriate unit for the evaluation of sustainability since the system can be well specified. The combination of agro-ecological zones, resource endowments and production systems characterization is to serve, ultimately, the definition of recommendation domains or homologous zones for technology transfer. It is important to note the limitations of this agro-ecological concept: technology application is not entirely governed by biological and bio-physical determinants but, in many instances, by the policy environment. This is evident from the large differences in yields that can exist within a given climatic and bio-physical endowment, indicating different technological levels of production due to socio-economic factors.

Production systems could initially be categorized as pastoral, small-scale mixed systems, lowland rice-based, upland cereal-based, irrigated smallholder systems, smallholder plantation crops, and shifting cultivation. To make the linkage with major AEZs, pastoral systems are predominantly, but not exclusively, found in drylands, small-scale mixed systems in highlands, cereal-based systems in drylands and humid lands (semi-arid and sub-humid), lowland rice-based and irrigated smallholder systems in irrigated areas, smallholder plantation farming and shifting cultivation in humid lands.

In the location-specific matrix, the column "Farm-household objectives and constraints" should mainly reflect the interactions between socio-economic environment (see Figure 2) and the farm-household as production unit and the possible resulting conflicts. It should further elaborate on the human factors determining resource-base use. The concept of technology assessment for sustainability is location/site-specific and will vary considerably according to production system and agro-ecological setting. It is therefore necessary to define how, in a given situation, the contribution of a technological intervention to a system's sustainability can be measured or, in other words, which criteria and indicators can be considered reliable parameters for the long-term performance of systems. The identification of technologies for SARD requires a holistic set of systems parameters. So far, this has not been attempted in a comprehensive manner:

AGRO-ECOLOGICAL ZONE:

	ASSESSMENT					TRANSFER	
	RESOURCE ENDOWMENT	FARM-HOUSEH. OBJECT. and CONSTRAINTS	UNSUST. IND./ CRIT. AREAS	OBJECTIVES & TECHNOL. REQUS. for SUST.	TECHN. OPTIONS info/mater.	ACCOMP. MEASURES FOR TECH. TRANSFER	INTERVENTION LEVEL & SECTORAL LINKAGES
PRODUCTION SYSTEM							

FIGURE 4. LOCATION-SPECIFIC ASSESSMENT MATRIX

available technologies largely address isolated constraints, due to a lack of information on the economic, biological or social value of the numerous factors that constitute and influence a system. Parameter sets that can be used for systems' assessment may include trends in net income of farm-households, yield trends, dynamics of pest/weed populations, vegetation and pest-predator survey data, soil organic matter, soil losses due to erosion, downstream flooding and sedimentation etc.

These sets of parameters will vary with location and, anticipating future experiences, over time. What is considered sustainable today may not be so tomorrow. This points to the significance of the time-factor and to the dynamic nature of sustainability. However, long-term testing of technologies (for *ex-post* assessment) has to be accompanied by an earlier dissemination of *ex-ante* assessed technologies.

To date, sustainability indicators are known for many production systems and agro-ecologies. Large-scale evidence of unsustainability includes vegetation changes, erosion and changes of herd composition in cereal-based and pastoral sytems in drylands; water-logging, saline soils, weeds, pests and diseases in rice-based and small-holder systems in irrigated lands; reduced vegetation cover, decreased fallows, weeds, diseases and physical and chemical soil degradation in cereal-based systems, under shifting cultivation and in smallholder plantations in humid lands; and run-off, erosion and downstream sedimentation in small-scale mixed systems in highlands. Among the listed indicators, the loss of vegetation cover and soil degradation are the most important threats to sustainability and the soil degradation risk is estimated to be highest in Asia, compared to other developing regions. New indicators will, undoubtly, emerge in the course of long-term evaluations of systems.

Contrary to the traditional goal of boosting production through increased productivity, the better understanding of critical areas and sustainability indicators for different production systems under varying agro-ecological conditions for increased efficiency of production will most likely emerge as the most important area for agricultural research. This should eventually lead to clearly definable objectives and technological requirements and options for sustainable agriculture.

The Asia Region as a whole features one of the world's largest variety of agro-ecological conditions. A vast majority of farmers, however, eke out a living from small mixed farming systems in a less favourable environment, i.e. rainfed/dryland areas. There is a commonality of problems and constraints and most Asian countries could benefit from a networking approach to technology assessment and transfer for these low-resource endowments. Objectives of technological interventions for sustainable agriculture can be summarized as food security and risk resilience, environmental compatibility, economic viability, and social acceptability. Different AEZs and production systems, however, require location-specific and tailored solutions. In drylands, objectives of technological interventions include diversification of production and bio-diversity conservation, soil and water conservation, crop/livestock/tree integration, and, where necessary, area rehabilitation. Where possible, a rather drastic intervention is irrigation and thus a change of the agro-ecological zone. Irrigation, however, requires proper management of water supply and drainage to counteract soil salinization.

In subhumid and humid areas, besides soil and bio-diversity conservation, a major objective should be the alleviation of soil acidity and phosphorus fixation. There appears to be scope for the expansion of irrigation in Asia to reduce pressure on upland areas with considerable migration.

Irrigated lands are prone to salinization and objectives should be water use efficiency and water resource protection. In highlands, the risk of erosion needs to be checked through conservation measures and afforestation.

Apart from the overriding concern for the environmental impact of technologies, due consideration is required for the socio-economic and institutional dimensions of technology transfer. To avoid the earlier failures of technocratic and top-down approaches, participatory technology generation and on-farm testing will have to feature more prominently. On-farm trials with truly representative cross-sections of the target communities and iterative participatory impact assessment would contribute greatly to an enhanced relevance and social acceptability of technological interventions for the intended beneficiaries. Problems lie with both material and information-based technologies: adoption of the former is hampered by lack of access to inputs and credit and by associated risks, the latter group of technologies often requires a higher labour input, incompatible with peak activities or people's readiness. Information- or management-based technologies, however, can be considered more appropriate in high-risk environments, i.e. rainfed/dryland areas, where high-input technologies meet with risk-aversion of the predominantly resource-poor farmers.

Evidence, particularly in Asia, suggests that there is a relation between poverty and land degradation, resulting in conflicting interests of the actors involved: the subsistence farmers' concern for daily survival and the analyst's view toward future system's performance will sometimes lead to opposite strategies. People who's survival is at stake can hardly be expected to consider sustainability issues. On the other hand, it is inappropriate on the part of the scientist to assume an inherent disregard of resouce-poor farmers for environmental concerns. Farmers have their own ideas about economically viable means of resource protection. Consequently, the economic advantages of proposed technologies will have to materialize within the first or second season of adoption, also for long-term interventions such as soil amelioration. If this cannot be ensured, any future chances for farmers' collaboration with "agents of progress" may be forfeited.

Besides individual farm economies, costs and returns to the national economy have to be considered. When there is a disparity between private and social costs and returns, farmers' preparedness to invest in production may override their investments in sustainable practices. Thus, a case can be made for the societal costs of unsustainable agricultural practices, e.g. sedimentation or silting-up of rivers and lakes as off-farm effect of soil erosion, besides the costs of top-soil losses, resulting from the short-term capturing of private returns. The societal costs may outweigh the societal benefits. Here, subsidization of certain conservation practices might be considered, which would widen the range of accessible technologies for resource-poor farmers. Where this is beyond the reach of national economies, development banks and other donors might consider to play a role in resources and environmental protection. Non-technological factors closely related to resource degradation that need to be observed at this level include population growth and inequitable land distribution, the latter being a prominent feature of most Asian rural economies.

The columns "Accompanying measures" and "Intervention level & sectoral linkages" in our matrix rather address problems of transfer of technological options and will largely be variations on themes, but have to be assessed thoroughly for each given situation. The former will relate chiefly to farmers' organizations, land tenure, input availability and prices, infrastructure and markets, credit, policies, research-extension-farmer linkages and on-farm technology testing. Intervention levels will include regional organizations and development banks, governments, NGOs, agribusiness firms, cooperatives, researchers, extensionists, communities and farmers. Institutional requirements for effective technology transfer include the establishment and exploitation particularly of sectoral linkages between public and private entities, e.g. NARS, extension, NGOs and farmers' organizations, and the comparative advantages of these sectors to serve a particular clientele.

On a fairly general level, the stage has been set for the major agro-ecological zones (Table 1). This agro-ecological assessment matrix is not exhaustive nor do the listed constraints, objectives and technological options apply only under their respective rows and columns. Given the considerable climatic variations within the major AEZs and the large number of existing production systems, many proposed technologies would be inter-changeable and suitable for particular conditions under several AEZs and production systems, e.g. water harvesting technologies in drylands and highlands. Furthermore, single technology components are applicable within several technology packages. However, this can serve as a starting point from which more refined and site-specific concepts could follow. Required technologies for sustainable systems will principally relate to soil fertility and erosion, water management, pest control, genetic diversity, animal feed resources and health, and value-adding. Such technologies would not merely represent solutions to technical problems but address rural development in a more comprehensive manner, e.g. risk resilience, economic benefit, rural employment (on-farm and off-farm through agriculture-related industries and services), and environmental compatibility.

Widely recommended technologies and technology packages, as reflected in FAO programmes, address the following issues:

TABLE 1. AGRO-ECOLOGICAL ASSESSMENT MATRIX

AEZ	Production Systems	Unsustainability Indicators	Objectives/Technological Requirements	Technological Options	
				information-based	material
Drylands <1000 mm rainfall, <180 d GP	*Cereal-based* (semi-arid): sorghum, maize, millets, cassava (food crops); groundnut, cotton, sesame (cash crops); ruminants *Pastoral:* nomadism, transhumance, sedentary	Vegetation changes or losses Erosion, Desertification Reduced yields Cropping of submarginal lands Change of herd compositions: substitution of large by small ruminants	Diversification Adjusted herd and population numbers Soil/water conservation Area rehabilitation Bio-diversity conservation Crop/livestock/tree integration	Agroforestry Agro-sylvo-pastoral systems Rangeland management IPNS Conservation tillage Mulching Water harvesting (bunds, tied ridges, contour planting) Grass strips (vetiver) Legume trees and shrubs	Irrigation, water management Drought toler. species & varieties Short duration varieties Residue treatm. & supplement. for ruminants Forage banks Fodder conservation Specialized products Storage technologies Solar energy
Irrigated Lands active water collection or diversion	*Lowland rice-based:* rice, soybean, maize, sorghum, sesame, mungbean, livestock *Irrigated smallholder systems:* sorghum, maize (food); cotton (cash); livestock	Waterlogging and salinization Lowered water tables Weeds, pests and diseases	Increased productivity Water resource protection Water use efficiency	Community/on-farm water management Fish culture in rice IPM IPNS	Rehabilitation of conveyance and drainage systems Residue treatm. & supplement. for ruminants Residues for energy
Humid Lands (subhumid: 1000-1500 mm rainfall, 180-270 d GP humid: >1500 mm rainfall, >270 d GP)	*Cereal-based* (sub-humid): maize, sorghum (food); cassava, groundnut, cotton, sesame (cash); livestock *Shifting cultivation:* upland rice, cassava, bananas (food); medicinal plants (cash) *Smallholder plantation farming:* cassava, maize, bananas, upland rice (food); rubber, oil, coconut, tea, coffee, sugar cane, vegetables (cash); dairy	Reduced vegetation cover Deceased bush fallows Weeds species, diseases Physical and chemical soil degradation	Bio-diversity conservation Soil conservation Soil organic matter management Counteracting soil addification and phosphorus fixation	Agroforestry Agro-sylvo-pastoral systems (alley-, inter-, relay-cropping) IPNS IPM Green manure Animal production/forage under trees	Legume fodder banks Sown pastures and fodders Residue treatm. & supplement. for ruminants Sugarcane/cassava for non-ruminants Bio-energy
Highlands	*Small-scale mixed systems:* rice, wheat, millets, sorghum, maize, potatoes, buckwheat, fruit trees, vegetables; livestock	Run-off Erosion, land slides Sedimentation & floods (downstream) Negative yield trends Increased time for food, fodder, fuel gathering	Bio-diversity conservation Afforestation Diversification Soil/water conservation	Agro-sylvo-pastoral systems Watershed management Rangeland management Grass strips (vetiver) Hedgerows (legume trees and shrubs) Terracing	Specialized highland products (high value) Small hydropower

IPNS (Integrated Plant Nutrition Systems):

IPNS foster the integration of benefits from all possible sources of plant nutrients for a long-term and optimum level of productivity with sufficient economic return.

IPM (Integrated Pest Management):

Against the background of annual losses of around US$ 300 billion due to pests and a further US$ 20 billion spent on pesticides, apart from the health and environment-related problems, IPM integrates several available pest control techniques (resistant varieties, chemical and biological control agents) in a synergic manner with a view towards healthy crops and least disruptions in agro-ecosystems.

Integrated Farming Systems:

The development of integrated farming systems aims at the intensification of biological processes, technology and input use, including labour, in order to meet demand growth for food and other farm products and to avoid further encroachment on fragile ecosystems.

Integrated systems should combine IPM, IPN, soil conservation and efficient water management and make use of the complementarity between different crops and crops and livestock.

Sustainable Livestock Systems:

Livestock production can pose a threat to sustainable development in two distinct ways: directly affecting the resource base through pasture degradation due to overstocking, and the inherent inefficient conversion of plant material into produce; and methane emissions contributing to global warming through the greenhouse effect and to the depletion of the ozone layer. This, however, has to be weighed against the production of high-quality food from otherwise often wasted non-edible material (crop by-products), besides the supply of intermediate products, e.g. draught power and manure, and considerable cash income.

Recommended strategies focus on the proper management of pastoral systems to enhance pastures' role as carbon-sinks (CO_2 and N-fixation), in plant nutrient recycling, and in the protection of soils and watersheds. Furthermore, the synergic effects of integrated crop/livestock/tree-systems receive considerable emphasis. Rumen methane emissions are addressed through strategies for improved feed utilization, which aim at balanced rumen fermentation for maximum degradation of complex carbohydrates to volatile fatty acids and balanced nutrient supply at the intestinal/cellular level. Practical technologies include the supplementation of rumen nitrogen and the supply of by-pass proteins and carbohydrates (sugarcane based systems, urea treatment of straw, molasses-urea blocks, legume and other fodder trees, naturally and artificially protected proteins). The underlying concept is to increase productivity per animal unit and to decrease the number of animals. There is a need, however, to evaluate bio-energetic efficiencies and environmental friendliness of different production systems.

Global warming is a priority area for the Global Environment Facility (GEF), however, there are pros and cons emerging in the public discussion (CO_2 fertilization and antitranspirant effects, increased biological N-fixation vs. ozone depletion, unstable weather conditions, sea level rise), depending largely on the location. The general course of action against global warming, however, indicates the overall agreement on counteracting greenhouse gas emissions. The major factors associated with global warming are presented in Figure 5.

V. Priority setting for a sustainability agenda

Priority setting is invariably a necessity and an important tool in research management. In agricultural research, a variety of formal and unformal methods have been applied to arrive at relevant plans and objectives. Salient features of the most common methods include the contribution of a commodity to AgDP (=congruence), cost/benefit analyses (national and international models), and subjective judgement (checklists/scoring). There are well recognized weaknesses

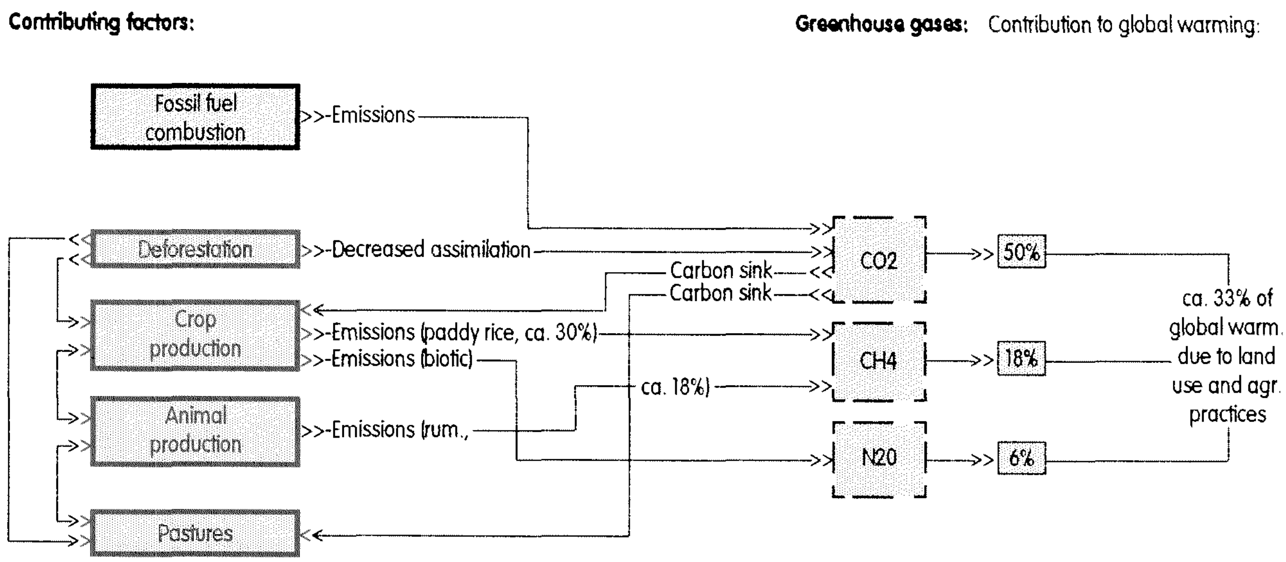

FIGURE 5. AGRICULTURE AND GLOBAL WARMING

inherent to these approaches, e.g. commodity orientation, disregard of production factors, extensive data requirements, and unverifiable assumptions on technology adoption rates and time lag.

In the context of sustainability, however, a ranking of issues according to their urgency and the ubiquitous scarcity of funds in the technology generation and transfer systems are sufficient reasons to apply a more or less formal approach to priority setting.

The underlying principle of research priority setting is the expected economic return to investments. Therefore, the economic significance of a commodity tends to determine its ranking on the research agenda. Technology for sustainability is somewhat more difficult to value: neither the costs nor the long-term returns (sustainability, by definition, implies rather long-term than short-term returns) of specific technological interventions can be sufficiently quantified at the moment. It is worthwhile mentioning here, however, that the losses of grain per year due to degradation and depletion of natural resources are currently estimated at US$ 6.5 billion: the guiding principle when granting priority to sustainability issues appears to be a general evidence of urgency.

Priority setting takes place when data, analysis and judgement are used to arrive at a recommended or binding agenda for action. Having accumulated and interpreted the information according to our matrix, quantitative criteria and comprehensive systems parameters are needed to allow for a prioritization of technologies according to expected returns. The long-term objective for a priority setting methodology would be to have at our disposal a quantification of technological effects so that assessments can be based on societal cost/benefit analyses. Research into cause-effect relationships is needed to support such analyses.

Sustainability considerations have found their way also into TAC's priority setting: baseline priority setting (value of production, poverty, land use) is modified by sustainability indicators, i.e. urgency of need for production growth, deforestation, soil degradation risk, besides efficiency and equity concerns. It is beyond the scope of this paper to place sustainability research and technology development in the overall technology development policy of any given country, due to the large variations in capacity and sustainability issues, but within a sustainability agenda, a few suggestions are made for gearing the decision-making process toward a relevant priority ranking. Some available benchmark data are presented in Table 2.

From a standpoint of environmental significance, and this might correspond to economic significance, the loss of forest cover (annually -1.4% between 1981 and 1990) appears to be the most serious threat, followed by *soil erosion* due to water and wind. Erosion currently exceeds the natural soil formation by 30-40-fold. Horizontal expansion of land use seems to have reached its limits and 16% of Asia's agricultural land are considered severely degraded (=loss of 50% of production potential). Furthermore, the loss of irrigated lands in India, for example, corresponds roughly to land expansion. *Land degradation*, in turn, is a major ob-

TABLE 2. AVERAGE ANNUAL GROWTH RATES (%, 1980/90) AND LAND/MAN RATIO IN THE ASIA-PACIFIC REGION

	Developing Countries	Developed Countries	Total Asia-Pacific	Rest of World	World
Rice	2.7	0.4	2.6	1.5	2.5
Wheat	4.3	1.3	3.9	1.5	2.2
Maize	3.5	1.5	3.5	0.5	1.1
Coarse Grains	2.1	2.6	2.1	0.7	1.0
Cassava	1.4	nil	1.4	3.0	2.4
Sweet Potatoes	-0.7	0.4	-0.7	1.3	-0.6
Potatoes	3.2	1.3	3.0	0.2	0.8
Roots and Tubers	0.6	1.0	0.6	1.2	0.9
Pulses	1.2	22.3	1.9	5.2	3.7
Groundnuts	4.2	-4.6	4.2	1.2	3.1
Soybeans	5.2	3.0	5.1	2.1	2.5
Sugarcane	3.2	1.0	3.1	2.8	2.9
Meat Production	6.8	1.5	5.8	1.9	2.9
Milk Production	5.2	1.9	4.4	0.9	1.5
Irrigation	1.2	0.6	1.1	1.0	1.1
Fertilizer	7.0	-0.3	6.2	1.5	2.7
Total Population	1.9	0.7	1.8	1.6	1.7
Agricultural Land	0.8	9.4	1.7	1.7	1.7
Land/man Ratio (ha/caput)					
1979	0.25	3.40	0.28	1.68	0.67
1989	0.23	5.91	0.26	1.60	0.62

Source: Adapted from FAO/RAPA 1991

stacle to intensification, which, viv-a-vis *land scarcity* and the lowest *land/man ratio* in the world (0.23 ha/person), is needed to feed a *population* with the highest *growth rate* in the world, while food security is vulnerable. Production increases during the last decade have been achieved at considerable costs to the resource base and largely by means of heavy external input use: irrigation, seeds, fertilizer, pesticides, animal breeds and feed. *Poverty*, another important indicator and closely inter-related with the above, has several aspects (limited assets, landlessness etc.) and is a considerable problem in parts of the Region, though poverty is not alone responsible for resource degradation. Country-specific poverty levels are not reported here since they are based on different indicators and therefore not directly comparable. However, the overall rural poverty proportion, according to FAO estimates, was declining between 1980 and 1987 (51.8% vs. 47.7%), with the total number of rural poor increasing (495 million vs. 506 million), though, and a large majority living in Asia (63.2% in 1980 vs. 62.6% in 1987). These figures exclude China. Real *incomes* in several countries of the Region are declining, the ratio of per capita incomes in China and India, for instance, in relation to European countries widened from 1:2 toward the end of the last century to 1:70 currently. Population growth poses a formidable challenge to *rural agricultural and non-agricultural employment*. Demographic pressure, furthermore, is most intensive in low-potential areas with a majority of poor people and threatens the fragile resource base. Land pressure, however, rather than individual production systems, emerges as the common denominator of agricultural sustainability in the Region and intensification of production systems has to be advanced in ways that do not further undermine but rather enhance the resource base and preserve the environment.

As mentioned above, it is still difficult to attach monetary values to the introduction and adaptation of sustainable agricultural practices, but the costs of not doing so are becoming more and more apparent. First steps, therefore, could be to assess such costs for a given country and rank the disaggregated negative effects, e.g. environmental degradation, food imports, unemployment etc. according to their accrued and expected societal costs. Since everything can be translated into economics, this can provide an overall "guesstimate" of the relative importance or urgency of various sustainability issues. Hard economic data also carry the promise to be convincing arguments for bureaucrats in charge of resource allocation. There are, however, inherent biases to the economic valuation of some commodities and groups of commodities, e.g. livestock. From the pure commodity perspective, livestock are commonly reduced to easily measurable outputs such as milk, meat, wool and hides. From a systems perspective, livestock contribute to mixed farming systems mainly through draught power/energy, manure and, consequently, soil fertility, besides the provision of food (essential amino acids), fuel and of capital against uncertainty, i.e. a risk management tool. The use of manure as fuel, however, has been described as an unsustainability indicator, resulting from fuelwood shortages and, subsequently, depriving the cropping system of fertilizer and organic material, weakening the soil structure and thus decreasing yields.

Livestock, e.g. buffaloes and cattle, play an essential role in the predominantly small-scale mixed farming systems of Asia. In some agro-ecosystems, e.g. the largely inaccessible hills and mountains of Nepal, food production depends totally on livestock for draught energy and manure. The economic assessment of livestock by production value alone has been seriously underestimating their importance in mixed farming systems. The problem of assessing intermediate products has been recognized by the TAC but, nevertheless, has not been tackled to date. To further illustrate the complex implications of intermediate inputs, it shall suffice to point out the combined effects of the lack of manure, reduced ground cover, and the reduced stabilizing influence of tree roots which, in mountain agro-ecosystems, can lead to surface erosion, land-slides, flooding and sedimentation. There are, furthermore, indications for a growing importance and higher priority of livestock, particularly buffaloes and cattle, on national agendas: increasing incomes in several countries of the Region and high income elasticities of demand for animal products; and the opportunity to absorb surplus family labour and to circumvent land availability contraints. The development and dissemination of integrated farm management technologies such as organic manuring and by-product utilization, e.g. technologies involving livestock, is recommended in UNCED's Agenda 21.

The above is not merely an advocation of more emphasis on livestock but is intended to underline the importance of a systems approach. It is recognized, though, that an empirical quantification of all parameters (technical, environmental, socio-economic) is very difficult, due to lack of information. Priority setting for the use of sustainability enhancing technologies will, for some time to come, not be a mathematical exercise but guesswork based on intelligent interpretation of available systems parameters. An appropriate indicator for the sustainable intensification of land use is *increased energy efficiency*. Sustainable intensification, in this sense, corresponds to *improved energy input/output ratios*, as opposed to intensification in an ''industrial'' context, which commonly implies a shift of the energy balance to the negative side. There are technologies available for the optimization of biomass utilization. A narrowing land base can be exploited efficiently by way of high biomass yield crops such as sugarcane, sugarbeets and cassava. Such systems are highly productive with both ruminants and non-ruminants and probably superior to traditional cereal-based systems. Multi-purpose trees can further contribute to the sustainability of such systems. Water availability, however, can be a critical factor.

Critical to technology application, i.e. farm level use, are capacities for adaptive research, considering the highly location-specific nature of most technology interventions. This applies particularly to crops and to a lesser degree to the livestock subsystem. Available capacities for technology fine-tuning, including farmers' readiness to experiment, will largely determine the efficiency of the assessment process and have to be considered when deciding on a priority agenda. Without such integration of adaptation and transfer, assessment takes place in a vacuum and remains an academic exercise.

VI. Implementation

A. National programmes:

Technology assessment, considering the need for a sound definition of location-specific agro-ecological, production systems' and socio-economic characteristics that pertain to sustainability, needs to be incorporated in national research and technology development programmes. Technology assessment, furthermore, requires a systems approach. This is to underline the necessity of demand-driven technology delivery. **The traditional approach to increase production of single commodities is giving way to increased overall systems' efficiencies, thus foregoing short-term returns for long-term resource protection.** The above, in turn, has major implications for organizational and managerial aspects of research and would require certain institutional changes in most national systems.

Making technology assessment primarily a national responsibility implies that pilot programmes should be identified initially in countries where there is a systems perspective applied to problems of rural development. This statement also relates directly to the recurrent concern in the CG system about NARS' capacities to make use of technologies developed by the IARCs. The approach would thus be to define for a number of selected testing grounds, i.e. production systems and AEZs, unsustainability indicators, the factors that determine sustainability, i.e. critical areas, and the implications for technology identification, adaptation and generation. Having defined precisely the agronomic and socio-economic characteristics, the recommendations gained from the exercise should be applicable to similar settings. While research and technology transfer for specific target groups have to be on the agenda, this alone is not enough. Major obstacles to adoption lie within the socio-economic environment: infrastructure, credit, prices etc. The limitations of research and technologies have to be recognized and complemented by political commitment and policy implementation.

To extrapolate and exploit experiences gained herewith, NARS in need of strengthened Farming Systems Development (FSD) capacities would require, besides the conceptual inputs, policy commitment and support for institutional innovations and human resources development. Here, donor support will have to fill the gaps of deteriorating financial situations in many national systems where FSD capacities have to be created in addition to the existing traditional commodity approach. However, recent studies show that the costs of on-farm research (=participatory technology testing) with its high requirements for continuous interaction with target groups are lower than commonly assumed and even lower than those for traditional research. Partners at the national level should include, besides public sector research and extension, NGOs and farmers' organizations to bring results to bear at village- and farm-level.

B. Regional cooperation:

Commonality of problems and the objective to further develop the assessment concept on the basis of location-specific applications call for a network strategy. Existing networks with objectives pertaining to the adaptation and generation of relevant technologies would lend themselves to the undertaking. Initially, the presence of institutional structures able to sustain a systems approach to technology assessment would be a prerequisite for pilot programmes.

Reverting to the problem of priority setting, it has hardly ever been attempted on a regional basis, except in the CG system. There are, however, different priorities for agricultural development in different countries, besides considerable differences in research and technology delivery capacity. Countries like India and China might be better placed, also for reasons of urgency, to tackle problems of soil erosion. Pakistan and Sri Lanka may have a comparative advantage in irrigation-related issues. It would certainly be cost-effective to identify leading institutions/programmes in particular fields and to coordinate assessment and transfer of technologies on the basis of "who-knows-best".

C. FAO/IARC collaboration:

The CGIAR is actively seeking partnership with entities that can work with governments on financial and policy problems of agricultural development and strengthen and/or undertake location-specific research.

Based on clear delineations of comparative advantages and respective responsibilities in technology identification, assessment and transfer, national pilot programmes could benefit from collaborative arrangements between FAO and International Agricultural Research Centres (IARCs). Integrated in country programmes, the IARCs' mandate would lend itself to technology identification for well defined agro-ecological conditions, production systems, resource endowments, socio-economic frameworks, and unsustainability indicators, consistent with the Centres' eco-regional approach. Considering FAO's experience in technology transfer over a wide range of production systems and socio-economic settings, the Organization's role could be that of a broker between strategic and location-specific solutions.

SELECTED REFERENCES

ABINGTON, J.B. (ed.) 1992. Sustainable livestock production in the mountain agroecosystem of Nepal. FAO Animal Production & Health Paper Series (in press).

ALTIERI, M.A. 1992. Where the rhetoric of sustainability ends, agro-ecology begins. Ceres 134: 33-39.

BEETS, W.C. 1990. Raising and sustaining productivity of smallholder farming systems in the tropics. AgBe Publishing, Alkmaar.

BLAIR, G., HOFFMANN, D., and ISMAIL, T. 1991. Contributions or possible contributions of technology to development problems within a sustainable framework in crop/livestock systems. In: Blair, G. and Lefroy, R. (eds.): Technologies for sustainable agriculture in marginal uplands in Southeast Asia. ACIAR, Canberra, 101-106.

BLAKE, R.O. 1992. Challenges for global agricultural research. Finance & Development, March 1992: 30-31.

BUNTING, A.H. 1987. Agricultural environments: characterization, classification and mapping. CAB International.

CSTD 1991. Environmentally sound technology assessment. New York.

CRASWELL, E.T. and PUSHPARAJAH, E. 1991. Soil management and crop technologies for sustainable agriculture in marginal upland areas of Southeast Asia. In: Blair, G. and Lefroy, R. (eds.): Technologies for sustainable agriculture on marginal uplands in Southeast Asia. ACIAR, Canberra, 93-100.

DIXON, J.A. and FALLON, L.A. 1989. The concept of sustainability: origins, extensions, and usefulness for policy. Society and Natural Resources 2: 73-84.

DYKE, P.T. 1984. A proposed design of general agricultural management systems for expediting technology transfer. Proceedings of the International Symposium on Minimum Data Sets for Agrotechnology Transfer. ICRISAT Centre, Patancheru.

FAO 1992. Sustainable development and the environment: FAO policies and activities, Stockholm 1972 - Rio 1992. FAO, Rome.

FAO 1992. The state of food and agriculture 1991. FAO Agriculture Series No. 24. FAO, Rome.

FAO 1991. Third progress report on the World Conference on Agrarian Reform and Rural Development (WCARRD) programme of action. FAO Conference, 26th Session. FAO, Rome.

FAO 1991. Elements for strategies and agenda for action (draft proposal). FAO/Netherlands Conference on Agriculture and the Environment. FAO, Rome.

FAO 1991. Issues and perspectives in sustainable agriculture and rural development. FAO/Netherlands Conference on Agriculture and the Environment. Main Document No. 1. FAO, Rome.

FAO 1991. Technological options and requirements for sustainable agriculture and rural development. FAO/Netherlands Conference on Agriculture and the Environment. Main Document No. 2. FAO, Rome.

FAO 1991. Strategies for sustainable agriculture and rural development in areas with different resource endowments. FAO/ Netherlands Conference on Agriculture and the Environment. Main Document No. 3. FAO, Rome.

FAO 1991. Sustainable development and management of land and water resources. FAO/Netherlands Conference on Agriculture and the Environment. Background Document No. 1. FAO, Rome.

FAO 1991. Sustainable crop production and protection. FAO/ Netherlands Conference on Agriculture and the Environment. Background Document No. 2. FAO, Rome.

FAO 1991. Livestock production and health for sustainable agriculture and rural development. FAO/Netherlands Conference on Agriculture and the Environment. Background Document No. 3. FAO, Rome.

FAO 1991. Sustainable agriculture and rural development in Asia and the Pacific. FAO/Netherlands Conference on Agriculture and the Environment. Regional Document No. 2. FAO, Rome.

FAO 1990. Population, environment and sustainable agricultural development. FAO/Netherlands Conference on Agriculture and the Environment. Preparatory Meeting, Rome, 8-12 March 1990. Miscellaneous Document Three. FAO, Rome.

FAO 1989. Sustainable agricultural production: implications for international agricultural research. FAO Research and Technology Paper No. 4. FAO, Rome.

FAO RAPA 1991. Selected indicators of food and agriculture development in the Asia-Pacific Region, 1980-1990. FAO Regional Office for Asia and the Pacific, Bangkok.

GEF 1992. The pilot phase and beyond. Working Paper Series No. 1. UNDP, UNEP, World Bank.

HILDEBRAND, P.E. 1990. Agronomy's role in sustainable agriculture: integrated farming systems. J. Prod. Agric. 3: 285-288.

HOLTER, J.B. and YOUNG, A.J. 1992. Methane prediction in dry and lactating Holstein cows. J. Dairy Sci. 75 (8): 2165-2175.

ICRISAT 1992. ICRISAT Report 1991. International Crops Research Institute for the Semi-Arid Tropics, Hyderabad.

JODHA, N.S. 1992. Agricultural growth and sustainability: perspectives and experiences from the Himalayas. MFS Series No. 25. ICIMOD, Kathmandu.

JODHA, N.S. 1991. Sustainable agriculture in fragile resource zones: technological imperatives. Economic and Political Weekly, March 30: 15-26.

KERR, J.M. (ed.) 1991. Farmers' practices and soil and waer conservation programs: summary proceedings of a Workshop. 19-21 June 1991, ICRISAT Centre, Patancheru. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and Winrock International.

KOPPEL, B. 1978. Technology assessment and research management. Southeast Asian Regional Centre for Graduate Study and Research in Agriculture (SEARCA) College, Laguna, Philippines.

KWASCHIK, R. 1992. Technology transfer to smallholders - straw treatment in China and Egypt. FAO Research Development Centre Working Paper No. 13. FAO, Rome.

LANH, L.V. 1992. Recipes for restoration. Ceres 134: 17-22.

LENG, R.A. 1990. The impact of livestock development on environmental change. Paper presented at the Expert Consultation for Sustainable Animal Agriculture in Developing Countries, Rome, 10-14 December 1990. FAO, Rome.

LYNAM, J.K. and HERDT, R.W. 1989. Sense and sustainability: sustainability as an objective in international agricultural research. Agricultural Economics 3: 381-398.

MERRILL-SANDS, D.M., BIGGS, S.D., BINGEN, R.J., EWELL, P.T., McALLISTER, J.L. and POATS, S.V. 1991. Institutional considerations in strengthening on-farm client-oriented research in national agricultural research systems: lessons from a nine-country study. Expl. Agric. 27: 343-373.

NELSON, R. 1990. Dryland management: the "desertification" problem. World Bank Technical Paper No. 116. The World Bank, Washington, D.C.

NIX, H.A. 1984. Minimum data sets for agrotech-nology transfer. Proceedings of the International Symposium on Minimum Data Sets for Agrotechnology Transfer. ICRISAT Centre, Patancheru.

OKIGBO, B.N. 1991. Development of sustainable agricultural production systems in Africa: Roles of International Agricultural Research Centres and National Agricultural Research

Systems. International Institute of Tropical Agriculture, Ibadan.

ORAM, P.A. 1988. Moving toward sustainability: building the agro-ecological framework. Environment 30 (9):14-36.

SCHUH, G.E. 1992. Sustainability, marginal lands and agricultural research. Staff Working Paper 4. IFAD, Rome.

TAC SECRETARIAT 1992. TAC review of CGIAR priorities and strategies, Part I. FAO, Rome.

TAC SECRETARIAT 1992. Priorities and strategies for livestock research in the CGIAR. Discussion Draft. FAO, Rome.

TAC SECRETARIAT 1992. Report of the fifty-eighth meeting of the Technical Advisory Committee. Draft. FAO, Rome.

UNITED NATIONS 1979. Technology assessment for development. Report of the United Nations Seminar on Technology Assessment for Development, Bangalore, India, 30 October - 10 November 1978. United Nations, New York.

UNITED NATIONS 1992. Adoption of agreements on environment and development: Agenda 21. United Nations Conference on Environment and Development, 3-14 June 1992, Rio de Janeiro.

U.S. CONGRESS, OFFICE OF TECHNOLOGY ASSESSMENT 1988. Enhancing agriculture in Africa: a role for U.S. development assistance, Washington.

WHITMAN, C.E. and MEYER, R.E. 1990. Strategies for increasing the productivity and stability of dryland farming systems. In: Singh, R.P., Parr, J.F., and Stewart, B.A. (eds.): Dryland agriculture: strategies for sustainability. Advances in Soil Science 13, Springer-Verlag, New York, 347-358.

WILBANKS, T.J. 1991. Institutional issues in capacity building for energy technology assessment. In: ATAS/CSTD: Energy systems, environment and development: a reader. Advanced Technology Assessment System, Issue 6, United Nations, New York, 13-26.

YORK, E.T. 1988. Improving sustainability with agricultural research. Environment 30 (9): 19-40.

ACRONYMS

AEZ	Agro-ecological Zone
AgDP	Agricultural Domestic Product
CGIAR	Consultative Group on International Agricultural Research
CSTD	Centre for Science and Technology for Development
FAO	Food and Agriculture Organization
FAO RAPA	FAO Regional Office for Asia and the Pacific
FSD	Farming Systems Development
GEF	Global Environment Facility
GP	Growing Period
IAR	CInternational Agricultural Research Centre
IPM	Integrated Pest Management
IPNS	Integrated Plant Nutrition Systems
NARS	National Agricultural Research System
NGO	Non-Governmental Organization
SARD	Sustainable Agriculture and Rural Development
TAC	Technical Advisory Committee (to the CGIAR)
UNCED	United Nations Conference on Environment and Development

Section I

CHAPTER 2

TECHNOLOGY TRANSFER FOR SUSTAINABLE AGRICULTURAL AND RURAL DEVELOPMENT IN THE ASIA-PACIFIC REGION

R.B. Singh [1]

CONTENTS

Abstract 17

I. Introduction 18

II. Major trends and impacts of technology development and transfer in the Asia-Pacific region 19

III. Conceptual framework of technology transfer for sustainable agriculture and rural development (SARD) 23

IV. New paradigms in technology transfer 25

V. Role of the FAO 32

VI. Future challenges and policy options 36

References 43

ABSTRACT

Technology is the cornerstone of agricultural growth. Development, transfer and adoption of high-yielding varieties of wheat and rice, and other technologies in the Asia-Pacific Region enabled the Region to attain the highest agricultural growth rate in the world during the past three decades or so. But the growth was associated with certain agro-ecological, environmental and socio-economic problems.

The pressure for accelerated food and agricultural production in the Region continues to be high, and the increased production had to be realized essentially through increased productivity as there is negligible scope for expansion of the cultivated area. The future path of growth, however, must emphasize not only the productivity issue but also the sustainability and equity issues. The technologies used to attain the desired goals should therefore be technologically feasible, economically viable, socially acceptable and environmentally benign. In order to identify such technologies, suitable methods of technology assessment should be available and used systematically.

Technology transfer must be based on a system approach and must proceed in a structured manner. Generally, the path should be demand-driven but, under certain circumstances, technology-driven transfer could also be successful, provided there exists adequate local capability to absorb the technology, including risk assessment and management capability. Besides congruency between productivity, sustainability and equity, participatory approaches to seek effective participation of farmers' and people's organizations should constitute new paradigms for successful technology transfer. This calls for new policy options and attitudinal change.

Technology transfer is a dynamic process and needs adequate and continuous support to be able to mould and evolve itself to effectively address the problems. The governments and institutional systems must not only reverse the current trend of declining financial support to research but further augment agricultural research and technology de-

[1] *Senior Officer (Int'l Agri. Research), Research Development Centre, Research and Technology Development Division, FAO, Rome, Italy*

velopment systems in the Region. Increasing attention ought to be paid to technology transfer to rainfed and fragile ecosystems and to resource-poor farmers. The commonalities of problems and prospects of technology transfer in developing countries in the Region, and the variable experiences of the countries, render the TCDC approach an important mechanism for technology sharing. Linkages among relevant sectors and key actors are often non-existent or are weak. This malady must be corrected and effective linkages and their management must be established to ensure judicious harnessing of the various resources and elements.

I. Introduction

Research and technology development has been the cornerstone of agricultural transformation, especially since the turn of this century. Driven by the forces of economic growth and profit-making, and the foremost need for attaining food security and poverty alleviation, technologies have successfully been applied for intensifying agricultural production. For instance, the generation and transfer of modern varieties, coupled with improved crop and resource management practices, since the mid-sixties, led to an unprecedented growth in cereal production which outstripped an equally explosive growth in population and averted wide-spread food famine in several developing Asian countries. Cereal production (all cereals including rice in milled form) in East, South-East and South Asia almost doubled from 332 million tons in 1969/71 to 618 million tons in 1988/90 (FAO, 1993).

The process of agricultural intensification has, however, often been accompanied with deforestation, soil erosion, loss of biodiversity, and agrochemical pollution, threatening the sustainability of the very natural resource base. For instance, in Thailand, for maximizing short-term income, high-yielding varieties of corn and cassava were expanded in forest and slopy lands causing serious soil erosion and forest loss. In Indonesia and other South-East Asian countries persistent and uncontrolled use of pesticides caused development of brown plant-hopper populations resistant to available insecticides, besides causing widespread water and land pollution. In India, in intensive rice growing areas, where once about 3 000 rice cultivars grew, presently not more than 30 cultivars are grown, causing vulnerability to diseases and pests. The widespread salinization in irrigated tracts of Pakistan and India are yet another example of serious degradation of the resource base linked with the intensification process.

Despite the phenomenal growth achieved in food and agriculture production, especially cereal production in the Region during the past three decades, an estimated 523 million people in the Region are malnourished and hungry. These constitute more than half of the world's malnourished people. It is projected that by the year 2030, the Region's population will double, thus more than doubling the food demand during the next 35 years. Considering that the scope for horizontal expansion of arable land is negligible and the productive land resources are shrinking through degradation as well as through diversion to urban and industrial constructions, the projected increases in food production must be brought about only through more than doubling of the yield levels without causing further damage to the resource base.

In the years ahead, therefore, the most important challenge that the political leaders and people of the Asia-Pacific will face will be the reconciliation of the potentially conflicting goals of achieving large, sustained increases in food and agricultural production, productivity and profitability leading to comprehensive food security on one hand, and improving environmental quality and restoration of the vast degraded natural resources on the other. The current mode of technology utilization and the available technologies would obviously not meet the challenge. A new paradigm in technology development and transfer will be needed to bring about the desired reconciliation between the agricultural production (economic) targets and environmental goals.

Of course, while essential, it is not sufficient only to transform the technology paradigm. Policies, priorities, lifestyles and values must also change to realise the desired results. It may be recognized that technologies *per se* are not destructive. It is their faulty mode of application which results in negative influences. The need for formulating and implementing suitable policies, models of development without destruction, infrastructures and institutional systems for harnessing positive and avoiding negative influences of technologies can hardly be overemphasized.

Research and technology generation, development, assessment, transfer and utilization are all parts of an interactive and mutually reinforcing continuum. Yet, there are serious gaps between research, technology development and transfer in most developing countries, resulting in poor performance of the system (FAO, 1986; Merrill-Sands et al., 1990). These gaps are manifested as farmers' fields' yields being half to one-third of those at demonstration plots, incomplete and disjointed packages of technologies and high proportion of irrelevant, non-productive and often poor quality research. These gaps must be filled to enable research systems to meet their ultimate goal of sustainable agricultural and rural development (SARD) by developing and transferring technologies which are technologically feasible, economically viable, socially acceptable, and environmentally friendly.

The issues of technology transfer for sustainable agricultural and rural development were on the agenda of two major international conferences held in the recent past, the United Nations Conference on Environment and Development (UNCED), June 1992, and the FAO/Netherlands Conference on Agriculture and the Environment, November 1991. Agenda 21 of the UNCED and Den Bosch Declaration of the FAO/Netherlands Conference had adopted a set of plans of action to be implemented at various levels. In fact, the FAO/Netherlands Conference was a kind of a forerunner to the UNCED deliberations on this subject and most of its recommendations on technology for sustainable agriculture and rural development appear in the Agenda 21. The concerned national and international systems are developing programmes to operationalize the UNCED recommendations.

The present paper, after briefly reviewing impacts and trends of technology development, clarifies a few technology transfer related concepts and describes strategies and approaches for technology transfer. It elucidates new paradigms in technology transfer for SARD in the Asia-Pacific Region and highlights the challenges and policy options for future work on technology transfer, including the need for greater attention to rainfed and other marginal conditions and to small and resource-poor farmers. Status and mechanisms of strengthening sectoral linkages for technology transfer constitute an important part of the paper. The role of FAO in technology transfer in the Region has also been described.

II. Major trends and impacts of technology development and transfer in the Asia-Pacific region

The Asia-Pacific Region has been on the forefront of agricultural technology generation, development, transfer and application. More than 100 million hectares, about 70 percent of the world's rice acreage, of Asian rice fields are planted to modern varieties. The percentage coverage is almost 85 in case of wheat. It is this large scale development and adoption of modern varieties of rice and wheat and associated technologies that resulted in an unprecedented increase in yield and production of these two foremost food crops of the world and was dubbed as "green revolution" by the popular press.

Besides genetic improvement and crop breeding, advances in soil fertility, including biological nitrogen fixation and management of micronutrients, integrated pest management (weeds, insect pests and diseases), irrigation and dryland water management and post-harvest handling, have synergistically contributed to increased productivity in the Region. Similar developments have taken place in the livestock and fisheries sectors, and to a somewhat lesser extent in the forestry sector.

A. The positive influences

During the past 30 years, rice production in the Region more than doubled from 227 million tons in 1963 to 482 million tons in 1992 (FAO database). The progress in wheat production was much more dramatic. During the same period, wheat production more than quadrupled from 47 to 211 million tons. These production increases not only averted large-scale hunger during the late sixties and early seventies, but rendered most countries of the Region food self-sufficient.

In this land-hungry Region, where the per caput agricultural land availability is one-sixth of that in the rest of the world, it was all the more important that the production increases were essentially due to increases in yield levels (Table 1). It may also be noted that the yield-increasing research has indirectly been contributing to environmental protection by increasing production in favourable environments, thus reducing the need to bring marginal land into production. For example, in India, the HYV wheat technology has saved more than 40 million additional hectares of land from being brought under wheat (Table 2).

TABLE 1. ANNUAL GROWTH RATES (GR, %) OF RICE PADDY PRODUCTION, AREA AND YIELD IN THE ASIA-PACIFIC REGION, 1950-1990

Period	Production GR	Area GR	Yield GR	% contribution to production GR	
				Area	Yield
1950-65	2.2	1.1	1.1	50	50
1965-80	2.9	0.9	2.0	31	69
1980-90	2.6	0.2	2.4	9	92

Source: FAO computer print-out

TABLE 2. IMPACT OF NEW WHEAT PRODUCTION TECHNOLOGIES ON LAND SAVING IN INDIA

	1961	1991
Harvest (million tons)	11.0	54.5
Area utilized (million hectares)	12.9	24.0
Area needed at 1960 yield (millions hectares)	12.9	64.1
Difference between needed and actually used area (million hectares)		40.1

Hybrid rice technology is the latest breakthrough in the Asian agriculture. In 1992, China grew F_1 hybrid rice varieties in about 17 million ha, more than 50 percent of the country's rice area, with an average yield advantage of over 1 t/ha over the best conventional varieties. Because of high productivity of the hybrids, China has reduced its rice area from about 35 million hectares in 1979 to about 33 million hectares in 1990, while its rice production increased from 140 to 188 million tons during the same period. India stipulates to put 2 million hectares under hybrid rice by the year 2000 and is already in the process of releasing 4 to 6 rice hybrid varieties in the near future. Vietnam is already growing about 25 000 hectares under hybrid rice varieties, mostly introduced from China, and plans to further intensify the effort. Several other Asian countries, along with IRRI, are in process of developing the hybrid technology and there is a great scope for transferring the technology from one country to other (Yuan and Virmani, 1988; Singh and Virmani, 1990).

Modern varieties of rice and wheat are often "period bound" and not "season bound", which has rendered rice-wheat cropping as the predominant cropping system in several countries with tremendous increase in grain productivity and food security. This intensification has also contributed considerably to rural employment, optimum utilization of production resources, farmers income, and risk distribution. The approach has also allowed spread of the crops to a wider range of geographic and ecoregional zones, viz. production of wheat in Bangladesh and Bengal State of India and of rice in the Indian Punjab.

Although more visible, the impact of new technologies was not restricted only to wheat and rice, modern technologies were developed for several other crops with excellent achievements. While wheat yields quadrupled, maize yield has tripled during the past 30 years (Table 3). It may also be seen from Table 3 that yield of roots and tubers, essentially due to impressive increases in potato yields, and also of sugar-cane had increased by 50 to 80 percent. The lack of technological breakthrough and poor adoption of known technologies is evident from the almost stagnant yield of pulses during the last 30 years. The low yields and poor gains in yield of pulses may be partly attributed to these crops having been pushed (by wheat, rice and other glamorous crops) to still marginal areas and the lack of policy and institutional support for these crops.

Commercial production of hybrid cotton to boost and stabilize cotton production in India is yet another Asian monopoly. Several countries in the Region are pursuing this

TABLE 3. AVERAGE YIELD OF MAJOR CROPS AND COMMODITIES FOR THE ASIA-PACIFIC REGION AS A WHOLE DURING THE TRIENNIA ENDING 1963 & 1993

Crop/commodity	1961-63 (kg/hectare)	1991/93 (kg/hectare)
Wheat	827	2,513
Rice paddy	1,930	3,641
Maize	1,183	3,400
Roots and tubers	8,124	14,129
Potatoes	9,500	13,253
Pulses	636	712
Sugar-cane	46,559	60,185

Source: FAO computer print-out

approach and there are bright prospects for sharing of this technology. In fact, in general, there is an accent on hybrid technology in almost all major annual and perennial crops. This has great implications for public-private sector linkages as well as for promotion of private sector in agricultural production through research on and production and distribution of hybrid seed.

Asia has almost a monopoly in rubber, oil palm and coconut production, accounting for more than 75 to 90 percent of the world's production of these commodities. Spearheaded by Malaysia, which accounts for about 75, 54 and 28 percent respectively of palm oil, cocoa beans, and rubber production of the Region, development and large-scale adoption of new technologies has resulted in rapid growth in production, post-harvest handling and utilization of these commodities. Integration of livestock production with plantation crops, such as cattle under coconut in the Pacific Island countries, and sheep under rubber in Malaysia, is a new thrust. Modern technologies such as *in vitro* culture of oil palm, hybrid approach in coconut and coffee are already paying rich dividends. The *in vitro* technique is being widely used in the Pacific island countries for exchange of disease-free planting materials.

Technologies encompassing dwarf, closely spaced, prolific and precociously bearing trees have boosted yield of several fruit crops, and are contributing considerably to income and nutrition in the Region. Several vegetable and cut flower hybrids have been developed and widely adopted, thus diversifying agriculture with significant augmentation of income, nutrition and food self-reliance. In white potato, the true seed and microtuber technique and the availability of varieties suitable for tropical lowlands had created unique opportunities for diversification for rice farmers.

As regards livestock, cross breeding in cattle between low performing but locally adapted indigenous breeds and high producing but non-adapted to tropical conditions exotic breeds has been highly effective in increasing animal production, particularly dairy production in the developing countries of the Region. Embryo transfer for efficient production of cross-bred animals is now a reality and almost a common practice in the developed countries. Even in the developing countries, such as in India, the technology is likely to be put to large scale practical use in the near future. Further, production of forages through selection and development of new varieties and cropping systems is an important programme in several of the countries of the Region. Low-cost treatment of straw and other agricultural by-products is being increasingly adopted even by small farmers.

With the availability of newer and more potent vaccines and opening of vaccine banks, animal health care, even in remote rural areas, is fairly strengthened in developing countries of the Region. As a consequence, livestock production in Asia and the Pacific during the decade ending 1990 increased annually by about 4 percent.

Regarding fisheries, the Asia-Pacific Region accounts for about 80 percent of the world's aquaculture production. It is gratifying to note that the production in the Region has been increasing annually by more than 13 percent during the past decade or so. Techniques for fresh and brackish water prawn culture, backyard hatchery, breeding of freshwater fishes under captivity, cage culture and integrated crop-livestock-fish culture techniques have emerged in the recent years and are paying rich dividends to small fisherfolk and the farming community at large.

Adoption of the various technologies, coupled with other development efforts, had resulted in a growth rate of about 4 percent in gross agricultural production in the Region during 1970-90, against 2.3 percent in the world as a whole (Table 4). Consequently, per caput food availability in the Region had increased from 2 030 cal/day in 1969/71 to over 2 400 cal/day in 1988/90, the differences being much glaring in the case of East and South-East Asia as compared with South Asia (Table 5). During the same period, the number of chronically undernourished people in the Region went down from 751 million to 523 million.

TABLE 4. GROWTH RATES OF GROSS AGRICULTURAL PRODUCTION

Region	Total		Per caput	
	1970-90	1990-2010	1970-90	1990-2010
East and South-East Asia	4.1	2.7	2.4	1.5
South Asia	3.1	2.6	0.7	0.6
World	2.3	1.8	0.5	0.2

Source: Adapted from FAO 1993

TABLE 5. PER CAPUT FOOD SUPPLIES FOR DIRECT HUMAN CONSUMPTION (CALORIES/DAY) AND POSSIBLE EVOLUTION OF THE INCIDENCE OF CHRONIC UNDERNUTRITION

Region	Per caput food supplies (cal/day)			Chronic malnutrition (No. of persons in million)		
	1969/71	1988/90	2010	1969/71	1988/90	2010
East and South-East Asia	2,020	2,600	3,060	497	252	70
South Asia	2,040	2,220	2,450	254	271	202
World	2,430	2,700	2,860	941	781	637

Source: Adapted from FAO 1993

Modern biotechnologies and other technologies such as informatics, advanced processing technologies and advanced materials are being used as cutting edge technologies in the three developed countries and in some of the developing countries in the Region. While modern biotechnology is already making significant contributions to pharmaceuticals, diagnostics and human health, the potential benefits are not being tapped adequately for agricultural production. Nonetheless, the technology is being used to produce genetically modified plants, animals and microbes resulting in superior quality-products, increased productivity and resistance to biotic and abiotic stresses. A number of transgenics are awaiting commercial releases in various countries. Australia was the first country in the world to have released a genetically engineered organism, *Agrobacterium radiobacter* K 1026 for the control of the disease "crown gall" (Kerr, 1989).

Major rice-growing countries in the Region are participating in a regional rice biotechnology programme and are sharing techniques. The use of anther culture for production of haploids to be used in conventional as well as hybrid rice breeding programmes is already highly successful. A regional cooperative programme on plant biotechnology to promote TCDC has recently been launched.

In vitro culture for micro-propagation of elite plant materials and freeing infected materials of viruses and viroids is being widely used in the Region. The technology has particularly been successful in promotion of cut flower, vegetable and fruit industries. A large number of private companies, even in developing countries, have taken to biotechnology, particularly *in vitro* culture, and are doing an excellent job in transfer and large-scale application of the technology (Mascarenhas, 1991). For instance, in Thailand, Philippines and other South-East Asian countries, large-scale production of *in vitro* cultured orchid flowers, other flowers and banana is a success story (Zamora and Barba, 1990).

In the livestock sector, biotechnologically designed vaccines and diagnostics are being developed and widely used in the Region. Embryo transfer is now being routinely used in some of the countries. Biotechological manipulation of rumen fauna, feed, growth hormones, and quality of meat and dairy products is being pursued in some of the countries. A regional cooperative animal biotechnology project, operational until recently, was actively promoting information and technology sharing (Mukherjee, 1989).

B. The negative influences

The above impressive technology-based developments were often linked with certain negative influences, especially environmental. The green revolution technology, being based on off-farm inputs, namely, improved seed, increased use of inorganic fertilizers, and expanded irrigation, generally bypassed rainfed dryland areas and resource-poor farmers, thus exacerbating inequity. Production of some of the poor man's crops such as pulses, which are main source of dietary protein for poor people, remained stagnant and their per caput availability declined sharply. For instance, in India, pulses availability dropped from 23 kg in 1965 to about 15 kg per year in 1988 (FAO, 1988).

Intensified cereal production, especially multiple rice cropping or rice-wheat systems, have exacerbated land degradation problems (Singh, 1992). The spread of the green revolution technology was closely linked with the irrigation expansion which often was unscientifically planned with little emphasis on on-farm water management. The Region accounted for more than 60 percent of the world's irrigated area, but also had the high share of the associated problem of salinization, alkalinization, waterlogging, and fall in water-table. For instance, in the Indus basin in Pakistan, more than 20 percent of the canal command areas are severely salt-affected (Yadav, 1989).

Under intensive production systems, especially with high levels of application of nitrogenous fertilizers and wide adoption of genetically uniform HYV's, pest and disease incidence have greatly intensified. During the past 15 years or so, epidemic breakouts of brown plant hopper causing up to 30 percent reduction in rice production in the affected areas, and its destabilizing effect on food security, is well known. To combat the aggravated pest and disease problems, use of pesticides in the Region had trebled during the past 20 years, causing pollution problems and increasing pesticide resistance in the target pests. The HYV's had also eroded valuable crop land races.

Fertilizer use in the Region grew annually by 8 to 12 percent during the past 20 years. But, the fertilizer use efficiency (particularly of N fertilizers) has been low, about 30 percent or so, causing pollution problems through leaching, volatilization and denitrification (De Datta, 1990). The vast multiple cropped flooded paddy fields of Asia are estimated to contribute about 20 percent of the global methane emission. Intensive use of agrochemicals in high-yield areas has polluted the aquifers.

III. Conceptual framework of technology transfer for sustainable agriculture and rural development (SARD)

A. Definition of appropriate technology

Appropriateness of a technology is a prerequisite for its transfer and adoption. The concept of an "appropriate" technology is a dynamic one and the elements of appropriateness vary over time and space. A good measure of appropriateness may be the cost/benefit ratio of a technology at a given time and space, provided the calculations are based on all the major factors involved and affected, such as price and cost of the physical and biological resources and products, the environmental cost, the risk factor and social and cultural factors. A ratio thus estimated may be attractive to one set of farm households, but not to others. For a given household, the attractiveness of the ratio may change according to the ever-changing environment to which the technology has been transferred.

For instance, the seed-fertilizer-water based HYV technology because of its high productivity under congenial conditions with adequate access to inputs and water was considered as one of the most appropriate technologies. The same technology, however, was found inappropriate for rain-fed dry-land conditions and resource-poor small farmers. Even under irrigated and high input conditions, because of the declining profitability and soil fertility and other environmental problems, productivity maximization is no more the criteria of an appropriate technology. Now optimization of production, consistent with socio-economic and natural and human resource endowments of households, is the widely used criteria of judging whether a technology is appropriate or inappropriate.

Therefore, an appropriate technology is the one which is not only technically feasible but will also enhance the ability of the users to meet their economic, environmental, sustainability and socio-cultural goals. These considerations must be kept in mind while planning, technology development and transfer. Capacity both for technology needs assessment and assessment of impact of technologies already transferred, including second order impacts, should be strengthened for identifying and transferring appropriate technologies. To the researcher, the criteria for selecting an improved/appropriate technology are high productivity under conditions of his experimentation, which are often non-representative of the farmers' conditions, and technical feasibility. To the farmer or end user, the main criteria are profitability under his settings, which are usually less than ideal, and marketability of the end product. A congruence between the criteria of the two groups are clearly called for.

B. Elements of technology transfer

Technology transfer is not just an extension of a particular message or knowledge of a specific technique. Instead, it is a process encompassing various elements: (i) hardware (equipment, tools, machines, varieties, breeds, vaccines, etc.); (ii) technique (know-how, the software procedures, agronomic practices); (iii) "humanware" (knowledge, education, attitude, human ability); (iv) organization or "orgaware" (includes institutional establishment, management); and (v) the final output or product that sets the direction and the level of effort, including marketing strategies, needed by the four other components. This implies that when discussing transfer of technologies, besides the hardwares and softwares, the human resource development, capacity of technology assessment for choosing appropriate technologies, ability to absorb, scale-up, commercialize and manage technology development should also be addressed.

Moreover, the technology transfer process occurs at various levels: intra-institutional, inter-institutional, national and international. This envisages that synergistic linkages and cooperation should exist among researchers, technology developers, extension workers, farmers, technology suppliers, technology recipients and development agencies to ensure the best possible results from transfer of technologies.

Technology transfer usually should proceed in a sequential manner. The foremost consideration in technology transfer is to ensure that the technology matches with the economic, physical and technical settings of the intended target. Conflicts between technologies and cultural norms or traditional divisional labour could also hamper the transfer. Inadequate access to material inputs and information and unfavourable tenurial systems are other hurdles to technology transfer.

The starting point should, therefore, be to assess the existing socio-economic fabric and identify local needs and constraints focused on each component of the technology and their linkages. The second step should be to define the new level of socio-economic status intended through application of new technology. The third step is to identify and procure appropriate technology (one or more or all components), or develop a new one which will bring about the desired transformation. This may involve "buy or make" decision which should be based on comparative advantages, ease of access to a foreign technology and possible biosafety and other environmental implications. Finally, marketing, distribution and commercialization are pursued.

It should be kept in mind that choice of technology should usually be demand-driven. Generally, technologies should be viewed as a means of empowering the farm household or any other user to increase productivity to attain the ultimate objective of better and sustained human standard and living. Sometimes it is observed that the sequential mode of transfer and adoption of technologies is not followed and there are possibilities of quick fix to register short-term gains or sometimes to meet an emergency situation. But, if unaccompanied with risk analysis and risk management capability, this approach is fraught with greater possibilities of environmental and socio-economic damage in the long run. For instance, in the late seventies, the Philippines, without adequate on-farm testing, imported in bulk MAWA coconut hybrids from Côte d'Ivoire to boost its coconut economy. Since the hybrids were not suitable for low-input management conditions of the coconut growers and soon gave way to the indigenous pest and disease pressure, the move proved almost disastrous. The hybrids also opened window of genetic vulnerability by displacing local resistant varieties/populations.

Technology-driven transfer of technologies could also be useful, provided a careful *ex ante* analysis of the technology, keeping in mind its agro-ecological compatibility, productivity, profitability and technical feasibility, has been undertaken in a systematic manner. For example, India, in the mid-sixties, while struggling to increase its food production, saw a hope in the semi-dwarf lodging-resistant rice and wheat HYV's and organized their large-scale on-farm testing. Convinced of their potential, it imported semi-dwarf CIMMYT-bred wheat and IRRI-bred rice varieties for large scale cultivation. This bold step paved the path for wheat and rice revolution in the country. The success of this "frog leap" model of technology transfer was attributed to the country's preparedness to absorb the technology through its on-the-ground comprehensive research and technology development and reproduction capability. The country was soon able to amend the shortcomings of the introduced varieties and develop location-specific management practices to fully exploit the new potential.

C. Complementarity between technology assessment and transfer

Technology transfer, in order to be effective, must be preceded and succeeded by technology assessment. How reliable has the assessment been can be judged by the effectiveness of transfer of a given technology. Therefore, technology assessment and technology transfer are complementary to each other. Technology transfer must be based on needs and capabilities of agro-ecological settings, resource endowments, agro-production and distribution systems and farm-households.

The effectiveness of transferring technologies to meet development goals consistent with SARD will be greatly improved if indicators of sustainability are known for assessing the impact of new technologies. The concept and definition of, and indicators for, assessment of technologies for SARD have been described by Kwaschik; Hamblin; and Williams and Munro (in this volume). It would be desirable to harmonize and standardize the approach so that reliable and uniform indicators could be developed both for *ex ante* and *ex post* assessment of technologies. The indicators will guide in identifying appropriate technologies for transfer, and for monitoring, evaluating and fine-tuning the technologies. As the indicators will vary according to matrix of agro-ecological features and resource endowments, the approach will assist in locating homologous zones nationally or internationally which could share same or similar technologies.

Notwithstanding site-specificity of biophysical and socio-economic constraints and prospects, the following may be considered as common points to be kept in view for ecosystem management for SARD:

- soil conservation and soil fertility management;
- water conservation, water use efficiency and irrigation management;
- control of insects, diseases and weeds;
- germplasm and biodiversity conservation and use for increased productivity and tolerance to biotic and abiotic stresses; and
- integrated farming, use of new and renewable sources of energy, and income enhancement.

Corresponding to the above common leverage points, interdisciplinary technologies such as integrated pest management, integrated plant nutrient management, integrated soil and water management, new and renewable energy technologies and integrated farming system would be considered as preferred approaches and packages of technologies for SARD.

D. Synergism between information-based and material technologies

The various technologies broadly include two interactive types of inputs, information-based and material-based (FAO, 1991; Hudgens, 1992). The information-based technologies comprise farm management techniques and skill and are based on an understanding of ecosystem interactions geared to optimize the efficiency of on-farm resource usage. Such technologies are particularly suitable for resource-poor farmers inhabiting noncongenial and risk-prone agro-ecological settings. The material-based technologies, such as improved varieties and mineral fertilizers, are favoured in irrigated and well-endowed areas by well-to-do farmers for maximizing short-term projects. Depending on the development goal and socio-economic and agro-ecological capabilities, choice of one or the other, or most appropriately a proper blend of the two types of technologies is called for optimizing production, productivity and profitability and at the same time maintaining the productive capacity of the resource base. The mechanism of technology transfer and extension services will differ for the two types of technologies.

IV. New paradigms in technology transfer

A. A system approach to technology transfer

A system perspective means that all research and technology transfer organizations serving a given target farmer/clients group are part of a single agricultural technology system and all the components share and adhere to one and the same agreed-upon vision, strategy, goal or mission of making relevant technologies available to farmers (Eponou, 1993). The following six interactive elements constitute the basic components of the system perspective:

- Shared strategic goals: all partners in the system must have the same goals. This will promote unity and commonality of the approaches.
- Synergy: by definition will result in outputs which will be more than the sum of the output of individual components. It demands high level managerial skill and dynamism to capture multitudes of changes.
- Strong leadership for the whole: a motivating, inspiring and unifying leadership capable of judicious and rational allocation of resources is essential. Priority, setting, fixing of responsibilities and accountabilities of all partners would be main task of the leader.
- Decision-making by consensus: to avoid conflict and poor implementation, it is always advantageous to take decision through consultation among all partners and by keeping the process transparent.
- Accountability to clients and policy-makers: along with responsibility, each partner should be held ac-

countable to policy-makers as well as to the clients for the agreed-upon task that it has to perform. Such a system, of necessity, should possess suitable evaluation and monitoring device and capability. The criteria for resource allocation and reward to individuals and partners should be consistent with the goals of the system.

- Farmers as partners: the ultimate users of the technologies - farmers - should be equal partners in the process and be involved in all the important steps such as problem identification, planning on on-farm trials, post-adoption trials, impact assessment and in the decision-making process.

The International Service for National Agricultural Research (ISNAR) studied linkages between research and technology transfer through 20 case studies in seven developing countries, namely, Colombia, Costa Rica, Côte d'Ivoire, Dominican Republic, Nigeria, the Philippines and Tanzania and found that generally the linkages were inefficient or non-existent particularly in the public sector. In most of the cases studied, one or more of the above six key elements were missing (Eponou, 1993).

B. Towards a participatory approach for technology transfer

The research systems strive to develop gradients of technologies to match the potential of different agro-ecological zones and to meet the needs of different groups of clients. Some are simple with a limited message, area of application and influence and can be adopted without much fine tuning such as post-harvest handling of a specific product. Others may be complex with manifold effects and linkages, such as farming system in rainfed/dryland areas. The approaches to transfer of these technologies will vary.

Four overlapping periods of shifting emphases of paradigm of technology transfer have been characterized since the early fifties (Rhoades, 1989). The first stage was characterized as production stage (roughly 1950-1975) which was signified by the green revolution, technology development and transfer. Breeding and genetics were the pioneering disciplines and farmers were seen as recipients of technology. In the initial stages it was thought (wrongly so) that Western technology was available and applicable to large areas of the developing countries. A transfer of technology (TOT) approach, based on extension of knowledge and "know-how" without appropriate assessment, was followed. Although some successes were achieved under simplistic, predictable and controlled settings, it was soon realized that there was nothing like a straight jacketed wholesale transfer of technology from developed to developing countries. Technologies successful in one context were often applied irrespective of context, with widespread failures. This induced national and international programmes to strengthen national capabilities in technology generation, development and transfer to address to their specific needs. HYV-based technologies emerged from national and international agricultural research systems which were transferred to the farmers through a high pay-off input model of TOT.

The TOT approach was found generally to be unsuitable for conditions and needs of complex, diverse and risk-prone agriculture. Under this paradigm, research decisions are made by the scientists, technology is developed on research stations and in laboratories, is handed over to extension to pass on to farmers. This approach has generally failed to help especially poor farm households and reduce inequity (Pretty and Chambers, 1992).

Superimposed on the TOT model was the World Bank T and V (training and visit) system and the role of extension in technology transfer was emphasized to encourage utilization of research results. The T and V approach is somewhat like a campaign approach and would succeed only when client's need and technology potential are clearly matched. In other words, both delivery and feedback systems must be in place for T and V approach to succeed. But, usually the flow of information is one-way and the feedback is minimal. The T and V system, a costly and labour-intensive system, was introduced to reform conventional extension system, but was found to be too narrow in its approach and not suitable for small farmers and rainfed areas which are surrounded with so many uncertainties (Rhoades and Booth, 1982; FAO, 1986; Pretty and Chambers, 1992).

The next stage was characterized as economic stage (roughly 1975-85), in which farming systems research was pioneered by economists and agronomists and farmers were seen as sources of information for technology design. The subsequent stage was characterized as ecological stage (roughly 1985-95), in which agro-ecology, geography and anthropology are pioneers and farmers participate in technology development and transfer process and are seen both as victims and the cause of unsustainable development. The next stage beyond 1995 was extrapolated to be dominated by management specialists, sociologists, political scientists and educators, and farmers will be full collaborators in research and extension. Further, in this stage, alliances are expected to be forged between different institutions and sectors and a multidisciplinary approach will be pursued.

The second to fourth stages are based on participatory approaches in which research, extension, farmers, NGO's, and private sectors are supposedly actively interacting partners at all stages of technology development and transfer (Farrington and Biggs, 1990). The following four models of farmer participation are known: contractual - role of farmer is minimal, merely provides resources for scientists to experiment on; consultative - farmers define the problem, researchers develop solutions; collaborative - joint participation in various stages; and collegiate - scientists work together with farmers to strengthen informal R and D systems of farmers (Biggs, 1989).

Several forms of participatory approaches, such as Farming Systems Research (FSR), Farmer Participatory Research and Development (FPR&D), Participatory Action Research (PAR), Rapid Rural Appraisal (RRA), and Participatory Rural Appraisal (PRA) are in vogue. There is considerable overlapping among these approaches, but their emphases vary on different aspects. For instance, RRA focuses more on problem diagnosis methodology, PAR focuses on community empowerment whereas FSR and FPR concentrate on facilitating on-farm work (Chambers, 1992; Cornwall et al. 1992).

Farming System Research is most common among the participatory approaches. Its key elements are as follows: an integrated effort by researchers, extensionists and farmers to design, test and modify improved agricultural technologies appropriate for local conditions; a holistic approach in which all major interactions that affect the performance of the farm system are considered; and an interdisciplinary perspective to problem analysis, technology design, trial implementation and evaluation (Tripp, 1992; FAO, 1994). In this system, the contractual and consultative approaches to participation are emphasized, whereas collaborative and collegiate approaches are usually not attempted. Farmers' knowledge is also not adequately tapped and the system has generally remained researcher-back-to-researcher. This shortcoming has been removed in Farmer Participatory Research and Development, Farmer First or recently advocated Beyond Farmer First approaches and methods (Pretty and Chambers, 1992).

The Investment Centre of FAO has adopted the FPR&D approach in its pre-project appraisals and investment proposals. The Centre has elaborated why, what and how of the approach in one of its discussion notes. It is argued that, when it comes to making technological changes in their systems of production, most farmers are eclectic. They pick and choose from a wide variety of sources the technical innovations which they consider potentially useful, either just to test, or to apply on a larger scale. When offered a package of technology, they often adapt it stepwise, or take up only those parts which match their resources or perceptions of risk. This is because the technologies which are expected to fuel the process of change at farm level in most developing countries are generally selected by researchers and extension agents with little say of the farmer. The result is that there is less farm-level innovation than is hoped for. Uptake of what is extended may be restricted to a few farmers able to muster resources similar to those of the research station; or it may be patchy, reflecting local variations in the continuum of farmers to whom a given recommendation was meant to apply. As a consequence agricultural development, and hence investment project benefits, often fall short of expectations. The shortfall tends to be most acute for the resource-poor or otherwise disadvantaged, who are often the people that investment projects most seek to benefit, and who have the least secure food supplies (FAO, 1991).

To address the problem of a lack of appropriate production technology in resource-poor, food-insecure areas, a farmer participatory approach to research and development (FPR&D) has been proposed. The key characteristics of FPR&D are:

- A widening of the filters applied to technologies selected by government researchers/technicians. This would give farmers a broader "menu" and greater freedom to choose for themselves what goes into on-farm tests or what they adopt, and leave them freer to make local adaptations of their own if they consider them necessary.

- A more systematic tapping of knowledge of farmer-developed technologies, to give farmers additional opportunities to innovate by direct imitation.
- The exposure of farmers to this broadened "menu" in a systematic manner, with structured arrangements for identification and selection of ideas, testing, recording of results and feedback.

This would more closely mimic the way in which farmers have always innovated, substituting the present restrictive, top-down approach of many government technicians with a more facilitating or supporting role for government. Given less focus on the research stations as the model for progress, it ought in particular to respond better to the needs of the inherently disadvantaged, resource-poor and food-insecure.

In the "participatory" paradigm of technology development and transfer, farmers' needs and priorities are put first and farmers participate in research and extension. If this is truly achieved, technology transfer and assessment will become highly effective and meaningful and technology transfer gaps will automatically be reduced. This shift in paradigm calls for professional, institutional and policy-related changes. This paradigm recognizes and emphasizes the differences at the farm household levels, and a pluralist approach would give voice to individuals and groups so as to participate in decision-making (Merrill-Sands and Collion, 1992). It further emphasizes on learning and skill development rather than on knowledge and technology *per se* which are generally contextual in time and space and hence limited in their transferability. However, resources development would have to be strengthened and attitudinal and behavioural barriers would have to be removed.

The participatory paradigm implies new roles for agricultural scientists and extensionists. They would be required to operate in a learning and not only teaching environment. They should be able to learn from and with farmers, and also enable farmers to learn for themselves. The "outsiders" should work more as facilitators and stimulators. It is envisaged that the participatory approach would enable people and professionals to make judicious use of the most of available biophysical and socioeconomic resources for environment friendly and sustainable agricultural and rural development (Pretty and Chambers, 1992).

Success stories of participatory approaches for SARD are building up fast. As mentioned earlier, poor management of irrigation has caused widespread soil degradation. A study in Sri Lanka on irrigation and groups in Gal Oya involving farmers in groups for rehabilitation of 25 000 hectares revealed the following (Pretty and Chambers, 1992): (i) water efficiency increased, and farmers increased the cropping intensity and crop production; (ii) the number of complaints about water distribution dropped nearly to zero as adjustments "were worked out amicably with field-level staff"; and (iii) the problem of broken gates disappeared (formerly they were broken 80% of time). The experience further revealed that cooperation among farmers and with officials was canalized within a few months despite a 30-year legacy of conflict and non-cooperation. As officials were involved in measuring the impacts of these groups, and saw the positive results, their support grew and became more active. Other conditions for success included continuity of personnel, strong government support at high levels, and the right kind of leadership in communities. One impact was that "government personnel started working more conscientiously and effectively once they came to know the real conditions at village level through the systematic monitoring and evaluation system".

The CGIAR International Agriculture Research Centres (IARC's) have also been involved in some technology transfer activities. They had generally adopted the one-way technology transfer approach. However, some of the centres have been conducting successful farming system and other participatory researches (Kelley and Walker, 1991). However, considering that strong NARS have been established and are further emerging in most developing countries in the Region, and recognizing that the IARC's have a comparative advantage (and as per their mandate and facilities) in undertaking upstream and strategic research, the CGIAR management may wish to consider as to what extent the centres would continue to deploy their shrinking resources in on-farm adaptive trials. It may be advisable for the IARC's to devolve some of their downstream activities to the NARS which have acquired necessary strength for undertaking such activities.

C. Congruency between productivity and sustainability

Sustainability divorced from productivity, especially in a land-hungry as well as a food-hungry region like Asia, will not be sustainable. The two must go hand-in-hand and must be mutually reinforcing. Often low productivity and poverty are the causes of environmental degradation and unsustainability, especially in marginal and fragile areas (Mellor, 1988; Oram, 1988; World Bank, 1992).Capacities of existing and potential land, water, genetic resources and other production resources should be systematically analyzed and appropriate technologies should be developed and chosen to judiciously exploit the resources to achieve the twin objectives of productivity and sustainability.

In the Asia-Pacific Region, while increasing attention must be paid to rainfed areas, considering that 75 percent of its food and agricultural production comes from its high to medium potential irrigated and favourable lowland areas, which constitute only about 35 percent of the total cultivated area in the Region, appropriate technological and policy interventions, with a proper blend of material-based and information-based technologies, should be made in these areas to further enhance and sustain productivity of these areas to meet the bulk of the food and other agricultural product demands. This approach will also relieve the pressure on ecologically fragile marginal areas (see Table 2 depicting land-saving in India through the adoption of HYV technology). China, during the past decade, as mentioned earlier, was able to relieve about 2 million ha of marginal lands from paddy cultivation and assigned it to other more appropriate uses viz. agro-forestry, while maintaining its high rice production growth rate by intensifying production in irrigated and high resource endowment areas.

Synergistic interaction among wider use of improved varieties, expansion of irrigation, increased use of fertilizers, and management techniques was responsible for the impressive gain in cereal production during the past two decades or so. This synergism is a *sine qua non* for the future increases in production by raising yield ceilings especially under irrigated conditions. However, the declining and plateuing yields, deteriorating soil fertility, and increasing agro-chemical toxicity under intensive management conditions call for improved management of the resources and greater synergism with information-based technologies in order to alleviate the problems and to ensure greater sustainability. Further, socio-economic adjustments in terms of input: output pricing, institutional supports, and redressal of the needs of small farmers, who constitute the bulk of the farmers, should be brought about to complement the technological gains (discussed in a later section).

The integrated approach to solve specific problems is being resorted to in some countries with obvious positive impacts. Cited below is a success story from China which shows as to how the stepwise technology generation, packaging of the information-based and material inputs, coupled with appropriate government policies could lead to transfer of appropriate technologies resulting in sustainable and highly productive agricultural system.

Table 6 presents cereal production and cropping index in Zhejiang Province of China during 1949-88. It may be seen from the table that the production has increased at a sustained high pace from 4.3 million tons in 1949 to 15.92 million tons in 1988. Further, this increase was primarily through the increase in yield per hectare from 2.55 tons to 11.15 tons, and through the increase in cropping intensity from 169 percent to 222 percent during the same period.

TABLE 6. CEREAL PRODUCTION AND CROPPING INDEX IN ZHEJIANG PROVINCE, CHINA, 1949-88

Period	Annual Production (mill. t)	Yield (t/ha)	% Increase over 1949	Cropping Intensity %
1949	4.30	2.55	0.0	169
1950-55	6.68	2.66	43.5	169
1956-66	7.96	4.74	85.9	188
1967-72	10.79	6.89	170.0	209
1973-79	13.01	8.28	224.7	220
1980-84	15.94	10.37	306.5	223
1985-88	15.92	11.15	337.1	222

Source: Wang, Z., 1990. Technology for Sustainable Crop Production and Agricultural Development in China - a consultancy report submitted to FAO RAPA, 47 p.

All along, a synergistic interplay of material-based and information-based technologies was emphasized. In the fifties, in the first stage, the "Seven Techniques" encompassing improved varieties, growing strong/healthy seedlings, intensive cultivation, proper plant population, balanced fertilizer application, rational irrigation, and control of pests and diseases, were popularized. In the second stage, the "Threefold Development" was adopted, which included the development of double cropping of rice, the development of three-crop a year system, and the development of high yield crops. In the third stage, noticing that the impact of individual factors was not as high as expected, emphasis was placed on an integrated approach for land development and fertilization, improved cultivation and cropping systems, and use of improved seeds. In the fourth stage, popularization of hybrid rice and hybrid maize with emphasis on multiple cropping, and use of new and improved seedling growing techniques increased the yields significantly.

The fifth and sixth stages, during 1980-88, integrated the socio-economic aspects with the technological aspects. In the fifth stage, the individual household responsibility system in agricultural production tapped the individual initiatives which fully exploited the available technologies. In the sixth stage, rural economy had bolstered, market forces had started dictating the prices, and the farmers were earning much more than ever before and had great enthusiasm to further intensify their production. With greater freedom for choice of crops, the farmers diversified to include cash crops and fruits which is reflected in the stagnation of total production of cereals and cropping intensity during the eighties, although the productivity had increased.

The development through the above-mentioned six stages, reflecting a comprehensive manifestation of the technological and political transformation, was not confined only to Zhejiang Province, but was adopted throughout the country. This is amply reflected in the phenomenal increase in Chinese agricultural production and sustained high yield growth rates through development and transfer of appropriate technologies during the past four decades. The Chinese success story is certainly replicable and other countries should take note of the successful sustainable agricultural development in China and elsewhere and undertake similar programmes suiting to their specific requirements and potentials.

The success story of Zhejiang Province is not confined to that province, but is almost a national story. The Chinese experience is a story just not of any country, but it is a story of about 800 million people who are directly involved in agriculture, accounting for about 30 percent of the world's agricultural population. With its arable land constituting only about 7 percent of the world's arable land, the country has to feed about 20 percent of the world's population. A land-starved country, depending for its food security essentially on the domestic production, must have an intensive agricultural production system to adequately feed its people and to meet demands of raw materials of its agro-based industries. The majority of the developing Asian countries are or will be faced with problems similar to those in China. It would, therefore, be useful for other countries to learn of the steps that China has adopted to tackle the problems, as briefly elucidated below.

Foremost, in order to achieve the production goals, the country recognizes that research and technology development and transfer would play a pivotal role in bringing about desired progress in productivity and sustainability, and has accordingly been strengthening the system, especially during the past 15 years or so. In 1991, there were 1 142 agricultural research institutions, including 61 at federal and 457 at provincial levels, with a total staff strength of 124 600 (Qi et al., 1994). The technology transfer gaps in China, even under the rainfed settings, are narrow.

As regards technology transfer, in 1991, 220 000 extension services dealt with crops, animal husbandry, fishery, agricultural machinery and management involving more than 920 000 salesmen. In the same year, the crop extension system completed 5 530 extension projects, covering 10.22 million hectares, resulting in an increase of 29.7 million tons of grain, 1.06 million tons of cotton and 1.29 million tons of oil. In 1991, there were 6.6 million technological model households and 110 000 technological research units run by the local people. Now, the "Law of Agricultural Technique Extension of the People's Republic of China" is being implemented in different parts of the country so as to stabilize and harmonize the national extension system (Qi et al., 1994).

The country's policy on agricultural technology development stipulates that priority will be given to agricultural inputs such as chemical fertilizer, pesticide, plastic film for agricultural use, and agricultural machinery. Emphasis will be put on agricultural basic constructions such as remoulding of middle-low yielding fields, building up a system of protection of agricultural natural resources and agricultural environment projects of key importance. Emphasis will be also put on supporting technical projects such as breeding and extension of new varieties of grain, cotton, oil, sugar, livestock products, vegetable, fruit; professional and vocational training for peasants; and evaluation and continuous utilization of natural resources of agriculture. The main mode of implementation of the policy is to develop a socialized service system on the basis of household management, taking rural collective or cooperative economic organizations as a base. Economic and technological departments provide backing and complement services to systems managed by peasants and help build up of multi-channel service systems at all levels which contain various economic components.

In recent years, the following research and technology strategies and performances are being emphasized in the national agricultural policy and plans (Qi et al., 1994).

- Build an effective and comprehensive management system of sustained agricultural and rural development on the lines of UNCED Agenda 21.
- Pay greater attention to the nutritive needs of women, children and old people, improve food-producing environment, provide safe and balanced food; set up an efficient system of food security and early warning and monitor the conditions of soil fertility as well as soil and water losses.
- Raise agricultural comprehensive production ability to achieve agricultural production target of the year of 2000, reduce environmental contamination, judiciously increase inputs essential to consolidate sustained development.
- Strengthen the evaluation and continuous utilization of natural resources of agriculture and environment, pay attention to new programmes of development and exploitation of biological and rare-earth resources for agricultural use, and guarantee continuous and efficient availability of basic natural resources of agriculture, mainly cultivated land, water and energy resources.
- Study, exploit and spread those agricultural techniques by which energy can be saved, production and quality improved and environment protected, study and spread techniques of efficient use of agricultural inputs, develop science and technology of saving resources, techniques of variety exploration and improvement as well as techniques of biological control and integrated control of pests, environment protection and treatment, and
- through various forms of professional training, quicken the transfer of rural labour to alternative rural employment so as to create new sources of rural income generation, leading to improved life quality of peasants and women's participation in the agricultural and rural sustained development.

The Enforcement of the Green Certificate System is one of the novel initiatives in China (Conroy, 1992). "The Farmer Certificate System for Technical Quality" (the Green Certificate System), enforced since 1992 aims to train key farmers in modern technology management skill as to improve the quality of the involvement of the rural workers in science, technology and culture. Crop production, animal husbandry, aquatic production, agricultural machine management and rural cooperation management are included in this programme. The programme is operational in 28 provinces and by the end of 1993 about 300 000 farmers would be trained and about 60 000 would receive the "Green Certificate". The products produced by the Certificate holders are likely to fetch premium prices in the market, thus providing an incentive to the farmers to adopt "green" techniques and practices.

Other technology transfer programmes, especially enterprise-oriented ones as the "Spark" and "Torch" programmes, are popular in the country and the approach could be shared by other interested countries. Like China, other Asian countries have also been adjusting their technology development and transfer programmes in response to new global developments such as UNCED Agenda 21, Biodiversity Convention, GATT agreements, and International Conference on Nutrition (ICN). These experiences should be monitored by international organizations/associations, viz. APAARI, and shared widely.

The Spark programme has been designed to introduce and disseminate technology into the rural economy. Its aim is to spread sparks of science and technology all over the rural areas, that is, through the spread and application of advanced achievements in scientific research to make farmers understand science and technology, change their concept of national economy and develop integrated economy and enterprises in villages and towns. "Then, science and technology can be implanted to the embryos of commodity economy so as to make the development of rural areas by means of science and technology, and common richness become a tidal current which will never be inversed" (State Science-Technology Commission, 1992). Formally launched in 1986, by the end of 1990, some 30 000 items were promoted, many being foreign-oriented. *A Collection of International Cooperation Projects of Spark Programme*, August 1992, had listed 142 items, including 10 directly in the field of agriculture and farm machinery and 22 of significant importance to agricultural development. The programme is reported to have added several billion yuan in increased output value with a cost benefit ratio of 1:5. However, many problems have arisen in implementing the programme at local levels; such as irrational selection of projects, poor project management, lack of prior feasibility studies and paucity of funds. Through World Bank funding, in some selected areas some of the problems are being solved. Considering the Government's thrust on rural employment and income generation and off-farm employment, the Spark programme could have a considerable impact on the national economy and people's way of life (Conroy, 1992).

In 1988, the Government announced the "Torch Plan" which is a Chinese economic system and capitalizes on the enormous potential held out by generic technologies and new technology systems, both domestically and through expanding exports of products which embody new technologies. It is not a mandatory plan, it is more of a guidance and is designed to create infrastructures and institutional support, including trained manpower, to promote industrial and private sector growth. The plan is particularly important in another sense that it has created entrepreneurial spirit usually lacking among the S&T community and has provided opportunity for a large number of under-employed S&T staff to be engaged adequately.

The specific aims of the Torch Plan for the period 1988-90 covered the following areas (Conroy, 1992): to create 2 000 high and new technology enterprises; to develop 2 000 products incorporating new technologies with 30 percent for export; to establish about 50 S&T service centres to help create the above enterprises products; to set up some key high-tech parks in cities with the necessary conditions; to attract 100 000 S&T personnel to the above work; and to establish the China Torch Company and other specialized and regional branch companies. The company was supposed to raise 200-500 million yuan annually.

The Torch Plan is innovative for China as it is very much a "bottom-up" approach, instead of the usual "top-down" system. It also represents the first step in developing an entrepreneurial approach towards the innovative process and breaking away from the traditional allocative practices which still dominate most domestic technology transfer and innovative activities. The new projects are assessed on the basis of technological feasibility, innovativeness, potential economic impact and whether they were in line with the nation's industrial policy. Ultimately, their screening through market competition will bring out the true value of the new projects. In the field of agriculture, biotechnology-based industries, especially in animal health, agro-processing and food industry, should benefit the most by the Torch programme.

V. Role of the FAO

Effective generation and transfer of improved technology is identified by FAO as a major policy and strategy instrument for sustained agricultural and rural development. FAO recognizes that generation and transfer of technology are part of a single process with the objective of assisting farmers, foresters, fishermen, herders - and their families, including the poor majority and the most disadvantaged among them, in applying improved technology and in managing their resources to achieve maximum production and income, consistent with sustained productivity and maintenance of environmental quality.

FAO emphasizes the system approach for technology transfer and sees that technology development (generation and transfer) is a continuum, encompassing a spectrum of interactive participants and activities, NARS, extension systems and farmers constituting the core. This theme has been reiterated through various FAO-sponsored national, regional and international seminars/consultations, and detailed in various FAO publications. The Organization's hundreds of field projects on technology transfer are based on this concept. On an average, in recent years, FAO has been operating/executing about 500 field projects, dealing exclusively or in part with extension, involving an annual expenditure of about US$ 25 million benefiting some 70 countries.

FAO has also been supporting development of national research, extension and technology transfer systems through cooperation with investment institutions such as the World Bank. In all this work, the emphasis is on objective analysis of local situation and subsequently draws on global experience to find solutions to the problems identified. Specially for technology transfer projects, the FAO Investment Centre (DDC), as mentioned earlier, has recently been including provision for participatory generation, testing and transfer of technology in the design of investment projects for resource-poor areas, the FPR&D approach away from the T&V extension which was financed in the past. The Centre suggests that the best way of creating initial awareness of FPR&D, and of assembling a nucleus of counterparts who can disseminate the idea within government institutions, would seem to be that adopted by the World Bank to launch T&V extension: to incorporate the necessary initial evangelism and "sensibilization" of governments into the design stage of investment projects. This could most conveniently be done by linking the design of such components with the sort of Socio-Economic and Production Systems Surveys (SEPSS's) which are increasingly used by the FAO Investment Centre in investment project design.

Government counterparts of SEPSS's could, during this work, be briefed on the FPR&D concept by FAO staff. At the same time, it would be an FAO responsibility to "sell" the FPR&D concept to government decision-makers at a higher level. The aim should be to secure the commitment by these higher level authorities to subsequent FPR&D pilot exercises or components. SEPSS counterparts would then enter FPR&D exercises with the blessing of the higher authorities, armed with first-hand knowledge of farm-level constraints and opportunities, and thoroughly briefed on FPR&D principles by close association with earlier FAO field work.

Depending on agro-ecological and socio-economic settings of the target areas, FAO has used various technology transfer and extension systems. FAO's experience shows that no universally applicable extension approach or system could be advocated; the emphasis should, however, be on skill and knowledge development of the farmer and not on passing straight-jacketed message which may not be applicable to the needs and problems of the user. The experience shows that generally, especially in context of majority resource-poor farmers in vast non-congenial production environments, farming system approach, forging an interactive linkage between researcher, extension and farmer is a preferred approach for technology transfer. A participatory farmer-demand-driven and "bottom-up" approach should be preferred over a "top-down" approach. This system also promotes use of indigenous knowledge and material along with judicious and environment-friendly conservation and utilization of production resources. Technology packages identified through this approach, besides increased production and income gains, emphasize on IPM, integrated nutrient management (IPNS) and resource conservation.

FAO's experience shows that no technology can operate in a vacuum. Earlier overpromotion of technology alone, as the answer to the problems of agricultural development, has been gradually replaced by the realism that it is only one of the several interacting elements in the complex of policies, services, and facilities needed for effective transfer and adaptation of technology. A system approach to technology transfer is called for. FAO's experience shows that when small farmers were organized in groups, with their increased receiving and delivery capacities, they as a group adapted new technologies more readily than when operating individually. FAO's experience also shows that decentralization of technology verification and transfer through satellite adaptive agricultural research stations in distinct agro-ecoregions is most effective in rainfed/dryland areas. The Strategic Extension Campaign (SEC) method, introduced by FAO in some countries, is a cost-effective approach for solving location-specific problems, and is commended for wider use.

Lack of adequately trained manpower, including technology transfer managers, subject matter specialists, extension workers and farmers, has been a major bottleneck in effective transfer of improved technologies. The paucity is getting acute as the process of technology generation and transfer is becoming increasingly complex. There is a need for strengthening capability for economic and social research within extension service which can potentially have a very high social pay off. A good number of FAO projects, especially those dealing with farming systems and people's participation, among other things, have been emphasizing training in agro-ecosystem and rural system analysis to identify constraints to technology transfer. Additional support is needed to strengthen priority setting mechanisms and to monitor, evaluate and identify appropriate packages of technologies.

Another thrust area is to strengthen national capabilities in information development and sharing, particularly the use of FAO's AGRIS and CARIS systems, which should facilitate intra- and inter-country technology transfer. Further, FAO has several inter-country TCDC projects, involving the IARC's and other regional and international programmes for technology identification, verification and transfer.

It is becoming clear that policy has to provide an environment conducive to technology utilization. Explicit care should be taken of the needs of the disadvantaged sectors of the society, the risk in prices and production under increased technology utilization, the profitability and sustainability of production under changed technologies, and the constraints of small farmers in financing technology adoption. FAO will provide neutral forum to debate the implications of adoption or non-adoption of new technologies, such as biotechnology. It will continue to strive to increase capabilities of the member nations in technology assessment and establishment of appropriate policy measures and procedures to increase their access to appropriate technologies.

A. The FARM programme

In Asia, FAO has recently launched a unique UNDP-financed inter-country programme, called Farmer-Centred Agricultural Resource Management (FARM) Programme for sustainable agriculture in Asia. The principal problems being tackled by the FARM Programme can be summarized as agricultural resource degradation and human deprivation, or more simply, poverty. It is a child of the Earth Summit, with the general purpose of supporting the implementation of Agenda 21 in eight countries. The programme is targeted to resource-poor communities and farm-households, with an overall objective of improved conservation, management and utilization of natural agricultural resources in rainfed lowlands and uplands. The participating countries are China, India, Indonesia, Nepal, Philippines, Sri Lanka, Thailand and Vietnam. FARM comprises seven sub-programmes: Rainfed Farming Systems Asia (FS), Watershed Management in the Tropics and Upper Himalayas (WM), Asia-Pacific Agroforestry Network (AF), Integrated Pest Management (IPM), Asian Biotechnology & Biodiversity (BB), People-Centred Sustainable Development (PCSD), Pesticides Production and Information (PPI), the last Sub-Programme is being implemented by UNIDO. UNIDO is also cooperating agency for the Asian Biotechnology and Biodiversity sub-programme.

One central issue in the FARM programme is resolving the paradox of generalist farmers, who attend to a multiplicity of issues every day, and specialist technicians/scientists who are trained in reductionist/scientific methods. Another key issue is ensuring effective participation of resource-poor communities in FARM implementation - not so much a matter of how farmers can participate in the design and implementation of FARM sub-programmes, but how FARM staff can participate in farmers' decision-making. Many NGO's have excellent experience in working with communities in a fully participatory mode, and so major role for NGO's in FARM is envisaged.

In line with the focus on farm-households, and especially resource-poor households, FARM will launch activities in selected pilot development areas. The farming systems diagnoses of farm-household constraints and opportunities in these areas will facilitate the refocusing, if appropriate, of the sub-programmes through a grass roots (bottom-up) process of prioritization. The criteria for pilot area selection include: agro-ecological and socio-economic representativeness for larger areas of Asia; preponderance of resource-poor households; existence of resource degradation; priority for national authorities; relevance to the main thrusts of a majority of sub-programmes; ongoing sub-programme activities, eg. IPM, AF; access/visibility, and logistical considerations. Although four or more sub-programmes will contribute to every pilot area, responsibility for supporting its management by national agencies will be given to one sub-programme (usually the resident sub-programme).

All sub-programmes are intended to support networks in their respective fields. FARM will explore mechanisms for cross-fertilization between these (groups of) networks. A small proportion of the training and study tour activities of each sub-programme will be allocated to training/awareness building of the broader systems aspects of sustainable agriculture and rural development. An international conference is planned which will have a systems orientation. A FARM Newsletter will emphasize cross-disciplinary issues in sustainable agricultural and rural development.

B. FAO/IARC/NARS collaboration in technology transfer

Another recent initiative is to forge greater linkage between FAO and IARC's for transfer of technologies. It is based on the premise that (i) good number of promising technologies developed by the International Agricultural Research Centres are sitting on their shelves, which if suitably refined and packaged could be transferred to farmers whom they were actually meant for; (ii) IARC's are generally mandated to work on upstream research to generate and not to transfer technologies, and (iii) while the national agricultural research systems (NARS), besides doing the research, are supposed to engage in technology transfer, but often had failed to do so because of poor infrastructures and weak linkages between the Centres and the NARS. In recent years, especially since 1991, FAO's collaboration with the IARC's for technology assessment and transfer has been streamlined and fortified, keeping in mind mandates, strategies and comparative advantages of the two systems. UNDP, through financial support and other stimulating interventions, has been instrumental in encouraging this synergistic collaboration. The main aim is to facilitate and further accelerate the process of technology identification and transfer.

The process had involved several rounds of discussions between FAO and IARC's, followed by active consultations with NARS and other relevant governmental and non-governmental organizations. The discussions and consultations were focused to technology identification and technology transfer pilot programmes conducive to on-farm adoption of improved and appropriate technologies and production systems that enhance sustainable and improved agricultural production. Provisions for large-scale adoption and commercialization of the technologies were also considered.

The approach has been to address the widespread lack of capacity in many NARS to identify, assess and capitalize on available technologies for adaption to location-specific problems and transfer to specific target groups. It is hoped that the national technology development systems will be geared toward perceived needs of agro-ecosystems and farm households, thereby focusing technology interventions on enhanced and assured food security, the improvement of rural livelihoods, and sustainability of the agro-ecosystems. Moreover, the approach provides for an effective feedback to all the partners - FAO, IARC's and NARS for future work and readjustments of their priorities and strategies.

FAO, IARC's and the NARS jointly combed the prospective technologies using the following criteria: (i) proven distinct superiority in production and productivity, (ii) agronomic, economic and environmental soundness, integrative nature of technologies such as IPM, IPNS, crop-livestock integrated farming, etc., which generally present unusual challenges for their transfer, (iii) availability of the proven technologies, especially the hardware component, (iv) potential impact, (v) needs and priorities of the national agricultural research systems, (vi) regional importance of the problem(s) addressed, and (vii) innovativeness of the approach. Six technology packages, as listed below, were finally selected and programmes are being developed to effect their transfer to farmers:

- Winter chickpea promotion in West Asia and North Africa, led by ICARDA;
- Insect pest management technology for rice (an IMP approach) in Amazonian countries, led by CIAT;
- Rice intercropping technology for improved pasture sustainability in Amazonian countries, led by CIAT;
- Corn downy mildew eradication in selected African countries, led by IITA;
- Striga and Alectra control in selected African countries, led by IITA/ICRISAT;
- Crossbred cows for increased milk production and traction in smallholder farming systems, led by ILCA.

It may be emphasized that, while the IARC's provided the leadership role, the technologies were developed in close association with the NARS. In the Asian region, prospects of such a collaboration are bright for hybrid rice technology involving IRRI, China and other NARS and for hybrid pigeonpea involving ICRISAT, India and other interested NARS.

VI. Future challenges and policy options

A. The challenges

Rapid population growth and accelerated urbanization, coupled with increasing income, have created unprecedented pressures for more and more agricultural outputs in the developing countries. This has resulted in ever-increasing pressures on the natural resource base, resulting in excessive deforestation, genetic erosion, loss of soils and various forms of environmental degradation.

The situation is particularly acute in the Asia-Pacific Region where more than half of the world population, two-thirds of that of the developing countries, and almost three-fourths of the world's farming households live (FAO, 1992). Of the more than one billion people estimated to be below poverty level and malnourished, about 800 million are concentrated in this Region. Every day, about 5 000 hectares of natural forest are destroyed in South and South-East Asia. The arable land available per caput is 0.2 hectare, the lowest in the developing world, and in most countries, it has further been declining. Therefore, future agricultural production and productivity gains must come from further intensification of use of new technologies.

The agricultural growth rates have slowed down in the recent years, from about 3.5 to 4 percent during the sixties to 3.0 to 3.5 percent during the seventies and to 2.5 to 3.0 percent during the eighties. On the other hand, widespread destruction of natural resource base has occurred. Given that the Region's population seems destined to double by the year 2030, if the present trends continue, the per caput food supplies will hardly change and there is little scope for the widespread alleviation of poverty. Even if the projected agricultural production growth rate of 2.7 percent in East and South-East Asia and 2.6 percent in South Asia is realized during 1990-2010, estimates suggest that 272 million chronically malnourished people will still persist in the Region (Tables 4 and 5). Of these, 202 million will be in South Asia; therefore a special effort would have to be made in the South Asian sub-region to increase agricultural productivity to further reduce the number of malnourished.

Agriculture feeds people. Further, it plays a preeminent role in employment, national economic growth and poverty alleviation in most developing countries. Therefore, sustainable intensification of agriculture is a must to meet present and future demands. The main problem faced today in the Asia-Pacific Region is that whether it is possible to meet the ever increasing demand for basic foodstuffs and other agricultural outputs and income growth from the ever-shrinking natural production base (land, water and biodiversity) without inflicting further injuries to the environment (physical, biological and socio-economic).

In order to meet the demands of sustainable agricultural and rural development, technologies must be developed, transferred and adapted to ensure judicious exploitation and enhancement of natural resource base, efficient use of inputs, environmental protection and balanced economic growth. A science-based and efficiently managed system of agriculture must be established and strengthened to render it more sustainable at progressively higher levels of productivity over time. The approach and its effectiveness will, however, depend on site-specific agro-ecological and socioeconomic conditions, government policies, and institutional arrangements. Taking lessons from the past, greater R&D attention and appropriate policy options will be needed to mitigate the problems of rainfed farming and resource-poor farmers and effective linkages would have to be established and efficiently managed among relevant actors and sectors.

B. Technology transfer for rainfed and other fragile ecosystems

Optimistic projections suggest that even after all the irrigable land in the Region is brought under irrigation, more than 50 percent of the arable land will remain rainfed. Rainfed areas have generally remained neglected. This neglect has been a harsh punishment to majority resource-poor inhabitants of rainfed areas and has hindered development of major crops predominantly grown in such areas, such as pulses, oilseeds, coarse grains, cotton and many other commodities, some of high export and economic value.

As seen from Table 7, there are wide gaps in technology transfer in rainfed crops (Singh, 1989). Relating these gaps, four questions arise: (a) is the dryland farming technology sound, (b) is it appropriate and compatible with the farm household socioeconomic setting, (c) is it viable and (d) is there a mechanism to update it. These questions can be answered only by undertaking well-focused research and technology development. This calls for strengthening NARS and IARC's for providing the needed technologies. Satellite adaptive research stations in distinct rainfed/dryland areas could play an important role in identifying and fine-tuning appropriate technologies. As mentioned earlier, information-related technologies are particularly important for rainfed/dryland ecological zones.

TABLE 7. YIELD GAPS BETWEEN NATIONAL FARMERS' FIELDS' DEMONSTRATIONS AND COUNTRY'S AVERAGE YIELDS UNDER RAINFED FARMING (1986-87), INDIA

Crop	Country's average yield (kg/ha)	National demonstration average yield (kg/ha)	% increase in yield of national demonstration over country's average yield
Maize	1,281	2,920	128
Sorghum	575	3,270	469
Pearl millet	400	1,705	326
Groundnut	841	1981	136
Mustard	700	891	27
Chickpea	678	1,550	129
Mung bean	345	682	98
Soybean	600	1,450	141
Sesamum	206	346	6

Source: Adapted from Singh, R.B., 1989

There is also ample evidence to show that the extension workers lack practical skills and competence in delivering messages to the farmers under the complexities of rainfed situations. Therefore, the extension personnel should be (i) aware of the "village conditions" of the farmers, (ii) able to administer plans and programmes based on the farming situation, (iii) competent in executing programmes under a given set of farming conditions, and (iv) conversant with technical knowledge on a wide variety of subjects with some farm management training. In order to facilitate a smooth flow of information, the extension organizations should also be geared to provide the required support to the extension workers. In most instances, transport, housing and other services have been reported as inadequate for the extension workers to frequently visit the farming communities in the rainfed areas, which often lack transport and communication facilities.

It may be emphasized that the extension services need to closely monitor the relevance of the technologies transferred and provide feedback to the research on the complexities of the rainfed farming. The training of extension workers have to be undertaken with a completely different orientation from that of irrigated agriculture and the same principle will apply to the training of trainers. The future training programmes should emphasize on:

- Linking the training to the varied resources available to farmers;
- Greater relevance to the socio-economic issues involving farming systems in specific locations;
  -Relevance of the training to the extension worker's functions;
- Information to be delivered in appropriate packages for specific situations.

Finally, it must be clearly understood that a majority of the poverty stricken farmers are concentrated in areas where rainfed agriculture is the only source of livelihood. Hence, a very pragmatic and risk-free strategy for research and extension will have to be evolved for the development of the areas. In achieving these objectives, the generation of appropriate technology based on detail knowledge of the complexities of the farming systems will be required. In the technology dissemination process the extension strategy should be modified with a policy shift for high investment with necessary support services and strong inter-sectoral linkages.

In a nutshell, minimizing and managing risk should be the guiding principle for technology transfer in rainfed/dryland areas. Besides concentrating on low-risk components of or steps in rainfed technologies, an appreciation of the total environment of the farm household; choice of efficient crop, variety, cropping system, livestock, agroforestry and integrated farming system based generally on information-related technologies; a participatory and farmer-first farmer-last approach, and integrated management of pests, nutrients, soil and water are strategically important for rainfed technology transfer.

C. Technology transfer to resource-poor farmers

The majority of the farm holdings in Asian countries are small, less than one hectare, and account for only small fraction of the total cropped area (Table 8). As seen from the table, for instance, in Sri Lanka, while three-fourths of all farming household's own less than one hectare land, they together account for only one-fourth of the total farmed area in the country. Therefore, technology needs of the majority small farmers cannot be ignored.

TABLE 8. SHARE OF HOLDINGS LESS THAN ONE HECTARE IN TOTAL NUMBER OF HOLDINGS AND IN TOTAL CROPPED AREA IN SEVEN ASIAN COUNTRIES

Country	% share in total number of holdings	% share in total farmed area
Bangladesh	54.1	18.7
India	54.6	10.7
Indonesia	70.4	29.0
Republic of Korea	65.0	38.4
Pakistan	51.8	15.9
Nepal	66.3	17.4
Sri Lanka	75.0	25.0

Source: Singh, R.B., 1990, Working Paper No.6, FAO Research Development Centre, FAO, Rome.

Generally, it had been believed that small farmers are sluggish in adopting modern technologies. This has, however, not been borne by studies undertaken in parity between the proportion of land area and proportion of rice production under the small, medium and large-size farms (Table 9).

TABLE 9. RICE PADDY PRODUCTION BY FARM SIZE IN THE REPUBLIC OF KOREA, 1987

Farm size		% of total cropped area	% of total rice production
Small	(< 1 ha)	38	37
Medium	(1-2 ha)	44	45
Large	(> 2 ha)	18	17

Source: Kim, D.S., 1989, FAO RAPA Consultancy Report on Republic of Korea.

In Bangladesh, as studied by Hossain (1988), the small farms generally recorded higher yields than the medium and large-size farms (Table 10). From the experiences in the Republic of Korea and Bangladesh it is thus clear that per hectare yield of small farms is not lower than that of larger farms. In fact, because of the greater availability of family farm labour at small farming households and the high pressure of earning of bread from the limited land resources, small farmers strive hard to maximize their production through judicious use of their limited purchased input resources and by intensive adoption of information-based inputs viz. timely transplanting, seeding at appropriate depth, weeding, hoeing and harvesting by deploying their readily available family labour force. Technologies based on low use of purchased inputs, intensive use of non-monetary components, improved efficiency of manual labours, and integrated farming systems should be development and transferred for the betterment of small farmers.

TABLE 10. RICE YIELD (T/HA) BY FARM SIZE IN BANGLADESH, 1982

Farm size	Local varieties	Modern varieties	All varieties
Small	0.72	1.29	1.10
Medium	0.71	1.13	0.93
Large	0.61	1.09	0.86

Source: Hossain, M. 1988. International Food Policy Research Institute Field Survey, Bangladesh Institute of Development Studies, 146 p.

Small farmers, besides being resource-poor and being largely confined to rainfed and marginal areas, have low-risk-taking capacity. The special settings, needs and concerns of small farmers should be kept in mind while generating and transferring technologies (FAO, 1986). Definite advantages are seen in involving such farmers right from the inception of research and technology generation plan to adoption of new technology. A farming system approach which seeks to link farmer's indigenous knowledge with the use of formal science and technology is a problem-driven approach to solve location-specific topical problems. On-farm research with farming systems perspective should provide necessary information and ideas for new research as well as for mode of transfer and adoption of new technology.

Appropriate policy environment is a prerequisite for benefitting from technological developments. Land tenure system continues to be a major policy issue. Although productivity of tenant farmers may not be adversely affected in the short-term, it certainly has a negative long-term influence on sustainability as the farmer has no incentive for investment in improvement of the land and other natural resource bases which do not belong to him. The land-to-the-tiller type of land reform as employed in Japan and Korea several years ago was a powerful instrument for achieving greater equity in rural income through rapid and uniform adoption of new technology.

In some of the countries where there is high inequity in access to land and other production resources, special technology transfer programmes to reach resource-poor farmers have been developed with varying success. For instance in India, the Small Farmer Development Agency (SFDA) seeks full participation of small and marginal farmers in the development process (Menon, 1985). An evaluation of the programme had revealed that the beneficiaries had significant income gain through this programme. The lab-to-land project was also targeted to small and marginal farmers. A total of 14 500 farm households were adopted during the Seventh Plan (1986-90). The various experiences of technology transfer to small and resource-poor farmers should be critically analyzed and the lessons learnt (the nuts and bolts of successes as well as failures) should be shared widely.

In India, there are four TOT systems: (i) first-line extension system of the ICAR, (ii) national extension system of the Union Ministry of Agriculture, (iii) state level extension system of respective state governments and (iv) rural development programme of the Union Ministry of Rural Development including extension efforts of NGO's and other voluntary organizations. Coordination linkage mechanisms have been provided at various levels. The ICAR Front-line Extension Model encompasses the following programmes/ projects:

- National Demonstration Project (NDP)
- Krishi Vigyan Kendra (KVK) or Farm Science Centre
- Trainer's Training Centres (TTC)
- Lab-to-Land Programme
- Operation Research Projects (ORP)

National programmes have also been adjusting their technology transfer approaches as their agriculture has moved forward and profiles of technologies have changed. For instance, in Malaysia, the approaches differ from the smallholder paddy production system to highly commercialised estate sector plantation crop system such as palm oil production. The agriculture is viewed as a business enterprise, and must be responsive to market trends. Thus, only those technologies are being promoted which are labour-saving and cost effective. Special research extension linkage mechanisms such as nucleus estate system (also in Indonesia) and programmes like FELDA, FELCRA were established.

In the Philippines, PCARRD pursues a two-pronged strategy for technology transfer, namely: (a) supply-push technology delivery programme through action/pilot project, under the auspices of the Comprehensive Technology Transfer and Commercialization (CTTC) of the Department of Science and Technology and (b) demand-driven or "bottom-up" approach emphasizing rural-based enterprise development. The country has adopted the following approaches of technology transfer: Farming Systems, Training and Visit, Community Organising, Legitimacy of New Technology, Participatory R and E and Utilization of Multidisciplinary Team.

In Korea, the Farming Systems approach coupled with the mobilisation of agricultural cooperatives, has been extremely successful as judged from negligible technology transfer gaps in the country. Using the FSR approach between 1983 and 1988, about 100 000 farms and 5 740 villages had participated in on-farm trials. During 1988, about 12 000 demonstrations were organized as given below (Kim, 1989):

Staple food grain:	5,158
Upland crops:	1,079
Industrial crops:	1,025
Vegetables and fruits:	872
Others/mushroom, sericulture and livestock:	3,493

In 1987, the scientists directly trained about 10 000 key farmers, devoting about 2 800 man-days. Other measures include easy access to inputs through cooperatives throughout the country and easy loan terms. About 90 percent of the Korean farming households are members of cooperatives which, among other things, participate in extension, organize input distribution and marketing of products. The story of the role of cooperatives in technology transfer in Korea is a success story. Other countries in the Region may wish to learn of the approach and actual functioning so that they can create analogous systems and institutions.

The Korean Government has promoted deliberate efforts to improve rural infrastructure and lifestyle. Government and farmers are also identifying export opportunities, and are strengthening measures to improve the rural environments and their agricultural-market infrastructures; social measures are also being implemented to help less productive farmers to retrain for non-agricultural employment, and to encourage and recognize successful young farmers. The national programme of agricultural technology development and transfer is correspondingly directed to labour-efficient, sustainable, high-technology production of market-oriented pollution-free crops. Innovative modalities in technology transfer include a local-level extension-based research capability, rural and elite farmers' clubs, model-farm groups to exploit specific market opportunities, and use of hometown rural support groups.

The Republic of Korea has invested heavily in education of farmers and specialists to ensure technology development and transfer, and the strengthening of farm-management capabilities and post-harvest entrepreneurial skills. Linkage between development and transfer is facilitated by having one single responsible authority - the Rural Development Administration - which is funded both by the Ministry of Agriculture, Forestry and Fisheries and by the Ministry of Home Affairs, and at both national and provincial levels. A Research Bureau and monthly joint research-extension meetings promote linkage between researchers, extension personnel, and farmers, and identify on-farm needs for new or improved technologies; linkage in agricultural education is formalized through an Institutional Cooperation Committee. Evaluations of technologies are made by a Technical Dissemination Bureau, and worthwhile technologies are featured in extension service guidelines. (However, there is no formal mechanism to commercialize promising technologies.) The Technical Dissemination Bureau, together with the Rural Guidance Bureau, the Technical Information Office, and the Farm Management Office, implements the national extension programme; there is complementary support from a Farmers' Training Division, whose mandate includes training for rural women. The successful extension programme ("Saemaul Undong") of 1970-90 has developed into new groupings which include "Future Farmers", "Farm-Improvement Groups", "Farm Leaders' Associations", and "Women's Groups". Recently, however, there is recognition that there is greater need for disciplinary specialism among the extension personnel.

In Australia, the Federal and State Governments have plans such as Rural Adjustment Scheme (RAS) and the Farm Homehold Support Scheme (FHSS) to restructure the rural sector to achieve economic and ecological sustainability. These programmes assess economic and ecological viability of a farming enterprise. As long as the enterprise is economically viable, technologically feasible and environment-friendly, the government will encourage the programme. Failing that, the Government will help the farmer to leave agriculture and pursue a new career.

D. Establishment and management of linkages for technology transfer

Given the complex multidisciplinary and intersectoral nature of technology development and transfer, effective linkages among concerned sectors and key players should be established/strengthened and properly managed. Described below are some of the important linkages:

Research, Extension, Farmer Linkage: The ultimate aim of researchers, extensionists and development agencies is to empower the farmer with the appropriate knowledge, techniques, skills and hardwares (quality, seed, agro-chemicals and irrigation) to enhance his capability to judiciously exploit his natural resource base and family labour for sustainable agriculture and rural development. However, it is often seen that the three partners operate independently, causing reduced efficiency for technology development, transfer and adoption. The result has been that technology has often not been adopted to solve farmers' problems or prepared for field use (Kaimowitz et al., 1989; Merrill-Sands et al., 1990).

There are several reasons for the research-development gap. The two departments are often under separate administration. Usually, there is vertical administrative control and discouragement for horizontal communication. Often, the research and development agendas are set independently and usually in a "top-down" manner by federal agencies, with little consultation with agro-industries, marketing institutions, cooperatives, input and output dealers, and farmers. In order to improve compatibility between technologies and support systems, governments should establish appropriate policies for both formal and informal linkages, and for lateral as well as vertical liaison. Some of the countries in the Region had restructured and renamed their national agricultural research systems to put "R" along with "D", such as MARDI in Malaysia, PCARRD in the Philippines, and AARD in Indonesia, and taken steps to coordinate and link the R and D activities across the ministries concerned. Yet, there are serious gaps in technology generation and transfer. For instance, a recent review of PCARRD had revealed that, of the 54 technologies recommended by the Council, only 11 had been adopted, to varying degrees, by the farmers. The reasons for these technology transfer and adoption gaps should be critically analyzed and the lessons learned should be shared by all the actors.

Public-Private Sector Linkage: The private sector plays an important role in technology development in the developed countries, but this potential has been exploited only partly or negligibly in the developing countries. In several countries, the private sector undertakes research and develops and transfers technologies. It also undertakes inputs supply and marketing. It is generally observed that the private sector performs some of the functions more efficiently than the public sector. Generally, governments in developing countries have not formulated appropriate policies to tap the potential of the private sector. But, lately, as in Thailand, Malaysia, India and Republic of Korea (particularly in the field of biotechnology), policies to promote the role of private sector in technology development and transfer have been initiated. The private-public sector linkage is slowly forging, but a lot more remains to be attained.

Of particular interest in the public-private sector linkage is the field of seed research, production and distribution. The two sectors could be, and in several cases have been, complementary and mutually stimulating (Dalrymple and Srivastava, 1992). The private sector, understandably, concentrates on high pay-off hybrids, irrigated and favourable areas, low-volume high-value crops such as vegetables, whereas the public sector takes care of low-value high-volume crops such as rice (conventional varieties) and wheat and synthetics/composites of maize and subsistence crops and commodities. Moreover, in small and low-income countries, where the seed market is limited, the private sector is least interested in the enterprise and the entire responsibility lies with the public sector. Generally, the strategic and basic research is done by the public sector but, as the market expands and the private sector is able to make considerable profit, strategic research on selected crops is now being increasingly undertaken by private seed companies. So far, however, the flow of information and material has generally been unidirectional, from public to private sector, although in some cases the two sectors have been jointly conducting on-farm trials. Some of the countries, such as India, Republic of Korea and Thailand, have formulated seed policies specifically promoting public-private sector linkage, but in several countries the policies, such as sale of seed at subsidized rates by the public sector, are counterproductive.

No doubt, the private sector would essentially be interested in programmes which yield profits, but occasionally the sector also strives to promote its "green" face, and such moves should be encouraged. The public sector should take care of "orphan" commodities and areas of community, regional and national interest such as improvement of degraded land, agroforestry programmes, development and transfer of environment-friendly technologies. The public sector would also be primarily responsible for formulation of laws, regulations and standards, and their enforcement, to ensure quality and consumers'/users' satisfaction. In doing so, care should be taken to ensure that the various controls have a positive approach to facilitate timely delivery of the inputs and products. This complementary approach will help increase investment in agricultural research and technology development.

Linkage with Regulatory Agencies: A lot of cutting edge technologies which can play a significant role in SARD, are under proprietary protection and often out of the reach of poorer nations which cannot afford the fees or do not possess necessary negotiating capability for procuring such technologies. Based on informed judgement, regulatory agencies in individual countries should develop mechanisms and national guide-lines and procedures to procure the protected technologies according to national needs and aspirations. International Organizations can play an important role in transferring the protected technologies to developing countries by creating intermediary services as well as by strengthening capabilities of the countries. Regulatory guide-lines and standards have a greater chance of being respected if these are included in technology packages. Linkages with harmonized international biosafety code of conduct will be essential for safe introduction or development and release of genetically engineered organisms. Under the GATT process, with market forces playing the key role in trade, and increased emphasis on quality and cost-effectiveness of production, the regulatory processes in the context of availability of new technologies would assume high importance. Countries must develop capabilities to deal with this process, otherwise they will lag behind in harnessing the new opportunities.

Linkage with Information Networks: Information is power and it underpins technology planning, assessment and transfer processes. Technology package, as mentioned earlier, is based on information (knowledge) and hardware (materials). Therefore, it is absolutely essential for any research and technology development system to have an effective linkage with information system. Information units, nationally, sub-regionally, and regionally, are required to disseminate information on available technologies, their sources, their environmental friendliness and risks, and the broad terms under which they may be acquired. The linkage will induce the information centres to operate on an information-demand basis and concentrate on information need of the end-users. The information infused in the research and technology development from information centres would highlight and detail concrete cases where environmentally friendly technologies were successfully developed and implemented. The information-sharing will also broaden knowledge about sources of advice, training, technologies and technology assessment. The clearing houses will thus facilitate the establishment of joint ventures and partnerships of various kinds.

Local capabilities should be developed for transforming, processing, analyzing, repackaging and value-addition of information. Several countries in the Region have established databases and are linked nationally and internationally with useful databases. Satellite imagery services and GIS are readily available in quite a few Asian countries, but a number of countries in the Region have yet to acquire the necessary competence. Thus there is ample scope for TCDC activities in this field. International development organizations should provide the necessary assistance for establishing an effective agricultural information network. (Several of the countries are not effectively linked even with the long-established FAO-supported AGRIS and CARIS systems.) Advantage should be taken of the explosion in communication technology and increasing availability of new and cost-effective communication mass media for reaching the farmers and empowering them and others concerned to take appropriate decision regarding adapting and diffusing technologies which would serve them best.

Linkage with Education: National agricultural research systems in developing countries should consider universities as an integral component of the system not only for formal training and producing graduates, but also for informal training, policy guidance, technology development and transfer. The universities should be encouraged to establish windows for joint ventures with private sector and industries, and undertake problem solving research.

There are several policy level and financial constraints to university's participation in technology transfer processes. Governments and international systems should formulate explicit policies and extend funds to establish links between universities and other institutions concerned with human resource and agricultural development. Universities should particularly be encouraged to develop conceptual frameworks, methodologies and modules for technology transfer and assessment. Universities should also develop capability for preparing target-oriented projects for updating, improving or developing missing components of technology packages to improve overall effectiveness of the packages, and seek competitive funds for implementing the projects in cooperation with other partners.

The experiences on the role of universities in technology transfer vary widely in the Region. In some countries such as India, the universities, especially the agricultural universities, play leading role in technology development, verification and transfer. Extension/technology transfer directorates/wings have been created in such universities whose main job is to organize adaptive/on-farm trials, develop human resources (including farmers trainings, training of trainers) and often produce breeder and foundation seeds and planting materials of approved varieties. In Malaysia, for instance, the University Pertanian Malaysia (UPM) through its multi-disciplinary and inter-institutional Malaysian Bee Research and Development Team (MBRDT), besides making several significant research contributions, played a leading role in helping establish more than 1 000 beekeepers throughout the country. Income of these households have increased by more than 50 percent which has been attributed to beekeeping. Several such experiences are known from universities in the Philippines, Thailand, Indonesia and Pakistan.

India, supported by the World Bank, has developed a unique National Agricultural Research Project (NARP) which empowers agricultural universities to undertake decentralized adaptive research and technology transfer in distinct agroclimatic zones throughout the country. Led by the State Agriculture Universities (SAU's), the NARP, following FAO's definition of agroclimatic zone based on soil type, had identified 120 agroclimatic zones in 17 major states and established about 350 satellite stations. Different farming situations were identified in each climatic zone and various adaptive trials conducted to identify/verify location specific technologies and for further fine-tuning, which were quickly adopted by the farmers with impressive gains in production, productivity and profitability (Ghosh, 1991; Singh, 1993).

Thus, again there are varied experiences, some very successful, of linking universities with agricultural technology development and transfer systems in the Region. Through the Asia-Pacific Association of Agricultural Research Institutions (APAARI), the Asian Agricultural University Association, and other relevant networks, the successful experiences could be shared under TCDC arrangements.

E. Strengthening of national technology transfer systems

As discussed earlier, development and transfer of technologies have been instrumental in accelerating agricultural production and national development in the Region. The rate of return to investment in agricultural research has been highly favourable, usually as high as about 30 to 40 percent. Yet, government and international supports to agricultural research and technology development have been declining. This is a matter of great concern as it is happening at such a time when the problems to be addressed, such as sustainability and improvement of rainfed agriculture and productivity of small farms, are getting more and more complex and becoming increasingly important. The trend must not only be reversed, but additional national and international funding and institutional supports should be provided to agricultural research and technology transfer. Measures to promote technical cooperation among developing countries to transfer technologies should be strengthened. FAO has recently evolved a special formula and programme to intensify the TCDC approach.

REFERENCES

BIGGS, S.D., 1989. Resource-poor farmer participation in research: A synthesis of experiences from nine national agricultural research systems. OFCOR Project Study No. 3. The Hague. ISNAR.

CHAMBERS, R., 1992. Rural appraisal: Rapid, relaxed and participatory. IDS Discussion Paper 311. IDS, Brighton.

CONROY, R., 1992. Technological change in China. Development Centre Studies. Development Centre of the Organization for Economic Cooperation and Development. Paris. 1992.

CORNWALL, A., GUIJT, I. and WELBOURN, A., 1992 Acknowledging process: Challenges for agricultural research and extension methodology. Overview paper for IIED/IDS Beyonod Farmer First Conference, 27-29 Oct. 1992. 34 p.

DALRYMPLE, D.G. and SRIVASTAVA, J.P., 1992. Technology transfer in plant cultivars in developing countries: seeds, sectors, and society. Paper presented at the Conference on Agricultural Technology: Current Policy Issues for the International Community and the World Bank, Airlie House, Virginia, USA, 21-23 Oct. 1991. 36 p.

DE DATTA, S.K., 1990. Sustainable rice production: Challenges and opportunities. International Rice Commission Newsletter 39: 209-219. (Special issue published as Proceedings of the 17th Session of the International Rice Commission, 4-9 Feb. 1990, Goiania, Goias, Brazil).

EPONOU, T., 1993. Integrating agricultural research and technology transfer. Public Administration and Development. Special Issue on Managing Agricultural Research. Vol. 13(3): 307-318.

FAO 1986. The technology application gap: Overcoming constraints to small-farm development. FAO Research and Technology Paper 1, prepared by D. Merrill-Sands. FAO, Rome, 1986, 95 p.

FAO 1988. Pulses in the Asia-Pacific Region. FAO/RAPA Publication No. 1988/13. Bangkok, Thailand.

FAO 1990. Strengthening pre-investment work in agriculture: An expanded programme for on-farm technology testing. FAO Investment Centre, Rome. 16 p.

FAO 1991. Technological options and requirements for sustainable agriculture and rural development. Main Document No. 2. FAO/Netherlands Conference on Agriculture and the Environment - Strategies and Tools for Sustainable Agriculture and Rural Development (SARD), 'S-Hertogenbosch, the Netherlands, 15-19 April 1991.

FAO 1992. Selected indicators of food and agriculture developoment in the Asia-Pacific Region, 1981-91. FAO RAPA, Bangkok. 211 p.

FAO 1993. Agriculture: Toward 2010. Conference document No. C93/24, 320 p.

FAO 1994. Farming systems development - A participatory approach to helping small-scale farmers. FAO Rome. 46 p.

FARRINGTON, J. and BIGGS, S.D., 1990. NGO's, agricultural technology and rural poor. Food Policy, December, 479-491.

GHOSH, S.P., 1991. Concepts of agroclimatic zones for research and development. pp. 1-20 - In: Ghosh, S.P. (ed.) Agroclimatic Zone Specific Research - Indian Perspective under NARP, Indian Council of Agricultural Research, New Delhi.

HOSSAIN, M., 1988. International Food Policy Research Institute Field Survey. Bangladesh Institute of Development Study, 146 p.

HUDGENS, R.E., 1992. Selecting technologies for sustainable agriculture. Development Studies Paper Series. 38 p. Winrock International Institute for Agricultural Development. August 1992.

KAIMOWITZ, D. *et al.*, 1989. A conceptual framework for studying the links between agricultural research and technology transfer in developing countries. ISNAR Linkages Theme Paper No. 1. International Service for National Agricultural Research, The Hague.

KELLEY, T.G. AND WALKER, T.S., 1991. On-farm trials as a component of overall evaluation and assessment of new technology adoption potential: The case of short-duration pigeonpea. ICRISAT. Paper presented at the 11th Annual AFSRE Symposium at Michigan State University, East Lansing, 11-18 Oct. 1991. 21 p.

KERR, A., 1989. Commercial research of a genetically engineered bacterium for the control of crown gall. Agr. Science, Nov. 41-44.

KIM, D.S., 1989. Increasing productivity of small farms through appropriate technology in the Republic of Korea - A consultancy report submitted to FAO RAPA, Bangkok. p. 26.

MASCARENHAS, A.F., 1991. Plant biotechnology in India - The role of plant tissue culture. Current Science (Indian Academy of Sciences) 60: 547-51.

MELLOR, J.W., 1988. The intertwinning of environmental problems and poverty. Environment 30(9): 8-30.

MENON, K.P.A., 1985. Indian agriculture - Administrative and organizational constraints. Arthashastri Prakashan, New Delhi. 232 p.

MERRILL-SANDS, D. and COLLION, M.H., 1992. Making the farmer's voice count in agricultural research. Quarterly Journal of International Agriculture 32: 260-279.

MERRILL-SANDS, D. KAIMOWITZ, D., SAYCE, K. AND CHATER, S., 1990. The technology triangle: Linking farmers, technology transfer agents and agricultural researchers. The Hagues: International Service for National Agricultural Research (ISNAR). 1990.

MUKHERJEE, T.K., 1989. Biotechnology development in animal production and health in Asia. pp. 32-48. In: Proceedings of the FAO/UNDP Workshop on Biotechnology in Animal Production and Health in Asia and Latin America, held at the Chinese Academy of Agricultural Sciences, Beijing, China, 9-13 Oct. 1989, 339 p.

ORAM, P.A., 1988. Moving toward sustainability: Building the agro-ecological framework. Environment 30:14-36.

PRETTY, J.N. and CHAMBERS, R., 1992. Turning the new leaf: New professionalism, institutions and policies for agriculture. Overview paper for IIED/IDS Beyond Farmer First Conference, 27-29 Oct. 1992, 39 p.

QI, B. *et al.*, 1994. Chinese agriculture, agricultural research and technical extension and exchange. Paper presented at FAO/UNDP meeting on North-East Asian Agricultural Cooperation and Support - Research and Technology Transfer, Beijing, 24-28 April 1994. 24 p.

RHOADES, R., 1989. Gatekeeper Series SA12, IIED, London.

RHOADES, R. and BOOTH, R., 1982. Farmer back to farmer: A model for generating acceptable agricultural technology. Agricultural Administration Network Paper 11. ODI. London.

SINGH, R.B., 1989. Rainfed agriculture in Asia and the Pacific Region: An overview. pp. 1-28. In: Singh, R.B. (ed.) Rainfed Agriculture in Asia and the Pacific Region. FAO RAPA, Bangkok, Publication No. 1989/14. 224 p.

SINGH, R.B., 1990. Increasing productivity of small farms through appropriate technology. FAO Research Development Centre Working Paper No. 6, FAO, Rome. p. 36.

SINGH, R.B. and VIRMANI, S.S., 1990. Recent progress in the technology and development of hybrid rice in Asia. International Rice Commission Newsletter 39: 133-145. (Special issue published as proceedings of the 17th Session of the International Rice Commission, 4-9 Feb. 1990, Goiania, Goias, Brazil).

SINGH, R.B., 1992. Research and development strategies for increased and sustained production of rice in Asia and the Pacific Region. FAO RAPA Publication No. 1992/17. Bangkok, Thailand.

SINGH, R.B., 1993. The role of state agricultural universities in decentralization of agricultural research and technology development in India, pp. 175-188. In: FAO Research and Technology Paper 5, *The role of universities in national agricultural research systems* (Report of the Expert Consultation on the Role of Universities in National Agricultural Research Systems, 10-12 March 1991, FAO, Rome) FAO, Rome 1993, 313 p.

TRIPP, R., 1992. Expectations and realities in on-farm research. Farming Systems Bulletin 11: 1-13.

WANG, Z., 1990. Technology for sustainable crop production and agricultural development in China - A consultancy report submitted to FAO, RAPA. 47 p.

WORLD BANK, 1992. Development and Environment. World Development Report. Washington.

YADAV, J.S.P., 1989. Irrigation-induced soil salinity and sodicity. pp. 47-62. In: Environment and Agriculture - Proceedings of the World Food Day Symposium. FAO RAPA. Bangkok, Thailand. 16 Oct. 1989.

YUAN, L.P. and VIRMANI, S.S., 1988. Status of hybrid rice research and development. pp. 7-24. In: Hybrid Rice - Proceedings of the International Symposium on Hybrid Rice. 6-10 Oct. 1986, Changsha, Hunan, China, IRRI, 305 p.

ZAMORA, A.B. and BARBA, R.C., 1990. Status of tissue culture activities and the prospects for their commercialization in the Philippines. Australian Journal of Biotechnology. 4: 49-53.

Section I

CHAPTER 3

INDICATORS FOR SUSTAINABLE AGRICULTURE IN THE ASIA-PACIFIC REGION

Ann Hamblin [1/]

CONTENTS

Abstract 47
I. Introduction 48
II. Issues and indicators of sustainability of Asian agro-ecological zones and agricultural systems 52
III. Indicators for agro-ecological zones or farming systems 70
IV. Recommendations for FAO's monitoring and statistical collection 75
V. Australia and New Zealand: a case study 78
References 79
Acronyms 83
Appendix 1, 2, 3 84-86

ABSTRACT

Agricultural sustainability is defined as the continuing productivity of agriculture while maintaining the resource base and minimising adverse environmental effects from farming activities. Indicators based on regularly collected statistics are already used to monitor the productive performance of agriculture, but they do not include measures of the natural and human resources involved, nor is there any regular institutionalized reporting of off-site environmental trends.

Current FAO statistics collected on agricultural products and some inputs (such as fertilizer use) could form the base to an augmented set of statistics that would be capable of trend analysis on agricultural sustainability in Asia. Without consideration of at least some of these issues, evaluation of the sustainability of agriculture and of the relative capacity of the sector to produce sufficient food for the increasing populations of Asia are liable to serious misinterpretation, - especially if reliance is placed solely on produciton statistics, or net farm productivity.

Water and nutrient balances could be estimated if supplemental information were gathered. Environmental impacts of significance in much of Asia include the use of pesticides, deforestation, and the loss of water quality, in addition to the significant special case of salinization and ground water change in irrigated lands. These on-site and off-site effects of agriculture can be monitored crudely by better regular reporting on statistics collected by national land and water agencies.

Land conservation practices are good indicators of improved land management, but less readily acquired as information, and may require special surveys at local level. Statistics on ground water changes and sand salinistation are critical to assessing irrigated land sustainability.

[1/] *Bureau of Resource Sciences, Department of Primary Industries and Energy, Canberra, Australia*
Present address: Director, Cooperative Research Centre for Soil and Land Management, Private Bag 2, Glen Osmaond SA 5064. Australia

I. Introduction

A. Sustainability

Sustainability has become a familiar, if somewhat ill-defined concept, in the past decade, triggered by the report of the World Commission on Environment and Development (1987), and focussing on issues of equity, interdependence and resilience of ecosystems with human activities (Pearce *et al* 1988). In essence the needs of current generations should be met, but without compromising the ability of future generations to meet their own needs.

In the agricultural context, definitions developed in submissions from countries and organisation to the United Nations Conference on Environment and Development (UNCED), in 1991, identified a number of common criteria, encapsulated in "Agenda 21". These include

- continued productivity (profitability) of agriculture for long time scales relative to human life,
- maintenance or improvement of agriculture's natural resource base,
- minimising of adverse environmental impacts from agriculture on surrounding lands and on people.
- social equity within agriculture and between rural and other sectors

The integration of economic development with environmental integrity is a major issue in sustainability; assessing sustainability of a system, rather than its productivity, produces a shift in the required knowledge base and the analysis of information used. In comparison with the traditional System of National Accounts (SNA) which measures short-term economic performance, evaluation of sustainability requires consideration of time scales for biophysical response times - say 30 to 100 years. Analysis of interactions between socio-economic and biophysical systems require the addition of natural resource accounts and human development indices to the SNA (World Resources Institute 1992, UNDP, 1992/3) and the identification of indicators which adequately represent the status of ecosystems and effects of land-use practices.

Changes to environmental condition cannot rationally be assessed independently of the systems of land use which have been developed on the biophysical resource base. Boundary conditions and regional classifications for land, water and vegetation are therefore more logically found in topographic and climatic criteria. At large scales, biophysical regionalisations start with climate. The FAO (1978-81) system of agro-ecological zones (AEZ) has been devised based on rainfed soil moisture availability related to the length and temperature conditions of the growing period for annual crops. In this classification there are two main scales: AEZs are the *global* zones of tropical, subtropical, temperate and boreal regions, subdivided by rainfall.

In Table 1 AEZs are numbered according to the FAO/CGIAR system (CGIAR 1992). Regional Agro-Ecological Zones (RAEZs) as they occur in each of the continental divisions [sub-Saharan Africa (SSA), West Asia - North Africa (WANA), Asia and the Pacific (AP),and Latin America and Caribbean (LAC)] are sequentially numbered in the FAO/CGIAR scheme, as shown in Table 1, starting with SSA (1-7), proceeding through AP (8-14) and then to LAC (15-23). Seven RAEZs occur in Asia. Winter-dominant rainfall and cool, montane tropics do not occur. Details of the growing conditions for rainfed, annual crops which form the basis to the classification are given in Appendix 1.

Agro-ecological characterisation allows farming systems and potential productivities to be assessed and actual productivities to be compared, relative to a production ceiling set by the climate. However, it does not provide a framework in which the socio-economic and biophysical interactions of agriculture can easily be assessed. Most socio-political and some economic aspects of agriculture operate within a national legal and cultural framework, and evaluation must be made at that scale. In the case of smaller countries which fall entirely within one climatic zone this presents no problem, but in the case of India, China and Thailand agro-ecological zones have been aligned as closely as possible to administrative boundaries (footnote to Table 1).

Because most of the information which is reported by FAO is in the form of national tables, and because irrigation strongly influences the location and productivity of the agro-ecological zones which are defined for rainfed conditions the development of indicators by AEZs is difficult to achieve. If statistics were collected and **reported in a locationally defined manner** and at the scale of AEZs, then the use of indicators by AEZs would be suited to monitoring sustainability.

TABLE 1. AGRO-ECOLOGICAL ZONES DESCRIPTIONS AND THE ASIAN REGIONAL AGRO-ECOLOGICAL ZONES NUMBERING AND LOCATION (from CGIAR 1992)

AEZ = Agro-ecological Zones; RAEZ = Regional Agro-ecological Zones

AEZ	Description	RAEZ	Location
1	Warm arid and semi-arid topics	8	*part* India, Thailand[1]
2	Warm subhumid tropics	9	Myanmar and *part* India[2], Sri Lanka, Thailand
3	Warm humid tropics	10	Bangladesh, Cambodia, Indonesia, Laos, Malaysia, Philippines, Vietnam and *part* Sri Lanka, Thailand
4	Cool tropics		
5	Warm arid and semi-arid subtropics, summer rainfall	11	Pakistan and *part* India, China[3]
6	Warm subhumid subtropics, summer rainfall	12	*part* India, China[4]
7	Warm/cool humid subtropics, summer rainfall	13	*part* China[5]
8	Cool subtropics, summer rainfall	14	Bhutan, Nepal, *part* China, India
9	Cool subtropics, winter rainfall		

Approximate correspondence with Provinces or States within countries

[1] *India:* Andhra Pradesh, Bihar (pt), Gujarat, Madhya Pradesh, Maharashtra, Tamil Nadu
Thailand: Chiang Mai, Chiang Rai, Lampang, Lamphun, Mae Hong Son, Nan, Phrae, Uttaradit

[2] *India:* Assam, Kerals, Manipur, Nagaland, Orissa, Tripura, West Bengal

[3] *India:* Haryana, Himachal Pradesh, Punjab, Rajasthan
China: Beijing, Hebei, Shandong, Tianjin

[4] *India:* Uttar Pradesh (pt)
China: Jiangsu, Henan

[5] *China:* Anhui, Fujian, Guandong, Guangxi, Hubei, Hunan, Jiangxi, Zhejiang

[6] *India:* Kashmir
China: Gansu, Guizhou, Heilongjiang, Jilin, Liaoning, Nei Mongol, Ningxia, Qinghai, Shaanxi, Shanxi, Sichuan, Xinjiang, Xizang, Yunnan

Here the aim is to develop generic indicators appropriate at the national to global scale within an agro-ecological framework. The scale at which various indicators operate most effectively is shown below.

Scales over which selected indicators operate

Scale	Type of Indicator							
	SNA	Land Qual.	Vegt. Cover	Agric. Prod.	Water Qual.	Land Use	Pop. Stats.	HDI
Global	**		**	**			**	**
AEZ		*	*	*	*?	*	*	*
National	***	*	**	***	**	**	***	***
RAEZ		**	**	**	***	**	*	*
Admin/Stat. Province	***	**	*	***	**	***	***	***

** = least appropriate, ** = moderate applicability, *** = most applicable scale*

SNA =System of National Accounts, HDI = Human Development Index.

When selecting indicators to reflect agricultural sustainability it is essential to know what such indicators will be used for, as there is a plethora of attributes to chose from, and many methodologies for information gathering and analysis. In this report the factors determining the selection of indicators include:

- precision required, which will depend on the attributes with the least reliable data sets;
- whether indicators are for planning, with feedback for management options or for public information and awareness;
- whether new information can be obtained, because benefit will justify cost, or indicators must be identified from existing bodies of information and statistics
- whether operational structures exist to process and analyse data sets to provide the interpretation of information into meaningful indicators.

B. Setting objectives for selecting indicators

This paper takes the Food and Agriculture Organization's principal objective, to relieve hunger and provide food security to the world's population through a variety of institutional, technical, educational and infrastructural programmes, as its objective for sustainable agriculture in Asia. Developing countries of Asia support 51% of the world population, and have managed to maintain food production for over three decades of increasing population growth at nearly 100% self sufficiency. This remains the most important criterion for sustainability of agriculture into the future, given the limitations to future expansion in agricultural lands on the continent and the predicted continued growth in Asian populations (Table 2).

In addition to the continuing imperative of providing sufficient food for their own populations, countries in the

TABLE 2. ANNUAL RATES OF CHANGE IN POPULATION, FOOD PRODUCTION AND AREA UNDER AGRICULTURE 1980-90 (FAO 1992)

Country	Population size			Index of food production*			Agricultural land area		
	1980	1990	% change	1978-80	1988-90	% change	1980	1990	% change
China	996134	1139058	1.4%	97	149	5.2%	100407	96563	-0.4%
India	688856	853094	2.4%	98	144	4.6%	168255	169080	0.0%
Indonesia	150958	184283	2.2%	93	153	6.0%	19550	22000	1.3%
Pakistan	85299	122626	4.4%	95	144	4.9%	20300	20750	0.2%
Myanmar	33821	41675	2.3%	95	122	2.7%	10022	10069	0.0%
Thailand	46718	55702	1.9%	98	124	2.6%	18298	22140	2.1%
Malaysia	13763	17891	3.0%	92	196	10.4%	4800	4880	0.2%
Vietnam	53700	66693	2.4%	94	145	5.1%	6418	6600	0.3%
Philippines	48317	62413	2.9%	96	109	1.3%	7801	7970	0.2%
Laos	3205	4139	2.9%	88	151	6.3%	880	911	0.4%
Cambodia	6400	8246	2.9%	106	203	9.7%	3046	3056	0.0%
Nepal	14858	19143	2.9%	98	141	4.3%	2319	2653	1.4%
Bangladesh	88219	115593	3.1%	99	123	2.4%	9158	9126	-0.0%
Sri Lanka	14819	17217	1.6%	95	101	0.6%	1873	1900	0.1%
Bhutan	1245	1516	2.2%	98	100	0.2%	122	132	0.8%
TOTAL	2246312	2709289	2.1%	96	140	4.4%	373249	377830	0.1%

* *Statistics form WRI 1992. Index is based on production figures for 1979-81 = 100*

region must also attempt to ensure that agricultural expansion, both in productivity and area, does not cause adverse impacts on other sectors of the economy, lead to deterioration in population welfare or cause irreversible environmental damage. Such off-site threats can be more costly than any immediate benefits deriving from agricultural productivity if they result in long-term rehabilitation costs. Increasing criticism on the adverse effects of past aid agriculture and development aid projects (George 1988, Pearce 1991) has strengthened the need for including the off-site effects in any assessment of agricultural sustainability (Australian Agricultural Council, 1991, Hamblin *et al.* 1993).

C. Methodology

To develop indicators appropriate at national to international scale, this study has principally used existing statistical data. The main sources of information were FAO, United Nations Development Programme (UNDP 1991-1993), Consultative Group on International Agricultural Research (CGIAR 1992), World Resources Institute (WRI, ArcWorld database, 1991, and WRI, 1992) and various World Bank publications.

Additional information on natural resource condition, crop production systems, plant pathology, sustainable and unsustainable practices and national policies was obtained from published literature, all in English and mainly from international publications. However, awealth of less formal information exists in published literature of each country (especially in China and India) most of which is poorly accessible to an international audience, while the knowledge base of experienced professionals, farmers and local administrators is not tapped by dependence on regularly gathered official statistics. Indicators that utilise this type of informal knowledge can have a precision and relevance of greater merit at provincial and local level lacking in the aggregated data sets available through conventional international sources.

Eco-regional aggregated statistics relating to land area, agricultural land and production and population and other land uses were available through CGIAR and FAO publications. For example, Table 4 presents statistics extracted at the level of RAEZs (CGIAR, 1992) and the same statistics are given in Table 3 by countries (FAO 1992). When more than one RAEZ occurs within a national boundary disaggregated statistics from provincial administrative districts were used where possible. However, many statistics are readily obtainable only at country level, particularly those relating to GNP, demographic components, urban-rural attributes and environmental statistics relating to water and vegetation (WRI, UNDP and World Bank), and analysis of these by RAEZ was not possible.

TABLE 3. AREA OF ARABLE LAND, CEREAL FOOD PRODUCTION (tons/ha) AND HECTARES OF ARABLE LAND RELATIVE TO TOTAL POPULATION IN EACH COUNTRY (1990 data from FAO 1992)

Country	Arable land		% arable	Food prod.	Population	Hectares
	'000	% total	irrigated	per ha	'000	per caput
China	96563	10%	50%	4.18	1139058	0.08
India	169080	57%	25%	1.15	853094	0.20
Indonesia	22000	12%	35%	2.36	184283	0.12
Pakistan	20750	27%	80%	1.01	122626	0.17
Myanmar	10069	15%	10%	1.43	41675	0.24
Thailand	22140	43%	19%	0.96	55702	0.40
Malaysia	4880	15%	7%	0.35	17891	0.27
Vietnam	6600	20%	28%	3.02	66693	0.10
Philippines	7970	27%	20%	1.78	62413	0.13
Laos	911	4%	13%	1.71	4139	0.22
Cambodia	3056	17%	3%	0.84	8246	0.37
Nepal	2653	19%	38%	2.20	19143	0.14
Bangladesh	9126	70%	32%	3.04	115593	0.08
Sri Lanka	1900	29%	27%	1.36	17217	0.11
Bhutan	132	3%	26%	0.80	1516	0.09
TOTAL	377830	21%	34%	2.07	2709289	0.14

TABLE 4. AREA OF ARABLE LAND, FOOD PRODUCTION (tons/ha) AND HECTARES OF ARABLE LAND RELATIVE TO TOTAL POPULATION IN EACH AEZ in 1990 (data from CGIAR 1992)

Agro-ecological Zone	Arable land		% arable	Food prod.	Population	Hectares
	'000	% total	irrigated	per ha	'000	per caput
1 Warm semiarid & arid tropics	85,900	58%	26%	1.32	466,200	0.18
2 Warm subhumid tropics	40,500	22%	19%	1.71	228,900	0.18
3 Warm humid tropics	45,000	12%	32%	2.77	474,500	0.09
5 Warm semiarid & arid subtropics	106,000	59%	41%	1.11	456,600	0.23
6 Warm subhumid subtropics	32,500	61%	31%	1.67	212,900	0.15
7 Warm/cool humid subtropics	78,400	53%	29%	1.76	485,900	0.16
8 Cool subtropics	74,200	8%	21%	1.56	414,700	0.18
TOTAL	462,500	23%	29%	1.58	2,739,700	0.17

Note: figures are for area of arable land rather than land under agriculture since data given for the latter exceeded the total land area in two of the zones.

D. Why use indicators?

The word "indicator" can be used in a number of ways:

- as a simple measure of performance (volumes or values of production)
- as an index derived from computed formulae, with a number of attributes which are known or assumed to be related functionally (as with the Consumer Price Index, or the Southern Oscillation Index (El Nino)
- as a symptom of response (generally a syndrome of responses) to a stressor (as with human body temperature rising with disease infection)

In all cases indicators are used because they allow complex systems to be evaluated or monitored more easily than can be achieved by assessing the total number of components which make up the system. If the relationship between the indicator and the full interactions of the system is not known or is inconsistent, the indicator has been poorly selected. "Profit" does not equate with "quality of life", nor does "decline in yield" necessarily reflect "soil erosion". Thus while traditional economic indicators of agricultural performance have been confined to systems of profitability based on the national accounts, natural resource accounting has emerged in recent years as a necessary adjunct (OECD, 1987, World Bank, 1992). However, as yet few countries are collecting statistics on natural resources in a systematic manner or on a regular basis. At national and international level the World Resources Institute (1993) has made the greatest progress towards systematic collection of statistics on natural resources.

As resource-base data sets are often insufficient to develop reliable indicators and trends in themselves, current indicators of agricultural land status must often rely on surrogates or proxies (World Resources Institute 1992, Hamblin *et al*, 1993). Existing research results on processes and mechanisms linking land use and farming practice to environmental condition may provide the necessary estimates and inferences of effects of farming systems.

II. Issues and indicators of sustainability of Asian agro-ecological zones and agricultural systems

A. Conceptual framework

All experience in developing indicators for sustainable agriculture at international to regional scales has shown the wisdom of establishing a framework of categories in which indicators operate. This has been clearly demonstrated for Australia and New Zealand (Australian Agricultural Council 1991), Canada, (Environment Canada, 1992), the USA (Hunsaker and Carpenter, 1990) and the Netherlands (Kluik and Verbruggen, 1991), and in the attempts to develop land and water indicators internationally (IBSRAM 1991, 1993; CABI, 1993).

Existing frameworks include operational, ecological, issue-based and criteria-based examples. For the needs of FAO at the regional scale of AEZs a statistical framework that is criteria-based is most appropriate (NZ Bureau of Statistics, 1988). The framework chosen here is based on that developed for Australia and New Zealand (Hamblin *et al* 1993) which relies on gathered statistical data sets and published environmental studies.

Agricultural indicators should cover the following aspects:

- inter-sectoral economic interactions (agriculture to other sectors of the economy)
- human resources (labour force, social constructs)
- productivity (either in monetary, energy or material units)
- natural resource base quality (land, water, air and biota)
- off-site physical impacts (on other land-users and uses)
- off-site social impacts (rural-urban effects)

B. Agricultural sector and population in Asian economies

In Asia, the issues which face medium and low income countries need to be distinguished from those facing the high income countries (classified as having a Gross National Product (GNP)/capita of more than $US 7,620 in 1990 dollars, World Bank, 1992) or $US 6,000 (UNDP 1992). In this report the rapidly developing economies of Taiwan, Korea and Singapore and the high income economy of Japan are excluded, as their agricultural sustainability problems are similar to those of other industrialised economies where high use of inputs in protected and distorted markets are causing major pollution problems.

In medium and low income countries the main goals are - **increasing productivity to provide food security and raise overall GNP/ capita**.

Economic needs

The role of agriculture in economic development has been considered central to most policy theories in the post-Second World War era. Industrialised economies are often taken as the model for economic development, where the pre-industrial society was mainly agricultural and relied on traditional production methods. The theory states that excess produce, resulting from advances in technology and from investment, generates sufficient income for industrial and structural development, with a gradual shift of population out of agriculture and into other sectors, while the proportion of GNP contributed by agriculture decreases (Lecaillon *et al.*, 1987, Tribe 1991).

Population pressure

This economic model may be valid for developing countries which do not have severe constraints to physical or economic productivity, either through population pressure, debt burdens or distorted market prices. However, these constraints have had severe effects on the ability of many developing countries to overcome the poverty trap in the last three decades. Where densely populated rural environments already exist, and populations are still increasing, there are social pressures which will affect agricultural sustainability in future.

High, though decelerating, rates of population

growth are still a characteristic of most of the countries in the region. Figure 1 shows the decadal change in population size for four of the most heavily populated countries in the region. Also shown is their basic agricultural status; while their agricultural area has hardly changed food production has risen in each by over 3%. The situation is most vulnerable for Bangladesh and Pakistan where population size is still increasing rapidly. Agricultural land pressure is evidenced by the reduction in amount of agricultural land per capita in the past two decades, and by the fact that, although the proportion of populations in rural environments has everywhere reduced since the 1970s, the absolute numbers have risen by an average of 10.2% (FAO, RAPA, 1992). A simple statistic such as arable land per capita does not tell us much about the sustainaiblity of an agricultural region, however.

A: the index of per capita food production: A more relevant indicator of the influence of population on land pressure is the index of per capita food production (FAO 1990). This index takes 1970 = 100 and traces the food production per capita for each year (integrating all crops grown between January and December). The centrally planned economies (China, Laos, Cambodia, Vietnam, Mongolia and North Korea) have had an average index rising from 120 to 160 over the 1980-90 decade; the rest of mainland Asia had an index which rose from 116 to 140 in the same period.

Agriculture's place in the economy

The negative effect of high population growth on agricultural sustainability can be demonstrated in many ways from the increased burden placed on distribution of basic health and education services to reducing the material wealth available for distribution. Sustainable agriculture will depend in many cases on improving the income distribution into the poorest sectors of rural society and in providing cash income to landless labourers and women (Anand and Ravallion 1993).

B: the proportion of rural population with off-farm (or cash) income is therefore a significant indicator for the sustainability of rural populations which are principally dependent on agriculture. At its most extreme this can be demonstrated in times of drought and food shortage. In India famines have been averted in the post-war period by government intervention to provide paid work to the poorest (landless) labourers during periods of acute food shortage for public works. This has provided them with purchasing power for foods which have then flowed into drought stricken areas in response to the prices people are willing to pay. Government intervention in India has also put a cap on upward movement of prices and has regulated distribution of food in periods of acute shortage (Sen 1981).

C: % of GNP contributed by agriculture is the sec-

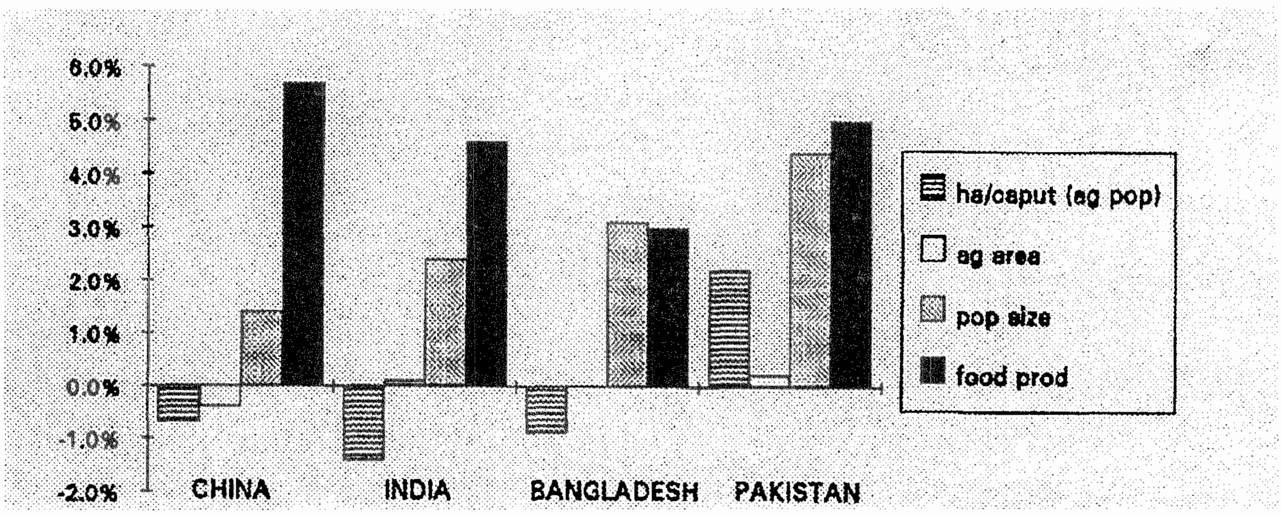

FIGURE 1. PERCENTAGE CHANGES IN DEMOGRAPHIC STATISTICS FOR FOUR COUNTRIES IN ASIA OVER THE LAST DECADE

ond significant indicator of overall sustainability. In many developing countries the debt burden from high interest rate loans has increased during the past decade (UNDP, 1992), and donor pressure on repayments has required an increasing proportion of production to go into cash crops for revenue generation.

Declining terms of trade have affected agriculture all over the world, but in high income economies, such as Australia, also in the region, with traditional reliance on rural commodities for exports, only 4% of GNP was in rural industries in 1990 (a drop from 9% in 1965), the export share having dropped from 73 to 29%. Thus the reliance on the sector to provide economic growth or recovery is less.

Loan repayments to foreign creditors have increased in the period 1970-90 for most countries. In those countries heavily dependent on agriculture for wealth creation the degree of indebtedness is the most serious concern for long-term agricultural sustainability, as much of the increased wealth generated from agriculture is spent in debt servicing. Despite no official figures for Cambodia, Laos, Vietnam and Myanmar these are poor countries with a majority of their populations based in agriculture, and should be considered in the same light as others with over 30% of their GNP in agriculture (Table 5).

Financial and food self-sufficiency

D: the relative importance of food : income-generating capacities of agriculture differs between countries depending on financial situation and national priorities, and hence the significance placed on food self-sufficiency relative to other sectors' economic growth and trading power. The critical question is whether different government or lending policies affect the degree to which generic indicators realistically reflect agricultural sustainability. Many studies have demonstrated the gains in efficiency which will flow from reducing subsidies and price support in OECD countries (Faeth *et al* 1991), the pressure on indebted countries to generate foreign income by substituting cash crops for food crops has also been widely criticised as unsustainable (Conway and Barbier 1991, George 1988).

TABLE 5. AGRICULTURE IN THE ECONOMY: TOTAL DEBT, DEBT SERVICING AND TERMS OF TRADE FOR ASIAN COUNTRIES IN 1990. (WORLD BANK 1992)

Country	Agric.as % GNP		Debt % of	Debt service ratio (%)		Terms of	ODA'*	Agric. % Exports	
	1965	1990	GNP	1970	1990	Trade	of GNP	1965	1990
Bangladesh	53	38	54	-	25.4	95	9.5	(85)#	25
Bhutan	-	43	32	-	6.8	-	18.3	-	-
Cambodia	-	-	-	-	-	-	0.7?	99	-
China	38	27	14	-	10.3	111	0.5	20	16
India	44	31	25	22.2	28.8	96	4.5	41	19
Indonesia	(51)	22	66	7.0	30.9	111	1.7	53	16
Laos	-	-	123	-	12.1	-	20.1	32	-
Malaysia	28	n.a.	48	3.8	11.0	94	1.1	60	37
Myanmar	-	-	-	-	-	127	-	94	93
Nepal	65	60	53	3.2	18.2	-	20	-	25
Pakistan	40	26	52	23.8	22.8	95	9.8	62	29
Philippines	26	22	69	7.5	21.2	93	2.8	84	26
Sri Lanka	28	26	73	11.0	13.8	90	8.1	99	47
Thailand	32	12	33	3.3	17.2	99	0.9	86	34
Vietnam	-	-	-	-	-	-	0.3	-	-

'ODA = Official development assistance received. # = East Pakistan in 1965. ! Terms of trade: 1987 = 100

BOX 1: POLITICAL REGIMES, NATIONAL GOALS AGRICULTURAL PERFORMANCE

Compare China and India. These are the two largest, agriculturally-based societies in Asia. In both governments have striven to increase food production in the post-war era, but with very different strategies. India rapidly adopted western technologies and research patterns, but retained traditional systems of land tenure and social organization. China's centralized government control and collectivization dominated that country till the late 1970s after which a market-dominated economy increasingly affected all aspects of society. Both countries have however, increased their food-crop production between 2 and 3% per year over the past decade (UNDP, 1992). Their radically differing approaches and social organization have apparently had little effect on aggregated production indices. In contrast, their political systems have had an effect on the incidence of famine. In 1967, 1973, 1979 and 1987 failure of the monsoon created severe food shortages in parts of India but famines were forestalled by government intervention. In China severe famines occurred between 1958 and 1961 with the failure of the Great Leap Forward agricultural programme (Sen 1981).

International and national policies

In Appendix 2 key words describing each country's policies and goals have been listed from a literature scan (CABI 1992). There is a marked consistency in them; the three most common stated issues being **food self-sufficiency, pricing interventions and poverty alleviation.**

E: degree of food self sufficiency is therefore included, as the goal of many countries is to achieve 100% or more, but it should be remembered that increasing overall GNP and purchasing power can substitute for self-sufficiency, and has been achieved in some of the rapid-growth economies of Asia. International organisations with mandates to alleviate hunger and poverty, have different objectives from countries whose policies do not include measures to improve equity of land and income distribution (eg, Myanmar, Nepal, Bhutan).

Indicators B, C, D, and E assess the relative importance of the agricultural sector to a total economy, and a country's dependence on it for income. Where a country is heavily reliant on agriculture, not only to feed a rapidly growing population, but also to provide income for debt servicing, and the for the growth of the whole economy, there is little resilience or flexibility. Natural stresses (droughts, floods) or commodity price drops may flow through into large scale pressure on rural populations and their agricultural environment.

Intra-generational and inter-generational equity are explicit targets of sustainability. Equity may be political (democratic freedom), economic (distribution of material benefit) or social (non-discriminatory to age, race, gender, class). Recently the UNDP has produced a Human Development Index (HDI). These reports describe the attempts to measure some of these aspects of equity. The index identifies the basic needs of health, education, water supply, food, sanitation and housing (Hicks and Streeton, 1979), and assesses disparities between high and low income countries, urban-rural populations and gender. Those indices which address the rural-urban and gender disparities are significant to agricultural sustainability and should become an integral part of FAO's system of agricultural statistics and regular reporting procedure.

Equity of property rights is not simple. Figure 2 shows how the relationships between communal, State and private ownership of natural resources operate, with different resources regarded having varying levels of common access for use. Box 2 explores the question of land ownership, and whether ownership is an important aspect of sustainability.

Education, health and welfare

Populations do not have to be rich to be literate, or to have access to information and choice. The effect of education, particularly on women, in rural areas is known to have striking effect on health, infant mortality and population growth rates. Improvements in access to sanitation, health care and education in rural areas have been substantial in some of the poorer Asian countries, such as Sri Lanka, as well as those with a higher economic standard. Studies on social conditions in Kerala (southern India) where the average GNP/ capita is only $US 270, (compared with India's average of $US 350), have shown that life expectancy in this predominantly rural province is now 70 years (compared to

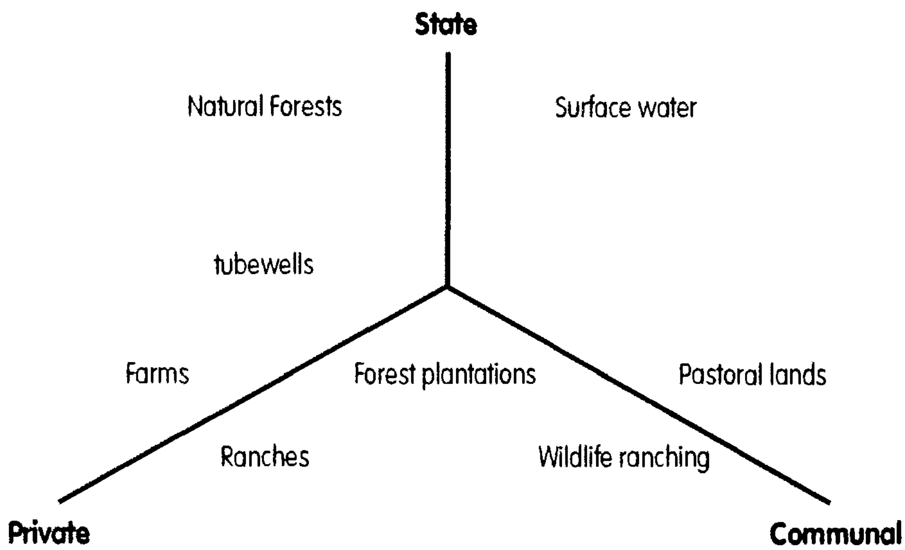

FIGURE 2. PROPERTY-RIGHTS ARRANGEMENTS (from World Bank 1992)

BOX 2: LAND VALUE, OWNERSHIP AND CARE

Inter-generational equity forms the basis to sustainability. It is also the ethic of tribal peoples to traditional lands. In settled agrarian societies land ownership is viewed as an essential condition to good management; security of tenure motivates farmers to maintain land for efficient production. Land tenure reform has been a central goal in aid schemes aimed at improving agricultural efficiency, based ont he notion that responsibility for the environment is related to ownership (World Bank 1991, 1992).

Landless rural poor and those deprived of rights of occupancy through development have, however become of increasing concern. Conflicts over land-rights are now common in countries where idigenous peoples have been displaced (WRI 1992). Displacement has occurred where common lands (forests, steep sloping woodlands and marshlands) were seen as vacant wastes, waiting to be "developed", as in Indonesia in the 1970s-80s..

The post-war development era has also seen an expansion of communal ownership of agricultural land in communist countries (China, Laos, Vietnam and Cambodia). Western economic theory has often equated low and variable produciton in socialist countries with lack of tenure and incentive. However, China has provided a marked exception both in agricultural performance and, more recently, market incentives.

How valid therefore is the argument that individual ownership is necessary for agricultural sustainability. While many different systems of tenure co-exist in Asia, UNDP (1992) identified five countries (Sri Lanka, Nepal, Pakistan, Philippines and Bangladesh) where inequity of ownership (by the Gini coefficient) was still very high.

The basic issue for each region is the size of land unit relative to the produciton capacity, food prices and population demand. These are as critical to the sustainability of the systems as the question of who actually owns the land. Where land is already degraded, population pressure high and food production fluctuates tenure becomes a powerful incentive to increased efficiency.

India's 60), the birth rate 20 per 1,000 (India's as a whole is 30/1,000) and ratio of women to men 1.05 (the biological norm), whereas in India as a whole it is 0.92 (Caldwell, 1986).

If agricultural sustainability increasingly depends upon improving productivity per unit area, increasing efficiency of inputs, managing more diverse and complex systems, and adopting research findings it will require an increasingly **literate** labour force with access to information. Table 6 lists some important indicators of social welfare. From these

F: % rural population, and rural : urban populations with access to education are critical indicators for agricultural sustainability. Overall, rural birth rates are affected by

G: % rural population with access to health and sanitation; this also determines the population pressure on land resources in many areas. Improved health of women and children is closely linked to reductions in the birth rate and improved life expectancy (WRI 1992).

In improving sustainable land management, professionals place considerable emphasis on particular forms of land and crop management. Integrated pest management is seen as the preferred option to using pesticides alone; reduced tillage and residue retention are preferred to clean cultivations. These practices require sophisticated management and farmers must acquire much new information, new skills and altered attitudes to implement them successfully. Extension of research information is the key strategy to adoption of these practices (Fujisaka, 1991), but unless investment is made at national level in research and extension there are few channels for international research findings (IBSRAM, 1991, Blair and Lefroy, 1991).

H: % GNP spent on research and extension is therefore a significant indicator of national commitment to sustainable agriculture.

C. Productivity

I: Productivity = all outputs / all inputs for each

TABLE 6. COMPARATIVE WELFARE STATUS OF RURAL AND URBAN SECTORS OF THE POPULATION AND GENDER DIFFERENCES IN LITERACY

Country	Human Development Index	% population in rural areas*	% population with access to						Adult literacy (total population)	
			Health care**		Water+		Sanitation+			
			Rural	Urban	Rural	Urban	Rural	Urban	Females	Males
China	0.57	67%	-	-	68%	87%	81%	100%	62%	84%
India	0.31	73%	-	-	73%	79%	4%	38%	34%	62%
Indonesia	0.52	69%	-	-	32%	65%	45%	40%	68%	84%
Pakistan	0.31	68%	50	100%	35%	84%	8%	56%	21%	47%
Myanmar	0.39	75%	-	100%	29%	43%	34%	30%	72%	89%
Thailand	0.72	77%	-	-	85%	67%	86%	84%	90%	96%
Malaysia	0.79	57%	-	-	66%	96%	94%	94%	70%	87%
Vietnam	0.47	78%	75%	100%	33%	70%	55%	48%	84%	92%
Philippines	0.60	57%	-	-	72%	93%	63%	79%	90%	90%
Laos	0.25	81%	-	-	25%	47%	8%	30%	-	-
Cambodia	0.19	88%	50%	80%	-	10%	-	-	22%	48%
Nepal	0.17	90%	-	-	34%	66%	3%	34%	13%	38%
Bangladesh	0.19	84%	-	-	-	39%	4%	40%	22%	47%
Sri Lanka	0.66	79%	-	-	55%	80%	45%	68%	84%	93%
Bhutan	0.15	95%	-	-	30%	60%	7%	80%	25%	51%

Sources: * *UNDP 1992 (definition of rural and urban varies with country)*
** *UNICEF (quoted in UNDP 1992, WRI 1992)*
+ *WHO 1985 (quoted in UNDP 1992, WRI 1992)*

production system in a cash economy, expressed in monetary units (conventionally $US) normalised to some past date as a baseline where comparisons of trends are being made. Productivity can be measured on a farm, district, statistical division or whole country basis, and, because the output is in monetary units, it has a general applicability which has substantial appeal.

Productivity growth is conventionally used as the basis to economic well-being at a national level. Some of the highest national rates of growth during the 1980-90s have been recorded in Asia (China, Indonesia, India, Thailand and Pakistan have all been over 5% for the past decade), although Repetto et al (1989) and others have pointed out that these figures do not include any natural resource accounting related to permanent destruction of forest, soil and water assets, nor do they include defensive expenditures for protection against loss of resources.

The productivity function method of analysis fails to take into consideration subsistence economies however, where many operations and transactions are in-kind, and where assessment of monetary value of production is unreliable (O'Brien, 1991). If excess production occurs in a subsistence sector of a country with a cash economy there will be an *increase* in cash flows as this extra production comes into markets. However, where subsistence production is *insufficient* for consumer needs, while the deterioration in food consumption per capita reflected in total calorie intake, food compositional decline and periods of shortage, malnutrition and starvation, it will not be detected in the productivity function.

National GNP/capita figures are not a good measure of rural productivity, although it is frequently presented in international statistics of overall economic performance. GNPs are frequently calculated on a national basis and aggregated by sector. However, per capita values for a sector are not derived from gathered statistics, but from GNP relative to rural-urban population figures.

As a convenient measure of production change over time FAO has used

J: Production indices = weight of all crop + livestock production/ country, relative to a nominated baseline (eg: 1979-81 averaged as the base value (= 100). [1]

Agronomists and extension workers are most familiar with using

K: Yield (biological productivity) = weight of harvested product / land area / year together with measures of **variance from long-term averages** of yield as the most immediate indicator of agricultural performance over time. Yields which are actually measured, by cutting known areas of crop and weighing the product are the most reliable statistics available (Colfer 1991).

When related to area in production and demographic indicators such as population growth and per capita food production, this attribute of agricultural production is regarded as a clear indicator of the sustainability. Concerns expressed over future food supplies frequently start from examination of yield trends. Recent discussion papers (Singh, 1992, de Datta et al 1984, CGIAR 1992) have shown a preoccupation with possible or current indications of declining yield trends in central grain-bowls of Asia. Figure 3 shows yield for the four most densely populated countries dependent on irrigated rice and wheat.

Yet despite the static or declining area of irrigated land per capita in each country, there has been an overall 4.5% increase annually in food production (Figure 1). While yield trends rise relative to population the assumption is made that agriculture is sustainable. When yield trends decline the interpretation is made that agricultural sustainability is threatened (as may be happening for rice in Pakistan). How correct are these assumptions?

D. Interpretation of yield and production indicators

Yield trends cannot be clearly interpreted without much supporting evidence to interpret the reasons for changes. Moreover, aggregated yield figures used at national to

---

1 *Statistics on production variables that are used internationally by FAO, the CGIAR, World Bank and other UN organizations are derived from FAO tapes of population and production statistics, to obtain per capita cereal production, cereal production yields and growth rates and area under production (CIMMYT, 1989, World Bank, 1992). The uncritical use and repeated requoting of unsubstantiated or dubious data has often led to the gradual aura of "respectability" around such data according to Biswas (1992).*

eco-regional scale tend to smooth out the significant variations which are related to changes in land and water quality (Hamblin and Kyneur, 1993). Among the factors commonly influencing yield which require consideration are

- price support systems
- world price variations
- social conditions (changes of government, adoption patterns, etc)
- seasonal climate fluctuations
- pest and disease epidemics (both crop and people)
- changes to resource base status
- changes in technology (germplasm, rotation, mechanisation, cultural practices, irrigation)

Few studies on yield trends consider all these factors, and in many cases it is not possible to identify the relative effect of each factor by formal multi-variate analysis. However, studies in the Punjab (Byerlee et al 1987, Byerlee 1987, CIMMYT 1989) and in China (CIMMYT 1989) provide interesting analyses of the positive and negative technical effects on wheat yield trends in these areas. While the effects of technical input can be quantified (as shown in Box 3) the social and policy effects are more difficult to quantify. Government price stabilisation, purchasing and loan schemes, socialist versus free market community structures and other policy factors can be either negative or positive in effect on yield increase (OECD 1987). Nevertheless the ratio of the physical inputs to outputs over time have been used to assess whether production trends are more or less sustainable.

In the late 1980s the rate of wheat yield increase in Pakistan declined relative to the rate of inputs, such as fertilizers, mechanisation (tractors), and extent of irrigated land (Figure 3). Although salt and waterlogging have been recognised as a significant constraint to agricultural production in Pakistan for at least fifty years, and despite the undisputed importance of drainage and improving water use efficiency to the 3.1 million ha affected (that is, some 20% of all irrigated land), adaptive research and actual implementation have been persistently neglected until recently (World Bank, Operations Evaluations Department 1989). Instead research on production constraints has focussed largely on crop improvement and management.

With irrigated land accounting for 80% of all agricultural lands in Pakistan and wheat accounting for two thirds of the food crops produced, the reduction in wheat yields which may be resulting from salinity, sodicity and combinations of these two with periodic waterlogging may be suppressing yield performance to a far greater extent than in countries which are rice-based, because of the relative salinity tolerance of rice compared with wheat (Abrol and Gupta, 1991). Control of waterlogging-salinity effects will have

BOX 3: POSITIVE AND NEGATIVE EFFECTS ON WHEAT YIELD IN THE PUNJAB, 1972-86 & 1988-91

Byerlee et al (1987)		*(Computed: FAO statistics)*	
Positive Components:	**1972-86**	**Yield change (kg ha^{-1} y^{-1})**	**1988-91**
Semi-dwarf varieties 9		Increased fertilizer 90 kg ha^{-1} and + 1 % increase in area of land cropped	25
• 32% area + increased fertilizer @ 40 kg ha^{-1}			
• on 67% area with newer semi-dwarfs and increase in fertilizer @ 73 kg ha^{-1}	+34		
Expected increase	+48		+25
Negative components:			
Reduction from av. 7 day delay in planting from increased cropping intensity	-13	Decreased yields from salinity and waterlogging (30% of expected yield - Yadav, 1989)	-7
Increased weed and disease losses	-3		
Soil salinity and waterlogging losses	-6		
Actual increases	26 kg ha^{-1} y^{-1}		18 kg $ha^{-1}y^{-1}$

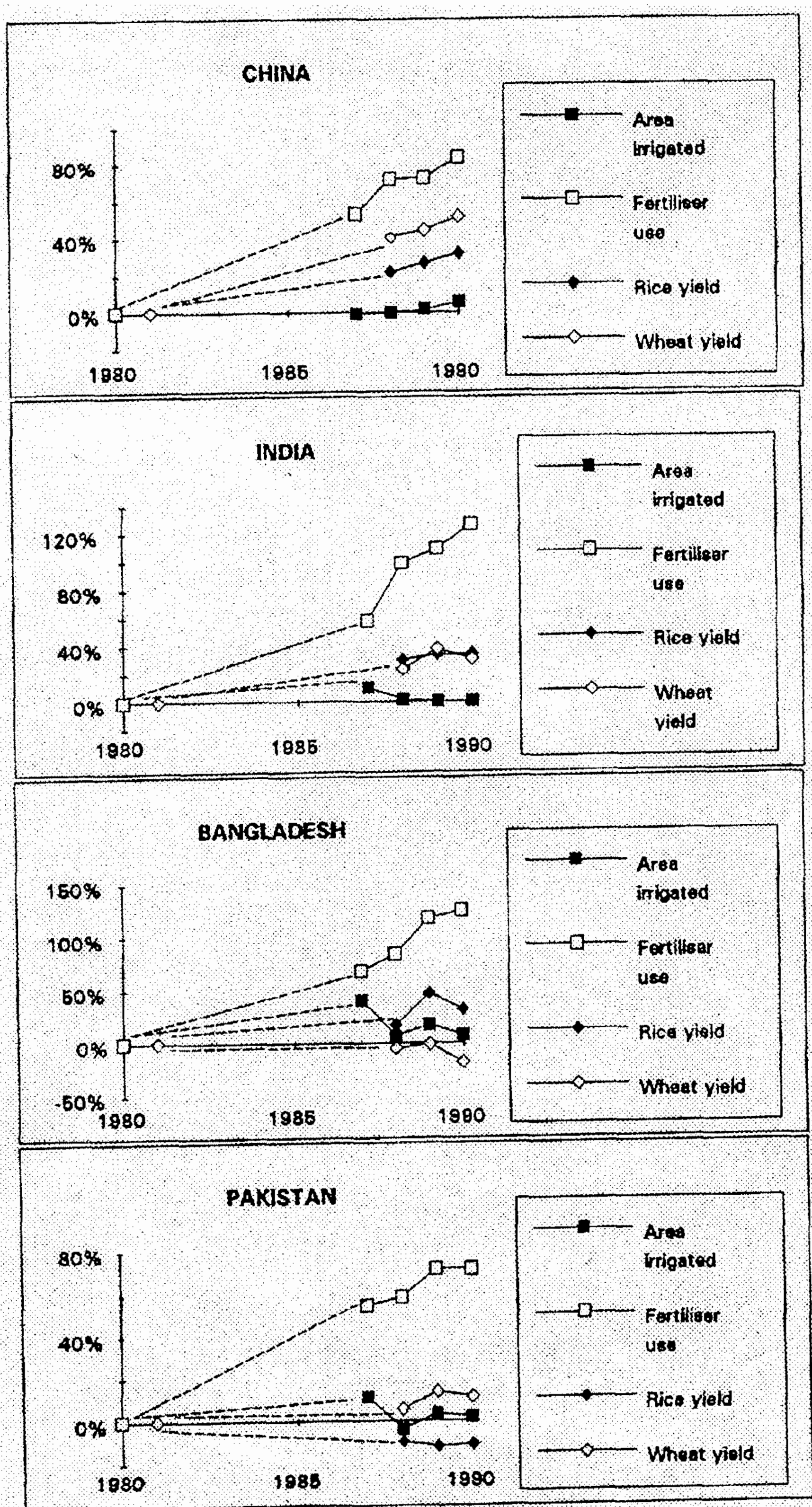

FIGURE 3. PERCENTAGE CHANGES IN AGRICULTURAL STATISTICS BETWEEN 1980 AND 1990 FOR FOUR COUNTRIES IN ASIA

larger effects than agronomic improvements in many cases.

While expansion of agricultural area and introduction of new production technologies have been largely responsible for increasing agricultural production during the 1960-80s in most of Asia, there is a general consensus that future increases in production must come from intensification and diversification of existing farming systems and land areas (Singh 1992, FAO 1989, IBSRAM 1991). Strategies for improved productivity include

- increasing the efficiency of inputs (fertilizers, pesticides, irrigation, tillage)
- price signals which promote increased efficiency of production
- rotations, relay and multiple cropping
- integrated pest, disease and weed control
- raising the level of production of all farmers, not just the top 20%

Many of these are predicated on improvements in education and extension. Thus Human Development Indices of levels of education, access to education and training and the status of rural women are valid indicators in conjunction with changes in management practices.

E. Efficiency

L: Benefit cost analyses of changes in technology: is an extension of the physical input: output analysis shown in Box 3, but uses financial accounting of the relative gain from each increment in changing farming practice and its effect on productivity growth. Such analyses may be best handled as case studies for different farming systems or agro-ecological regions. In Asia the benefits from high yielding rice and wheat varieties have been studied in detail by the International Rice Research Institute. Techniques for partitioning and weighting each of the factors associated with incremental improvements in crop production have been developed (Gomez and Abejuela 1991). However, these assessments have not always included the long-term site costs or off-site costs from practices such as irrigation.

M: Efficiency Indicator: (- ratio of physical inputs : outputs) There is a substantial scientific literature and many studies on the relative efficiency of fertilizer use, pesticide management, irrigation-water use and reduced tillage systems (FAO 1985, FAO 1992, IAEA 1991, Cornish and Pratley 1987). In nearly all agricultural systems which depend on increased inputs there is substantial inefficiency in their use. However, good quantitative estimates of the proportion of fertilizer nutrition and water taken up by crops relative to losses and transformations depends on sophisticated and detailed field research in specific conditions (Jirapornchareon et al, 1991, Swatdee et al 1991, Weller et al, 1984).

BOX 4: IRRIGATION WATER BALANCE IN KANDULIA, SRI LANKA, 1978-83 (Weller et al 1984)

A distributed canal system with two rice crops a year (wet and dry season).

Inputs: m³ x 10⁶		Season (5 year average) Wet	Dry
i.	Rainfall	47	12
ii	Total Irrigation	50	48
	(- land preparation	17	16)
	(- crop	33	32)
iii.	Total input	97	60
Outputs:			
i.	Evaporation	20	17
ii.	Percolation	3	2
iii.	Crop transpir.	24	25
iv.	Canal losses	10	5
v.	Deep drainage	40	11
	Total	97	60
% Use by Crop		**25**	**42**
% Loss to drainage		42	18
% loss through canals		10	18
% loss to soil evaporation		22	22

A substantial loss of water through canals and deep percolation reduced the efficiency to less than 50%, even in the best situation. Too much irrigation water habitually went on land preparation. These data are representative of many canal systems in rice producing areas.

Considerable scope for improved efficiency of input use is possible in nearly all production systems (Box 4). Incentive for improving this efficiency comes not only for increased production demands and declining farmers' terms of trade, but from the environmental imperative to reduce water and soil degradation and pollution. The example in Box 4 shows, however, that a substantial field monitoring program may be needed to estimate the major parts of the water balance equation. Not all these parameters are readily available but canal schemes have sufficient data on issues and offtakes for an

N: Irrigation water-use efficiency ratio to be recommended as an important supplement to the Efficiency Indicator.

A common feature of improving agronomic management of one input or component in a farming system is that it leads to the expression of the next, most critical constraint (Figure 4). This is most clearly seen when, in drought-prone environments water stress is relieved by irrigation. Plant growth increases but is then constrained by nutrient deficit and weed competition. Adding larger amounts of fertilizers increases the biomass greatly with development of a humid microclimate ideal for pests and diseases. The management of canopy-related diseases and weed burdens thus becomes a central issue for higher input, large biomass crops (Ceccarelli et al 1992, CIMMYT 1992).

Nitrogen fertilizer management is one of the most difficult components in which to improve efficiency of use because of the wide variety of growing conditions, and biological and chemical transformations that nitrogen undergoes. Figure 5 shows the range of fertilizer application and response for field crops in Asia.

Improvements in efficiency can be achieved by selecting a form of fertilizer which will not be leached or volatilised too readily from the type of soil to which it is

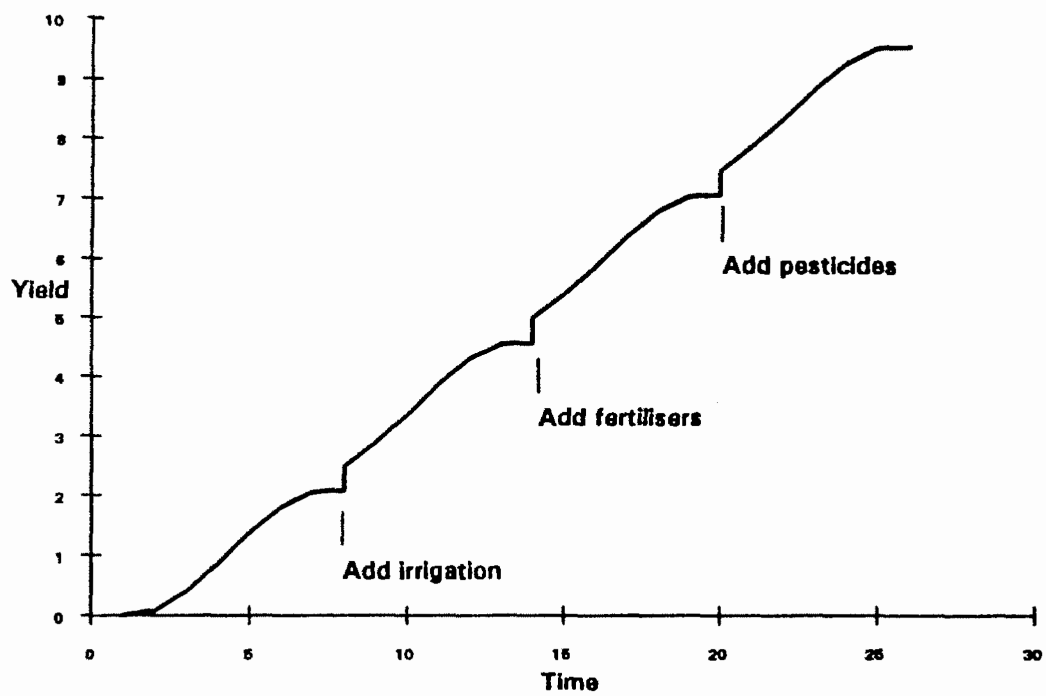

FIGURE 4. GAIN IN YIELD WITH EACH ADVANCE IN TECHNOLOGY

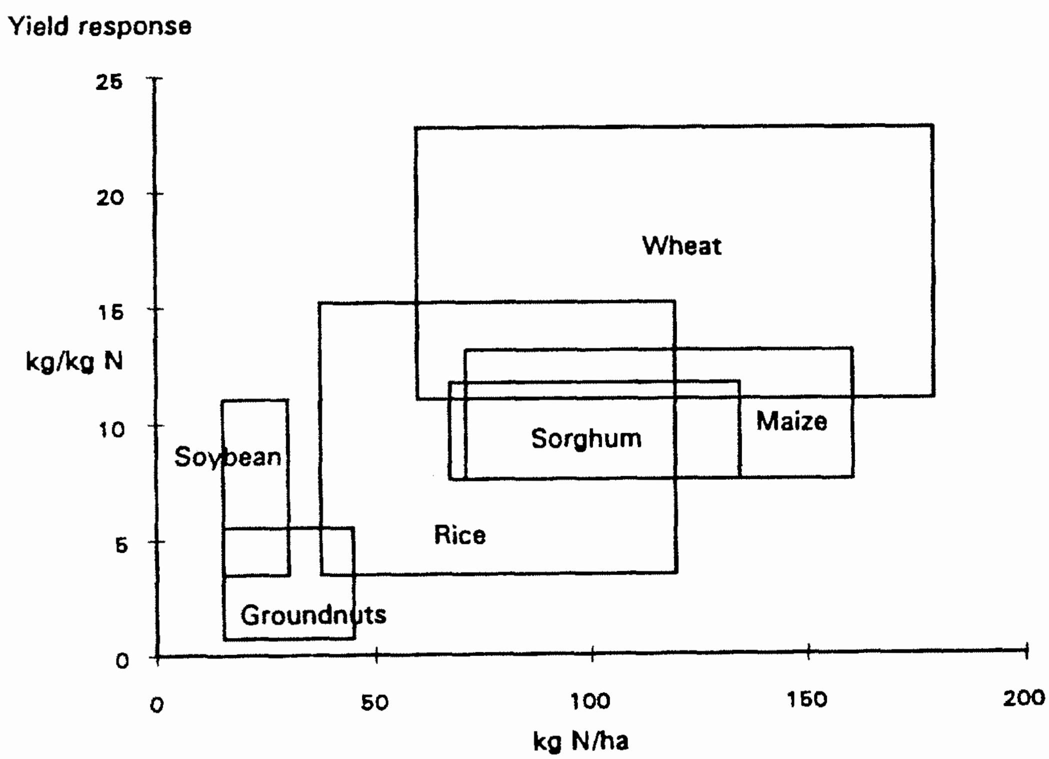

FIGURE 5. ENVELOP OF RESPONSE TO NITROGEN FERTILISER FOR VARIOUS CROPS IN EXPERIMENTAL PLOTS (from data in FAO 1987)

applied (for example, avoiding urea on alkaline clays at high temperatures, or nitrate salts on sands in humid regions). Deep placement, slow release coatings and use of N-fixing legumes in rotations are effective strategies for improving nitrogen use efficiency (IRRI 1991, Flinn and Mariano 1984). Nevertheless efficiency of nitrogen fertilizer uptake seldom exceeds 50%, and is often much less (Craswell and Godwin, 1984). Isotopic nitrogen tracer experiments provide the most conclusive evidence of the relative inefficiency of most forms of nitrogen fertilizer (IAEA 1991).

European countries with high input systems and wet climates are now troubled by accumulation of nitrate in ground and drinking waters, eutrophic waterways and acidifying soils and acid rain. In these countries fertilizer nutrients have been applied at rates 150 to 250 kg ha^{-1} [2] for the past twenty years (FAO 1987, FAO/IFA/IFDC 1992). Consumption in the United Kingdom has moved from 168 to 222

TABLE 7. FERTILIZER SUBSIDIES (FAO 1988) AND CONSUMPTION BY COUNTRIES (FAO/IFDC/IFA 1992)

Country	Subsidy	Price Control	$N+P_2O_5+K_2O$ Kg/ha	
			1972	1992
[Australia	No	Retail price	29	22]
Bangladesh	Farmgate price 90% of costs**	Retail price	20	71
Cambodia	n.a.	n.a.	1	0.4
China	n.a.	n.a	52	157 (262[3])
India	No, but farmgate price 70% of costs**	Statutory max.price fixed by govt.	17	75
Indonesia	Farmgate price 80% of costs**	Fixed by govt.	24	117*
Laos	n.a.	n.a.	0.2	0.6*
Malaysia	No	Retail price	53	150
Myanmar	n.a.	n.a.	5	7
Nepal	To farmers /transporters	Fixed by govt.	5	22
Pakistan	To farmers, transport and manufacturers	Fixed by govt.	25	107
Philippines	No	Retail price	27	35 (653)[3]
Sri Lanka	To importers farmgate price 60% costs**	Fixed by govt.	52	113
Thailand	No	Retail price	11	47
Vietnam	n.a.	n.a.	42	20 (62)[3]

** *World Bank 1992.*

3 *Figures in FAO Fertilizer Yearbook v.38 (1988) differing from those collected by FAO/IFDC/IFA 1992, which used many sources, including fertilizer companies and district agronomists.*

kg ha^{-1} and in Belgium from 200 to 240 kg ha^{-1}. If the increase in application rate in China, Malaysia and Indonesia continues, some farming systems and regions may face similar future problems (Table 7).

Identification of the point of diminishing returns should be part of any interpretation of the efficiency indicator (M) to determine the point where the cost of physical inputs exceeds the value of outputs (see Figure 6). Trying to increase yields when their value is less than that of fertilizer applied is unsustainable. An additional concern for long-term sustainability of annual cropping systems from the rapidly increasing amounts of artificial fertilizer applied is the decline in use of manures, organic wastes and suppression of nitrifying and phosphate fixing organisms (Parish 1993, Singh 1992, Kumazawa 1984, Kikuchi et al 1984). Such fertility management was effective in maintaining traditional farming systems in Asia.

O: % arable land receiving organic manures and legumes in rotations. This information is not collected in national statistics, but is obtained in the course of individual studies (Guar 1984, Blair and Lefroy 1989, ICRAF 1990). It is recommended that such data be collated through FAO and reported on a regular basis to assist interpretation of yield and fertilizer trends in FAO's own statistics.

A powerful strategy for improving efficiency is to **reduce subsidies on inputs**. This argument has been particularly strongly put in relation to irrigation water (Simmons et al, 1991, World Bank 1992). All countries subsidise irrigation water very considerably. The World Bank quotes values of direct water charges for China, Philippines, Indonesia, India and Bangladesh, in that order, being subsidised between 80 and 95% of operating and maintenance plus partial annualised capital costs.

Removing subsidies from agricultural inputs, while improving the efficiency of production, creates flow-on effects to consumer prices unless these are government controlled or subsidised in turn. Thus for countries which wish at the same time to increase food production and provide cheap food to the poorer parts of the community shifting from a highly protected agricultural sector to a competitive market sector is a lengthy process.

However, the negative environmental effects from over-use of agricultural inputs can become a larger-scale

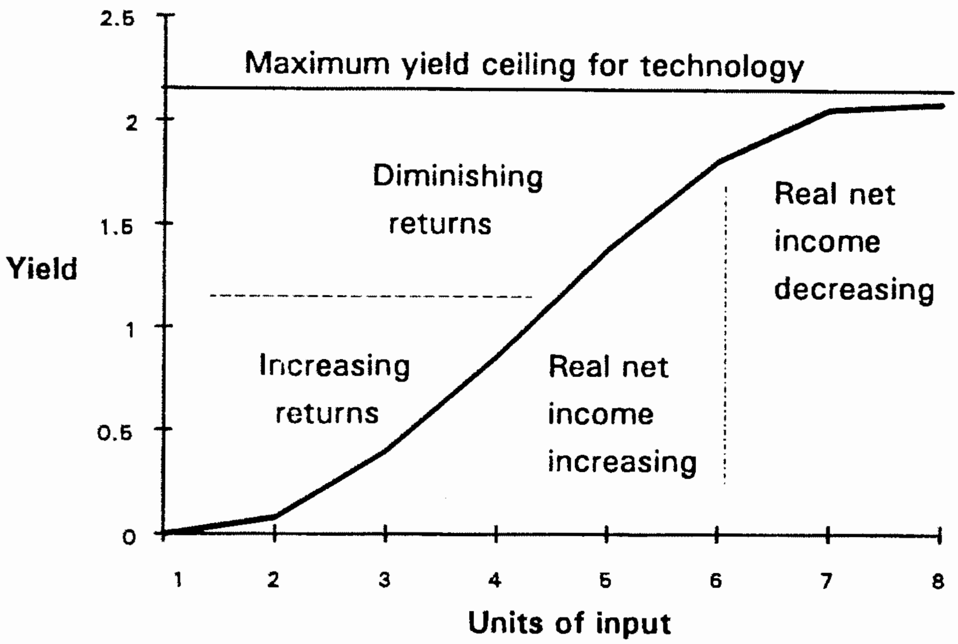

FIGURE 6. EFFECT OF INCREASING INPUTS ON YIELD. DEPENDING ON PRICE RECEIVED AND INPUT COSTS, THERE COMES A POINT WHERE INCREASING THE LEVEL OF INPUTS IS NOT PROFITABLE. THIS THRESHOLD OF MAXIMUM ECONOMIC RETURN INVARIABLY FALLS BELOW THE MAXIMUM YIELD CEILING.

problem over time than any immediate price support warrants, involving costly rehabilitation schemes. In a study which included evaluation of 102 of its irrigation projects, the World Bank (1989) found there had been resource damage to 23% of schemes in rainfed lands and in Pakistan all Bank irrigation projects in the past 15 years have been for rehabilitation of earlier projects.

F. Significance of irrigated food-crop production

The dependency of Asian countries on irrigated agriculture varies substantially; a decision-tree is proposed which can be used to aid the interpretation of production and environmental quality indicators for irrigated lands (Box 5).

P: Relative Dependency on Irrigation. Because irrigated lands are particularly vulnerable to long-term land and water quality deterioration the dependency level of food crop production on irrigation in Asia is of critical importance to agricultural sustainability. Table 5 shows the areas irrigated, and as a proportion of total arable land in Asian countries for the period 1980 - 1990. The dependency of food production on irrigation is already a critical issue in Pakistan, but with intensification of existing arable lands being the only feasible option for increased production in many parts of Asia, the degree of dependency on irrigation becomes ever more relevant in many areas.

BOX 5: DECISION TREE FOR ASSESSING THE IMPORTANCE OF CHANGES IN IRRIGATED LANDS TO AGRICULTURAL SUSTAINABILITY

Dependency on irrigated or rainfed cropping

>50% food from irrigation	50-10% food from irrigation	<10% food from irrigation
drainage and salt control highest priority	irrigated land condition as important as in rainfed lands	rainfed land condition highest priority
• Pakistan • Indonesia • Bangladesh	• Philippines • Thailand • China • Vietnam	• Malaysia • Myanmar • Cambodia • Laos • Nepal

Investment in irrigation (and hydro-electricity) has been very heavily supported by international donors and national governments in the post-war era. It has been seen as a means of simultaneously stabilising and increasing production, and reducing losses from flooding and irregular river flow. Between 1950 and 1990 the number of large dams over 15m height in the world increased sevenfold. Over half were in China,- 18,820 in all out of a total of 23,555 in Asia as a whole (WRI, 1992). This has been a major contributor to the increase in irrigated area of 20 million ha in China between 1960 and 1990, although the development of small scale irrigation systems dependent on tube-wells also expanded rapidly in the period 1971-90. Tube wells now account for 23% (11.2 million ha) of all irrigated land (People's Republic of China, 1987).

As well as the concern expressed about waterlogging, salinised and sodic soils in semi-arid and arid irrigation systems, there has been increasing concern over the life of dams and canals which feed supply irrigation systems in the humid tropics and subtropics. In these regions expected siltation rates of reservoirs and canal systems were often underestimated (Pearce, 1992).

Q: Siltation rate of reservoirs and main distributary canals is an important indicator of both the sustainability of irrigation systems and the erosion losses from surrounding watersheds, but separating natural from induced-erosion rates may not be possible (Box 6).

This attribute is suited as an estimate of the sustainability of central irrigation systems only.

BOX 6: SILTATION RATES IN RESERVOIRS CONSTRUCTED FOR IRRIGATION SCHEMES 1960-90

The Sanmenxia dam on the Yellow (Huanghue) River was built in 1960 to control flooding, provide hydroelectricity and irrigate lowlands. Four years later its storage capacity had been reduced to half by silt from the loess plateau. Extensive re-engineering now diverts silt through the original turbine housings. The 1.5 billion tonnes of silt which is annually transported from the Huanghue catchment results both from natural erosion, and two thousand years of agricultural activity on these fragile lands.

Under-estimation of rates of sedimentation in Asia has been a chronic failure of planners and funding agencies. Asia's large rivers drain the most geomorphologically active mountain system in the world, there high levels of erosion occur naturally because of monsoonal rains, large snow melts, landslips and unconsolidated materials.

The fate of many reservoirs constructed in the past thirty years in Asia has been similar. The Tarbela Dam on the Indus, one of two major dams supplying Pakistan has been silting at a rate of 2% per year since 1974. Such dams are generally planned to have a working life of 100 years. Many will be out of commission within half that time, with severe consequences for the sustainability of irrigation schemes.

Accelerated (induced) erosion has superimposed a very large additional load on the total sediment carried. Increasing severity of floods on the Brahmaputra and Ganges in Bangladesh may be related to deforestation in Assam, Nepal and Bhutan.

How much of the siltation results from accelerated, human induced erosion? This is not well established. Tributaries deforested or cleared for agriculture are seldom gauged because affected lands occur in remoter steep parts of basins, with little road or power development. Such deficiencies are clear in the late flood warnings for Bangladesh delta regions, which are still dependent on main river gauging stations. The link between clearing and flooding is well recognised however (Pearce, 1992). Disastrous floods in Thailand in the late 1980s led to a total ban on forest logging, after 25 years in which forests were reduced from 55 to 28% of land.

Note: silt now trapped in dams was a valuable source of nutrition to delta and lowland farmers in Myanmar, Bangladesh, China, India, and Pakistan. The Mekong flow varies by thirty-fold between the dry season and the monsoon, and natural floods spread silt over some 30,000 km2. Plans to dam the Mekong would affect soil fertility of this area.

G. On and off-site pollution aspects of agriculture

Indicators and surrogates for water and wind erosion have been the subject of substantial scientific discussion, because of the difficulties of distinguishing natural from accelerated forms, relating anthropogenic forms to specific land-uses, and correlating various types of soil loss to any changes in agricultural production.

Distinguishing the impact of agriculturally-induced erosion from that of deforestation is difficult as logging and attendant forest damage is often followed by shifting cultivation once forests are opened by the logging process (Rao, 1989). The best estimates are that some 30 million people are dependent on shifting cultivation in the region, with perhaps 75 million ha of forest affected, particularly in Kalimantan (Indonesia), Central States of India, central highlands of the Philippines and parts of Myanmar, northern Thailand and Bangladesh. In addition there are an unknown number of displaced people (Box 2) squatting in such areas. The best estimates which can be used to identify upland, deforested areas at risk are

R: % deforestation for agriculture, where this is the conversion of once shifting-cultivation (slash and burn, *ladang* forms) and squatting of landless poor on common lands (forested slopes and uplands)

A review of accelerated erosion in Asia notes that estimates of the extent of land degradation are poor, and a survey by FAO's Regional Office was unable to determine the extent to which land had gone out of production due to wind and water erosion (Dent 1989). There was a lack of clearly demonstrated relationship between such figures and any production data. Dent also pointed out that many small farmers show little interest in changing practices which are leading to land degradation. These observations pose some powerful questions for agricultural sustainability. Soil conservation is not an end in itself; if it cannot be tied to improved crop productivity, security of food supply and profit, few farmers are likely to employ more sustainable practices if they are not already part of their operations.

This survey, and that of Olderman *et al* (1990) for the GLASOD (Global Assessment of Soil Degradation, stored on Arcworld) project, estimate the areas of degraded lands, and have attempted (in the case of FAO) to provide some estimates of rehabilitated lands or (in the case of GLASOD) the relative severity and current versus historical nature of the degradation.

Table 8 provides a synopsis of the FAO survey, showing the high preponderance of water erosion, and the much smaller proportion of rehabilitated land to degraded land. However, the degraded lands include estimates of deforested regions which were cleared for timber, as well as from land pressure for shifting cultivation. A possible indicator for resource sustainability would be

S: ratio of area of land degraded (D) to land rehabilitated (R) - if this figure could be obtained with any degree of precision.

The need to demonstrate the link between land management and erosion holds for indicators of land degradation as well as for extension activities. If indicators cannot demonstrate the causal agents in erosion, and the effects of erosion on productivity they will have little credibility. This, and the problem of averaging soil types and slopes over large scales, are the major criticisms against the application of such methods of estimation of erosion as the Universal Soil Loss Equation (USLE). Productivity-erosion linked models are in use (Littleboy *et al* 1989, Biot 1989), but they often require large sets of input data and detailed information on local environments for application.

Tropical and subtropical landforms and soils have been developed under conditions of high temperature and rainfall, where the major differences in weathering and natural erosion processes relate to wet and dry seasonality. Distinguishing accelerated erosion lies in the ability to identify practices which remove vegetation cover during periods when soil will be exposed to the high intensities of wet season rainfall. These are the regions most affected by accelerated soil erosion .

In south-eastern Asia 70% of arable land is sloping, and 35% with slopes greater than 30% (Craswell and Pushparajah, 1991). The increasing pressure on marginal uplands (traditionally used for shifting cultivation and forest products) but for the past 2-3 decades cultivated nearly every year for grains or tubers often after initial clear-felling for timber, have low inherent fertility most of which was in a thin surface soil now lost to oxidation and erosion. Monitoring the amount of soil loss is not, Dent (1989) suggests,

TABLE 8. ESTIMATES OF ERODED AND REHABILITATED AGRICULTURAL LANDS IN ASIA (Dent, 1989)

Country	Area degraded (D) (million ha)	% Total Land Area	Area Rehabilitated (R) (million ha)	D:R
Bangladesh	0.989	7.00	.128 + 0.06 (planned)	7.4
Bhutan	-	-	0.05 (terraced)	-
China	150 (water) 13 (wind)	30	44 (revegetated and terraced)	3.4
Cambodia	-	-	-	-
India	144.4 + 3.7 annually	48.5	30	4.8
Indonesia	43	24	4.5 targetted	9.6
Laos	8.1 (all water)	35	0.011	810.0
Malaysia	? low	?<5%	24 departments with watershed management	?
Myanmar	0.21 (water)	3.2	0.032	6.6
Nepal	60% deforested	>55% (severe)	0	>1000
Pakistan	15.5 (8 to wind,7.5 water)	17.4	0.132	117.4
Philippines	5	16.8	1.2 underway	4.2
Sri Lanka	0.7 (upland farmland)	10.8	0.112	6.3
Thailand	17.2 mainly water	33.7	10 contouring etc	1.7 ?>100
Vietnam	10 (2.2 b.t soil/y)	49 bare of veg.	-	

likely to tell us much more than is already known about the unsustainability of these environments.

T: Absence or occurrence of more sustainable practices, such as

- agroforestry
- alley cropping
- perennial crops
- legumes in rotations
- hedgerow and grass contours

as described in many research publications eg: Watson and Tacio, 1990, Kang *et al,* 1984, Huxley 1986, Young, 1986) are more reliable indicators of soil conservation and erosion in previously forested uplands. As these land management practices are not reported in most conventional land use statistics this is a topic which may require special attention.

Remote sensing and the use of GIS (Geographic Information Systems) appear to be particularly suited to improved evaluation of the sustainability of land-use systems in tropical sloping lands (Huizing and Bronsveld, 1991). Land use changes over time can be identified using low resolution satellite imagery.

U: % area and location of perennial to annual vegetation provides significant information on the relative degree of reclamation and degradation in uplands. When this is combined with the reported statistics on agricultural production and economic status, and integrated via a GIS to cadastral and topographic information the interpretation of those reported statistics becomes much more meaningful (Box 7).

Pesticide residues: direct measurement and the alternatives?

FAO estimates that 35 % of losses in annual crop production worldwide are due to pests, weeds and diseases. Pesticide development and use has risen in some parts of Asia over the past twenty years but data are sparce for many countries. Asia and the Pacific region together account for only 16% of the world pesticide market, with 76% of the expenditure being on insecticides, and most of the rest on herbicides. The annual rate of increase in pesticide is 7% and this is expected to continue well into the next century (Asian Development Bank, 1987).

Experience with increasing reliance on pesticides in industrial countries has given rise to many expressions of

BOX 7: SUSTAINABILITY OF DEFORESTED SLOPING LAND IN LOM KAO DISTRICT, THAILAND

Hilly catchments in northern Thailand which were deforested in the last 20 years are now being used by farmers for annual cropping (mostly maize as a cash crop, sometimes followed by mung beans). Land is ploughed up and down slope, and stovers are burnt at the end of the dry season.

A research study developed an interactive GIS with models validated with a set of crop trials and field erosion measurements. Landsat coverage over three years was used to generate land-use maps, which could be overlain on the regular cadastral and topographic maps of the area. Alternative perennial crops were tested and sweet tamarind selected as well adapted. The GIS modelling generated values of soil erosion, maize production, income from maize, tamarind production and income and differences in income between maize and tamarind for each part of the watershed. As well as providing a higher value crop, the perennial tree crop with grass cover reduces erosion significantly and soil productivity increases progressively with time (Huizing and Bronsveld, 1991).

Years from clearing	Maize yield (av)	Rel yield (%)	Land Suit. class	Gross margins ($US ha^{-1})		
				Maize	Tamarind (partial)	Tamarind with cover
0-3	3500	100	S1	200-300	400-500	1600-2000
4-8	2700	80	S2	130-200	200-400	1000-1600
11-15	2100	60	S3	50-130	50-200	300-1000

A transition period has to be managed when sweet tamarind is being grown on part of the land, with annual plantings, but still leaving less suitable land (S2 or S3) for maize was calculated because of the time lag (4-6 years) for the perennial crop to grow to full bearing capacity.

concern for similar environmental and health problems in Asia, as this trend increases. The health risk issue is of greater significance in some areas, because levels of literacy, training and regulations for use of pesticides are frequently poorer than in industrial regions. Statistics on pesticide use are patchy, collated from several different sources and only expressed in gross terms of tons of active ingredient, rather than as class of compound, persistence or relative biohazard (Table 9). FAO does not produce the same detailed information on pesticide use as on fertilizers, tractors or other agricultural inputs.

The average application rates in industrialised countries of North America and Western Europe are still on average higher than in Asia (Belgium 16, UK 5, and USA 2.2 kg ha^{-1}), but, as with fertilizers, Asian countries which are pursuing goals to increase food production will suffer the more intractable problems of pest resistance, residues in foods and loss of natural predators as pesticide application becomes a regular feature of high-input systems.

Integrated pest management (IPM): how can it be identified and reported?

The wisdom of adopting IPM for pest control is constantly encouraged by researchers and extension workers (Conway, 1985, IRRI 1989, Singh, 1992). However, the widespread use of IPM as a regular management practice has to be tailored to individual crops and farming system. It involves a knowledge of the biological cycles of each pest, weed and disease, flexibility in planting dates of crop types, programmes of crop breeding and sequential introduction of resistant varieties and, probably most important of all a well-informed, cooperative and self-disciplined farming population capable of implementing the system (Deuter, 1992, Hearn, *et al* 1988).

National (NARs) and international (IARCs) agricultural research and extension agencies are in the best position to report these developments (Voluntary Health Association

TABLE 9. AVERAGE ANNUAL PESTICIDE USE (METRIC TONS ACTIVE INGREDIENT) IN ASIA, 1975-7 AND 1982-4.

Source: World Resources Institute, 1992.[4]

Country			kg ha^{-1} applied to agric. land	
	1975-7	1982-4	1975	1985
Bangladesh	-	234	-	0.025
Bhutan	-	-	-	-
Cambodia	1,593	833	0.520	0.273
China	150,467	159,267	1.498	1.649
India	52,506	53,087	0.312	0.313
Indonesia	18,687	16,344	0.956	0.743
Laos	-	-	-	-
Malaysia	-	9,730 (1 year)	-	1.993
Nepal	-	-	-	-
Pakistan	2,120	1,856	0.231	0.203
Philippines	3,547	4,415	0.454	0.553
Sri lanka	-	697	-	0.366
Thailand	13,120	22,289	0.717	1.006
Vietnam	1,693	883	0.263	0.133

[4] *Primary sources: United Nations Industrial Development Organisation (UNIDO) special survey "Global overview of the pesticide industry sub-sector", Sectoral Working paper PPD. 88. Regioanl Network for the Production, Marketing and Control of Pesticides in Asia and the Pacific (RENPAP) and its predecessor (RENPAF): "RENPAP gazette: pesticide data collection system" 1985 and 1988, Bangkok.*

of India 1992). The alternative strategy of developing resistant varieties by plant breeding (Indian Council of Agricultural Research, 1992, CIMMYT, 1992) is frequently the most effective way of managing above-ground pests and diseases. Therefore improved reporting of

V: types of pesticide used, target crops and environments [districts, cropping systems and areas practicing integrated pest management- in future] and

W: occurrence of disease and pest resistant varieties, and extent of adoption by farmers

by NARs and IARCs to FAO and other agricultural statistical agencies would increase the effectiveness of assessing agricultural sustainability.

H. Proposed Generic Indicators for Asia:

- recorded as changes over time

Agriculture relative to other sectors:

A: index of per capita food production

B: proportion of rural population with off-farm income

C: agriculture as % GNP per region or country

D: relative importance of food : income generating capacities of agriculture

E: degree of food self-sufficiency

Human resources in agriculture:

- rural : urban population

F: rural : urban education levels

G: % rural : urban access to water, sanitation and health

H: % GNP expenditure on research and extension

Agricultural Productivity:

I: productivity (all outputs/all inputs)

J: production index (weight of all produce/ country on 3-year moving mean)

K: yield (weight of harvested product/area/year)

L: benefit cost analyses of changes in technology

M: efficiency of physical inputs:outputs

N: irrigation water use efficiency

O: % arable land with organic manures and legumes in rotation

On-site Environmental sustainability:

P: % relative dependency on irrigated agriculture

S: ratio of degraded to rehabilitated agricultural land

T: absence : occurrence of sustainable practices (agroforestry, alley cropping, perennial crops, grass contours, legumes)

U: % area and topographic location of perennial and annual crops

V: number of pesticides used and numbers of application per region

W: proportion of pest/disease-resistant varieties grown

Off-site Environmental sustainability:

Q: siltation rates of reservoirs and distributary canals

R: % deforestation for agriculture

III. Indicators for agro-ecological zones or farming systems

Asia's large topographic features, of mountain chains, major river valleys and steeply sloping island terrains dominates the location of agricultural systems on the continent. In addition the pre-eminent role played by irrigation in nearly every AEZ apart from Numbers 3 and 8 (Warm humid tropics and cool subtropics), as shown in Table 4, reduces the need for separate indicators of agricultural sustainability for each AEZ. In this chapter the generic indicators outlined in Chapter 3 are matched against the circumstances of the agricultural systems in each AEZ.

AEZ 1. Warm semiarid and arid tropics

Agriculture in this zone is dominated by rainfed cropping of cereals, pulses and other annual food crops, usually with two crops a year on soils which can store sufficient water from the monsoon season for a post-monsoon crop, and one crop in less favoured areas of sloping or shallow soils. Erratic rainfall makes **risk** of crop failure significant in this zone.

While none of the generic indicators are inappropriate to this region, the high proportion of the population which is dependent on rainfed agriculture, sloping lands and low fertility Alfisols, Ultisols and Inceptisols in parts of India and northern Thailand suggest that the priorities for indicators of sustainability in this zone are:

Agriculture relative to other sectors:

- proportion of rural population with off-farm income; - as a risk-spreading measure
- % of rural population with education (via rural : urban education levels); - as a lever to alternative incomes and sustainable practices

Productivity:

- production index and real yield of each crop; - as measures of food self-sufficiency
- % land with legumes in rotation

On-site environmental sustainability:

- % arable land with organic manures
- % area and topographic location of perennial : annual crops; - particularly significant in regions of steep slopes, where annual cropping is associated with high rates of water erosion
- absence : occurrence of sustainable practices; - particularly agroforestry, grass-hedgerow contours and perennial cropping

Off-site environmental sustainability:

- siltation rates in local dams, reservoirs and sources of water; - these are used as human water supplies in many more remote upland regions in this zone
- ratio of eroded to rehabilitated agricultural lands

The amount of deforestation for agriculture has been high in this region in the past twenty years. A critical question is the extent to which such lands can be developed sustainably for agriculture by converting previously shifting cultivation practices to stable sedentary systems. Abrol (1993) linked land tenure security with improved adoption of sustainable systems in upland parts of India. In these areas therefore, provision of greater security of tenure may be a critical indicator of improved sustainability. As poverty and lack of access are significant problems of much of the more sloping land in this zone, improved transport and communications, grain storage and local credit systems are also regarded as important strategies for improved rural existence (World Bank, 1989, IBSRAM, 1991).

Specific indicators for this zone include:

- absolute increases in the use of fertilizer, water and other physical inputs; - will be indicative of increased stability of supply in this zone where poverty is widespread.

- relative risk of rains failing in different parts
- changes in land tenure security to smallholders
- metalled road and drainage construction
- rural schools and communications services
- rural credit banks

AEZ 2. Warm subhumid tropics

Because of the higher and more consistent rainfall in this zone than in AEZ 1, rainfall effectiveness is substantially greater and agricultural production more reliable. The range of perennial species which can be grown is larger and traditional farming systems in southern India, Myanmar, Sri Lanka and Thailand have included diversified garden-agriculture as well as rice-based irrigation. Increasing production levels and greater intensification of rice crops has not always been accompanied by commensurate **efficiency of physical inputs**. There is a large gap between the best and average production levels (Singh, 1992) and there is substantial room for improvement in farming practices. Thus the most important of the generic indicators are:

Agriculture relative to other sectors:

- relative proportion of food : cash generating sectors of agriculture; - as this zone has the capacity to supply substantially more of the increase in cereals needed for expanding populations
- proportion of rural population with off-farm income; - as a strategy to relieve land pressure and prevent excessive subdivision of small farms

Human resources:

- % rural : urban population with access to water, sanitation and health
- % rural : urban population with education access; - if improvements in the alternative sectoral growth is to occur

Productivity:

- productivity; - this zone will see an increase in all agricultural inputs, requiring an equal or greater increase in outputs for efficiency maintenance or improvement
- yield: basic food crops should show substantial increases
- relative efficiency of physical inputs; - one of the most significant indicators in this zone

On-site environmental sustainability:

- irrigation water-use efficiency
- % arable land with organic manures; - as tractors replace draft animals in rice-cultures this will be difficult to maintain
- % area and topographic location of perennial and annual crops; - of particular significance in the sloping and dissected regions of southern India and central Sri Lanka
- proportion of pest/disease resistant rice varieties grown

Off-site environmental sustainability:

- % deforestation for agriculture; - this has particular significance for dissected sloping lands in the zone which are vulnerable to substantially increased erosion risk where vegetation protection is lost.

Specific indicators for this zone:

- use of integrated pest management;- improvements in crop production in potentially higher yielding localities are frequently constrained by high weed and pest burdens
- total number of crops sold into local markets and traded; - diversification of production and income are necessary to maintain rural growth

AEZ 3. Warm humid tropics

High rainfall regimes with either two growing seasons or continuous growing conditions provide good potential productivity in this region. However, over 70% of arable land is sloping, and in some regions, such as parts of Indonesia and the Philippines, steeply sloping lands (>30% slope) predominate. **Erosion** is the greatest environmental hazard, with shallow, **acid soils** the greatest constraint after slope, in much of the upland regions.Valley floors, in contrast are densely populated, with intensive production of paddy. Not all the paddy rice is high yielding, but as this zone also includes the majority of countries which have been severely disrupted by **civil conflict** in the past twenty years (Myanmar, Cambodia, Laos, Vietnam, Sri Lanka) overall agricultural improvement can be expected when civil infrastructures and services re-establish. This factor emphasises the importance of category 1 of the indicators;-

Agriculture relative to other sectors:

- all indicators are important to countries in this zone.

Human resources:

- conditions here vary greatly among the countries represented in the zone and few general recommendations will have merit. For Malaysia, Thailand and Indonesia, the investment in research and extension is probably more relevant to future agricultural sustainability, in environments where existing systems require intensification or diversification, and to improve land management on sloping lands (Sajjapongse, 1992, Blair and Lefroy, 1989).
- % GNP expenditure on research and extension

For the poorer countries with significant proportions of rural populations remote from welfare services and education these indicators will be of greater significance in assisting improvements needed in general social conditions.

Productivity and on-site environmental sustainability:

In densely populated *paddy-based regions* comparisons of production over time are meaningful

- production indices and yield
- relative efficiency of inputs
- % arable land with legumes
- % arable land with organic manures
- numbers of pesticides and applications
- proportion of pest/ disease-resistant varieties

In more remote, *hilly regions*, where erosion on sloping lands is a constant threat to sustainability;

- yields (where possible)
- % land with legumes
- % absence : occurrence of sustainable practices
- % area and topographic location of perennial : annual crops

Off-site environmental sustainability:

- % deforestation for agriculture
  - but the sustainability of recently deforested lands may be even more important to monitor (in the transmigration districts of Indonesia, and spontaneous settlement in the Philippines and Thailand).

Specific indicators in this zone include:

- ratio of landless to landed rural population; - tenure is insecure on formerly common lands
- development of roads, communications, and other forms of infrastructure in war-affected countries and remoter upland regions
- diversification of production in densely populated paddy-rice regions.

AEZ 5. Warm arid and semi-arid subtropics, summer rainfall

High population densities in much of this zone reflect long-established, agricultural systems which have developed dependent on irrigation. Large river systems flowing through semi-arid regions have traditionally been used for irrigation, but rapid **population growth** and concomitant large-scale expansion in all forms of **irrigation** (local, tube-well, central command and supplementary) pose the two greatest concerns for agricultural sustainability. Arid soil types with natural accumulations of **salts** increase the potential for future instability in some parts of northern China and Pakistan's irrigation areas.

Agriculture relative to other sectors:

- agriculture as %GNP of region
- proportion of rural population with off-farm income; - critical in areas of high rural population density

Human resources:

- rural : urban education levels; - particularly significant where improved management of soil and water in irrigation reclamation is being tackled
- % rural : urban access to water, sanitation and health; - Pakistan's situation is most critical as the gap between male and female demographic statistics is greater than in other parts of the zone
- % GNP expenditure on research and extension; - also significant for regions where intensification and increased efficiency of production is seen as imperative

Productivity:

- productivity and yields
- benefit cost analyses of changes in technology

- relative efficiency of inputs; - a critical indicator
- % arable land with legumes

On-site environmental sustainability:

- % land with organic manures; - statistics comparing Chinese and Indian practices would be instructive
- % dependency on irrigated agriculture
- rates of accession and decline in water-tables
- absence : occurrence of sustainable practices
- number and applications of pesticides
- proportion of resistant varieties grown

Off-site environmental sustainability:

- siltation rates of reservoirs
- ratio of eroded to rehabilitated lands; - a critical indicator

Specific indicators for the zone include:

- number of additional agricultural products reaching local markets; - this is closely associated with the diversification and additional rural income generation required for densely populated areas, especially where the soil productivity potential may be declining
- specific aspects of *irrigation* systems;
  - extent of waterlogging : drainage installations
  - rate of increase in salt affected soils
  - production of salt-tolerant to salt-sensitive crops (particularly wheat : rice)
  - levels of nitrates and pesticides in groundwaters and surface drinking supplies

AEZ 6. Warm subhumid subtropics, summer rainfall

This zone is represented by densely populated, river flood plains in India (Uttar Pradesh) and China (Honan, Jiangsu and Anhwei). Agricultural production is based on irrigated rice and wheat (India), with two to three crops per year. Integration of other food and fibre production systems has a long history in these regions, and issues for sustainability relate closely to maintaining the balance between traditional socio-cultural practices and improved technologies, on an **increasingly pressured soil and biological resource**. Techniques for maintaining soil fertility, minimising soil erosion loss, managing ground-water depletion and improving regional GNP are priorities for agricultural sustainability.

Agriculture relative to other sectors:

- agriculture as % GNP per region; - urban migration and poverty traps are potential problems to regional stability
- proportion of rural population with off-farm income

Human resources:

- rural : urban population changes
- % rural : urban education levels
- % rural : urban water, sanitation and health
- % GNP expenditure on research and extension

Productivity:

- productivity and yields
- relative efficiency of inputs
- % arable land with legumes in rotation

On-site environmental sustainability:

- % arable land with organic manures; - a significant issue in China where traditional practices can break down with improved overall standards of living and sewerage
- % dependency on irrigated agriculture
- rate of drop or rise in ground waters; - used for tubewell pumping, and as a result of tree planting
- absence : occurrence of sustainable practices; - particularly in Uttar Pradesh with pressure on trees and other perennial vegetation
- number of pesticides used and numbers of applications
- proportion of pest/disease-resistant varieties grown.

Off-site environmental sustainability:

- siltation rates of reservoirs and canals;- particularly in relation to constructions on the Yellow river
- ratio of degraded to rehabilitated lands

Specific indicators which derive from the discussion above:

- indicators of *irrigation* sustainability;
  - ratio of waterlogged : drained irrigated lands
  - water-use efficiency of canal-based irrigation systems
- total number of agricultural products per district; - traditionally these regions, particularly in China pro-

duced a wide variety of products; intensification of cereal crops, urban migration etc, may reduce labour available for these.

- levels of nitrates and pesticides in groundwaters and human water supplies

AEZ 7. Warm/cool humid subtropics, summer rainfall

This zone falls entirely within south-central China (Appendix 1) and is similar in many characteristics with AEZ 6 other than the more restrictive growing season temperatures and higher altitudes. The dissected hilly terrain in much of this zone imposes a significant threat to sustainability through **erosion**, particularly where timber has been removed for fuel and construction. Large industrial cities located in the major river valleys (eg: Wuhan, Hangchou) provide major markets to rural produce and a focus to rural migration. Treatment of this zone is limited to the specific indicators which are required in addition to the generic ones identified in AEZ 6.

- number of agricultural products reaching urban markets
- water erosion surrogates (extent of contouring systems, watershed tree planting)
- restoration of historical erosion features

AEZ 8. Cool subtropics, summer rainfall

This zone has cooler mean temperatures because of the altitude of much of the terrain. While some parts of the zone are either forested or grasslands, lightly populated, little used for agriculture (western Szechuan, Yunnan, Ningsia, highland Kashmir) valley basins, coastal plains and undulating uplands have always been heavily populated and intensively cultivated. Continued increases in production from these regions requires substantial watershed and slope management from headwaters of rivers in western provinces such as Gansu, Ningsia, Gueichou. Details of current environmental condition in these regions are patchy but satellite and special survey data suggest significant environmental problems are rapidly developing.

As in AEZ 3 there is a partition between the sustainability issues for uplands and valleys, but the valleys' agricultural sustainability will be dependent on the **condition of uplands**.

Agriculture relative to other sectors:

- agriculture as % GNP of the region; - there will be big differences between upland and lowland regions
- proportion of population with off-farm income;- ditto
- degree of food self-sufficiency; - arid interior parts of China are poor and dependent on other regions

Human resources:

- % rural education levels; - the largely Muslim population of Kashmir as a minority in India, and the ethnic minorities in western China's autonomous provinces make this issue particularly important in terms of equity
- % rural access to water, sanitation and health

Productivity:

- yields; - but disaggregated for upland and lowland districts
- relative efficiency of inputs; - particularly for intensively farmed lowland regions
- % arable land with legumes in rotations

On-site environmental sustainability:

- % dependency on irrigated agriculture; - expansion of irrigation in south eastern China will be dependent on managing river flows and waterlogging-prone soils
- absence: occurrence of sustainable practices; - particularly in upland regions
- % area and topographic location of perennial : annual species
- numbers of pesticides used and applications: - in lowlands

Off-site environmental sustainability:

- % deforestation for agriculture; - particularly on steeply sloping lands of recent geological origin, highly erosive
- siltation of reservoirs; - in valley irrigation regions
- ratio of degraded to rehabilitated lands

Specific indicators of the zone:

- % area of bare ground in western pastoral areas; - as evidence of level of grazing pressure
- levels of nitrates and pesticides in groundwaters and surface drinking supplies

A. Specific indicators which are of general merit

The occurrence of several proposed indicators more than once in the treatment by AEZs shows the gaps in the generic treatment. Further gaps will be identified when RAEZs are investigated at the sub-country, regional level. Those listed in preceding pages are:

- number of rural credit banks per '00,000 rural population.
- ratio of landless to landed rural population
- total number of rural products sold and traded
- concentration of nitrates and pesticides in groundwaters and drinking supplies
- irrigation sustainability indicators:
  - rate of accession and decline of groundwater levels
  - extent of waterlogging: drainage installations
  - rate of increase in salt-affected lands
  - yield of salt-tolerant : salt-sensitive crops

IV. Recommendations for FAO's monitoring and statistical collection activities:

This report has identified a number of areas in which additional indicators are needed to supplement those already collected by FAO and its collaborators, to monitoring the sustainability of agriculture in Asia. In some cases information may already exist (as in the case of the proportion of disease-resistant cereal varieties grown), but is not reported in that fashion to FAO. In other cases the information is neither collected regularly, nor is easy to obtain. This is the case with the majority of environmental attributes. Strategies for selection of unambiguous, practical monitoring and reporting procedures for such attributes fall outside the scope of the report. However, the following indicators have been identified in the text for consideration:

A. Supplemental indicators

Agriculture in the Economy:

- number of **rural credit banks per '00,000** rural population

Comment: not regularly collected internationally, but information available in at country level

- **accessibility of rural credit to the poorest** section of rural population (landless)

Comment: some statistics in World Bank, associated Development banks, and UNDP. Scattered information from research studies within countries

- ratio of **landless to landed** rural population

Comment: requires special surveys of sample areas within the regions of known concern

- total **number of rural products** sold or consumed

Comment: requires special surveys of sample areas

Human resources:

- **literacy levels** in rural populations

Comment: collected in many cases, and capable of being reported.

- **gender gap** in vital statistics, and literacy, of rural populations

Comment: collected in most countries and capable of being reported.

- sources of **off-farm rural incomes**

Comment: not collected, and might require special surveys

- **% GNP spent on agricultural research and extension** by region within countries

Comment: reported within government agencies in most countries. Differences in expenditure between regions of a country may be politically sensitive.

Productivity:

- use of **organic manures and plant residues**; area, cropping systems and amounts, or equivalent nutritional value.

Comment: not collected; would require special surveys from samples of different farming systems.

- **fertilizer efficiency** and **irrigation water efficiency**.

Comment: not collected, but can frequently be computed from existing research studies, providing these can be geographically located with accuracy, and integrated in space and time.

- effects of **price subsidisation on input efficiency** and environmental pollution.

Comment: not currently reported routinely, but the subject of many internal reports of aid and government agencies.

- Sustainable **Land-use: presence and absence of agroforestry**, alley cropping, hedgerows and contours, perennial crops and legumes in rotation.

Comment: statistics for agricultural crops and pastures and for types of land use do not currently list items in this form, but in many cases the necessary information is collected although presented in other ways.

Environment:

- **pesticide use**
  - categories of compound used
  - areas treated, numbers and rates of application
  - residues in groundwaters and drinking water

Comment: reporting on pesticide use is fragmented and patchy. Standardised reporting on a routine basis requires concerted international and national effort. Residues are monitored in drinking water in some countries but information is hard to obtain in the public arena. This issue requires concerted action as reliance on pesticides increases in intensively cropped regions of high population density.

- extent and proportion of **pest and disease-resistant varieties** of crops and animals

Comment: not collected, but the International Agricultural Research Centres (IARCs) have been responsible for many of the releases and have the capacity to collate this information. With the collaboration of National Agricultural Research Institutions (NARIs) they and FAO could compile such statistics.

- **irrigation sustainability indicators**
  - extent of regular waterlogging : drainage installations
  - rate of increase in salt-affected lands
  - yields of salt-tolerant and salt-sensitive crops

Comment: in some irrigation districts this information is well documented, by the Irrigation Commission, through special research and government studies. However, little of it is regularly reported to FAO or other responsible international and national bodies. In other districts there is little information.

- **status of groundwaters** in irrigation areas and major aquifers
  - accessions and declines in levels
  - concentration of nitrates and pesticides

Comment: detailed information is held by government agencies and private companies in some regions, but is not reported in a regular manner for agricultural purposes to FAO.

- **erosion from loss of vegetation cover** through agriculture

Comment: a difficult parameter to measure and to distinguish from other forms of vegetation loss (eg: droughts, deforestation). Current developments in the use of remote sensing and GIS technologies may improve the capacity for FAO and national agencies to improve estimates.

B. Applications for indicators

Indicators can be used for organisational planning and management (as with market indicators in a commercial company), for performance appraisal (ratings, examinations), to give warning of impending change (as used in weather forecasting or demographic analysis) and to assist in decision-making. In all cases the significance attached to the information supplied by the indicators depends on the **level of professional analysis** which is undertaken by trained staff to interpret the signal. Weather forecasting is carried out by trained meteorologists for example. Discussion in Section 2.4 on interpretation of yield and production figures showed the fallacy of taking these statistics at face value as indicators of agricultural sustainability. National agencies may require staff training support in monitoring, statistical computation, operating computer software and report presentation if any of the indicators suggested here are to be used effectively.

The most significant effect of using indicators is when their use influences behaviour favourably, through the feed-back supplied to decision-makers and operators. Regular reports on the amount of salt-affected irrigated land, or levels of nitrate-polluted drinking water, communicated to relevant national departmental heads provide improved standards of information. These can be assessed alongside budgets and political targets. Such feed-back generally occurs only where there is official endorsement of the use of indicators because their utility is understood. Scientific and technical reports are not read by political advisers.

C. Suggestions for FAO's support to Asian NARS

- Experience in developed countries (Canada, Australia, the Netherlands) that have adopted strong government-endorsed sustainable development strategies has shown the need for a professional public-relations policy in presenting the information on complex natural resource and environment issues meaningfully. The same is needed in developing countries.
- Adding indicators of sustainability to the conventionally reported economic and production indicators requires political will and organisational action. In countries which are now signatories to international environmental conventions, the mechanism now exists by which such reporting can be a required function of government. The World Resources Institute has responded to this need by providing annotated bibliographies in electronic and print form (WRI 1993).
- Section 4.1 showed that some of the additional indicators suggested for use by FAO can be derived from existing statistics, collected by other organisations and regularly reported. Small analytical units are all that is required to provide regional administrators with profiles on aspect of rural education and health relevant to the needs of agricultural development.
- In the case of many of the environmental aspects of sustainability however, special surveys are needed to make measurements, analyse the data and report them to central agencies. Frequently such field research is undertaken by academic institutions in an ad hoc manner, and the information is not used for planning or management purposes. In many cases aid programmes are associated with funding of such research, with inventories of research projects are kept in-house, or in publications, by the donor agencies. The task for FAO here is more substantial, in setting up routine procedures so that relevant field studies are reported in a regular manner in a geocoded format.
- Environmental data are most readily managed through GISs. Base cadastral information on each country, provinces within countries, RAEZs and major global zones (on scales ranging from 1:100,000 to 1:10 million) are available through standard software. Subsequent "layers" of topographic, climatic, administrative and geological or soils information are then added. Land use and vegetational cover interpolations have been developed through transcribing remote-sensed imagery such as FAO's ARTEMIS (Real Time Environmental Monitoring Information System) programme onto these bases. Changes in land-use and cover can be followed using a variety of statistical techniques, but this is still largely a research activity.
- Combined GIS-Remote Sensing is a rapidly developing technology of great potential for development projects and resource management. However, it requires skilled operators and has a high staff-training requirement. There is a high maintenance cost in keeping the systems updated as new information comes on line. NARS which are acquiring this technology for resource management may need strong international support for in-house training.
- Alternative measuring and reporting systems which rely on small (village-based) local monitoring are well-suited to pest management or crop yields for foods consumed by households, where monitoring is part of a self-improvement goal. This approach is being used by extension officers in Indonesia (for yield measurement) and in the Philippines (for pest and disease management and reducing pesticide use). The experience with "Landcare" groups in rural Australia has shown that such groups can be powerfully self-motivating in setting group goals for increasing productivity or rehabilitating degraded lands.
- Present needs for improving the use made of indicators of sustainability by Asian NARS will vary greatly from country to country, but training in computing and analysis of statistical and scientific survey information is a generally felt need in high, medium and low income countries. Access to relevant data is also a high priority. Many forms that are available through electronic format (CD-ROM, E-mail etc) in the developed world depend on access to reliable electricity and telecommunications networks. Experience with improving the information flows to remote and educationally-disadvantaged communities in Australia has shown the need for a range of communication formats (print media, videos for local TV, software packages for personal computers, access to short-term training courses). As so much statistical and professional information is available in European languages (particularly English), improved translation facilities may be the most important priority for regionally-based agency staff.

V. Australia and New Zealand: a case study

As a part of national initiatives to implement sustainable development strategies in these countries, their governments commissioned a report on indicators for sustainable agriculture. The primary goal was to identify a set of practical indicators for use by decision makers to evaluate the sustainability of agricultural systems at regional and national scales, primarily using existing statistical information.

Key issues for Australia and New Zealand are the links between socio-economic and biophysical aspects, including the off-site effects of agriculture. Indicators that reflect such linkages required a conceptual framework and the development of an accepted methodology which goes beyond the existing measures of profitability and success used in the agricultural statistics in these countries, and allows the status of the resource base to be reflected in the overall worth of the industry. Because agriculture plays a very different role in the society and economy of these countries from many Asian countries not all the issues or indicators selected will be the same for each country.

The Report (Hamblin *et al,* 1993) identified improved management practices as the most significant factor needed to achieve maximal net social benefit from agriculture. Changes in farming practice and their effect both agricultural and surrounding non- agricultural lands and water resources need to become part of the reporting process in the future.

A. Objectives and assumptions

Taking the overall objectives of the Australian ESD strategy as the framework

> "using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased" (Australian Agricultural Council 1991)

the Report saw indicators of agricultural sustainability to be **tools** for better early warning of deleterious environmental and other changes for trace-back enquires on causation, and for better comparisons between farming practices, management decisions or systems' performance.

The Report considers sustainable agriculture in Australia and New Zealand will have to operate within the constraints of market conditions and political and social expectations. It is anticipated there will be no change in the declining terms of trade for agriculture or the lessening of fiscal protection. At the same time there is an increasing expectation from society for natural resources to be fully considered in valuations, and for the influence of agriculture on other ecosystems to be taken into account.

The study revealed substantial differences in the quality and availability of information dealing with the natural resource status, particularly soils, compared with what is known of

the economic situation of farmers and their industry. There was also weak methodological development in the social indicators needed.

B. Indicators and attributes

Four key indicators were identified, which reflect the desired outcomes for sustainable agriculture in Australia and New Zealand. These outcomes are the nationally-stated objectives of economic viability, maintenance of the resource base and minimising the impact of agriculture on other ecosystems.

Each of the key indicators is composed of a number of major attributes which can be measured by using existing sources of information in most cases. In a few critical areas, data are not collected regularly or on the same locational basis and surrogates have been chosen temporarily.

Financial indicator: The on-site financial indicator chosen was the "change in long-term real net farm output (income); that is, the real value of agricultural production minus the real value of farm costs". Attributes of financial performance which are relevant to this indicator are productivity (defined as the ratio of the index of the volume of production to the index of the volume of resources used), and farmers' terms of trade. Changes to the area of land used in agriculture and the number of farms provide additional information needed to interpret farm financial viability.

Farm Environmental indicator: The on-site environmental indicator selected was the "change in the quality of land and water which affect production of vegetation and animals at levels set by climate and land capability''. Selecting attributes which adequately describe this indicator, and are available from regular surveying statistics, presented problems. While much detailed information on natural resource status exists it can seldom be related to specific farm locations or cultural practices, having generally been collected for a special research study. Surrogate measures of water and soil status were chosen; these are water use efficiency of crops and pastures (via stock) and nutrient balance of the farm. The attributes which reflect biological diversity and resilience of the system are the area of native (remnant) vegetation and its degree of fragmentation.

The Expert Group found that most data on soil erosion were taken for special surveys and cannot be related to specific farming practices except where the particular survey addressed that question. The lack of regular monitoring of soil erosion at scales relevant to farm practice has precluded the use of a descriptor of soil erosion in the attribute of land quality. This is an area of deficiency which requires further work and implementation.

Human Resources indicator: The on-site social indicator identified as most important to sustainable agriculture was ''change in managerial skills of farmers, landowners and land managers, in finance, farming practice and environmental stewardship''. The attributes which describe this include formal knowledge levels, a skills index (currently with few data collected through census statistics), attitudinal approach which can be recorded through membership of landcare groups, and managerial competence. This last is described by the proportion of farmers using farm plans.

Off-site Environmental Impacts indicator: An off-site environmental indicator was proposed as ''changes to food quality, landscape hydrology and native ecosystems attributable to agricultural practice''. The Report attempts to distinguish which off-site effects are capable of interpretation at regional and national scale from those of special local significance. The attributes suggested include food chemical contamination levels (reported by the National Residue Survey), river turbidity and dust storm frequency as attributes of land and water quality which reflect the off-site impact of agriculture, and the change in the length of contact zone between agricultural and non-agricultural lands.

Consideration was given to off-site financial and social indicators. While the overall rate of assistance between trading countries does affect agricultural sustainability it is not easy to identify different categories of expenditure, and the off-site costs from agriculture in current SNAs. Off-site social impacts to and from agriculture are small in Australia and New Zealand where less than 2% of the population is employed in agriculture. Integrated economic-environmental indicators have attractions and the use of **land values and water prices** were considered as financial indicators which could reflect the condition of the resource base, but rejected it at this stage as being too difficult to assess unambiguously.

Implementation: These concepts and proposals require testing before any implementation. In July 1993 four State departments of agriculture and their colleagues in associated conservation and water departments agreed to test the scheme within selected regions of their respective States. The aim was to see whether the attributes and indicators selected in the Report will work or not, whether data are available, are meaningful and reflect what experienced professionals and other public assessments tell us of the status and trends in agriculture in those districts. Adoption of this system of reporting is expected if testing is successful, to supplement, rather than replace, the existing national and State agricultural reports and statistics.

REFERENCES

ABROL, I.P. 1993. Restoration of degraded lands in India. In: ''Soil resilience and sustainable land use''. Symposium and workshop of the Hungarian Academy of Sciences, International Soil Science Society and CAB International. September 28- October 2 1992. Budapest, Hungary. CABI (in press).

ABROL, I.P. and GUPTA, R.K. 1991. Managing salt-affected soils and poor quality irrigation waters for sustainable crop productivity. In: Evaluation for sustainable land management in the developing world. Proceedings of the International Workshop on Evaluation for sustainable land management in the developing world. Chiang Rai, Thailand. IBSRAM Proceedings No. 12, vol. 2. Technical Papers. pp. 253-278. IBSRAM, Bangkok.

ANAND, S. and RAVALLIAN, M. 1993. Human development in poor countries: on the role of private incomes and public services. Journal of Economic Perspectives 7, 133-150.

ADB 1987. Manual of the use of pesticides in the Asia and Pacific region. Manila.

AAC 1991. Sustainable agriculture. Standing Committee on Agriculture, Technical Report Series No. 36. CSIRO, Melbourne.

BIOT, Y. 1991. Forecasting future production. In: Evaluation for sustainable land management in the developing world. Proceedings of the International Workshop on Evaluation for sustainable land management in the developing world. Chiang Rai, Thailand. IBSRAM Proceedings No. 12. pp. 593-611. IBSRAM, Bangkok.

BISWAS, A.K. 1992. Irrigation and environmental management: some major issues for developing countries. In: Developing and improving irrigation and drainage systems: selected papers from World Bank Seminars. eds G. LeMoigne, S. Barghouti, and L. Garbus. World Bank Technical Paper No. 178. pp. 155-161. World Bank, Washington D.C.

BLAIR, G. and LEFROY, R. 1991. eds. 1991. Technologies for sustainable agriculture on marginal uplands in southeast Asia. Proceedings of a seminar at Ternate, Cavite, Philippines, December 1990. ACIAR Proceedings No. 33.

BYERLEE D. 1987. Maintaining the momentum in post Green Revolution agriculture. A microlevel perspective from Asia. MSU International Development Paper No. 10. Michigan State University, East Lansing.

BYERLEE, D., AKHTER, M. and HOBBS, P. 1987. Reconciling conflicts in sequential double cropping patterns through plant breeding: the example of cotton and wheat in Pakistan's Punjab. Agricultural Systems 24: 291-304.

CABI 1993. Soil resilience and sustainable land use. Symposium and Workshop of the Hungarian Academy of Sciences, International Society of Soil Science and CAB International. September 28 - October 2 1992. Budapest, Hungary. CABI (in press).

CALDWELL, J.C. 1986. Routes to low mortality in poor countries. 171-220. Population and Development Review, 12.(2).

CECCARELLI, S., GRANDO, S. and HAMBLIN, J. 1992. Relationship between barley grain yield measured in low and high-yielding environments. Euphytica 64: 49-58.

CIMMYT 1989. 1987-1988 CIMMYT World Wheat Facts and Trends. CIMMYT, Mexico.

CIMMYT 1992. CIMMYT 1991 Annual Report. Improving the productivity of maize and wheat in developing countries: an assessment of impact. Mexico, D.F. CIMMYT.

COLFER, C.J.P. 1991. Towards sustainable agriculture in the humid tropics: building on the Trop Soils experience in Indonesia. Trop Soils Bulletin Number 92-02. North Carolina State University, Raleigh, N.C.

CGIAR 1992. Review of CGIAR Priorities and Strategies - Part 1. AGR/TAC:IAR/92/18. TAC Secretariat, FAO Rome.

CONWAY, G.R. 1985. Agricultural ecology and farming systems research. 43-59. In: Agricultural systems research for developing countries. Proceedings of an international workshop, Hawksbury, Australia. May 1985. Ed. J.V.Remenyi. ACIAR Proceedings no. 11.

CONWAY, G.R. and BARBIER, E.B., 1990. After the green revolution: sustainable agriculture for development. Earthscan Publications, London.

CORNISH, P.S. and PRATLEY, J.E. (ed), 1987. Tillage; new directions in Australian agriculture. Inkata Press, Melbourne and Sydney.

CRASWELL, E.T. and GODWIN, D.C. 1984. The efficiency of nitrogen fertilizers applied to cereals in different climates. Adv. Plant Nutr. 1: 1-55.

CRASWELL, E.T. and PUSHPARAJAH, E. 1991. Soil management and crop technologies for sustainable agriculture in marginal upland areas of south east Asia. In: Technologies for sustainable agriculture on marginal uplands in south east Asia, eds G. Blair and R. Lefroy. Proceedings of a seminar, Ternate, Cavite, Philippines, December 1990. ACIAR Proceedings No. 33. pp. 93-100.

DE DATTA, S.K. and HUNDAL, S.S. 1984. Effects of organic matter management on land preparation and structural regeneration in rice-based cropping systems. In: Organic Matter and Rice. pp. 399-416. IRRI, Manila.

DENT, F.J. 1989. Land degradation in Asia and the Pacific. In: Environment and agriculture: environmental problems affecting agriculture in the Asia and Pacific region. World Food Day Symposium, October, 1989, Bangkok, Thailand. pp. 21-45. FAO RAPA, Bangkok.

DEUTER, P. 1992. Assessing sustainability in intensive horticultural production: a regional example from the Lockyer Valley. 31-36. In: Environmental indicators for sustainable agriculture. Report of a National Workshop, November 28-29. 1991. Bureau of Rural Resources, Australian Government printing Service. Canberra.

ENVIRONMENT CANADA 1992. The State of Canada's Environment. Government of Canada, Ottawa.

ESRI 1992. ArcWorld 1-3M User's Guide. Environmental Systems Research Institute Inc., Redlands Ca.

FAETH, P., REPETTO. R., KROLL. K., DAI, QI., and HELMERS, G. 1991. Paying the Farm Bill: U.S. agricultural policy and the transition to sustainable agriculture. WRI, Washington.

FAO 1978-81. Report on the Agro-ecological Zones Project. World Soil Resources Report No. 48, vols 1-4. FAO, Rome.

FAO 1985. Maximising fertilizer use efficiency. FAO Fertilizer and Plant Nutrition Bulletin No. 6. FAO, Rome.

FAO 1987. Fertilizer strategies.FAO Land & Water Development Series No. 10. FAO, Rome.

FAO 1988. Fertilizer Yearbook. vol. 38. FAO, Rome.

FAO 1990. FAO Quarterly Bulletin of Statistics Vol. 3. FAO, Rome.

FAO 1992. CROPWAT. A computer program for irrigation planning and management. FAO irrigation and Drainage paper No. 46. Developed by M. Smith, FAO, Rome.

FAO/IFA/IFDC 1992. Fertilizer use by crop. FAO, Rome 1992.

FAO RAPA 1989. Environment and Agriculture: Environmental Problems Affecting Agriculture in the Asia and the Pacific Region. World Food Day Symposium, 11 October 1989, Bangkok, Thailand. FAO RAPA, Bangkok.

FAO RAPA 1992. Selected Indicators of Food and Agriculture Development in Asia-Pacific Region, 1981-1991. FAO RAPA Publication 1992/15, Bangkok.

FLINN, J.C. and MARCIANO, V.P. 1984. Rice straw and stubble management. In: Organic Matter and Rice. pp. 593-611. IRRI, Manila.

FUJSAKA, S. 1991. Thirteen reasons why farmers do not adopt innovations intended to improve the sustainability of upland agriculture. In: Evaluation for sustainable land management in the developing world. Proceedings of the International Workshop, Chiang Rai,Thailand, Sept. 1991, pp. 509-522. IBSRAM Proceedings No.12, vol. 2.

GAUR, A.C. 1984. Response of rice to organic matter: the Indian experience. In: Organic matter and rice, pp. 503-514. IRRI, Manila.

GEORGE, S. 1988. A Fate Worse than Debt. Penguin, London.

GOMEZ, A.A. and ABEJUELA, A.G. 1991. Moving technologies from research laboratories to commercial application. In: Technologies for sustainable agriculture on marginal uplands in south east Asia, eds G. Blair and R. Lefroy. Proceedings of a workshop, Ternate, Cavite, Philippines. ACIAR Proceedings No. 33, pp. 114-126.

HAMBLIN, A. and KYNEUR, G. 1993. Trends in wheat yields and soil fertility in Australia. Bureau of Resource Sciences, Canberra.

HAMBLIN, A., BRIGGS, H. DAVIDSON, D., GOSS, K., OAKLEY, G. SINNER, J. and WALKER, J. 1993. Tracking the indicators of sustainable agriculture for Australia and New Zealand: A Discussion Paper of the Standing Committee on Agriculture and Resource Management of Australia and New Zealand. (in press)

HAMILTON, L. and KING, P. 1983. Tropical Forest Watershed: Hydrologic and Soils Response to Major Uses or Conversions. Westview Press, Boulder Co.

HEARN, A.B., BROOK, K.D. and BEGG, L.E. 1988. The Siratac experience. 124-9. In: The impact of computer-based information systems on pasture and crop productivity. Workshop of the Department of Agriculture and Rural Affairs Victoria. Melbourne, August 1988.

HICKS, N. and STREETON, P. 1979. Indicators of development: the search for a basic needs yardstick. World Development 7: 567-580.

HUIZING, H. and BRONSVELD, K. 1991. The use of geographical information systems and remote sensing for evaluating the sustainability of land-use systems. In: Evaluation for sustainable land management in the developing world. Proceedings of the International workshop on evaluation for sustainable land management in the developing world. Chiang Rai, Thailand, September 1991. IBSRAM Proceedings No. 12, vol. 2, Technical Papers, pp. 545-562. IBSRAM, Bangkok.

HUNSAKER, C.A. and CARPENTER, D.E. (eds) 1990. Ecological Indicators for the Environmental Monitoring and Assessment Program, EPA 600/3/-90/060, US Environmental Protection Agency, Office of Research and Development, North Carolina.

HUXLEY, P. A. ed. 1986. Rationalising research on hedgerow intercropping: an overview. ICRAF Working Paper No. 40. Nairobi, ICRAF.

IAEA 1991. Stable isotopes in plant nutrition, soil fertility environmental studies. Proceedings of an International Symposium on the use of stable isotopes in plant nutrition, soil fertility and environmental studies, Vienna, 1-5 October, 1990. IAEA & FAO.

IBSRAM 1991. Evaluation for sustainable land management in the developing world. IBSRAM Proceedings No. 12, vol. 2. Technical Papers. IBSRAM, Bangkok.

IBSRAM 1993. Second International Workshop for sustainable land management. June 1993. Lethbridge, Alberta. (in press).

ICRAF 1990. ICRAF Report 1990, Nairobi, Kenya.

ICAR 1992. Annual report 1991-2. New Delhi.

IRRI 1989. IRRI 2000 and beyond. Manila, The Philippines.

IRRI 1991. IRRI Annual Report 1990-91, Manila, The Philippines.

JIRAPORNCHAROEN, S., KAI, H. and AIBE, T. 1991. Long-tern nitrogen-balance studies in lowland rice soils. In: Soil Management for Sustainable Rice Production in the Tropics. IBSRAM Monograph No. 2.

KANG, B.T., WILSON, G.F. and LAWSON, T.L. 1984. Alley cropping: a stable alternative to shifting cultivation. International Institute for Tropical Agriculture, Ibadan.

KIKUCHI, M., WATANABE, E., and HAWS, L.D. 1984. Economic evaluation of azolla use in rice production. In: Organic Matter and Rice, pp. 557-568. IRRI, Manila.

KLUIK, O. and VERBRUGGEN, H. (eds) 1991. In Search of Indicators of Sustainable Development. Kluwer Academic Publishers, Dordrecht.

KUMAZAWA, K. 1984. Beneficial effects of organic matter on rice growth and yield in Japan. In: Organic Matter and Rice, pp. 431-444. IRRI, Manila.

LECAILLON, J., MORRISSON, C., SCHNEIDER, H. and THORBECKE, E. 1987. Economic policies and agricultural performance of low-income countries. Development Centre of the Organization for Economic Co-operation and Development. Development Centre Studies, Paris.

LITTLEBOY, M., SILBURN, D.M., FREEBAIRN, D.M., WOODRUFF, D.R. and HAMMER, G.L. 1989. PERFECT: a computer model of productivity erosion runoff functions to evaluate conservation techniques. Bulletin QB 89005. Queensland Department of Primary Industries, Brisbane.

OLDERMAN, L.R. HAKKELING, R.T.A. and SOMBROEK, W.G. 1991. World map of the status of human-induced soil degradation: an explanatory note. Global Assessment of Soil Degradation (GLASOD). International Soil Reference and Information Centre, Wageningen, and United Nations Environment Programme, Nairobi.

NZBS 1988. State of environment reporting in New Zealand; a proposal for a multi-agency project. SER information paper 1. Department of Statistics, Ministry for the Environment, Wellington.

O'BRIEN, G.C. 1991. Economic aspects of sustainable land management: regional experience. In: Evaluation for sustainable land management in the developing world. Proceedings of the International workshop on evaluation for sustainable land management in the developing world. Chiang Rai, Thailand, September 1991. IBSRAM Proceedings No. 12, vol. 2, Technical Papers, pp. 437-458. IBSRAM, Bangkok.

OECD 1987. National policies and agricultural trade. OECD. Paris Cedex, France.

PARISH, D. 1993. Agricultural productivity, sustainability and fertilizer use. Paper Series No.18. IFDC.

PEARCE, D., MARKANDYA, A. and BARBIER, A.B. 1988. Blueprint for a Green Economy. Earthscan Publ., London.

PEARCE, F. 1992. The Dammed: Rivers, Dams and the Coming World Water Crisis. Bodley Head, London.

PEOPLES' REPUBLIC OF CHINA. 1987. Irrigation and drainage in China. Ministry of Water Resources and Electric Power, Beijing.

RAO, Y.S. 1989. Forest resources in tropical Asia. 1-12. In: Environment and agriculture: environmental problems affecting agriculture in the Asia and Pacific region. World Food Day Symposium, 11 october, 1989, Bangkok, Thailand, FAO, Rome.

REPETTO, R., MAGRATH, W., WELLS, M., BEER, C. and ROSSINI, F. 1989. Wasting Natural Assets: Natural Resources in the National Income Accounts. WRI, Washington.

SAJJAPONGSE, A. 1992. The management of sloping lands for sustainable agriculture in Asia, Phase 1: 1988-91. Technical Report, IBSRAM Network Document No. 2.

SEN, A. 1981. Poverty and Famines: an Essay on Entitlement and Deprivation. Oxford University Press, Oxford.

SIMMONS, P., POULTER, D. and HALL, H.N. 1991. Management of irrigation water in the Murray-Darling Basin. Australian Bureau of Agricultural and Resource Economics. Discussion Paper 91.6.

SINGH, R.B. 1992. Research and development strategies for increased and sustained production of rice in Asia and the Pacific region. FAO RAPA Publication 1992/17, FAO RAPA, Bangkok.

SWATDEE, P., VENTURA, W., WATANABE, I. and ESKEW, D. 1991. The use of ^{15}N in azolla research. In: Soil Management for Sustainable Rice Production in the Tropics. IBSRAM Monograph No. 2.

TRIBE, D.E. 1991. Doing well by doing good: agricultural research feeding and greening the world. The Crawford Fund for International Agricultural Research and Pluto Press, Australia.

UNDP 1992. Human Development Report 1992. Oxford University Press, New York.

UNDP 1993. Human Development Report 1993. Oxford University Press, New York.

VHAI 1992. Proceedings of the national seminar on sustainable agricultural development. Ed. S. Sangupta. September 12-13, 1991. Gloria Land, Pondicherry.

WATSON, H. and TACIO, H.D. 1990. Sloping land agricultural technology (SALT 1). In: Resource Book on Sustainable Agriculture in the Uplands, ed. L.N. Capistrano, J Durno and I. Moeliono. International Institute of Rural Reconstruction, Cavite, Philippines.

WELLER, J.A., HOLMES, D.W., and GUNSTON, H. 1984. Irrigation water management study at Kadulla, Sri Lanka. Overseas Development Unit, Research Report: OD 66. Institute of Hydrology, Wallingford.

WORLD BANK 1989. Renewable resource management in agriculture. A World Bank Operations Evaluation Study, Operations Evaluation Department, World Bank, Washington, D.C.

WORLD BANK 1992. World Development Report 1992: Development and the Environment. Oxford University Press, New York.

WCED 1987. Our Common Future. Oxford University Press, Oxford.

WRI 1992. World Resources 1992-93. Oxford University Press, New York.

WRI 1993. Directory of Country Environmental Studies: an annotated bibliography of environmental and natural resource profiles and assessments. Eds. Tunstall, D.B. and van der Wansem, M. International Environmental and Natural Resource Assessment Information Service, WRI.

YADAV, J.S.P. 1989. Irrigation induced soil salinity and sodicity. In: Environment and agriculture: environmental problems affecting agriculture in the Asia and Pacific region. World Food Day Symposium, Bangkok, Thailand, October 11 1989, pp. 47-62. FAO, Rome.

YOUNG, A. 1986. The potential for agroforestry for soil conservation. Part 1. Erosion control. ICRAF Working Paper No. 42. ICRAF, Nairobi.

ACRONYMS

AAB	Australian Agricultural Council
ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AEZ	Agro-ecological zones
AP	Asia-Pacific
CABI	Commonwealth Agricultural Bureau International
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize & Wheat Improvement Centre
ESD	Ecologically Sustainable Development
ESRI	Environment Systems Research Institute
FAO	Food and Agriculture Organization of the United Nations
FAO RAPA	FAO Regional Office for Asia and the Pacific
GDP	Gross Domestic Product
GIS	Geographic Information System
GNP	Gross National Product
IAEA	International Atomic Energy Agency
IARC	International Agricultural Research Centre
IBSRAM	International Board for Soil Research and Management
ICAR	Indian Council of Agricultural Research
ICRAF	International Centre for Research in Agro-Forestry
IFA	International Fertilizer Association
IFDC	International Fertilizer Development Centre
IPM	Integrated Pest Management
LAC	Latin America and the Caribbean
NARS(I)	National Agricultural Research Stations (Institutions)
NZBS	New Zealand Bureau of Statistics
ODA	Official Development Assistance
OECD	Organization for Economic Cooperation and Development
RAEZ	Regional agro-ecological zones
RAPA	Regional Office for Asia and the Pacific, FAO
SNA	System of National Accounts. The flow and balance of national finance, as used in the United Nations Statistical Department.
SSA	Sub-Saharan Africa
UNCED	United Nations Conference on Environment and Development (Rio de Janeiro 1992).
USLE	Universal Soil Loss Equation
UNIDO	United Nations Industrial Development Organization
UNDP	United Nations Development Programme
VHAI	Voluntary Health Association of India
WANA	West Asia-North Africa
WCED	World Commission on Environment and Development
WRI	World Resources Institute

Appendix 1

Agro-ecological zones - definitions and descriptions

At the highest level of aggregation, CGIAR (1992) distinguished nine agro-ecological zones (AEZ) within the land classifications developed by FAO (1978-81). These nine zones are:

Tropics

1. Warm arid and semi-arid tropics
2. Warm subhumid tropics
3. Warm humid tropics
4. Cool tropics

Subtropics

5. Warm arid and semi-arid subtropics with summer rainfall
6. Warm subhumid subtropics with summer rainfall
7. Warm/cool humid subtropics with summer rainfall
8. Cool subtropics with summer rainfall
9. Cool subtropics with winter rainfall

The definitions of the moisture and thermal conditions in these zones are as follows (from CGIAR 1992):

Tropics:	all months with monthly mean temperature, corrected to sea level, above 18°C
Subtropics:	one or more months with monthly mean temperature, corrected to sea level, below 18°C
Length of growing period:	period (days) during the year when rainfed available soil moisture supply is greater than half potential evapotranspiration. It includes the period required to evapotranspire up to 100 mm of available soil moisture stored in the soil profile. It excludes any time interval when daily mean temperature is less than 5°C.
Warm:	Daily mean temperature during the growing period greater than 20°C
Cool:	Daily mean temperature during the growing period in the range 5-20°C
Warm/cool:	Daily mean temperature during part of the growing period greater than 20°C and during another part, less than 20°C
Arid:	Length of growing period less than 75 days
Semi-arid:	Length of growing period in the range 75-180 days
Subhumid:	Length of growing period in the range of 180-270 days
Humid:	Length of growing period greater than 270 days

Appendix 2

Issues in national agricultural policies

as listed in CAB Abstracts Publication Data 1992 on CD-Rom. Key words for search were "agricultural policy" and country.

Country	No. abstracts	Descriptions
China	35	poverty, food security, food self-sufficiency, nutrition levels, agrarian reform, adoption of technology, education, need for capital investment, rural credit, market reforms, redistribution of income, off-farm employment, rural-urban sectoralisation, price interventions, trade policies, erosion control, resource use efficiency, sustainability
India	22	poverty, food self sufficiency, standard of living, agrarian reform, land ownership reform, strategies for peasant farming, farm mechanisation, rural employment, rural credit, market integration, value of cooperatives, agricultural education, rural-urban sectoralisation, price distortions, trade policies, watershed management, pest policy, resource use efficiency, environmental degradation
Philippines	7	poverty, food security, land ownership reform, role of cooperatives, rural employment opportunities, rural credit, price interventions, public management structures
Thailand	7	poverty, food security, nutrition levels, rural credit, price interventions, trade issues
Malaysia	6	poverty, introduction of technology, urbanisation of rural populations, price interventions, pest and disease management
Indonesia	4	food security, price interventions, water pricing,
Sri Lanka	4	food security, land tenure issues, rural-urban sectoralisation, education and health care services, price interventions
Pakistan	3	poverty, food security, nutrition, rural credit, extension and marketing, price interventions, trade policies
Vietnam	1	maintenance of peasant farming
Bangladesh	0	
Bhutan	0	
Cambodia	0	
Laos	0	
Myanmar	0	
Nepal	0	

Appendix 3

Types of basic indicators in use by FAO, CGIAR, World Resources Institute and UNDP.

	FAO	CGIAR	WRI	UNDP
Land use				
Area under agric.	y	y	y	
Individual crop area	y			
Production				
Index of total production	y	y	y	y
Tonnage of major crops	y			
Inputs to agriculture				
Area land irrigated	y	y	y	
Tonnage mineral fertilisers	y	y	y	
No. tractors	y		y	
Pesticides			y	
Demography				
Total no.	y	y	y	y
No. in agriculture	y	y	y	y
No. rural poor		y		y
Urban-rural gaps		y		y
Economic indicators				
GDP	y	y	y	y
GNP	y		y	
Agric. GDP	y	y	y	y
Income per caput		y		y
ODA	y		y	y
Food security				
Food self sufficiency	y	y	y	y
Calorie intake	y	y		y
Natural resources				
Area forested	y	y	y	y
Water resources			y	y
Soil erosion			y	

For the indicators of agricultural sustainbility proposed here, additional data required are:

- cash generating potential, including surplus crop production (on-farm income), off-farm income
- rural:urban separation of data on education and other demographic statistics
- costs and benefits of technology adoption
- water use efficiency
- level of pesticide use by crop

Section I

CHAPTER 4

ANIMAL PRODUCTION TECHNOLOGIES FOR INTEGRATED SMALL FARM SYSTEMS IN THE ASIA-PACIFIC REGION: RELEVANCE AND ASSESSMENT OF NEEDS FOR SUSTAINABLE DEVELOPMENT

C. Devendra [1/]

CONTENTS

Abstract 87
I. Introduction 87
II. Animal populations 88
III. Ruminant production systems 89
IV. Small farm systems 89
V. Major constraints to production 91
VI. Potentially important technologies 92
VII. Implications for development and impact: utilization of research results and institutional requirements 93
References 94

ABSTRACT

Animal production technologies are discussed in the context of their potential importance and transfer for sustainable development in the Asia-Pacific region. The justification for promoting successful transfer and adoption by small farmers is associated with rapid population increase, increased demand for food, resource degradation, inadequate technology application and inefficient transfer, and unsustainable ecosystems. The characteristics, types of small farms and integrated systems are described, including the rationale for integration. Major constraints to production are identified. Several potentially important practical technologies involving both annual and perennial tree cropping systems have shown demonstrable success, and can be extended more widely. The systems approach is essential for defining real needs of farmers which need to be integrated into effective development policy. The implications for development, issues that need to be addressed, and institutional requirements are discussed.

I. Introduction

The importance of sustainable agricultural development in the Asia-Pacific region is derived from a number of urgent considerations, i.e. rapid population increase, increased demand for food, resource degradation, inadequate technology application and inefficient transfer, and unsustainable ecosystems.

The projected population increase in Asia is of overriding concern, and is expected to increase to 4.4 billion by 2025. The population increase will be more acute in South Asia, where it is anticipated to reach about two billion in 2025. Associated with the increased population is rampant poverty, which is also more acute in South Asia, involving an estimated population of about 525 million people. Projections of poverty in the future suggest that by the end of the century, one-half of the world's poor will live in Asia compared to one-quarter in Sub-Saharan Africa (World Bank 1990).

Population growth has direct effects not only on food needs but also on land use systems, demand for land, and varying stresses on the use of the natural resources. In recent

[1/] *Senior Programme Officer (Animal Production Systems), International Development Research Centre (IDRC), Singapore*

years, this has been further exacerbated by urbanisation with increased pressure being placed on the use of precious arable land. Population pressure will place a major stress on the natural resource base. The demand for food has been coupled with resource degradation of which four categories are distinguishable in the Asia and Pacific region:

i) overgrazing of rangelands in the semi-arid tropics of Pakistan, India and Nepal,

ii) overcultivation of croplands, especially in lowland irrigated areas, essentially in rice-based systems,

iii) salinization of irrigated lands, which is increasingly apparent in many parts of South East Asia, and

iv) deforestation throughout Asia.

With specific reference to animal production, the situation is even more serious as questions have been raised about the efficiency of existing animal production systems and the utilisation of resources that support them, and in particular, their inability to meet the needs of national targets relative to crops. Additionally, criticisms have been levelled about resource degradation, and inadequate demonstration of the role of animals in the development of sustainable systems. Notwithstanding these issues, it is emphasised at the outset that the role and contribution of animals in mixed small farm systems is one of much importance (Devendra 1983). In resource-poor situations such as in mixed small farm system where the role of animals is extremely important for a variety of reasons, it is further suggested that sustainable agricultural development under these circumstances is only feasible with the participation of animals.

This paper focuses on the role and contribution of animals and in particular, their role in potential technology development that can promote sustainable production systems in small farms. It alludes to the implications for development, and examines the determinants of technology transfer and institutional requirements that are essential to achieve demonstrable impact.

II. Animal populations

The Asia-Pacific region has a very large variety of animal populations of economic importance. The magnitude of these animal resources is reflected in Table 1. Notable among these, in terms of percentage of the total world population are 98% buffaloes, 86% ducks, 57% goats, 50% pigs, 38% chickens, 30% cattle and 28% sheep. In addition, there also exist sizeable populations of camels, horses, and mules which account for about 24, 26 and 38% of the total world populations, respectively.

TABLE 1. ANIMAL RESOURCES IN ASIA AND THE PACIFIC (FAO 1989)

Species	Population (10^6)	Percentage of total world population (%)	Annual rate of growth 1979-1989 (%)
I. Herbivores			
Buffaloes	137.7	98.0	1.2
Cattle	855.0	30.4	1.5
Goats	463.2	56.8	1.5
Sheep	601.2	28.3	1.8
Asses	38.8	50.5	3.7
Camels	17.2	23.9	0.8
Horses	42.6	26.2	-ve
Mules	14.7	38.2	2.9
II. Non-ruminants			
Chickens	396.5	38.2	7.8
Ducks	472.2	85.9	3.7
Pigs	423.8	50.1	1.6

Within the animal populations, ruminants (buffaloes, cattle, goats and sheep) are numerically more important than non-ruminants and are generally more widely reared. Both categories are owned by small farmers, landless peasants and agricultural labourers. They are renewable resources and have varied functions, from food production (meat, milk and eggs) to various miscellaneous benefits such as security, draught power, fertiliser (dung and urine), fuel, utilisation of coarse crop residues, social values and recreation.

Over the period 1979-1989, the annual growth rate of individual animal population was 1.2 - 1.8%. Among ruminants, the goat and sheep populations grew the fastest (1.5 - 1.8%), followed by cattle and buffaloes. Among non-ruminants, the chicken population grew at a very rapid rate, followed by the ducks.

The pig and poultry industries continue to be advanced animal industries in many countries in Asia and the Pacific. The two industries have already assumed large industrial proportions and are usually found in urban-fringe areas which can absorb the growing domestic market outlets for the products.

III. Ruminant production systems

The prevailing ruminant production systems in Asia are of three categories as follows:

i) Extensive systems

ii) Systems combining arable cropping
- Roadside, communal and arable grazing systems
- Tethering
- Cut-and-carry feeding

iii) Systems integrated with tree cropping

It has been suggested that future trends in ruminant production systems in Asia and the Pacific are unlikely to change. New proposed systems and returns from them would have to be demonstrably superior and their introduction would need to be supported by major shifts in the use of, access to and efficient utilization of resources (Mahadevan and Devendra 1986; Devendra 1989). This situation is especially likely in countries in South Asia where land would be increasingly limiting in the face of increasing human and animal populations. The principal aim, with good justification, is to make maximum use of the basic feed resources available.

More efficient use of the production resources will bring about shifts within the systems through intensification, from the more extensive to systems combining arable cropping, and integration with tree cropping systems. The poorest of the resource-poor farmers and especially the landless will obviously continue practising extensive systems, but strategies need to promote intensive systems that reduce grazing pressure, provide for control animal numbers and promote sustainability and environmental integrity. Factors which are likely to influence this process in the future include:

i) increasing density of animal populations,

ii) control of grazing ruminants,

iii) availability of grazing land,

iv) available feed resources,

v) growth in human populations and demand for animal products,

vi) consumer preferences and marketing opportunities, and

vii) sustainability and environmental integrity.

IV. Small farm systems

There exist a number of definitions of small farms. They have been defined as household units that make most management decisions and that control most of the farm labour supply and normally much of the capital as well. Since the family and the farm unit are the same, labour and capital expenditure decisions represent a choice between household and farm considerations. A more precise definition of small farms is that they represent a complex system of interactions between the animals, crops and farming families, involving small land holdings and minimum resources of labour and capital. The key elements in all of these definitions are *subsistence*, *low income* and *illiteracy*.

A large proportion of these small farms is found within the category of high potential land, which in Asia accounts for 60% of the total area, followed by 21.8% problem land, and 18.2% low potential land (FAO 1988). FAO (1988) has projected that for Asia excluding China, there will be a small increase in agricultural land, much of which related to irrigated agricultural land and tropical forest areas.

A. Characteristics of small farms

The small size of holdings, the low level of economic efficiency, and the diversification of agriculture are all distinctive characteristics of small farm systems. The actual holding size varies between countries. Table 2 illustrates differences between countries within the Asian region. The smallest farm sizes occur in Bangladesh, while households cultivating paddy in Sri Lanka have average holdings of 0.3 ha of land. The average size of small farms in South East Asia is about 1-2 ha.

Diversification of agriculture is the backbone of small farm systems, providing high stability by involving animals and crops. Farmers consciously diversify the use of their resources to embark on a mix of activities which are economically rewarding. Within this broad variety of agricultural activities, opportunities are created for the shift of emphasis in production, for example within crops and animals, with diversification rather than specialisation being the primary consideration. Thus, goats and sheep together with chicken and ducks are commonly reared.

TABLE 2. VARIATION IN THE SIZE OF SMALL FARMS IN SOME COUNTRIES IN ASIA (Adapted from FAO/UNDP 1976).

Country	Definition
Bangladesh	a) Subsistence farmers-cum-croppers <0.4 ha. b) Viable and potentially viable owners, 0.4 to 0.8 ha.
India	a) Small farmers, 2 to 4 ha of dryland (1 ha wet = 0.8 ha of dryland). b) Marginal farmers, 0.8 to 2 ha of dryland and annual income. c) Agricultural labourers, <0.8 ha of dryland and annual income.
Indonesia	a) Java 0.66 ha. b) Average size was 1.2 ha.
Korea	a) Less than 1 ha.
Malaysia	a) Rice farms 1.6 to 1.7 ha. b) Rubber smallholdings 2.1 ha.
Nepal	a) Terai, 4 bighas (2.5 ha). b) Hills, 1.75 bighas (1.0 ha).
Philippines	a) Average size is 2.8 ha.
Sri Lanka	a) Agricultural households, 1.2 ha of land. b) Paddy cultivating households, 0.3 ha of land.
Thailand	a) Non-canal-irrigated areas: 15 rai*.

* *1 rai = 0.16 ha*

The inclusion of animals is based on the consideration that they provide power, food, are a source of supplementary income, insurance and a means of investment. Seldom are more than two species of ruminants reared together. Usually there may be one to two heads of cattle or buffaloes, and more often than not, there are also goats and/or sheep (Devendra 1982). In the humid tropics, where abundant supplies of crop residues are produced from cereal or sugarcane cultivation, the ownership of ruminants provides a means of converting these residues into useful animal products.

B. Types of small farms

There are three broad categories of small farms in Asia:

i) Farms in rainfed agriculture

ii) Farms in irrigated agriculture

iii) Farms in plantation agriculture.

Farms in rainfed agriculture can be found both in lowland and upland situations, and usually in areas with fluctuating rainfall (1000-1500 mm per year). The system is usually traditional and very sedentary, and involves both crop and animals. Both ruminants and non-ruminants are involved, but in general, the upland regions tend to have a higher concentration of animals, mainly small ruminants (goats and sheep), cattle and swamp buffaloes.

In irrigated systems, intensive crop cultivation, mainly rice, is common. Cereal production is therefore the predominant activity and livestock are secondary to this thrust. Large ruminants, especially swamp buffaloes and cattle, however, play a vital role in providing draught power. Pigs, poultry and ducks also form part of this system and are especially suited to this environment where they use available feeds and post-harvest losses of rice to great advantage. Small ruminants are of less importance.

The importance of draught power from cattle and buffaloes on these farms is reflected in Table 3 for farms in Philippines and Thailand. Of particular significance is the fact that for farms up to 2 hectares, both manure and animal power are the most important intermediary inputs. Of the two, animal power is the most critical. It is equally interesting to note that only 2.3% of the farms are associated with mechanical power.

TABLE 3. ESTIMATES OF FARM POWER SOURCES FOR DIFFERENT FARM SIZES IN THE PHILIPPINES AND THAILAND (RAPA/FAO 1989).

Farm size (ha)	Farms with Manual Power		Farms with Animal Power		Farms with Mechanical Power		Farms with Mechanical & Animal Power	
	(10³)	(%)	(10³)	(%)	(10³)	(%)	(10³)	(%)
1	355	40	495	55	19	2	27	3
1-2	263	19	1026	75	23	2	62	4
2-5	267	14	1484	76	40	2	166	8
5	76	7	852	74	31	3	190	16
Total (avg.)	96	18	3857	72	113	2	445	8

Plantation agriculture involves land under tree crop such as coconuts, oil palm and rubber in South East Asia. However, countries with considerable plantation activities also have a sizeable proportion of small farms, including government settlement schemes for them (e.g. Federal Land Development Authority, FELDA) in Malaysia within which animals are found. The animals are reared mainly for food production such as dairy cows for milk, small ruminants for meat and milk production, pigs for meat, and poultry and ducks for meat and egg production.

C. Types of integrated systems

Two broad types of integrated systems can be distinguished. Integrated crop-livestock production systems refer to the combination of one or more types of animal species with crops and fish in a manner such that although each of these sub-systems may function independently, they are nevertheless complimentary and their products additive. Thus, the output from one sub-system, e.g. excreta, becomes the input to the other sub-system, e.g. feed for fish. This synergism in integration and orchestration of the sub-systems produces a greater output than the sum of their individual effects (Edwards et al. 1988). The major types of integrated systems include:

- i) Systems combining crops, non-ruminants, ponds and fish. Pigs and ducks are especially important animal species in these mainly annual cropping systems, and they are very important in China and Vietnam. Major crops that generate feeds are sugarcane, cereal crops and multi-purpose trees.
- ii) Systems combining crops and ruminants. Examples include coconuts, oil palm, rubber and fruit trees. The system is potentially significant in those regions where tree crops are important such as in South East Asia.

There are eight principal advantages of integrated systems:

- i) Diversification in the use of production resources
- ii) Reduced risk
- iii) More complete use of farm labour to ensure high farm productivity, income and access to goods and services
- iv) Integration of components which through their interactions and complementarities provide for high efficiency of resources use
- v) Use of biological and chemical energy are more efficient within the system including less dependence on external sources
- vi) Increased economic output
- vii) Development of sustainable ecological systems that are less dependent on external inputs, require less recycling and produce less pollution, and
- viii) Development of stable households.

V. Major constraints to production

A number of major constraints affect the development of small farm systems, influencing to varying degrees the productivity and operational efficiency of these farms. These constraints can be divided into several sub-categories, i.e. resources (small size of farms, forage production, draught animal power, animal breeding, and animal health), institutional issues (failure to consider the totality of small farms, failure to apply a systems approach, and institutional rigidities and commodity-focused research), and socio-economic factors (common property rights, support services, market outlets, illiteracy and manpower training).

Many of these factors have been discussed at various occasions, usually in reference to either crop or animal production. A systems orientation, however, has been singularly lacking where the following steps and issues merit attention:

A. Stages of the systems approach

Descriptive (diagnostic) stage, technology design, testing and extension

B. Natural resources

The diagnostic approach enables an important understanding of the various factors affecting resource use and potential, the need to ensure appropriate and multiple use efficiently within the totality of the production, post-production and consumption system

C. Interactions and participatory research and development

Interactions occur between the different components of the system, given the multiple use of resources. Thus, the dynamic nature of research and development on-farm requires continued communication between farmers and researchers as well as farmers' active involvement in the process, utilising traditional systems besides productivity-increasing innovations in a progressive path

D. Eco-regional relevance of interventions

Eco-regional relevance recognises location-specific peculiarities in order to develop appropriate strategies that are technically feasible, economically viable and socially acceptable to farming communities

E. Inter-disciplinarity

Inter-disciplinarity is essential to link different components of farming systems: crops, animals, land and water, including socio-economics and others as appropriate.

The value of the systems approach has been frustrated by institutional rigidities that are restricted to, and generally only promote, commodity-focused research. In view of the importance of food grains and crops in general, these sectors have received considerable emphasis, with the animal component generally left out of the research programme. Even where there is recognition of the limitations of such compartmentalisation within institutes or departments, efforts are seldom made to link different sectors. These difficulties are often compounded by administrative, professional obstacles and vertical or top-down approaches. The situation has tended to perpetuate strong commodity-oriented programmes at the expense of developing joint crop-animal research efforts that are well conceived, formulated to resolve problems, challenging, and potentially capable of promoting increased productivity and sustainable development of small farm systems.

VI. Potentially important technologies

Potentially important technologies that can make a significant contribution to the sustainable development of small farm systems have recently been reviewed (Devendra and Chantalakhana 1992). These technologies are referred to briefly:

i) Annual cropping systems
   - a) Food-feed intercropping
   - b) Relay cropping
   - c) Three-strata forage system
   - d) Crop-animal systems in lowland rain-fed areas
   - e) Integrated systems combining crops, non-ruminants, ponds and fish
   - f) Integrated systems combining crops and animals.

ii) Perennial tree cropping systems
   - g) Integrated small ruminant-tree cropping systems

In an eco-regional context, all the technologies are suited to the lowland and upland areas of the humid tropics of South East Asia, where indeed their application has proven to be very successful. Tables 4 and 5 are illustrative of the beneficial effects, clearly demonstrating the value of integrated resource use.

The three-strata forage system has been especially beneficial to the low rainfall and drier upland areas, such as in eastern Indonesia and elsewhere. The concept of the three-strata forage system (TSTS) involves grasses and ground

TABLE 4. ECONOMIC IMPACT OF CROP-ANIMAL SYSTEMS IN TRANSMIGRATION SCHEMES. BATUMARTA, SUMATRA, INDONESIA (CRIC 1991)

Farming systems*	US$/ha/year**	Contribution to income (%)
Model A	1,230	Rubber - 53%
Model C	2,055	Food crops - 30%
Net gain	825	Animals - 17%

* *Model (A) - Farmer's existing system without animals*
Model (C) - Introduced farming system with animals (1 cow + 3 goats + 11 chickens)

** *US$ = 1963 In. Rups (approx.)*

TABLE 5. THE EFFECT OF MIXED CATTLE AND GOAT GRAZING ON THE YIELD OF FRESH FRUITS IN OIL PALM CULTIVATION IN MALAYSIA (Devendra 1991)

Year	Grazed area (Yield of fresh fruit bunches/ha/yr, MT)	Non-grazed area (Yield of fresh fruit bunches/ha/yr, MT)	Difference (fresh fruit bunches/ha/yr, MT)
1980	30.55 (C)*	25.61	4.94
1981	17.69 (C)	15.87	1.82
1982	25.12 (C + G)**	22.97	2.15
1983	23.45 (C + G)	18.29	5.16
Mean	24.20	20.29	3.51

* *C = cattle*

** *C + G = cattle and goats*

legumes (first stratum), shrub legumes (second stratum) and fodder trees (third stratum).

Three major highlights of the work done are illustrative of the success of the project:

i) The availability of increased forages enabled higher stocking rates and live weights to be achieved; 3.2 animal units (375 kg/ha/year) in the TSFS compared to 2.1 animal units (122/ha/year).

ii) Cattle in the TSFS were less infested by endoparasites. This was presumably due to less contact with the traditional cattle, since the TSFS cattle were always kept in confinement.

iii) The introduction of forage legumes into the TSFS reduced soil erosion by as much as 57% in the TSFS compared to NTSFS. Additionally, soil fertility in the TSFS was considerably improved.

iv) With the presence of 2000 shrubs and 42 trees logged twice a year, the firewood production of 0.25 ha TSFS was 1.5 tonnes per year. Since the firewood requirement of a household was 4.2 MT annually, the TSFS supplied 64% of the farmer's requirement. Table 6 summarises the results.

TABLE 6. COMPARATIVE PRODUCTIVITY OF TSFS AND NTSFS PLOTS (kg dry weight/plot per year) (Nitis *et al.* 1990)

Parameter	TSFS*	NTSFS**
Food	853	1260
Straw	750	1218
First stratum	455	-
Second stratum	310	-
Third stratum	15	-
Shrubs	-	132
Trees	-	2
Improved grasses	-	10
Native grasses	-	242
Firewood	1049	475
Cattle live weight gain (kg/3 year)	186	166
Carrying capacity (cattle/ha)	4	2
Maximum live weight (kg/head)	300	200
Soil erosion (mm/2 years)	11	20

* *Three-strata forage system*

** *Non-three strata forage system*

With a view to increasing the sustainability of the system, the integration of goats will provide greater flexibility of resource use by farmers. Associated with the success of each of these projects is the parallel demonstration of the promotion of sustainability, involving the following issues:

i) Efficient management and use of natural resources in which the following elements are significant:

ii) Low input sustainable agriculture - this includes soil fertility management, water and integrated pest management

iii) Efficient use and management of the animal resources that is consistent with optimum production, stability of farming systems, and environmental protection

iv) Conservation of on-farm genetic biodiversity

v) Community-based participatory processes

vi) Alleviation of poverty, and

vii) Consideration of production, post-production and consumption as a system.

In the light of the potentially important benefits of these proven technologies to sustainability involving the integral role of animals, accelerating their application through more effective technology transfer processes backed by increased resource use becomes a particularly important challenge for the Asia-Pacific region in the future. For animal production, this task becomes even more compelling in order to demonstrate the relevance of animals as an important determinant of promoting the development of sustainable agriculture. Increased commitment to this task is justified on the grounds of proven impact, especially since doubts are being expressed about the current role and contribution of animals and the resources being used to support production systems.

VII. Implications for development and impact: utilization of research results and institutional requirements

Current approaches to technology transfer are generally haphazard and not well coordinated and there are a variety of reasons for this. The most common limitation is that of weak linkages between research and extension which often tend to work independently. If future projects are going to make a significant contribution to sustainable small farm systems and also make an impact, clear project programming is essential.

Such programming should be undertaken along certain well established criteria: the nature, importance and magnitude of the problems to be addressed have to be identified. Researchable issues involved and the potential effects need to be defined. The capacity to use fully utilize available natural resources should be evaluated. Interventions should be timely and research feasible within a given time frame. The degree of integration of systems and especially commodities (e.g. rice, pigs and fish) have to be clearly identified with a view to efficient resource management, sustainable development and sound environment. Particularly important is the definition of potential users and target populations where the participation of farmers is central. Potential benefits (optimisation of income and renewability), impact, contribution to solutions, and economic and social costs have to be assessed. Programmes should further establish their expected effects on the imbalance in development between rural and urban people, the contribution to the alleviation of rural malnutrition and poverty, national and regional development goals, and the regional relevance and potential for the transfer of technology and replication without any negative impact.

The utilisation of research results at the farm level merits highest priority in technology development and demonstration. Strategic options should be formulated which can be identified with action programmes which have as ingredients understanding of traditional systems, real needs of farmers, and effective development policy.

There are many institutional requirements for supporting the task. Commitment to the concept of integrated systems and a systems approach is essential. Provision of manpower and support services for the duration of projects and beyond are further ingredients. Inter-institutional coordination and collaboration need to be established, providing support to training, both formal and informal, information exchange services, and dissemination of information.

REFERENCES

CRIC 1991. Crop-Animal Systems Phase II. Terminal Report, Bogor, Indonesia.

DEVENDRA, C. 1982. Small farmer goat production in the less developed countries. *Proc. 3rd Int. Conf. on Goat Production and Disease*, Tucson, Arizona, U.S.A., p 329-330.

DEVENDRA, C. 1983. Small farm systems combining crops and animals. Proc. Wrld. Conf. Anim. Prod., Tokyo, Japan, *Vol.* I, 173-191.

DEVENDRA, C. 1989. Resource utilisation in ruminant production systems in developing countries. In: Feeding Strategies for Improved Productivity of Ruminant Livestock in Developing Countries, IAEA, Vienna, p 5-30.

DEVENDRA, C. 1991. The potential for integration of small ruminants and tree cropping systems in South and South East Asia. Wrld. Anim. Rev. (FAO), 66: 13-22.

DEVENDRA, C. and Chantalakhana, C. 1992. Development of sustainable crop-animal systems in Asia. Proc. VI Asia-Australasian Anim. Sci. Congr., Bangkok, Thailand. (In press).

EDWARDS, P., PULLIN, R.S.V. and GARTNER, J.A. 1988. Research and education for the development of crop-livestock-fish farming systems in the tropics. ICLARM Studies and Rev., No. 16, 53 pp.

FAO/UNDP 1976. Regional Office for Asia and the Far East, Bangkok, Thailand (Mimeograph), 66 pp.

FAO 1988. World Agriculture: Towards 2000. An FAO Study. (Ed. Alexandratos, N.), Belhaven Press, London, England, 264 pp.

FAO 1989. Production Yearbook. Vol. 3, FAO, Rome, Italy, x + 346 pp.

MAHADEVAN, P. and DEVENDRA, C. 1986. Present and projected ruminant production systems of South East Asia and the South Pacific. In: Forages in South East Asia and the Pacific, ACIAR Proc. No. 12, p 1-6.

NITIS, I.M., LANA, K., SUKANTEN, W., SUARNA, M. and PUTRA, S. 1990. The concept and development of the three-strata forage system. In: Shrubs and Tree Fodders for Farm Animals (Ed. C. Devendra, International Development Research Centre, IDRC-276e, Ottawa, Canada, p. 92-102.

FAO RAPA 1991. Selected indicators of food and agriculture development in Asia-Pacific, 1980-90. RAPA Publ. 1991/18, Regional Office for Asia and the Pacific, Bangkok, Thailand, 211 pp.

WORLD BANK 1990. Poverty. World Bank Rpt., Oxford University Press, U.S.A., xii + 260 pp.

Section I

CHAPTER 5

TECHNOLOGY ASSESSMENT AND TRANSFER - AN AUSTRALIAN PERSPECTIVE

M. Williams [1] *& R. Munro* [2]

CONTENTS

Abstract 95
I. Introduction 95
II. General Agricultural Background of Australia 96
III. Technology Assessment for Varying Agro-Ecological Zones, Production Systems and Resource Endowments 98
IV. Strategic Technologies in Agriculture 101
V. Technology Transfer in Australia 105
VI. Regional Collaboration in Technology Assessment and Transfer 108
VII. Recommendations 109
References 110

ABSTRACT

This paper outlines the current Australian approach to technology assessment and transfer for sustainable agriculture. It describes Australia's general agricultural situation and the major agricultural production systems. Current actions to develop indicators of sustainability for each of the major agro-ecological zones are reported, along with an assessment of the major strategic technologies likely to impact on the sustainable development of Australian agriculture. Finally, the paper describes the governments' roles in technology assessment and transfer in Australian and Asia-Pacific regional development.

I. Introduction

Australia lies in the mid-latitudes and is dominated by high pressure systems which give rise to arid and semi-arid climates. Its total agricultural area has remained fairly constant over the last 40 years ranging between about 450 to 500 million hectares (M ha). Only 5 percent of the Australian workforce is currently employed directly in agriculture. In 1989, 390,000 people were employed on 125,000 agricultural establishments. In 1989, $A 23.5 billion was produced by the agricultural industries, and $A 16.3 billion of this was exported.

In Australia, a major emphasis of technology assessment and transfer is now to ensure that agriculture is ecologically sustainable. Implementing sustainability requires the development of indicators and monitoring programmes to help managers evaluate the sustainability of agricultural practices in each of the 11 major agro-ecological zones. The indicators being developed relate to farm management, production balance and the resource base, particularly the state of the soil.

As world production increases, economic demands increase and the supply of arable land becomes fully used, technology will be required to make an increasing contribution to meeting the rising demand for agricultural products.

[1 & 2] *Bureau of Resource Sciences, Department of Primary Industries and Energy, Canberra, Australia*

The impact of new technologies on sustainable agriculture can only be assessed fully when the goals for and indicators of sustainable agriculture are understood.

Four technologies and their likely uses are described - information and communication technologies, biotechnologies, advanced processing technologies and advanced materials.

Technology transfer in Australia is provided by government and private commercial organizations. The government sets the broad economic, regulatory and information framework within which the commercial sector operates. It also provides services aimed at maximizing community benefits from sustainable use of national agricultural resources. The private commercial service is aimed primarily at the private benefit of farmers.

Public sector technology transfer in Australia links with other regional government services, research (publicly and privately funded), regulation, farm assistance services, education and diagnostic services.

In the Asia-Pacific region, Australia aims to participate in cooperative programmes of technology assessment, research and technology transfer that produce benefits for all participants.

II. General agricultural background of Australia

Australia is a large country of 7.7 million square kilometres. The population in 1989 was 16.8 million people, growing at about 0.23 million people per year. Population growth comes almost equally from natural increase and immigration (0.13 and 0.11 million year respectively).

Australia lies in the mid-latitudes and is dominated by high pressure systems which give rise to arid and semi-arid climates. Nearly 70 percent of Australia receives less than 500 mm precipitation annually. Variability of rainfall is also high Figure 1) and drought (defined as less rain received than in the driest 10 percent of all years) has occurred over a large part of the continent in more than 30 percent of years since 1965. These climatic features have important implications for land use and productivity in Australia. One 60 percent of Australia can be used for agricultural purposes, and much of this is arid rangeland of low productivity. When Australia's latitude is compared to that of Europe and North Africa, this is not surprising (Figure 2).

Australia's total agricultural area has remained fairly constant over the last 40 years ranging between about 450 to 500 million hectares (M ha) (Table 1). The use to which this land has been put has changed, with a gradual increase in the area under cultivation, and a dramatic expansion of the area under sown improved pasture during the 1950s and 1960s.

This area supported about 125,000 commercial agricultural establishments in 1989, a marked reduction from the 200,000 establishments of the decades of the 1950s and 1960s. This contraction in number has reflected the commercial pressures as farmers have attempted to maintain financial viability by expansion of property size. The number of

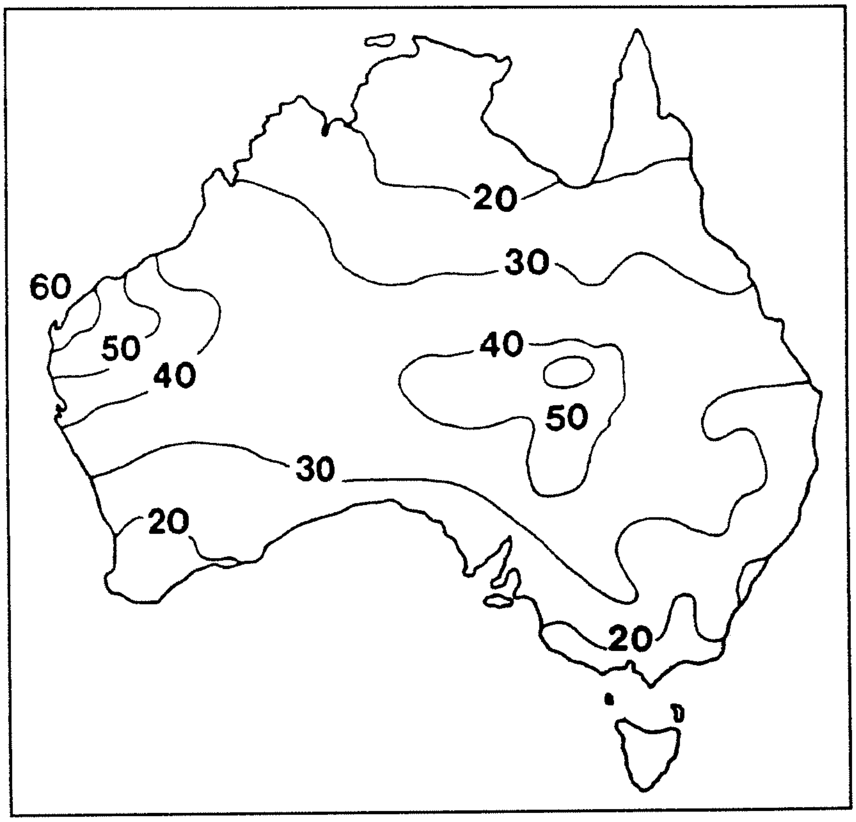

FIGURE 1. VARIATION IN ANNUAL RAINFALL IN AUSTRALIS (percentage of mean)

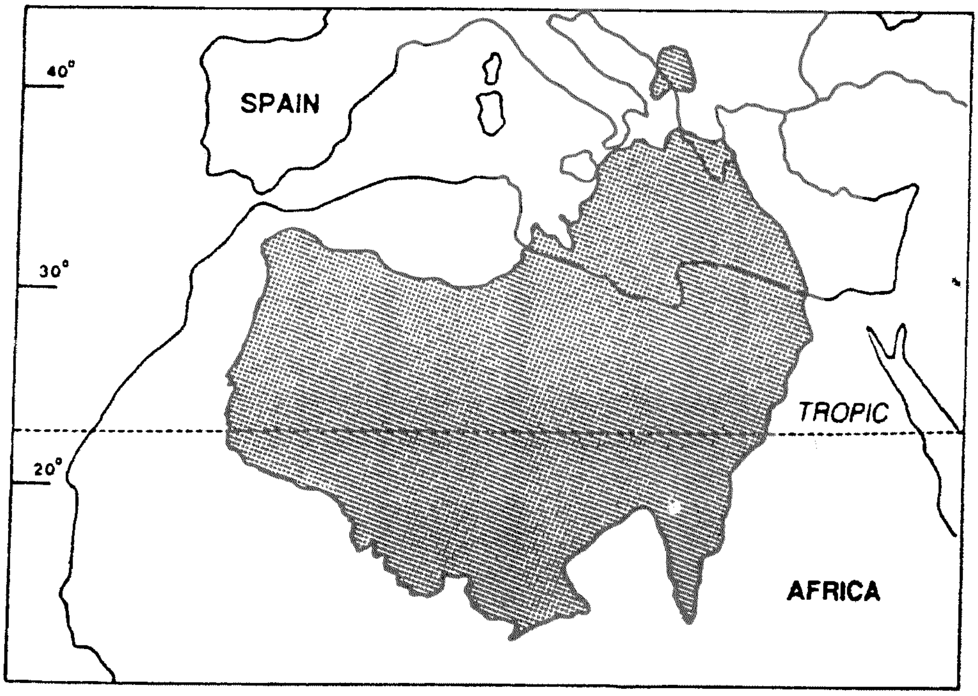

FIGURE 2. SUPERIMPOSITION OF AUSTRALIS'S LATITUDINAL POSITION ONTO EUROPE, DEMONSTRATING THE SUBTROPICAL EXTENT OF AUSTRALIA

people employed in agriculture has also fallen, from about 480,000 in the 1950s to about 390,000 in the 1980s.

This decline has occurred while total employment in Australia has risen from 4.3 million to 7.8 million people over the same period. Only 5 percent of the Australian workforce is currently employed directly in agriculture.

The large area of pastoral land and sown pastures in Australia supports large numbers of grazing animals and is reflected in the value of animal production in Australia. In 1989, the gross value of production of major sectors was:

Crops	$A 9.9 billion
Livestock slaughtering	$A 5.7 billion
Livestock products	$A 7.8 billion
Total	$A 23.4 billion

The populations of domestic animals that have contributed to this level of production have been primarily cattle and sheep. Accompanying the increased area of improved pastures, their numbers have increased in the last 40 years, with the exception of dairy cattle (Table 2). Dairy cow numbers have fallen to half their 1950 level but this has been compensated for by a doubling of output per cow. The net result has been a relatively constant output of milk through much more is now used for cheese production and less for butter (Table 3) than in the 1950s, 1960s and 1970s.

TABLE 1. AREAS OF MAJOR LAND USE TYPES IN AUSTRALIA (million ha)

	1950	1960	1970	1980	1990
Wheat	4.1	4.9	9.5	11.1	9.0
Other crops	3.8	5.2	6.1	6.9	8.0
Sown grasses and pasture	7.5	13.5	26.2	26.2	30.9
Total area of farms	441.3	464.5	494.7	495.6	466.8

TABLE 2. NUMBER OF CATTLE AND SHEEP IN AUSTRALIA (million)

	1950	1960	1970	1980	1990
Dairy cattle	4.6	4.9	4.2	2.8	2.5
Beef cattle	10.3	11.6	17.9	23.2	20.7
Sheep	110.2	149.0	174.2	132.7	173.8

TABLE 3. AUSTRALIAN DAIRY INDUSTRY STATISTICS

	1950	1960	1970	1980	1990
Number of cows in milk (million)	3.1	3.2	2.8	1.8	1.6
Milk yield/cow (litres)	1,729	1,971	2,659	2,888	3,788
Total milk production (10^9 litres)	5.6	6.3	7.5	5.4	6.2
Butter production (kilo tonne)	162	198	223	84	104
Cheese production (kilo tonne)	45	46	76	151	175

Australia produces a surplus of food and is a major exporter of food and agricultural products. The value of Australia's major exports in 1989 were:

Cereal grains and products	$A 3.2
Sugar products and honey	$A 1.0
Meat and meat preparations	$A 3.9
Wool and sheepskins	$A 3.8
Other products (including dairy)	$A 4.4
Total	$A 16.3

III. Technology assessment for varying agro-ecological zones, production systems and resource endowments

The traditional approach for technology assessment and transfer in Australia has focused on enhancing the productivity of agricultural systems. However, the realization has grown that despite the ability of man to manipulate the agricultural ecosystem the ability of that system to remain productive is still governed by the laws of physics, chemistry and biology. This realization has prompted concerns over the state of the ecosystem which go beyond the traditional concerns of productivity and embrace the notions of stability and sustainability. A major emphasis of technology assessment and transfer is now to ensure that agriculture is ecologically sustainable. In consultation with policy-makers, researchers, industry and community groups, the Australian government has recently examined the issues concerned with achieving ecologically sustainable development in agriculture and other land uses.

It is the concern with ecologically sustainable development that will be the focus of this section. Section 3 will discuss a broad range of strategic technologies that will affect agriculture and the sustainability of agricultural systems in Australia.

Agriculture is defined as sustainable when it remains the dominant land use over time and the resource base can continually support production at levels needed for profitability (cash economy) or survival (subsistence economy).

Implementing a desire for sustainability has required the development of monitoring programmes and techniques to help managers evaluate the sustainability of their agricultural practices. Linking early warning of ecological deterioration, and associated loss of productivity, with specific practices is important to agriculture. It is also a challenge to scientific analysis in an area where complexity and the presence of interacting and confounding factors are common.

The current work on indicators for sustainable agriculture in Australia is being linked with the work of the Australian Bureau of Statistics on developing a set of natural resource accounts to complement the purely economic current accounts presently reported.

A. Major agricultural ecosystems in Australia - a regional approach

An understanding of the agricultural ecosystem is the basis of formulating a programme for achieving sustainability. A system based on climate, land form, lithology, natural vegetation, soils, land cover and river basins has been used in Australia to divide the continent into eleven major agro-ecological zones (Figure 3) with 46 sub-zones which are not presented here but are described in other publications (Hamblin 1992). A brief description of the nature and use of the major agro-ecological zones follows:

Wet temperate coasts

This incorporates the southern coastal region of NSW, the south-west coast of Western Australia, and all of Tasmania. The region encompasses narrow coastal plains, hilly and mountainous coastal environments. climate is wet and cool with a strong winter-dominant rainfall. The primary agriculture is dairying, intensive crops, beef and horticulture.

West sub-tropical coast

This region consists of coastal lowlands, plains and bordering ranges. The landscapes are characterized by

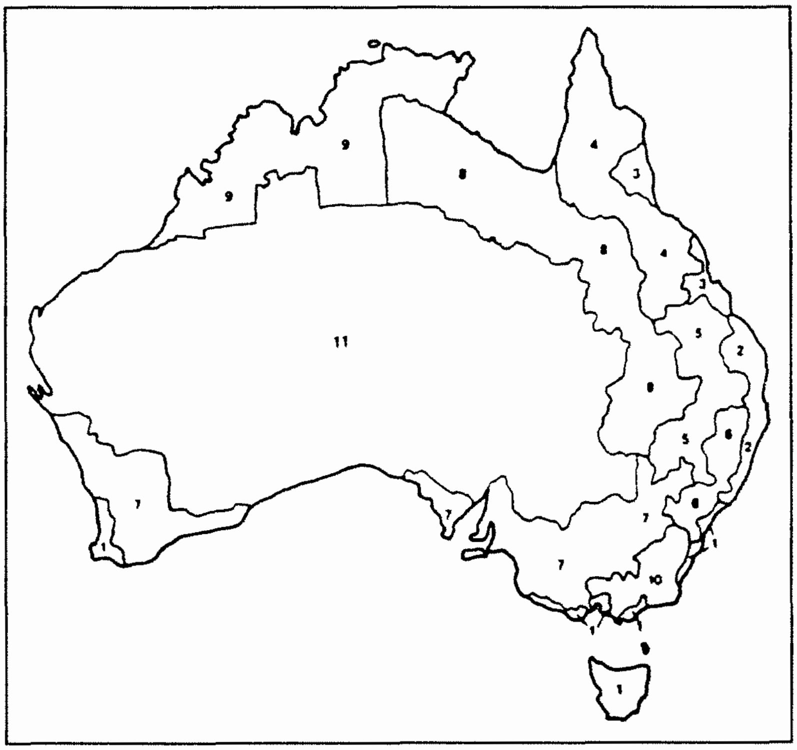

FIGURE 3. MAJOR AGRO-ECOLOGICAL ZONES OF AUSTRALIA

cleared alluvial plains backed by forested hill lands. Climate is warm and wet with uniform to summer-dominant rainfall. Forestry, dairying, sugarcane, maize, intensive crops, horticulture and increasing tourism are the principal land uses.

Tropical wet coast and tableland

In the norther section, the narrow alluvial plains and hills have been cleared of native vegetation and all used intensively for sugarcane production. The mountains to the west remain under eucalypt and mixed closed rainforests. The southern section has alluvial plains and rolling hills with small mountain areas. The climate is hot and wet with a strong summer-dominant rainfall. Sugarcane and intensive cropping occupy the alluvial plains and hills while beef cattle grazing occurs over most the region.

North-eastern wet/dry tropics

This region includes extensive plains as well as extensive rolling and hilly lands with some mountains. The plains of Cape York are frequently inundated. The climate is hot but the whole region is used for extensive beef cattle production. The Burkekin Irrigation Area has intensive cropping of sugarcane, rice and a whole range of horticulture.

Sub-tropical slopes and plains

This region is dominated by plains which are in the north divided by low but frequently rugged ranges and in the south bordered by slopes and upland areas to the east. Cracking clay soils dominate the whole region. The climate is dry with hot summers, warm winters and in general a summer-dominant but variable rainfall. Land use includes sheep, cattle, irrigated cotton, oil seeds, and the area is important for production of high protein wheat.

Sub-tropical highland

This region consists of rolling, undulating and hilly country. The climate is moist and cool with a generally uniform rainfall distribution in the south which becomes summer-dominant in the north. Intensive livestock grazing of sheep and cattle and irrigated agriculture and horticulture are important, although the mining of coal is a significant competing land use.

Temperate semi-arid slopes and plains

This is a diverse region. The climate is dry with hot summers, cool winters and a winter-dominant rainfall. Throughout the eastern region, irrigation farming and horticulture is very important.

Semi-arid tropical and sub-tropical plan lands

This huge region is characterized by plains, considerable areas of which are alluvial and estuarine. Grazing of both sheep and cattle is the dominant land use.

North-western wet/dry tropics

The climate is strongly monsoonal, characterized by a hot summer followed by a very dry warm winter. Large areas of the region are of very rugged topography, currently are unused, or are part of important national arks. A great deal of this region is under Aboriginal ownership. Extensive been cattle grazing is the dominant agriculture. Dryland cropping and irrigated intensive cropping and horticulture are of growing importance in the valleys of the northern rivers.

Temperate highlands

Much of the region is above 1,500 metres with peaks rising above 2,000 metres. It is one of the better watered regions in Australia. The climate is wet with cold winters and hot dry summers. The large variation in altitude and proximity of coastal influences, generates a considerable diversity of environments over this region. The grazing of sheep and cattle on improved temperate pastures for wool, lamb, beef and dairy products dominates the agriculture. Forestry, water resources and tourism are very important land uses in the region.

Arid interior

This extremely large region of arid land encompasses considerable diversity of soils, geomorphology and vegetation. Generally the land is of low relief but important and well-known mountain ranges characterize ares of this region. With the exception of dune fields and gibber plains, much of the area has been used for extensive livestock grazing. This remains the major agricultural use of the region. Mining, and increasingly tourism, are important land uses.

B. Indicators of sustainability for model agro-ecological zones

The concept of sustainability is appealing because of its apparent simplicity by applying the concept to specific problems can be difficult. Because of this a workshop (Hamblin 1992) in Australia was organized to develop indicators for six typical Australian agro-ecological zones. The most important indicators were assembled in a matrix (Table 4). Indicators relate to three important aspects of sustainability:

i) management level, including financial and production aspects;

ii) production balance, particularly the relationship between inputs such as water, nutrients, and the agricultural outputs; and

iii) resource base and status particularly the state of the soil which is a fundamental resource for agriculture.

C. Soil nutrient balance

One of the results of preparing sustainability indicators is the realization that soil nutrients are not inexhaustible. The export of soil nutrients from a region, in agricultural products or through erosion and leaching must be balanced by inputs, such as weathering of rock to soil, deposition of alluvium of deliberate importation of nutrients in fertilizers. A nutrient budget can be prepared for a region as an initial indicator of the sustainability of this aspect of an agricultural system.

TABLE 4. THE THREE MOST IMPORTANT PRIMARY INDICATORS OF SUSTAINABLE AGRICULTURE, SELECTED DISCUSSION GROUPS AT A BRS WORKSHOP

Agro-ecological region	Primary indicators * = data or measurement required		
	Management level	Production balance	Resource base
Rainfed crops and animals	Farm management skills *cash flow, equity, planning	Water use efficiency *yield/area/rainfall	Soil health *pH, nutrient balance, biota
High rainfall rangeland for animals	Production/area *animal weight/hectare	Plant growth/cover *percentage greenness, species/area	Soil bi-indicators *worm, termite, etc., numbers and species
Low rainfall rangeland for animals	Management capability *planning, debts, assets condition, record keeping	Animal health and productivity *live weight gain quality/quantity, fleeces, carcases	Pasture and soil conditions *percentage bare ground, pasture composition
Irrigated crops and pastures	Farm and district profitability *debt, equity etc. for farm level; true cost/benefit (including environmental costs) at district level	Water use efficiency *plant use/water applied, water table trends/crop weight/water used	Soil health *infiltration rate, percentage subsoil compaction, biomass activity, chemical residue level
Intensive horticulture and viticulture	Percentage integrated pest management adopted in industry *chemicals sales, grower records, faunal surveys	Nutrient balance yield and nutrient *contents, fertilizer sales, surface water composition	Soil permeability/watertables *irrigation water use, piezometry, soil infiltration
High rainfall tropical systems	Diversity of production *number of land uses or crops, number of isolated vegetation patches	Water quality *surface water composition, blooms, pesticides, sediments	Soil productivity *pH and organic matter trends, subsoil compaction, soil structural condition

A nutrient budget for Australia has been prepared (Hamblin 1991) and is presented here as Table 5. The figures show the large removal of nutrients in exports and the need for inputs to replace this loss. Current levels of fertilizer use are able to maintain the S and P balance, while without legume N fixation there would be a deficit of N. The K reserves are currently being depleted, though the quantities involved are much less than in the N balance. From this simple budgeting approach emerges the importance of legume N fixation to Australian wheat production and appropriate research and technology transfer can then be directed to ensuring the sustainability of soil N levels.

TABLE 5: AN APPROXIMATE NUTRIENT BUDGET FOR AUSTRALIA (N,P,K, and S)

Exports (1987-88)		
Nitrogen (N), phosphorous (P), potassium (K) and sulphur (S) exported in wheat, barley, wool and meat, calculated from average elemental composition:		
N	397	kilo tonnes
P	51	kilo tonnes
K	89	kilo tonnes
S	54	kilo tonnes
Total	591	kilo tonnes
Inputs (1987-88)		
Fertilizers applied to crops and pastures:		
N	200	kilo tonnes
P	279	kilo tonnes
K	4	kilo tonnes
S	85	kilo tonnes
Total	568	kilo tonnes
Additional N from legumes about	780	kilo tonnes*
Total inputs	1,348	kilo tonnes

**Assuming 26 million hectares of legume-based pastures and grain legumes, and an average contribution of 30 kg N/ha/year.*

IV. Strategic technologies in agriculture

Technological developments in agriculture are occurring at an increasingly rapid rate and it is predicted that this rate will accelerate rather than decline as the world's demand for agricultural products rises in the future. Technology will be required to made an increasing contribution to meeting this demand, especially as the world's supply of arable land is expected to be fully exploited by the end of the 1990s.

The impact of new technologies on sustainable agriculture can only be assessed fully when the goals for, and indicators of sustainable agriculture are understood. As indicated in the previous section, Australia is moving quickly to define indicators of sustainability for its main agro-ecological systems pending these definitions, governments and industry are using the concept of sustainable agriculture to give strong guidance on the appropriate use of new technology, using the basic concepts shown in Table 4.

Technological developments in agriculture may be applied to improve:

i) on-farm production, through increasing control over production, diversifying products and replacing labour;

ii) post-farmgate processing, through adding value, replacing labour; and

iii) management of natural resources through enhanced assessment and monitoring.

This section describes the technologies most relevant to fostering sustainable progress and competitiveness in Australian agriculture and, therefore, which are likely to have significant impacts on agriculture and land management in the future. A significant fact in the selection of these technologies for Australia is the national drive to maximize return form agricultural production through the development of a larger agri-business sector, including food and fibre processing from local produce. The major generic technologies of significance are classified into:

i) information and communication technologies including computers, farm models, remote sensing, geographic information systems and high speed communication systems;

ii) biotechnologies including genetic engineering, reproductive technologies and biosensors;

iii) advanced processing technologies including farm and factory mechatronics and automation; and

iv) advanced materials.

A brief description of each of the generic technologies follows. The description indicates likely agricultural uses for the technologies, current progress in their development and Australia's state of expertise in their development and application.

A. Information technologies and communication

These technologies include computer and telecommunications hardware and software such as telephone and facsimile systems, computer simulation models/decision support stems/expert systems, geographic information systems, control systems, data handling and analysis, sensors and peripherals, new data storage technologies (e.g., CD ROMS) and remote sensing. Increasingly, they are important technologies for rural landholders, researchers and government agencies because they assist the assessment and management of natural resources and they are critical to technology transfer through the dissemination of information to dispersed rural communities.

Application of these technologies in agriculture include:

i) Telecommunications and high-density data storage devices such as CD ROMS for bringing detailed news and data to those in remote areas. These technologies are helping farmers to make effective use of the large volume of information that is becoming available to them.

ii) Identification of profitable, ecologically sustainable farming stems. Computer models to assess these systems over a wide range of seasons have been developed for several of the major agricultural systems in Australia, and incorporated into support systems.

iii) Remote sensing technologies to monitor drought, vegetation type and land degradation. Estimation of the areal location of rain and of soil moisture is being improved. Improvement in crop yield prediction is also being addressed. These technologies were used very effectively in Queensland during the 1991-92 drought.

iv) Decision support systems and geographical information systems technologies will aid in the development and implementation of farm plans and regional management plans that take the variability of the climate and agro-ecosystems into account.

v) National, computer-based breeding schemes using the basic principles of population genetics to assist the genetic improvement of livestock flocks and herds (e.g., BREEDPLAN for beef, WOOLPLAN for sheep and PIGBLUP for pigs in Australia).

vi) Models to help determine whether a particular plant or animal is potentially suited to a particular environment.

vii) On-farm and factory process control (e.g., irrigation control, electronic pasture probes for assessing feed-on-offer, laser levelling of fields) to improve sustainability and efficiency of resource use.

Progress in developing agricultural uses of information and communications technology is very rapid and likely to remain so for the foreseeable future. In Australia, there has been a rapid rate of uptake on-farm of computers for financial and other forms of farm management. At least 15 percent of farms now own computers.

Technologies such as remote sensing are now benefiting from other developments in the IT area. Remote sensing is a well tried and tested technology. In the past the availability of data has been an issue to organizations most needing it, and the computing power to handle the data has not been generally available. The situation has changed on both fronts and we now have the data supply, technology and trained personnel to make use of the information afforded from remotely sensed data.

Australia has well developed research capabilities and a high rate of usage of IT in agriculture and related industries.

For example, Australia's expertise in remote sensing lies in the applications area and the integration of remotely sensed data with other spatial information and modelling .capabilities. At the present time the research thrust is in using remotely senses data for monitoring the time series of data in areas such as in climatology and land management.

B. Biotechnologies

The techniques of molecular biology, including genetic engineering, are increasingly being applied to traditional areas of agriculture to increase man's control over the biological processes of production. The development and use of biotechnologies offer significant tools to sustainably increase productivity. However, they must be developed, tested and applied with the performance of complete agricultural systems in mind, including soil, water and the human food chain.

Examples of biotechnologies are plant and animal breeding, disease and health diagnostic tools, therapeutics and product processing. The technologies include (a) genetic engineering, (b) reproductive technologies, (c) cell receptor manipulation, (d) protein engineering, (e) biosensors, and (f) other drugs and vaccines.

(a) genetic engineering

This technology is seen to have the greatest potential of any of the biotechnologies to improve agricultural yields, provided appropriate environmental and human health safety standards can be developed for the field releases.

Genetic engineering is being applied to agricultural plants and animals, insects, and micro-organisms such as bacteria and viruses. It is being used to promote genetically modified organisms which have more desirable market characteristics, better growth rates and resistance to pests and diseases.

Compared to more traditional breeding technologies, genetic engineering should provide the possibility of more rapid development of new, tailored varieties of agricultural plants and animals to cope with a range of environmental conditions.

In the last two years, several genetically modified organisms in Australia and overseas have been released to the field under experimental conditions. Those released or approved for release in Australia are all either micro-organisms or plants. Genetic modification of farm animals is not yet sufficiently advanced for field release.

There are 12 planned releases of genetically modified organisms in Australia. One of these (*Agrobacterium radiobacter* K1026) has been registered for the control of the disease "crown gall". This was the first genetically engineered product released in the world.

There have been six planted releases approved y the Genetic Manipulation Advisory Committee in 1992: Canola plants, which are expected to show an increased yield, carnation plants which will have a much longer vase life, potato plants with both increased tuber number and increased yield, a tomato that is able to ripen on the plant longer and as consequence has a better flavour and the ability to withstand damage in transport, potato plants with a resistance gene go potato leaf roll virus and a cotton plant with a gene from the bacteria *Bacillus thuringiensis* that confers resistance to some insect pests.

A key issue for the use of genetic engineering is its regulation to ensure safe and efficient releases of new organisms. The Australian Government is considering the recommendations of the House of Representatives inquiry and Cabinet is expected to formally respond to these recommendations in the near future.

Intellectual property rights, patents and plant variety rights are also at issue in the use of novel organisms, whether created by traditional or new techniques.

(b) Reproductive technologies

Animal and plant reproduction technologies are used to increase reproductive rates, prevent reproduction so as to divert energy to production of food or fibre, and to control the quality and type of offspring.

The reproduction processes of plants and animals at the cellular level are becoming well understood. Manipulations and enhancement of these processes mean that animal cloning and selection of production traits in embryos is an approaching reality in animals. Globally, animal industries look about to become more dependent of reproductive technology.

In plants cell micropropagation has been in practice for many years. The process allows the mass production of uniform high quality plants to meet specific market requirements.

Animal embryo manipulation including cryogenics (freezing) is developing to the stage where frozen embryo trade will probably replace most live animal trade in the 1990s. This will significantly reduce disease risks because many bacterial and viral diseases are not transmitted by embryos.

Top quality stock may multiply rapidly in Australia using embryo manipulation technologies. This could be particularly useful in restocking after droughts and rural downturns such as the recent wool slump.

Two vaccines affecting animal reproduction have been developed by CSIRO and are in use. One vaccine improves the rate of multiple births in sheep. The other vaccine is used in cattle as a form of chemical castration and spaying.

(c) Cell receptor manipulation

Animal and plant cell processes can be controlled through cell surface "switches" or receptors on the outside of the cell membrane. Small proteins, such as hormones, can attach to these receptors and switch on specific genes in the cell nucleus so that the genes become active. This mechanism may enable the control of sex determination in embryos. It may become possible to determine sex *in utero* thus producing a desired animal, for example female dairy calves and male beef calves.

Other uses include host-specific vaccines such as a cattle-tick vaccine, and various diagnostic tests such as those using monoclonal antibodies to detect diseases and parasites.

Cell receptor manipulation will not reach its full potential, particularly for vaccine developments, until we have an improved understanding of the mechanisms of immunity and of the control of other cell processes such as hormone production.

Australia is in a strong research position on these technologies but because of the high commercial potential of the products and the lack of local chemical and drug manufacturing, it is unlikely to be able to readily commercialize research products on its own.

(d) Protein engineering

An understanding of how proteins are made inside cells has enabled the production of small proteins or polypeptides outside cells. This chemical approach to the manufacture of biologically active proteins has major implications for the pharmaceutical industry, although the production of these products, such as insulin, using genetic engineering techniques is probably more practical at present.

(e) Biosensors

These are biological active molecules linked by membranes into electronic circuits. This integration of basic immunological knowledge, electronics and cell membrane biology has great potential in the diagnosis of plant and animal diseases, food processing quality assurance, and environmental monitoring.

Australia has an active research programme in biosensor development but commercialization of products will likely be internationally rather than domestically driven because of the small domestic markets.

(f) Other drugs and vaccines

A widening range of new drugs and vaccines are being produced by traditional technologies to enhance production in agricultural animals and plants. These take advantage of the knowledge of basic biological processes revealed through research at the molecular level, especially over the last decade.

Uses include drugs and vaccines to enhance meat production by affecting growth and body composition (e.g., favouring muscle rather than fat deposition), drugs used in milk production and drugs used in wool production (e.g., defleecing of sheep by temporarily halting wool growth with epidermal growth factor), and slow-release devices used to deliver micro-nutrients to aid animal nutrition and wool growth.

The various drugs are in different stages of development and more will be possible as we discover more about the basic biological processes.

Non-therapeutic drugs and vaccines to enhance production (such as hormonal growth promotants (HGPs) and bovine somatotrophins (BSTs) to enhance milk production) present animal welfare and animal health concerns. For example, BST has not yet been approved by the Australian Agricultural and Veterinary Chemical Council for use in Australia due to concerns over trade.

Australia has a good research and development capability in the veterinary drugs and vaccine area and in molecular biological research in general.

C. Mechatronics and farm automation

This encompasses tools, machinery and robotics. Increasing use will be made of new mechatronic technologies in a range of activities but particularly bulk handling. Use of "seeing" robots and intelligent robots is increasing on production lines for a range of purposes, including quality control and packaging.

Prototype robots have been developed for shearing sheep and deboning meat (robot butchers). Australian science has been among the forefront in these developments.

Technologies for farm and factory automation are already widely used in Australia. There is a perception though that there are many opportunities to increase productivity of labour by developing and applying these technologies at almost every stage in production from growing, through processing to packaging and delivery of agricultural commodities.

D. Advanced Materials

Worldwide, scientists in physics, chemistry, metallurgy and engineering are seeking new materials that are lighter, stronger and better wearing than existing materials. Application for these technologies in agriculture would reach every area in which machinery and other materials are used, including irrigation equipment, fermentation, food processing, packaging, micro-electronics (the super conductors), widespread gantries in horticulture and capturing and using solar and wind energy.

An important post-harvest application of advanced materials is in the use of membranes for value-adding and processing of a wide variety of agricultural products. Australia has recently developed a plastic membrane which will keep flowers, fruit and vegetables fresh for several weeks, thus bringing new export markets within reach and reducing losses from production. The dairy, wine and brewing industries use a range of membrane technologies in processing their products.

New lightweight polymers or plastics in tillage implements have the potential to improve sustainability through minimising soil compaction.

V. Technology transfer in Australia

There is a strong recognition of Australia's integration with the global economy and the benefits this integration brings in transmitting technology and generating economic growth. In a broad sense, Australian governments assist technology transfer through promoting domestic competition, setting the micro and macro-economic framework and supplying information services.

Two important elements of successful uptake of technologies for sustainable agriculture are the generation of relevant innovations through research and development and the ready access to these technologies. In Australia, some of the technologies are generated through domestic research and development, funded both from government and industry funds while many are imported, using normal supply-side channels (e.g., direct sales, foreign investments, labour movements).

Technology transfer services in Australia are currently provided by both government and private commercial organization. The commercial providers of technology transfer operate on a fee for service basis and are motivated by private profit. A farmer's decision to engage of these commercial advisers is a commercial decision made on the basis of the potential enhancement of the farm's profitability.

Government technology transfer services in Australia once operated in a similar manner to these commercial operators. Although they did not charge fees, they were still essentially concerned with enhancing the profitability of individual farming enterprises. Re-assessment of the role of government funded technology transfer in Australian agriculture has led to a fundamental change in the aims of government technology transfer services.

A fundamental question that has driven these changes is whether government resources should be used in a way that producers private benefits to farmers, or whether they should be used to produce community benefits. In this context community benefits are seen to relate primarily to the protection of the national agricultural resource base and its use in an efficient and sustainable way. This re-interpretation of function has naturally led to major restructuring and focusing of government technology transfer services in the past few years, and a subsequent expansion in private services to replace those services previously offered by government.

Technology transfer in agriculture in Australia is therefore moving to a situation where there will be a private commercial service aimed at the private benefit of farmers and a government service aimed at maximizing community benefit from sustainable use of national agricultural resources.

The following section will describe the structures and policies of government technology transfer services that are required to fulfil this function.

A. Public sector technology transfer

Public sector technology transfer is usually provided where there is likely to be a net economic benefit to society, where the operation of private sector technology transfer alone may result in under-investment or in outcomes that are unacceptable to the community on grounds of ecological sustainability or social equity.

Major priorities for government technology transfer services are:

i) long-term issue of restoring resources degraded (e.g., by salinity, pollution, erosion, soil acidification and compaction), and the development and implementation of economically and ecologically sustainable production systems;

ii) economic development of major industries particularly where there are opportunities for developing new products or new markets that will result in greater return from similar levels of inputs;

iii) assist industries to fund research and development that produces private benefit but is beyond the capacity of individual farmers;

iv) regulatory and standard setting services to ensure public health and safety, including enhancing existing services through the uptake of new technologies;

v) agricultural and general education facilities for primary, secondary and tertiary levels;

vi) coordinate the activities of elements of the private and public sector and through this harmonize regulations, ensuring regulations do not hamper desirable developments, and facilitating resource sharing between sectors where this enhances efficiency.

In Australia, public sector technology transfer is primarily the responsibility of the States and Territories with the Federal government coordinating elements of the programmes that have a national perspective. There are differences between individual State and Territory approaches to technology transfer that accommodate the differences in state industries and needs, however the basic approaches are similar.

Effective implementation of public sector technology transfer policies requires:

i) that funding is adequate to provide essential human and material resources;

ii) that monitoring and evaluation processes, including discussions with industry members and organizations, should be an ongoing and integral part of the planning and implementation of technology transfer;

iii) staff with appropriate skills; these will probably be in three main categories:
  - information specialists who can access information systems and handle enquiries for information;
  - extension specialists to focus on integrated industry objectives of sustainability and profitability;
  - scientific discipline specialists to maintain contact with scientific research providers and introduce scientific advances to the technology transfer system.

B. Linking with other activities

Farmers will often drive greater benefit from technology transfer if it is presented as an integrated package containing information from many sources. This also provides an opportunity for synergism between agencies in providing information, education, advice and regulatory inputs to the industry. For this synergism to occur, technology transfer services need effective liaison with a range of external agencies and effective transfer of information within the service.

Internal structures need to facilitate communication within the technology transfer agency. In much of Australia technology transfer is based on a regional model to allow all the elements appropriate to that agro-ecological zone to be grouped together without institutional barriers to communication. This has had advantages in allowing regional managers to make linkages with other agencies that can make inputs pertinent to the needs of that region's industries. These linkages provide the information needed in the preparation of integrated technology transfer packages.

In Australia, strong linkages have been forged between the sustainable development initiatives of the governments and farmers through the heightened awareness of farmers and their interest groups. There have been more than 1,000 Landcare groups formed over the last three years to halt the degradation of rural lands through activities such as tree planting and refencing. The peak body representing all producer groups in Australia, the National Farmers Federation, has a strong stand on conservation issues affecting sustainability on the land.

C. Linkages with research

Links between technology transfer and research, as alluded to in the previous section, are essential if knowledge of the latest developments and proven approaches to agriculture are to be transferred to industry. Australia has a system of industry sector oriented and funded research and development corporations (the Primary Industries and Energy Research and Development Corporations). They also receive government funding and operate under government policies which makes transfer of developed technologies to industry one of their prime responsibilities. This obligation has led to improved communication between the two sectors and an improved quality of information for farmers.

This linkage has two other important benefits:

i) target groups of technology transfer now have the opportunity to be involved in planning, evaluation and implementation of research; and

ii) the linkage provides field intelligence to research providers allowing them to evaluate the areas of agriculture where inefficiencies exist or where innovations may lead to enhanced productivity. This is invaluable in targeting limited research resources to areas that will produce mot benefits.

All of the research and development corporations are required to have five-year plans approved by the Federal government. These plans include objectives for sustainability and several are actively funding researchers to develop indicators of sustainability in their sectors.

Linkages with international research development still rely largely on the international networks of Australian researchers and normal commercial channels. Research institutes and funding bodies, however, are improving their access to international research. Australia is also in touch with international research and development through the international agricultural research centres and through international databases of research in progress and bibliographic material.

D. Linkages with regulation

The linkages between government regulatory activities and technology transfer have often been associated, but rarely integrated, into a single package for farmers. The integration of these aspects would have some important benefits such as:

i) the awareness of government regulations by farmers and technology transfer staff would be improved and remove the possibility of farmers receiving misleading advice;

ii) the extent to which regulations may inhibit productivity or efficiency would be more apparent;

iii) regulation to achieve sustainable management of natural resources could be incorporated in production advice;

iv) effectiveness of regulations may be enhanced if presented to farmers in the technology transfer package, rather than by an explicit enforcement agency that may not have the farmers' confidence or cooperation;

v) regulation through the technology transfer service may reduce the costs of government infrastructure;

vi) regulation that is based on standards of performance, rather than on the processes of an industry are generally more effective. Technology transfer can provide the most efficient ways of achieving those standards in specific agricultural conditions.

E. Government intervention in agricultural restructuring

The Federal and State governments have two major programmes that aim to restructure the rural sector to achieve economic and ecological sustainability. These are the Rural Adjustment Scheme (RAS) and the Farm Household Support Scheme (FHSS). These two programmes interact to assess the economic and ecological viability of a farming enterprise. Where an enterprise can be made viable by adopting "world best practice" then government expertise and financing is available to assist the process. Where this is not the case, then government services are available to assist the farmer to leave agriculture and receive training to pursue a new career.

Assessment of the viability of farms can be a complex problem. The assessment can however utilize many of the decision support systems developed to assess the productive capacity of land for agriculture, e.g., stocking rate, or to cope with climatic variability such as drought. These systems can be used to predict the output of land in specific agro-ecological zones and from this an assessment of economic viability can be made.

Where farms are not viable and are left, there are opportunities for farm amalgamation and the expansion of successful operations into new areas. In some instances where farmers have left their land, restoration of degraded areas will be required to return it to full productivity. Government technology transfer is very much involved at this stage of the process as well.

F. Linkages with eduction

Technology transfer is generally viewed as an extension of education, in that it enables the latest advances in knowledge to be implemented at the farm level. In achieving this transfer of knowledge it is important to be aware of the educational standards and experience of farmers and their cultural background aspirations, which may affect their ability to accommodate change. In Australia, primary producers tend to be older than the general workforce (average age of farmers is now 58 years), more likely to be male than female, English speaking and literate to secondary school levels but with virtually no formal tertiary training in agriculture.

Technology transfer services therefore have a critical role in assisting farmers to develop their educational background and learning skills to enable them to benefit from the increasingly complex technical and financial material that is involved in decision making in agriculture.

The educational input required for these purposes may be beyond the capabilities of individual technology transfer staff and in these instances close links need to be created with secondary and tertiary level educators in the region to utilize their skills and resources.

Australia has a well developed system of tertiary education in agriculture. Courses are offered at over 30 institutions and annual enrolments are of the order of 10,000 students. Post-graduate (Masters and PhD) awards serve Australian as well as overseas students and from 1986 to 1990, 400 awards were made to Australians and 260 to overseas students.

A number of secondary school curricula now include agricultural units, especially in rural schools.

G. Linkages with diagnostic services

The capability to provide accurate and timely diagnoses of problems in the field is often the basis of designing problem solving programmes. Technology transfer staff may often be called upon as the first contact when a problem arises and referral to a specialist diagnostic service is often required. Liaison with the diagnostic service will usually provide important information for solving the problem and acquaint the farmer with any regulatory needs, such as quarantining an infectious disease. Diagnostic services are recognized as pre-requisite for efficient technology transfer in agriculture.

VI. Regional collaboration in technology assessment and transfer

Australia's objective in participating in regional technology transfer is to improve the well-being of people in the region, including Australia, by appropriate natural resource management and the development of sustainable agricultural systems. Australia funds and participates in a range of organizations and activities in this area, including:

i) Australian Centre for International Agricultural Research (ACIAR);

ii) Australian International Development Assistance Bureau (AIDAB);

iii) many FAO bodies including the Animal Production and Health Commission for Asia and the Pacific (APHCA);

iv) Bilateral agreements with Papua New Guinea;

v) South Pacific Commission;

vi) Tripartite Committee involving Australia, Papua New Guinea and Indonesia; and

vii) Agreements on Cooperation in Agriculture with the People's Republic of China.

Australia's aims are to participate in cooperative programmes of technology assessment, research and technology transfer that produce benefits for all the participants. ACIAR is an excellent example of the success Australia has had in establishing research programmes concerning the agricultural problems of developing countries. ACIAR's role is to initiate and develop new projects, to fund research, to monitor the progress of each project and to communicate the research results. ACIAR has formulated a number of priority programmes. They are:

i) *Animal sciences*: Identification of constraints to improvement of animal production in the agricultural systems of Asia and the South Pacific, and management of remedial activities to alleviate those constraints.

ii) *Crop science*: Improving the productivity of major cereals, food legumes, oilseeds, root crops and fruit corps by breeding for increased yield and disease resistance and by controlling insect pests and weeds.

iii) *Economics and farming systems*: Promotion of agricultural development through identification, design and implementation of high (economic) priority technologies and policies, provision of advice that contributes to an understanding of farmers' problems and improves the capacity of scientific research to meet farmers' needs.

iv) *Fisheries*: Development of management techniques suitable for traditional coastal fisheries, particularly in the utilization and maintenance of natural resources and in the culture of high-value aquatic species.

v) *Forages*: Improvement of forage productivity within a sustainable agricultural framework by promoting Australian forage production techniques on marginal soils in Asia and the Pacific.

vi) *Forestry*: Identification of suitable Australian trees and shrubs for the specific needs of developing countries, and assistance with their introduction and domestication.

vii) *Plant nutrition*: Improvement of crop productivity and the more efficient use of inputs in developing countries, through diagnosis of nutritional disorders of important crops, development of ways to use fertilizers to correct disorders, and enhancement of biological nitrogen fixation.

viii) *Post-harvest technology*: To develop cost-effective methods for the save handling and storage of cereal grains and related commodities, fruit and vegetables, and fish, particularly under the difficult physical conditions and constraints of developing countries in the humid tropics.

ix) *Soil and water management and land use*: Development of soil and water management systems and technologies that alleviate constraints to food production, foster sustainable agricultural production and ensure efficient utilization of land and water resources.

Some 90 individual projects are currently being funded by ACIAR within the priority programme areas listed.

VII. Recommendations

For successful technology transfer in the region, Australia's experience, especially through AIDAB, has highlighted many of the features that characterize successful technology transfer programmes. In this experience these features can apply to projects in most discipline areas and should be considered during programme planning and execution. They are referred to briefly under the following headings:

Technology transfer: To improve the adoption rate, programmes should:

i) support pilot scale projects, introducing, testing, and adapting technology;

ii) support projects designed to test ways in which the uptake of improved technology is likely to be enhanced;

iii) increase projects designed to improve institutional capacity of government services capable of finding, testing and ensuring adoption of improved technology;

iv) critically assess the chances of Australian technology being the answer to small farmers' needs;

v) recognize that economic technology does not often exist, nor it is likely to be developed in the near future, for impoverished lands in harsh climatic zones.

Economic and risk analysis: This could be improved by:

i) improving the scrutiny of programmes and screening out low priority and high risk operations;

ii) ensuring that risks are fully weighed in the economic and sensitivity analysis of projects;

iii) strengthening the guidelines to programme and appraisal staff on the economic criteria and type of analysis required for different types of agricultural projects.

Technical assistance: To maintain the quality of Australian input, agencies should:

i) require that managing consultants have satisfactory language capability for the project;

ii) introduce a scheme whereby a small number of new graduate staff are included in technical assistance teams stationed in-country;

iii) critically assess previous consultant performance and use such an assessment in selecting firms and managing consultants;

iv) encourage smaller and less experienced firms to act as junior partners in contract proposals so that the pool of experience can be widened;

v) ensure that candidates are jointly selected by recipient governments and Australia for specific future posts. Language training should be provided wherever necessary;

vi) assess training needs against institution building objectives and build in proper evaluation and feedback throughout projects' lives.

Monitoring and evaluation: This could contribute to greater efficiency of programmes with effort to:

i) ensure that consultants' and managing consultants' reports are timely, at not less than quarterly intervals, and report outputs and achievements against plans and targets;

ii) ensure that base line indicators and data are established against which to measure project impact;

iii) establish agreed performance indicators at the design stage to provide consistent progress monitoring;

iv) catalogue and maintain key reports for later evaluation.

Environmental impact: Full implementation of environmental policies will require experienced personnel particularly in the consulting industry.

Socio-economic and cultural awareness: Poverty must remain a major concern for development programmes. This should be considered in programme selection and include elements that address alleviation of poverty directly. Awareness of other issues in this area can be raise by:

i) ensuring proper socio-cultural and economic scrutiny of programmes by full participation of in-house sociologists and socio-economists;

ii) ensuring that feasibility study teams include sociological and socio-economic skills;

iii) giving preference to consultants, with proven track records in addressing socio-cultural concerns.

Women-in-development issues: this area will continue to need attention by:

i) screening all projects for their likely impact on, or potential for, assisting women;

ii) subjecting projects to careful gender analysis during design and implementation;

iii) request country and regional desks to state clearly how their policies are to be implemented.

REFERENCES

HAMBLIN, A. 1991, Sustainability: Physical and biological considerations for Australian environments. Bureau of Rural Resources Working Paper WP/19/89 (revised edition) 53 pp.

HAMBLIN, A. 1992, Environmental indicators for sustainable agriculture. Report on a national workshop, November 28-29, 1991. Bureau of Rural Resources, Land and Water Resources Research and Development Corporation, Grains Research and Development Corporation, Canberra, 96 pp.

Section II

Country scenarioS

Section II

CHAPTER

6

BANGLADESH

M.S.U. Chowdhury [1/]

I. Technology assessment for varying agro-ecological zones, production systems and resource endowments

The introduction of new technologies in the form of high yielding varieties was initiated in Bangladesh after the great famine of 1943. Since then, seed technologies under different development programs were introduced more or less successfully. Emphasis was given on development of much needed infrastructural facilities in the agricultural sector. It got momentum in 1966 when IRRI varieties were introduced and a Green Revolution in the country essentially began. The present Bangladesh Agricultural Development Corporation (BADC) was established in the early 1960s to provide institutional support mainly in the form of inputs for disseminating new agricultural technologies. BADC in its farms tested new varieties and compared production management packages. At that time there was no organized assessment of technologies at national level. After the establishment of what is now the Bangladesh Rice Research Institute (BRRI) in 1970 and the introduction of new HYV rice varieties the necessity of assessing the technologies became more urgent. This led to the establishment of the Seed Certification Agency (SCA) in 1974. The main responsibility of the agency is to identify suitable seed technologies that can be recommended for dissemination to farmers. The establishment of SCA was the first step towards the institutionalization of assessment of agricultural technologies in the country. Though acceptance of seed technology at farmers' level was commendable, it was realized that since the vast majority of farmers are resource-poor, there is a need to develop improved management technologies, requiring minimum input but at the same time being more suitable to the small farming environment. Such type of research was initiated since 1974 through Cropping System Research (CSR) followed by the Farming Systems Research (FSR) programme in the early eighties. Within a short span of time, CSR/FSR developed a sizeable number of location-specific technologies. These technologies were validated through annual workshops, seminars, etc. for dissemination. However, there was no mechanism at national level to verify performance of these technologies in the farmers' fields. The establishment of the National Technical Coordination Committee (NTCC), Regional Technical Committees (RTCs) and District Technical Committees (DTCs) in 1982 took care of this situation and also helped in establishing research-extension linkages. RTCs and DTCs are working closely with the extension agencies and farmers and have proved to be effective in assessment and transfer of technologies.

Some research institutes have mechanisms of technology assessment. The Bangladesh Agricultural Research Institute (BARI) has a strong On-Farm Research Division (OFRD), which is responsible for carrying out verification trials for technologies in different agro-ecological zones, in the research stations and in farmers' fields. On-farm trials are carried out at different Multilocation Trial (MLT) sites with farmers' participation and under supervision and with support from OFRD. The Bangladesh Rice Research Institute has a rice-based farming system as well as Adaptive Research Division (ARD) which play a role in the assess-

1/ *Executive Vice-Chairman, Bangladesh Agricultural Research Council (BARC), Dhaka, Bangladesh*

ment and transfer of technology developed by the institute. The annual research and extension workshops held regularly also play an indirect role in technology assessment, transfer and feed back. The Bangladesh Jute Research Institute (BJRI) performs technology assessment and transfer activities through a small number of subvention centres in some jute growing areas of the country. The Sugarcane Research Training Institute (SRTI) does not have any exclusive set up for assessment and transfer of technology, but it has a rather strong training activity extending down to farmers' level. This has created a positive impact in the diffusion of technology. All these four institutes (BARI, BRRI, BJRI and SRTI) have farming systems research programmes which contribute to technology assessment and transfer.

Prior to 1947, rural development work in this part of the sub-continent was a casual affair. Soon after 1947, the attention of the Government was drawn to rural development. Such efforts were limited and unorganized. An organized nation-wide extension network for technology transfer started from 1983 by merging six extension-oriented divisions into a Department of Agriculture Extension (DAE). The NTCC at the national level coordinates the technology transfer mechanism between research and extension. At the regional and district level the RTC and DTC is responsible for diffusion of technology and its feed back to NTCC. The district is the most important focal point for managing the operations of DAE. Each of the 64 districts of the country has a technical set up of one Training Officer and 2-3 Subject Matter Specialist (SMS) headed by a Deputy Director of Agriculture Extension (DDAE). The next institutional service to the farmers are the Thana. Each of the 460 Thanas has a technical set up of one Thana Agriculture Officer (TAO), two Subject Matter Officers (SMO), and one Additional Agriculture Extension Officer (AAEO). A block is the closest unit of institutional service to the farmers. In each block there is one Block Supervisor (BS) to provide extension services to nearly 900 farm families. The number of block stands at 12.640. The total staff (professional/technical/support) strength of DAE is 23,422. The role of agricultural extension is to assist farmers, through education, in improving farming methods and techniques, increasing production and income and thus enhancing their quality of life. It makes all technological information available to the farming community and provides training and guidance for adoption of modern technology. It gives possible solutions to the problems of the farmers and brings unresolved problems to the notice of researchers for finding solutions. The agricultural extension system, therefore, acts as a bridge between researchers and farmers. With the emergence of the National Agricultural Research System (NARS) concept under BARC and the creation of a unified extension services under DAE, the concept of technology transfer mechanism gained importance and BARC established the Technology Transfer Monitoring Unit (TTMU) in 1989 to provide leadership for the development and implementation of the technology transfer programmes. It is a complex programme involving many agencies such as 10 NARS institutes, four public extension agencies, private organizations including NGOs, agribusiness enterprises, progressive farmers and concerned individuals.

The basic purpose of TTMU is to facilitate the rapid transfer of technology by promoting the free flow of NARS-generated technologies through a network of private, public, NGO and other agencies which can transfer technology to farmers. The functions of TTMU can be grouped into four categories:

i) Identification of mature technology.
ii) Assessment and verification of technology.
iii) Development of technical information packages.
iv) Transfer of technology.

The TTMU maintains close contact with the NARS institutes and collects mature technology from them. It has four Sectoral Technical Advisory Committees on crops, livestock, fisheries and forestry. These committees have members representing NARS institutes, public extension agencies, NGOs, donor communities and farmers representatives. They validate the mature transferable technology and provide guidelines for preparations of information materials in a package. TTMU disseminates the technology through technology transfer agencies to farmers. TTMU is primarily concerned with the "wholesale" of technical information to many different intermediaries (public and private extension services including NGOs) who will adopt and retail the appropriate information to farmers. Once a technology is identified for transfer to the beneficiaries by the Sectoral Technical Advisory Committee, a technology transfer working group comprising scientists, extension personnel, communication specialists and NGO representatives is assigned to develop booklets, folders, fact-sheets, audio-visuals, slides, with sound transfer systems. Thus the quality of work is ensured. Moreover, linkages, coordination and cooperation among technology producing and utilizing agencies continue to improve. The NARS based technology transfer programme through TTMU, although a new concept, has proved useful.

A. Major agro-ecological zones

Bangladesh has a highly diversified agro-ecology. Thirty main agro-ecological regions and 88 sub-regions have been identified, but there are large variations in micro-climate within each zone. Some 521 soil series have been recognized in Bangladesh in the three major physiographic units of flood plains (80 percent), hills (12 percent) and terraces (8 percent).

B. Major farming/production systems

Production systems used by farmers in Bangladesh are characterized by low efficiency. The majority of the farming community cultivate their land under input-starved conditions. Poverty of small and marginal farmers limits their ability to make adequate investments in production systems. Moreover, natural hazards like flood, heavy rainfall, drought, salinity, storm, etc. have been affecting the production systems at different levels and also act as strong determinants of land use in each of the production environments. Bangladesh farming systems are basically subsistence in nature, but reasonably well balanced and broad-based, covering activities involving crops, livestock, forestry, homestead, fisheries etc. Thus, agro-climatic conditions and resource potentials are the main determining factors for farming systems in Bangladesh.

C. Objectives and constraints of farm households

The estimated income per household was Tk. 34,379 in 1988-89. The average household size is 5.54 persons which gives a per capita income of Tk. 6,205. The average number of earners per household is about 1.5 persons. Nearly one-fifth of the households own very little land (less than 0.02 ha) and another 35 percent own up to 0.20 ha, who can be considered as functionally landless. The aggregate share of landless and functionally landless thus was about 53 percent in 1988-89 as against 40 percent recorded in the 1983-84. Average income earned by landless and functionally landless households constitutes about 21-28 percent of the mean income recorded by the large landowning households during 1988-89. A substantial proportion of income earned by land-poor households originates in non-farm and non-agricultural sectors. About 38 percent of households are classified under various non-agricultural occupational categories indicating the growing importance of non-farm and non-agricultural income. About 23 percent are predominantly agricultural labourers and fishermen, but their share is restricted to only 14 percent of rural income. About 14 percent of households are female-headed. Average monthly income of the female headed households is about 35 percent less than that of the male-headed households in rural areas.

The main objective of farm households is to produce more food from the limited land available to them. Farmers are capable of maximizing production per unit area when they have adequate control over the factors of production. Farmers' choice and decision making in the production process are greatly constrained by factors which are beyond their control. The poor performance of their agriculture is generally ascribed to its physical, institutional, socio-economic and organizational environments, which together determine agricultural growth. The constraints faced by the farmers vary from region to region, and even within a region and among different districts, thana, union, villages and even farm families. Allocation of resources is mainly determined by the family needs in foods, availability of resources and degree of risk in farming. The farmers realize well that under risky conditions investments have to be made in a manner which will not cause a great loss.

D. Unsustainability indicators

Crop production in Bangladesh is risk-prone. Environmentally, the country is and has always been a hot spot of problems that often trip her agricultural production system off the balance. These problems are triggered by the recurring events of floods, droughts, salinity, erosion and land instability.

In Bangladesh, water for crop production is available in a relatively uncontrolled manner. It is too much and too uneven during monsoon and too little during the dry season. Heavy and highly uncertain rainfall in most parts of the country cause frequent flooding and waterlogging and make crop cultivation extremely hazardous. About 5.6 million ha of flood prone land are now cultivated. Given the high risk in these areas, farmers minimize their potential losses by growing low-yielding varieties and reducing the use of modern inputs. There are also large variations within the seasons and from year to year in the quantum of rainfall received which cause considerable instability in agricultural productivity. Even in the years when the total rainfall is normal, long drought spells or inadequate rainfall in crucial months of transplantations and plant growth adversely affect production. About one fourth of the total cultivable land is affected by drought in every year with different intensity. About 0.3m ha are waterlogged. Over the centuries, the natural topography of this densely settled region has undergone changes to such an extent that poor drainage and waterlogging have become acute problems in large areas. Colossal losses to property and crops every year result due to floods and waterlogging. The heavy, erratic and uneven seasonal patterns of rainfall also create serious soil erosion problems, constraining agricultural development. Some of the coastal soils have developed problems of salinity. Different degrees of salinity occur mostly in the dry season in about 0.82m ha of coastal and offshore tidal plains in Bangladesh. The extent of salinity ranges from less then 2 to more than 15 milli mbhs. The large number of rivers and rivulets are now silted up, making vast areas prone to floods. About 2 billion tons of silt and clay are carried by rivers every year. The annual losses due to pests, diseases and weeds ranges from 20-50 percent of the total yield and even higher in some crops. Losses during storage account for another 14 percent. The production capacity of the cultivable land has been diminishing due to extensive use of land to produce a number of crops all the year round, unbalanced use of chemical fertilizers, and injudicious use of pesticides. It is reported that about 60 percent of cultivable land are deficient in sulphur and zinc. As a result, production per unit area is declining in some cases and almost stagnant in others.

E. Critical areas and determinants of sustainability

The problems of sustaining agriculture are many and they are growing in extent, intensity and complexity. At the heart of the agricultural sustainability is the conservation of soils for future long-term food production. But the population boom has made an unprecedented pressure on cultivable lands to grow more food. The population of 71.5 millions in 1971 increased to 114 millions in 1991. The increasing pressure has adversely affected the man-resource ratio and this is primarily manifested in depletions, non-conservation and sub-optimal utilization of natural resources. The large population base and high rate of population growth have created a highly unfavourable demographic scenario frustrating the agricultural development efforts in the country. Land-man ratio is extremely low and landlessness has been continuously rising.

Application of proper doses of NPK, zinc and sulphur is the key factor in increasing production and if fertilizers are not applied properly in time, dose and method the production of HYV crops is hampered. Though the use of fertilizers has increased over the years, it is still among the lowest in the region. Balanced and location-specific fertilizer recommendations are not used widely. On the other hand, chemical fertilizers are used by farmers with no consideration of the actual requirement of the soil. The use of nitrogenous fertilizer is higher than others. According to 1989 data the NPK ratio was 10.8:4.4:1. Due to the continuous use of NPK without any zinc and sulphur, about 25 percent of the arable land is deficient either in S or Zn. At present, the fertilizer use efficiency is also very low. As a result, the soil fertility is decreasing gradually. Therefore, to sustain soil fertility proper management is necessary. Lack of adequate drainage facilities is another major constraint to agricultural production in Bangladesh. The provision of infrastructure, highways and irrigation canals has contributed to the obstruction of natural drainage resulting in problems of waterlogging. This problem is particularly acute in command areas of irrigation projects. There is inadequate coordination among the various agencies responsible for the public utility services.

F. Objectives and technological requirements for sustainable agriculture

Increased production per unit of land is the best way to increase agricultural productivity. But improving productivity has a direct relation to the natural environment and sustainability. Changes in soil and water management practices are needed to achieve increases in productivity. Traditional agricultural production systems have been sustained for centuries. However, to meet the demand for food and to save resource endowments for future generations, a more dynamic view of overall agricultural development is needed. Sustainability issues are relatively new aspects of agricultural development in Bangladesh and all agricultural activities centre around these issues now. At the heart of sustainability is food security which is one of the fundamental problems being faced by Bangladeshi farmers and it depends on the reliability of production and peoples' access to food supplies. At present, research activities are directed towards meeting future food needs and developing technologies that help to mitigate the risk of farmers and do not bring major changes to the farming environment. Chemical fertilizers, pest and disease control, irrigation, reduction in post-harvest losses, etc. are necessary to increase production. New technologies should be economically profitable, socially acceptable and technically sound. It is not sufficient to seek self-sufficiency in food production. It is also essential that food quality is improved to maintain normal health. Food should no longer be comprised of rice and wheat alone, it should encompass a wide variety of crops to overcome the problems of malnutrition or undernutrition. There is a need for crop diversification integrating the crop component with livestock, poultry and fisheries. This means that traditional commodity research needs will have to be balanced with a farming systems research/whole farm approach.

G. Technological options

Technological advancement is crucial to sustainable agriculture. Major portions of such advancement will come from traditional agriculture, but a significant role will be played by the application of modern technologies that need to be developed locally. At present, major emphasis is being given to develop technologies in the following areas:

- i) Biological nitrogen fixation
- ii) Bio-technology
- iii) Enhancement of photosynthetic activity
- iv) Water harvesting technology (including irrigation)
- v) Multiple cropping systems
- vi) Erosion control and soil management
- vii) Integrated farming systems
- viii) Waste utilization and organic matter recycling
- ix) Post-harvest technology

II. Technology transfer

A. Technologies in operation in farmers' fields

The farmers of Bangladesh are used to living with nature. Over centuries, they have used traditional indigenous technologies adapted to various risks. Such technologies range from those of minor casual crops to pulses and food staples. Farmers adapted drought tolerant varieties of Aus and B.Aman and flood tolerant varieties of B.Aman rice. A further risk aversion technology is the mixed cultivation of Aus and B.Aman. The local plough, minimum tillage, traditional cultivation of sugarcane, mixed cropping of vegetables, etc. are some examples of farmers' innovative technologies. These technologies require almost no or very low input and their productivity is also very low, but they are well adapted to local conditions.

Farmers in Bangladesh are also using modern production technologies. Over the last two decades, a major thrust in research was given to develop modern varieties of different crops. The Bangladesh Rice Research Institute has developed 26 modern varieties of rice which cover at present 35 percent of the total rice cropped area. A major breakthrough has been achieved in wheat production. At present, 95 percent of total wheat area are planted to modern varieties, developed/adapted by BARI. High-yielding varieties of potatoes developed/adapted by BARI are now grown in 64 percent of the potato area and contribute to 70 percent of total potato production in the country. Some improved varieties of pulses, oilseeds, tubers and vegetables have also been developed.

Varietal development of cash crops also is in progress. So far, 19 improved sugarcane varieties and seven jute varieties have been developed. These varieties have a high yield potential. Poultry rearing in scavenging condition, use of urea-treated straw, cockerel exchange programme, introduction of exotic breeds of poultry and duck, beef fattening, etc. are some of the technologies that have already been adapted in Bangladesh. Technologies on bamboo propagation and preservation have been developed and strong location-specific agro-forestry programmes are in progress. It has been estimated, however, that only 40 percent of the developed technologies have so far reached the farmers. Besides, farmers are adapting some of these technologies only partially on a component basis, thereby failing to derive full potential yield benefit. The Bangladesh NARS has developed a sizeable number of production management technologies, such as fertilizer and irrigation management, pest management and cropping systems, etc., which are expected to have a positive impact on production.

B. Gaps in technology transfer

A wide gap exists between potential yield and what farmers are getting out of the new technologies (Table 1). The national average of improved rice, wheat, potato and mustard varieties is far below the achievable potential yields. Rice, potato and wheat yields could be increased by 3, 4 and 2 times, respectively. This analysis has been based on the results of national demonstrations and averages of the results of maximum yield potential studies for five years. Even in pulses and oil seeds the use of modern available technologies can double production. Research results established that more than 50 percent increase in crop production may cone from HYVs of different crops using only recommended doses of fertilizers.

TABLE 1. YIELD GAPS IN MAJOR CROPS IN BANGLADESH, metric ton/ha

Crop	5 years average yield (1984-1990)	Achievable yield with farmers' management	Yield gap
Rice Aman	2.01	3.75	1.74
Boro	2.63	4.50	1.87
Aus	1.83	3.00	1.18
Wheat	2.13	2.98	10.85
Potato	10.25	24.80	14.55
Mustard	0.75	1.84	1.13
Sugarcane	41.40	94.3	52.91

C. Reasons for transfer gaps

It has been recognized that agricultural research institutes have generated a large number of technologies which can increase production tremendously if they are quickly transferred to and properly utilized by the end-users. There are obvious deficiencies and gaps in proper dissemination of technologies to the farmers but the major problem is the chronic inability of most of the farmers to utilize those technologies properly. The gaps in yields are mainly due to improper and unbalanced use of inputs, primarily fertilizer and water. Acceptance of new technologies by farmers is mainly hampered by financial problems and insecurity. Various resources in kind and cash are needed to adopt the new technologies which are beyond the reach of resource-poor farmers. On the other hand, resource-rich farmers who are capable of adopting new technologies are selective and not always interested in accepting new technologies due to weak input delivery structures. Moreover, lack of adequate irrigation and drainable facilities, poor research and extension linkages and inadequate power, transport and marketing arrangements have made farmers reluctant to accept modern technologies.

D. Accompanying measures for technology transfer

A distinctive feature of Bangladesh agriculture is the predominance of very small farmers and the large number of fragmented holdings, scattered over different parts of the villages. The consequence of sub-divisions and fragmentations are serious and very harmful for agricultural development. To alleviate population pressure and unemployment, farmers cultivate their land intensively. To meet the immediate needs, inputs are used only for rice and some pulses. This has narrowed down the scope of diversification of crops as well as agriculture. The attempts to increase agricultural production over the years were accompanied by soil erosion, land and environmental degradation. Moreover, less than 40 percent of the total arable land is used during Rabi season. Technological innovations backed by support services and input supplies are needed to bring more land under cultivation.

Rainfed farming dominates Bangladesh agriculture. Although technologies for irrigated crops and water management are now available, nearly 70 percent of the farmers dependent on rainfed agriculture are not getting enough technology support. In rainfed farming, supplemental irrigation in T. Aman, minimum tillage and surface mulching technologies have been developed which help conserve post monsoon residual soil moisture and support dry season crops.

The adoption of new technologies and any increase in the gross cropped area will require further expansion of credit facilities for farmers. However, the assessment of farmers' credit needs is difficult. The flow of institutional credit to agriculture increased by more than 35 time from a low base of Tk. 32.5 crores in 1970/71 to Tk. 1,150 crores in 1984/85. The slow recovery of credit money has posed a serious limitation on the capacity of the lending institutions to extend further credit. Bangladesh Krishi Bank (BKB) is the largest source of institutional credit to farmers and accounted for 66 percent of the total disbursed credit in 1986/87. Institutional sources can meet only a very small proportion of the total credit needs of the rural people. The local money lenders have been the prime source of credit to the farmers. A study conducted on the Grameen Bank loanees in 1985 shows that they received 24.1 percent of their credit need from institutional sources and 75.9 percent from private lenders. The NGOs and private voluntary organizations are also providing grants and loans. Government subsidy for major inputs such as fertilizer and seeds to the farmers has been withdrawn for improving commitment of farmers.

A cooperative movement in Bangladesh exists since 1904. Farmers' cooperative societies were formed and typically functioned for obtaining credit. Farmers' organizations as technology recipient media are yet to be organized. Several NGOs and the Grameen Bank also are now engaged in organizing such groups.

New technology packages normally consist of improved seeds, fertilizer, water and pesticides. In the public sector, the responsibilities for input supplies lie with the Bangladesh Agricultural Development Corporation (BADC). Supply of inputs by BADC, however, is not adequate. Besides, non-availability of inputs in time is also a major problem. In order to improve the situation, the privatization of input supplies has been launched and farmers have begun procuring inputs from local markets.

Nearly 1.5 billion farm households exist in the country and the present Government Extension Department is not in a position to serve all of them. On the other hand, there are many NGOs which are also providing agricultural extension services to the farmers. They have some advantages over the public extension services. Considering the strong infrastructural development of some NGOs, BARC, as the apex body of NARS, is trying to involve NGOs at national, regional, district and thana levels in its diverse activities. Some NGOs have commendable credit facilities and grassroots-level organizations. BARC has recently initiated a technology transfer programme by involving NGOs in the process. This effort has already started to produce satisfying results.

E. Dissemination strategies

Bangladesh has used the Training and Visit system (T and V) in the extension programme since 1979. Prior to this, research-extension linkages were weak. At present, linkages between research scientists and extension personnel are operative at the national, regional and district levels. Recently, the Agricultural Support Service Project (ASSP) has started functioning. Under this programme, a farmers group approach will be followed in extension service instead of an individual approach followed earlier in the T and V system. The District Technical Committee will play a main role in the technology disseminating process. Monthly research-extension workshops will also play a vital role in technology dissemination and provide feedback to researchers.

On-farm testing:

Farm-level evaluation is a pre-requisite for assessing the maturity of a technology. The evaluation criteria are the same as those used by the farmers. Extension workers and farmers along with researchers are involved directly in the on-farm testing activities to keep all concerned abreast about the merit of the technology. Researchers and extension personnel jointly monitor and evaluate the performance of the newly introduced technology which also help provide feedback. They also organize farmers rallies with a view to accelerating the process of technology transfer.

Besides this, Agri-business newsletter, slide-films with sound, fact-sheets, etc., are being used for the rapid dissemination of technology. Bangladesh has a strong FSR programme. At present, 20 FSR sites are functioning across the country with the major objective of on-farm testing of technologies.

Information management systems:

An Agriculture Information Centre (AIC) has been established at BARC with a modest capacity. This is linked to NARS institutes by a network called National Agricultural Information System (NAIS). Besides these, BARC has a computerized database on agro-ecological zones, climate, temperature and rainfall of the country. This information is used frequently in technology transfer activities. Agriculture Information Service (AIS) and Fisheries and Livestock Information Services (FLIS) of the Government of Bangladesh are also functioning to provide information in their respective areas. But access to these sources for the field level workers is limited. Measures are being taken to provide up-to-date information to the districts and thana level workers by establishing appropriate linkages.

ACRONYMS

AAEO	Additional Agriculture Extension Officer
AIC	Agriculture Information Centre
AIS	Agriculture Information Service
ARD	Adaptive Research Division
ASSP	Agricultural Support Service Project
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BJRI	Bangladesh Jute Research Institute
BKB	Bangladesh Krishi Bank
BRRI	Bangladesh Rice Research Institute
BS	Block Supervisor
CSR	Cropping Systems Research
DAE	Department of Agriculture Extension
DTC	District Technical Committee
FLIS	Fisheries and Livestock Information Services
FSR	Farming Systems Research
HYV	High-yielding variety
MLT	Multilocation Trial
NAIS	National Agricultural Information System
NARS	National Agricultural Research System
NTCC	National Technical Coordination Committee
OFRD	On-farm Research Division
RTC	Regional Technical Committee
SCA	Seed Certification Agency
SMO	Subject Matter Officer
SMS	Subject Matter Specialist
SRTI	Sugarcane Research and Training Institute
TAO	Thana Agriculture Officer
TTMU	Technology Transfer Monitoring Unit

Section II

CHAPTER

7

CHINA

Wang Lianzheng [1]

I. Technology assessment for varying agro-ecological zones, production systems and resource endowments

With a large population and relatively scarce land resources, China puts considerable emphasis on increasing agricultural labour productivity, crop yields per unit area, and the effective utilization of resources. Sustainability considerations have come to play an important role in this respect.

Soil fertility problems are being addressed by several single and combined technologies: rotation and intercropping of non-legume and legume crops, planting of green manure crops, the use of organic manure, the combination of long- and short-release fertilizers, proper amounts of chemical fertilizers, and the integration of crop and livestock production. In the large areas of sandy arid and semi-arid lands, agro-forestry measures (grass and tree planting) are used to fix sand and create windbreaks. Adapted crop varieties are being developed to suit different environmental conditions. The utilization of water resources receives special attention, given that 47 percent of China's total arable land is irrigated. Technologies include the use of rainfall and underground water and the deployment of sprinkling irrigation and tube irrigation.

A. Major agro-ecological zones

Agro-ecological zoning in China is based rather on political and administrative boundaries than on climatic and topographic criteria. There exist, though, distinctive features of agricultural production in each of the ten main agro-ecological regions. It is important to note, however, that each region is made up of varying agro-ecological environments. There is a large difference between the eastern and western agricultural regions of China. In the east, the climatic conditions are more favourable, with a long history of agricultural development and a dense population. Most of China's arable land and forestry and fishery resources are in the eastern part of the country. In the west, with unfavourable climatic conditions, a sparse population, shortage of labour and small and scattered farming regions, pastoral production systems dominate. Agro-ecological conditions in the east range from dry-land farming in the northeast to the subtropical and tropical zones of the southeast, with paddy rice and cash crops. In the northwest, farming depends totally on irrigation and in the high and cool areas of the west, agricultural production relies mainly on livestock grazing.

B. Major farming/production systems

China's most important production systems are based on grains, including (in order of cropping area) rice, wheat, corn, soybean, sorghum, millet and also other crops such as cotton, rape seed, peanut, fibres, sugarcane, sugarbeet, tobacco and fruits.

In the vast areas of arable land in the northeast, cereal production relies on the system of one single crop per year.

[1] *President, Chinese Academy of Agricultural Sciences (CAAS), Beijing, China*

Natural hazards in this area include droughts and floods as well as low temperatures. In the southern tropical and subtropical areas, two to three crops per year are possible. Here, rice dominates agricultural production, besides oil and cash crops.

Animal production can be found in several areas (Inner Mongolia, central Provinces, western area, etc.) with varying degrees of integration with crop production and the predominance of grazing systems in mountainous areas. Problems include adjusted stocking rates and herd composition and better integration with existing land use systems.

C. Resource endowments

The total land area of China is 9.6 million km^2, with 0.993 million km^2 of arable land, 33,000 km^2 of gardens, 3.6 millions km^2 of grass land, 1.2 million km^2 of forests, 267,000 km^2 of inland water area and 200,000 km^2 of coastal beach and shoal.

Plant cover and soil formation in China follow distinctive latitudes and belts. South of the Tropic of Cancer, equalling the southern subtropical and tropical belts, tropical monsoon forest with laterite and red loam dominates. In the northern and central subtropical area, north of the Tropic, evergreen broadleaf forests grow and red-yellow soil is formed. Further north, in the Huang-Huai-Hai plain and Shandong Peninsula of warm temperate climate, deciduous broadleaf forests and brown soil can be found. In the north-eastern cold temperate zone, extensive growth of mixed coniferous and broadleaf trees and dark brown and black soils prevail.

China is rich in biological resources. The glaciation in the Quaternary Period was far less strong as that in the same latitude in Europe and rich resources of animals and plants evolved in China. For example, Chinese pteridophytes include 52 families and gymnosperms 10 families, and angiosperms 291 families, accounting for 80 percent, 90 percent and 53 percent of the world's resources, respectively. Animal resources in China are also very rich. Amphibians comprise 196 species (7 percent of world total), reptiles 315 species (5 percent of world total), birds 1,166 species (13.5 percent of world total), and domestic animals 414 species (9.7 percent of world total). Total animal species in China (2,091) account for 10 percent of the world's total.

D. Objectives and constraints of farm households

The main objectives of farm households include the provision of food and clothing, improved environment and enriched cultural life. Net incomes per farmer increased by 58.5 percent between 1985 and 1990. However, the poverty problem in some areas of the country has not been solved yet. Constraints to farmers' improved livelihood are manifold. Although the introduction of the production responsibility system created incentives for farmers, total incomes are small because of the small scale of the enterprises. In the rural areas, much surplus labour force are idle. However, during recent years the development of enterprises in towns and villages has made use of more than 90 million people and resulted in a considerable increase of income for farmers.

E. Unsustainability indicators

Indicators of unsustainability include water loss, soil erosion, floods, saline and alkaline soils, and weed and pest damage. Each year various kinds of natural disasters account for about 10 million tons of yield loss. Floods occur in the big rivers' regions, droughts in western China, water loss and soil erosion near the Yellow River, and pest damages in all agricultural regions. The incidence of water loss and soil erosion has been decreased through grass planting and afforestation. At present, projects and biological measurers are taken to reduce the losses due to natural disasters.

F. Critical areas and determinants of sustainability

Population pressure is an important factor for agricultural sustainability in China, though large variations occur in the different Provinces (1.8 persons per square kilometre in Tibet, 2,118 in Shanghai, nation-wide average 118).

Supply and judicious use of production factors (e.g. water) as well as labour availability will play a decisive role in the sustainable growth of agricultural production. The combination of organic manure and chemical fertilizers, the balanced use of NPK and the effects of micro-elements have to receive attention. To reduce environmental pollution through the use of chemical pesticides, biological control measures and microbiological pesticides are being advocated. Stable and high yields in lowlands require that proper attention be paid to drainage aspects.

G. Objectives and technological requirements for sustainable agricultures

The objectives of sustainable agriculture in China are to continuously supply the population with agricultural products of good quality while maintaining soil fertility with economically feasible means. Concrete measures should be in line with local conditions to improve both production and quality at low costs, achieving economical efficiency and causing no harm to the environment, using technology that preserves water and soil resources. To this end, biological control in plant protection and organic and green manure in crop production have to receive more attention.

H. Technological options

Soil, climatic and other ecological conditions largely determine the range of technologies to be selected from. Economic feasibility and efficiency along with easy popularization are major factors for the choice of technological options. Examples include irrigation techniques that do not cause soil salinization such as drop irrigation for fruit trees and sprinkler irrigation for wheat and cotton, and a technology package combining plastic ground cover, quality seeds and fertilizers particularly in remote and mountainous areas.

I. Risk assessment and management

Recommended technologies need to be assessed as to their location-specific applicability and adaptability. To minimize the risk of adoption, selection of technologies is based on technology testing to assess the performance within local conditions. In this respect, further strengthening of the extension service and the capacities for technology adaptation and economic assessment require more attention.

II. Technology transfer

A. Technologies in operation in farmers' fields

Some examples of technologies that have been successfully transferred to farmers' fields are given below.

Plastic ground cover for corn

Swift adoption of this technology with significant effects on yields occurred in poor areas after frontline demonstrations. Farmers were quickly convinced of its advantages which led to its successful extension.

Poultry raising

Traditional poultry raising of a few animals per household was replaced by large-scale production after the introduction of superior breeds and advanced feeding techniques.

Improved horticultural practices

The introduction of a foreign apple variety (Red Fiji) has replaced the traditional variety and led to higher profits. Superior properties of the new variety (good storage quality, big size, proper acidity) led to its broad adoption. Planting of the new variety is combined with the traditional technique of planting green manure, a key factor in maintaining soil fertility.

B. Transfer gaps and reasons for failures

Gaps between experimental plots and farmers' fields are mainly due to failures in the timely delivery of inputs and the reduced applicability of whole technology packages. Furthermore, technological guidelines for local conditions frequently tend to be incomplete and management capacities lag behind actual requirements. This situation is similar in crop and livestock production as well as forestry.

The shortage of trained manpower for extension is at the root of the problem, besides sufficient availability of inputs and funds for large-scale extension. Technical training of farmers has to receive highest priority, as it often suffers from lack of timely technological guidance.

C. Accompanying measures for technology transfer

Since the introduction of the production responsibility system in 1979/80, agricultural output has been continuously increasing. Furthermore, the Agricultural Bank of China has increased the credit supply to farmers which contributed significantly to this achievement. Further measures include large-scale soil amelioration, e.g. for sandy soils, lowlands and alkaline/saline soils. Equally important is the enlargement of the irrigated area, accounting for more than 40 million ha or 45 percent of the total cultivated land, and requiring the construction of water conservation and conveyance systems.

D. Intervention level and sectoral linkages

Extension of technology in China involves various governmental departments, the agricultural bank, commercial organizations, research and extension departments, and farmers' associations (presently more than 120,000).

Farmers' organizations should play a prominent role in the process of technology transfer, supported by scientific and technical personnel. Contract research could be beneficial in this respect. To improve the applicability of recommended technology, all aspects of agricultural production should be considered. Due respect should be paid to the important role of services, e.g., input supply and marketing aspects.

Universities and colleges should be called upon for technological advancement and popularization. Scientific and technical personnel have to be mobilized to actively contribute to increased agricultural production and the improvement of living conditions in rural areas. This includes better servicing of farmers with a view to enhanced management capacities.

Considerable funds are needed for technological progress and can be drawn directly from the various links in the production chain, linking contributions to incomes. Furthermore, the various organizations and institutions concerned with technology development and transfer have to be strengthened as regards their capacities for fund raising. At the national level, key projects should be identified within a comprehensive research plan and receive funding accordingly. Long-term development objectives call for increased overall funding of agricultural research and concerned departments have to be coordinated in a comprehensive way.

E. Dissemination strategies

Research-extension linkages:

Joint efforts of various levels of research and extension department have led to the successful transfer of numerous research achievements to farmers' fields. Newly developed varieties are currently being planted on 42 million ha.

On-farm testing:

Before the extension of a technology, on-farm testing is carried out to assess its applicability under location-specific conditions. Due to the climatic variation between subsequent years, this kind of evaluation requires usually 2-3 years. Programmes for location-specific technology testing exist in all Provinces and Prefectures.

Section II

CHAPTER

8

INDIA

V.L. Chopra [1]

I. Technology assessment

A. Government policies

Concerns about future growth and development in Indian agriculture require an approach based on a policy which will ensure sustainable use of land, water and energy resources. The following issues need to be addressed:

Ecosystem management

While significant advances have occurred in Green Revolution areas, the concerns for improving production and productivity in rainfed areas, wetlands, mountain areas including cold deserts, coastal areas, etc., still persist. Ecosystem imbalances will have to be corrected through proper strengthening of research and development programmes. Special emphasis will have to be given to the eastern region. This region is bestowed with high precipitation and considerable irrigation potential which could be realized through the exploitation of underground water. Most arid regions, wastelands and degraded areas can be brought under more sustainable and environment-safe silvi-pastoral systems or agroforestry for energy generation both through biomass and livestock production.

Water management

The conservation and judicious use of water must occupy a very high priority in the national agenda for sustainable development. On-farm water management and energy management will hold the key to improved production. The productivity of farming systems will have to be improved through proper soil-water relationship studies in an integrated manner. Waterlogging is a major problem in the irrigated ares of north Bihar and several parts of eastern India during the *kharif* season. Drainage and ground water use during rabi could improve both the yield as well as the infiltration capacity of the soil. Unless the management of command areas of irrigation projects and water sheds becomes a joint sector activity, based on shared goals and perceptions between farmers and Government officers, the existing inefficient and often harmful methods of water use will continue. The precise priorities in water management will vary from region to region. These issues need to be precisely addressed and tackled appropriately as a national priority.

Land management

Horizontal expansion of land resources for agricultural use will not be possible in the future. Hence, strategies will have to be framed that consider land use planning and measures to check fragmentation of holdings and land degradation. This will require policy delineation and appropriate legislation. Wasteland development programmes need to be accelerated through a watershed approach.

Proper drainage systems should be devised in areas frequently affected by floods or high water tables as well as salinity. Corrective measurers would also be required to overcome nutritional imbalances through effective soil survey and land use planning.

[1] *Director-General, Indian Council of Agricultural Research (ICAR), New Delhi, India*

B. Technology assessment for varying agro-ecological zones

Technology generation and technology in India are rendered location-specific by dividing the country into 120 agro-climatic zones. The assessment of technologies is being carried out at various stages, i.e., the development, verification and adaption stages. Technology transfer considers the combined effect of all technologies introduced in a given area on the productivity of land, animals, machines and human beings.

During the 1980s, varietal improvement programmes placed emphasis on (i) yield stabilization in the irrigated ecologies, (ii) yield enhancement in the rainfed ecologies for sustaining the targeted growth in production and productivity and (iii) crop varieties bred for better fit into new cropping and intercropping systems.

The eastern part of India is categorized as a "difficult ecosystem" with inadequate infrastructural facilities. Super-fast and fast growing varieties together with "technology packages" have now been well established to yield 3-4 tonnes of rice per ha. Rice varieties for lowland, deep water ecosystems have been developed. Groundnut varieties suitable for eastern India have been evolved and introduced. Due to the development of certain varieties, the cultivation of wheat and rapeseed and mustard has been introduced in eastern India.

A large area in coastal Andhra Pradesh used to remain fallow following the paddy crop. A variety of urd-bean has been developed that fits into the paddy crop cycle and utilizes the rice fallow lands. Large areas in Bihar and eastern Uttar Pradesh are planted to Rabi maize due to the evolution of certain suitable varieties and technology packages.

Introduction of sunflower in Punjab, early pigeonpea (Arhar) for *Arhar*-wheat rotation and early maturing cotton varieties for successful cotton-wheat rotation are leading a silent crop revolution in the norther states. *Rajma* and soybean are becoming successful crops in the plains of Central India and the acreage under these crops is increasing. Promising varieties of soybean have been developed even for Haryana.

India has been the world leader in developing hybrids for Rabi sorghum, castor, pearl millet and pigeonpea. A strong programme for developing hybrid rice is under way. India developed the first cotton hybrid in the world, resulting in self-sufficiency in fine and superfine varieties of cotton.

Improved tanks for collecting and preserving rain water for drinking have been extensively adopted by the Water Mission of the Government of India. The concept of integrated management of resources in a watershed has been experimented upon and the developed technology has been promoted through several ICAR and SAUs studies. The concepts have now been accepted at the Central Government level for promoting watershed-based development of rainfed areas. Destruction of village level water harvesting systems has, in the past, led to the reduction in underground recharge. Traditionally, each Indian village had its own cropland, grazing land, forest land, wastelands and ponds. Each of these components interacts with others and what happens to one component invariably affects the other. A holistic enrichment of each of the village ecosystems is needed in a manner which raises the productivity of each component of its resource base. And it has to be implemented in a manner which is equitous and sustainable.

The drip irrigation system has been perfected and widely adapted in areas of low discharge tubewells in Maharashtra. The system is being adopted extensively for irrigating grape orchards. It is also being extended to sugarcane areas.

Technologies have been perfected for the reclamation of the vast area of alkali lands in the Indo-Gangetic plains. The technologies have been extensively adopted by the Sate Government of Punjab, Haryana and Uttar Pradesh to rehabilitate alkali soils for crop production.

High density plantation of pineapple and banana have had a major impact on the production of these crops in Tamil Nadu, Gujarat and Karnataka. Production technology in grapes has made India to stand first in productivity (50 tonnes/ha) while a maximum average of 30 tonnes/ha has been achieved in Maharashtra and Andhra Pradesh.

True potato seed technology developed recently as an alternative technology to the traditional system of potato cultivation by seed tubes has been found to be economically viable, cutting short the seven years cycle of seed production to two years, eliminating the danger of seed-borne diseases and economizing on space requirements. Twenty-seven varieties of potato have been recommended for various regions. Available potato varieties and technology in India have a potential to give yields of more than 25 tonnes per hectare.

C. Resource endowments

India is blessed with enormous natural resources which constitute the very basis of agricultural growth and development: a land area of 328 million hectare, 1,190 mm average rainfall, 2.02 million km^2 of ocean EEZ (Exclusive Economic Zone), tropical, sub-temperate and temperate climate, a large percentage of productive soils, an enormous wealth of fauna and flora and the capability of producing a variety of crop, forest, animal and fisheries products. Combined with centuries old wisdom of practising agriculture, India's natural resources, when scientifically and judiciously utilized, can lead to sustainable progress both for the present and the future.

Technology assessment has led to the identification of new issues relating to sustainability, ecological safety and conservation of natural resources.

The concept of sustainability requires that the capacity to produce today should not compromise the productive capacity of the system in the future. In India, sustainability has come into sharp focus due to changing ratios of nutrient input and agricultural output in the agricultural advanced regions, like the Punjab, Haryana and Western Uttar Pradesh. While the return in the Punjab to a kilogramme of input nutrients was close to 16 kg of grain in the 1960s, this has been reduced to less than 8 kg at present. Obviously, during this period, the productive capacity of the system has suffered due to the deterioration of overall soil conditions. Water availability from lower soil layers is also facing unprecedented stresses.

Ecological safety is the second important element of the changed scenario. It is now understood that environmental degradation and threats to the ecological balance are unacceptable casualties and too high a price to pay for achieving agricultural self-sufficiency. Excessive use of inorganic nutrients and agro-chemicals for crop protection in pockets have clearly brought out the penalties of intensive farming. Injudicious use of water for irrigation in Canal Command Areas (CCA) has posed serious problems of waterlogging and salinization. Balancing ecological safety with higher agricultural productivity will be an important consideration of future strategies.

Productive systems depend upon the health and efficiency of their components. Resources of soil, water, and biological diversity need to be conserved for sustained productivity. According to recent estimates, erosion of the top soil by water, the single most important factor leading to soil degradation is adversely affecting the productive capacity of nearly 153 million ha, largely in the arid regions. Degradation of soils through accumulation of soluble salts (soil salinization) is a threat to sustainability in the irrigated as well as arid and semi-arid regions where groundwater is naturally loaded with salts. Use of this water for irrigation or the redistribution of salts following introduction of canal irrigation is responsible for reduced productivity of some 11.0 million ha of otherwise productive soils.

Conservation of another resource that will take the centre stage of the changed agricultural scenario is biological diversity which provides the building blocks for developing crop varieties with high productivity and certain nutritional and processing characteristics. The pressure on land and water resources is also threatening the native plant and animal populations. India has a uniquely rich and diverse genetic base whose properties are far from fully evaluated and understood. Under assured irrigation and intensive agriculture, the replacement of local cultivars with high yielding varieties is around 60%. Mixed varieties are being replaced by mono-cultures and the total number of crops grown by farmers is also decreasing.

D. Critical areas and sustainability determinants

Land availability and holding size

The per capita land availability has declined since independence because of the increasing population, and by the year 2000 will be 0.15 ha. Considering the growth of urban areas, productive land is likely to come under severe constraints.

The number of farms has increased leading to a decrease in average farm holding. This process is just the opposite of that in the industrialized countries where the farm size has been increasing and the number of farmers has been decreasing.

Poverty and employment

India has made progress in reducing the level of poverty. During the last three decades, real wages and real expenditure by the poorest groups increased and the percentage of the population below the poverty line fell. Even though the percentage of poor has fallen, the absolute numbers of those living in poverty has risen. Two-thirds of India's poor live in states with low or moderate growth in agricultural production.

During the 1981-91 period, the number of workers in rural areas increased by 17.46 percent for male workers and 40.25 percent for female workers. The percentage increase of employment opportunities in rural areas is lower as compared to urban areas.

The increase of employment in urban areas is 34.76 and 60.99 percent for male and female workers, respectively. Consequently, there is a substantial movement away from agriculture. Virtually all the industrialized countries have traversed the same road to modern economic development.

Due to vide variations in labour use by crop and region, employment growth varies across the country. Patterns of labour absorption show high agricultural growth, high labour absorption and increasing worker productivity in three states (A.P., Gujarat and Maharashtra) and low employment absorption and growth in per hectare employment in seven states (Karnataka, W.B., Rajasthan, Orissa, Bihar, M.P. and Tamil Nadu). This trend will pose a growing concern as the Central and Eastern States will account for a growing share of future work force age increments (65% in 1980-2000 compared to 51% in 1960-80).

Climate and environment

Environmental concerns with regard to the sustainability of natural systems, pollution problems and conservation of biological diversity are stirring the private and public conscience more than ever before. Worldwide concern is growing about the possibilities of climate change in the coming decades. The control of emissions of greenhouse gases from agricultural systems and adaptation of crops, livestock, inland fisheries and forests are important challenges for the future. The livestock population of India is more than the country can possibly afford. Lack of sufficient quantities of fodder, feed, and pastures have made it inevitable for livestock to encroach upon forest land.

There seems to be a grater interannual fluctuation in climate, particularly rainfall and temperature. Therefore, abiotic stresses are becoming strong determinants of agricultural production, including food crops, fodder, fruits and vegetables, and animal products.

Biodiversity

India has a rich and diverse genetic base as regards many crop species. In addition, several medicinal, aromatic and forest plants are unique to the country. Encroachment of land because of agricultural expansion, urbanization and unmindful exploitation, has brought about a situation where a number of plant species are at the verge of extinction. Protection of biodiversity, however, is important for future generations.

India is also blessed with an enormous diversity in animals and fisheries because of its many ecological regions. Protection and assessment of this biodiversity is in the national interest.

Improvement in productivity of crops

There has been significant improvement in the productivity and production of several important crops such as wheat, rice, sorghum, maize, sugarcane, cotton, potato and oilseeds. However, both productivity and production of pulses and coarse cereals continue to be low. Production in many horticultural crops has increased but yields are relatively lower than those obtained in similar climates elsewhere in the world.

Imbalances in crops and regions

Past growth in agriculture has been highly variable among regions, groups of farmers and crops. While this might be expected, given the varying resource endowments in different agro-ecological regions, much of the inequity is attributable to patterns of investments and agricultural policies which preferentially benefitted certain states, groups and crops. The sharpest contrast is between the north-west and the east.

Irrigation and water management

It has been estimated that the total precipitation of around 400 million ha-m in the country, surface water availability is around 178 million ha-m (45.5%). Out of this, only about 50% can be put to beneficial use because of topographical and other constraints. In addition, there is an underground potential of about 42 million ha-m. The availability of water is highly uneven in both space and time. Precipitation is confined to only 3 to 4 months in the year and varies from 10 cm in the western parts of Rajasthan state to over 1,000 cm at Cherrapunji in Meghalaya.

The irrigation potential of 80 million ha was created by the end of the Seventh Five-Year Plan, a three-fold increase since independence, but in the irrigated ares the required productivity of at least 4 tonnes per ha has not been reached. On the other hand, the irrigation projects in high rainfall areas of over 1,500 mm annual rainfall have resulted in problems of soil degradation because of inefficient drainage and insufficient use of water for crop production and/or agroforestry programmes. Despite heavy investments in the creation of agriculturally available water resources, there has not been adequate adoption of efficient water use systems. Excess supply of water is as much a problem as poor availability.

Availability of quality seeds

Among the various inputs, improved and quality seeds have played a key role in the transformation of agriculture through the Green Revolution. The public institutions created to meet the seed requirements have not been able to satisfy the needs of the farmers. Presently, public and private sector and industry put together are able to produce only 11% of the quality seed demand.

Post-harvest losses

There are varying estimates of losses ranging from 20% to 30% of the various fruits and vegetables which are produced at a high cost. There are also considerable losses during storage of grain crops because of poor storage conditions, pests and animals, and poor handling and management. It is generally estimated that these losses could be of the order of 5% or even more.

Livestock population

The livestock population is in excess of what the country can afford. Lack of sufficient feed and fodder forces livestock to encroach on forest land. The quantum of feed resources, both conventional and non-conventional need to be enhanced. While the present numbers are not sustainable, they also cannot be reduced substantially due to the shortage this would create in bullock power. This paradox is to be tackled for a solution.

Selective mechanization

To meet the increasing demands in food, feed, fibre and fuel, there is an increasing need for mechanization. The change from animal power to sophisticated machinery has been the route to improvement of agriculture in industrialized countries. Thus, modern agriculture is inseparably linked to intensive energy use. The approach of industrialized countries to agriculture, however, will not be possible in India because of several factors. It is imperative, though, that selective mechanization with efficient energy use is employed according to the needs and the level of development.

Energy in agriculture

The agriculture sector contributes about 34% to the total gross domestic product (GDP), but the share of agriculture in commercial energy consumption has remained around 2.5%. When considering the contribution of agriculture to the energy sector, particularly the non-commercial energy, it is estimated at approximately one-third. Thus, agriculture is, at present, a donor of energy to the total energy sector of the country.

The increasing need of food production, including animal products, processing and marketing will make increasing demands on commercial energy for the agriculture sector. Therefore, a judicious mix of energy sources including draft animal power as well as wind power will have to be developed depending upon regional conditions.

Disaster management

Every year the country experiences droughts and floods in one part or the other. One-third of the country is drought prone. Floods effect on average around 9 million ha per year which is about one-fourth of the total area rated as susceptible to floods. In addition, there are cyclones or earthquakes which affect the lives of millions of people directly or indirectly by disrupting agriculture. There is a need for organized efforts to meet these natural disasters as a national problem.

Women in agriculture

Women play an important role in agricultural practice and management and production in India. Despite their significant contribution, they have been deprived of education, training and tools to avoid drudgery. However, it is the effective involvement of women which will eventually lead to a prosperous agriculture and rural development.

II. Technology transfer

There are four technology transfer systems operating in India, *viz.* (i) the First-line Extension System of the Indian Council of Agricultural Research (ICAR), (ii) the national extension system of the Union Ministry of Agriculture, (iii) the state level extension system of the respective State Government, and (iv) the rural development programme of the Union Ministry of Rural Development including extension efforts of the non-governmental organizations (NGOs)/voluntary organizations.

First-line Extension System

The main purpose of the First-line Extension System is to reduce the time-lag between the generation of technologies and their transfer to farmers. The specific objectives of the system are:

i) Prompt demonstration of the latest agricultural technologies to farmers as well as extension workers of the State Departments of Agriculture/non-government organizations with a view to reduce the time-lag between the technology generation and its adoption;
ii) Testing and verification of technologies in the socio-economic settings of farmers and identification of constraints;
iii) Getting first-hand feedback for scientists, in order to keep them abreast with the performance of technologies and the actual farming problems to reorient research, education and training programmes accordingly;
iv) Provision of training and communication support to the State Departments of Agriculture/NGOs;
v) Based on field work and experience, development of extension models to be adopted by the general extension system for large-scale multiplication; and
vi) Promotion of research in extension and studies including comparative studies of extension systems.

There are six first-line extension projects of the ICAR which are given to the SAUs, research institutes, and a few reputed NGOs/voluntary organizations for implementation. They are:

i) National Demonstrations;
ii) Operational Research Projects/On-Farm Research;
iii) Krishi Vigyan Kendras (Farm Science Centres) - KVKs; and Trainers' Training Centres;
iv) Lab-to-Land Programme;
v) Upliftment of Scheduled Castes; and
vi) Socio-economic Improvement of Scheduled Tribes.

The extension projects of the ICAR have been able to involve scientists in the extension projects for direct interaction with farmers. The generation of technologies, education programmes of the agricultural institutions and farming courses are influenced by such feedback and make them more appropriate and relevant to the farmers needs.

National Demonstrations Project

The National Demonstrations Project (NDP) was launched by ICAR in 1965. The Project aims at demonstrating the maximum production potential of crops in different parts of the country. At present, 48 National Demonstrations Projects are functioning in 48 districts. The projects are shifted to different locations/districts every 5-6 years. Keeping in view the thrust of the agricultural production programmes, lately more attention has been given to demonstration for oilseeds and pulses.

Krishi Vigyan Kendras (KVKs)

The Krishi Vigyan Kendras project (Farm Science Centre) was stated by ICAR in 1974 and is based on the principle of "teaching by doing" and "leaning by doing". In other words, the training is imparted by giving work-experience and skills vis-a-vis the traditional lecture methods.

Trainers' Training Centres (TTCs)

The concept of Trainers' Training Centres (TTCs) was launched for training the trainers of the Krishi Vigyan Kendras and also the subject-matter specialists of the State Governments. So far, eight specialized Trainers' Training Centres have been established in different parts of the country.

Lab to Land Programme

The Lab to Land project was designed and implemented in 1979 to reach small and marginal farmers. The approach was to adopt farm families and give them technical advice as well as critical inputs. A total of 14,500 families were adopted during the Seventh Plan.

Operational Research Projects (ORPs)

The Operational Research Project (ORP) concept has been introduced to the ICAR research systems as an interphase between research and extension. These projects were initiated in the Fifth Plan period (1974-1979).

The broad objectives of these ORPs are to (i) test the performance of new research results in farmers' fields at an operational level with existing resources and socio-economic frameworks; (ii) determine the profitability of new technologies under actual farm conditions; (iii) demonstrate the potential of these technologies to the farmers of the area; and (iv) study constraints (technological, institutional and administrative) and provide scientific feedback to the appropriate agencies to remove barriers in the rapid spread of improved technologies and for reorientation of research programmes.

III. Case study

Planning for self-sufficiency in food fodder and fuel for a village

A benchmark survey for the assessment of resource availability and total energy needs of Islamnagar village on an annual basis for crop production, post-harvest operations, animal husbandry and domestic activities was carried out in 1981. The degree of self-sufficiency with regard to food, fodder and fuelwood was assessed. The actual utilization pattern as well as the potential of plant, animal and human biomass for the preservation of the ecological balance in the village biosphere were determined and assessed as to energy needs in the domestic sector and sources of plant nutrient.

The village was deficient in fuelwood production by 20% (98.8 tonnes/year), cattle feed by 30% (812 tonnes/year), pulses by 32% (7.2 tonnes/year), and oilseeds by 72% (22.9 tonnes/year).

The village achieved self-sufficiency from available resources based on alternate (renewable) energy sources. In order to meet fuelwood and fodder requirement of the village, an appropriate area was identified on the basis of land use planning and brought under silvi-pastoral development. Soil and water conservation measurers taken include contour survey, cut-off trenches along the contour vegetative waterways, drainage channel, open trenches and service road along the boundary of the area, temporary erosion control structures and micro-catchment water harvesting for *in-situ* water conservation.

In order to cut down fuelwood requirements, three community biogas plants of 85, 35 and 35 m^3 capacity, respectively, and 50 individual biogas plants were planned. One community plant of 85 m^3 capacity and 40 family size biogas plants that were constructed in the village take care of 32% of the cooking energy needs of the village against a target potential of 52% while the slurry from these plants has met 16% of the nitrogen requirements against a target of 28% as a replacement of the chemical fertilizer at self-sufficiency level. The cropping intensity increased from 99.5% in 1981 to 130% by 1986 and the productivity increased from 0.986 tonnes/ha to 1.38 tonnes/ha.

The implementation of various programmes for making village self-reliant has led to better resource utilization and increased harnessing of solar energy for conversion to food, feed, fuel and fibres. Overall photosynthetic efficiency increased from 0.087 to 0.144%. With the removal of drudgery in the domestic sector and increased activities in afforestation and grassland management, an additional 12,500 mandays per year could be generated in the village.

The combined initiatives have had the following advantages:

a) For the first time, a complete material and energy flow in a village ecosystem has been drawn up in the flow chart and the total solar energy flow in the ecosystem has been depicted. Scientific planning, based on natural resources and appropriate technologies, has led to a 65% increase in photosynthetic efficiency for conversion of solar energy into food, feed and fuel.

b) The extent of resources used by different categories of villagers has been documented for production agriculture, post-harvest operations, animal husbandry and domestic activities.

c) The extent of recycling of biomass in the village ecosystem has been studied and its potential exploited. The animal biomass alone could meet 52% of cooking energy needs of the village and 28% of the nutritional requirement of crops.

d) Self-sufficiency plans in terms of fuelwood, fodder, pulses and oilseeds were drawn based on the natural resources available in the village and were implemented in cooperation with state/central government agencies. The village produced surplus in pulses, oilseeds and fuelwood. Sufficiency in cattle feed, however, could not be achieved.

e) For the first time, renewable energy technologies were integrated with production agriculture, animal husbandry and rural living.

f) The combined effect of all technologies/managerial skills/cultural practices/policies on the productivity of land, animal, machine and human being and on income and employment generation has been estimated.

g) A simulation model has been evolved for maximizing the solar energy harvest through food, fuel and fodder production and for minimizing energy input from commercial energy sources.

h) Various state/central government agencies were involved for accelerating integrated rural development while optimizing human and material resources.

Section II

CHAPTER 9

INDONESIA

Soetatwo Hadiwigeno [1]

I. Technology assessment for varying agro-ecological zones, production systems and resource endowments

Several means have been used by AARD to assess its research programmes and activities. The main objective is to assess: (i) the appropriateness of research activities vis-à-vis the needs for the national and agricultural development, (ii) the relevance of research and development activities for agricultural commodity development programmes launched by the Ministry of Agriculture, and (iii) the effectiveness of the research and development activities and results in meeting information and technology demands of the users: policy makers, scientists, educators, extension personnel, farmers and others.

A. Agricultural research policies

Agricultural research is directed to identify and develop alternative development policies and technological innovations for every ecological zone which are economically, socially and environmentally viable. These agricultural research policies are an integral part of the national development policy.

To ensure that research funds are efficiently utilized, AARD research programmes provide the inducement for both research activities and investment initiatives supported by other public sector bodies and the private sector. Research activities are increasingly inter-disciplinary, focus on overcoming critical constraints to higher productivity, efficiency, profitability, and stability, and will provide location-specific recommendations designed to enhance the comparative advantage of the nation's varied production environment.

B. Priority setting

The effective and efficient use of agricultural research resources requires that a set of criteria be established for prioritizing demands on research resource allocation. The following criteria are used to set research priorities:

a) To ensure that adequate research is done on a core set of policies, resource endowments, and commodities which form the mainstay of agricultural development, highest priority for agricultural research resource allocation will be given to those commodities and research areas which are of political, economic, social, and strategic importance.

b) To ensure that research contributes to the sector objectives of increased growth, income, employment, and equity, agricultural research on other commodities and areas will be conducted where there is a high probability that the research will generate a fair balance of growth and equity-oriented development expenditures that yield:

   i) ample social and economic benefits, and

   ii) a broad spread of such research benefits to include the low income population sections and areas of marginal resource endowment.

c) To ensure that research provides a foundation for long-

[1] *Director-General, Agency for Agricultural Research and Development (AARD), Jakarta, Indonesia*

term sector development, a portion of agricultural research resources will be allocated to pioneering research such as biotechnology and new product development, which will serve to expand the frontiers of the agricultural sector. This will include research which will lead to greater diversification of the farm sector.

Research on commodities in relation to resource endowments follows the government guidelines for development by diversifying, intensifying, extensifying, and rehabilitating by matching appropriate research initiatives to the quality of the natural resource base in the numerous agro-ecological ares of Indonesia, including inventory aspects of regional natural resource potential as well as comparative advantages of community regionalization. In the context of land use, three useful productivity classes of land are:

i) high potential, where diversification and intensification goals may be appropriate;

ii) future potential, where the goals of extensification may be best suited; and

iii) less potential, where rehabilitation may be most appropriate.

Priorities in research resource allocation have to ensure that strategic needs are met, regional resource endowments are efficiently utilized and new opportunities for agricultural growth and development are generated. Research programmes to support the development of commodity agribusiness systems will also be taken into account. An agro-ecological classification of land and water resources which will serve as one dimension of a planning matrix includes the following areas: (i) irrigated, (ii) rainfed, (iii) upland, (iv) swamp, (v) marine, (vi) coastal, and (vii) inland water. The second axis of the planning matrix lists the commodity and discipline research ares which will contribute to the innovations for improving agriculture in these agro-ecological areas. These include (viii) food crops, (ix) horticulture, (x) estate crops including industrial crops, (xi) livestock, (xii) fisheries, (xiii) soil, and (xiv) socio-economics for agriculture. Scientists from these commodity and discipline groups are to devise innovations which will enhance the productivity and stability of the farming/harvesting systems of the area, reduce product losses, add value to the product through processing, and enhance the well-being of both producers and consumers through more efficient marketing, pricing and transporting systems.

C. Organization and management of research

To provide a long-term integrated planning perspective for agricultural research, a set of master plans has to be prepared and updated periodically. Individual research centres and institutes have to develop plans based on the role identified for their institute in the sector and commodity-wide plans have to be revised to conform with the agenda resulting from the overall development plan.

To ensure that research projects and programmes are planned in accordance with the criteria established for prioritizing agricultural research expenditure, the existing procedures should be improved through the external and internal review of research proposals to evaluate conformity with plan objectives, to assess the relative technical merits of the research proposal and to gauge the likely impact and probability of success of the research activity. Review of the research proposals should be conducted by a multi-disciplinary group of experts to ensure a greater degree of inter-disciplinary involvement in research activity planning. The research project review model will serve as a basis for developing an improved planning procedure. There is also a need to further define the operational statement pertaining to the linkage among working units from the time of programme formulation up to the transfer and application of the technology.

Databases which are required for long-term resource use for planning will continue to be developed. This information will be used to ensure that sustainable agricultural resources are utilized to their fullest extent, while preserving the quality of the natural environment. Particular attention will be paid to collecting and assembling the information required to plan for the rational use of land, water and fishery resource.

To provide a sound database for programme management, a Management Information System (MIS) should be used as a tool for effective use by agricultural research managers. The MIS should be fully automated and should contain information that is vital to informed decision making regarding the allocation of agricultural research resources. The MIS will provide data to research programme managers in a timely and accurate fashion and will be an important tool for planning, monitoring and evaluating research programmes.

To increase the efficiency of research resource utilization, greater stress should be placed on inter-disciplinary and inter-institutional agricultural research. The continued use of the farming systems approach to solving area specific technology problems will be strengthened and institutionalized in the research programme of AARD.

To foster greater economies of scale in research problem solving, greater networking amongst the technical discipline specialists in the various research units should be encouraged. Technical specialists in some professional peer groups have already conducted regular meetings, prepared widely circulated publications and exchanged information on recent developments in their fields. This practice will be extended throughout the AARD, should be strongly encouraged, and institutionalized in the AARD programme.

To capture benefits of research conducted outside Indonesia, continued effort should be made to tap into the research results of the International Agriculture Research Centres (IARCs), the other national research systems and the research services supported by larger private sector establishments. An aggressive research search and collaboration approach needs to be intensified to enable Indonesia to gain from third-party research investments. Many memoranda of understanding already exist with international, regional and national institutions and the intensification of these contacts should be encouraged. The organization of seminars both nationally and internationally is one way to encourage such interaction. The implementation of international research collaboration and the execution of the actual research for global research development will be the responsibility of the concerned staff of research institutes/centres.

II. Technology transfer

To ensure the more rapid dissemination of agricultural research results, links between agricultural research and extension staff have to be intensified. Linkages between researchers and users will be further intensified in order to facilitate speedy communication of research results as well as to obtain feedback for future research programme formulation according to established priorities. This will be accomplished by increasing the number of field days, by conducting on-farm farming systems research jointly with the local extension staff, by cooperating with the local agricultural service staff on site selection, design and evaluation of verification trials, and by conducting periodic training courses for the subject matter specialists in the region so as to keep the extension service abreast of the latest research findings. The research units will, furthermore, intensify their active participation in the Commission on National Agricultural Extension at the national level and the Forum for Coordination of Agricultural Extension at the provincial level. In addition, efforts to minimize and resolve research communication problems due to uneven distribution of research units throughout the country as well as improvement of extension specialist skill will receive high priority.

A. Dissemination strategies

The main objectives of AARD's dissemination efforts are to make maximum use of research findings to support agricultural development, to meet the need of the research users to generate agricultural information and technology derived from research results, to share experiences and to exchange research findings among scientists for the advancement of agricultural science and technology, to provide current information to the extension personnel and educators to enable them to formulate extension and teaching materials to solve farm problems.

Research results are disseminated through formal and informal channels and mass media. Recently, electronic media have been included in this effort. The various means and strategies employed are as follows:

i) Publications are the most important channel in disseminating research results to different users located throughout Indonesia. The strength of publications is the possibility to reach users in all locations simultaneously. Several types of publications have been used by AARD and its research institutions, such as:
   - Scientific publications as communication media between AARD researchers and other scientists and users. Articles are written in English or Indonesian with an abstract in English.
   - Scientific reviews presenting research results on certain scientific disciplines, specific commodities, aspects of agricultural development and other subjects for policy-makers, research managers and researchers. Published in Indonesian and English.
   - Newsletter, presenting important research activi-

ties and findings in popular style for rapid use by extension personnel, practitioners and other users. Published in Indonesian.

- Technical Guidance, presenting technical information on research results in manual form for their direct utilization.
- Proceedings of seminars, workshops, and other meetings discussing research activities and results.
- Special publications such as leaflets, brochures, books, presenting certain aspects, progress, state of the art, etc. of the research activities and their results.

ii) Various meetings such as seminars, symposia, workshops and other meetings discussing research results. The meetings are attended by policy-makers, extension personnel, farmers and other users with the main objective to disseminate research results and obtain feedback from the research users.

iii) On-farm research, i.e., the testing of the adaptability of certain research results in farmers' fields in terms of physical as well as social environment. A more comprehensive type of on-farm research is conducted on a commercial scale (developmental research). On-farm research is implemented with active participation of extension personnel and farmers who can benefit directly from tested and adapted new technologies.

iv) Field-days on research results, presenting the relevance of research results to extension personnel, farmers, practitioners and other users.

v) Various research-extension consultative meetings to solve farm problems that could not be solved by extension personnel alone.

There are further means to disseminate research results such as informal visits of farmers and extension personnel to research institutions, personal contacts between researchers and extension personnel and similar activities.

Efforts to improve the dissemination of research findings are being undertaken in line with the fast development of science, technology and research activities, the dynamic changes of the behaviour of the research users, the increasing demand for agricultural development based on science and technology and increasing need for information on research results by users.

More effective guidance to agricultural research and more rapid translation of research findings into government policy is accomplished by increasing the frequency and quality of seminars and presentations of research results to key government policy-makers. The format for an occasional forum between policy makers and researchers will be developed to promote greater frequency of direct contact and interchange of ideas between these two groups. This will facilitate policy formulation and increase the relevance of agricultural search. In order to facilitate technology adoption and applicability, it is anticipated that research reports will contain an assessment of economic costs and benefits and the impact on employment.

To enhance the market-responsiveness of the agricultural research system, increased linkages between the private sector and the AARD scientists are encouraged. A system is devised to encourage research institutes to enter into collaborative projects with the private sector. However, such collaborative research ventures will not be allowed to substitute for higher priority research which is required to satisfy the broader mandate of the research units. Private sector representatives, however, are invited to participate in major planning and reporting events sponsored by AARD.

B. Case study: Agricultural research-extension linkages

In 1991, an agricultural research-extension linkage programme was initiated by AARD, with the aim to assess the need for specific technology and to improve the flow of information through an action programme. The programme is intended to find effective systems and mechanisms for disseminating research results and providing feedback from the field, with the final objective of accelerating the information flow and technology transfer from research to the users. This programme involves personnel from diverse institutions and farmers working together on improving communication systems and strengthening linkages.

Initially, the programme concentrated on five provinces, the selection of which was based on the complete lack of research institutes catering for these areas. Activities included:

i) the identification of resource potentials and constraints to the adoption of new technologies,

ii) the identification of available technologies to meet the local technological needs, and the scope for training the extension personnel and key farmers in the use of new technologies,

iii) demonstration of the performance of identified technologies in farmers' fields, and

iv) research field-days to show and discuss implications for the adoption of identified technologies.

The technological needs for the Bengkulu province were identified as developing farming systems for food production which simultaneously conserve the land resources. For this purpose, the alley cropping system was considered most appropriate. Coffee was used as alley crop, while soybean, corn and ginger were planted between the alleys. Although the results of the technology have not been demonstrated yet, the interaction among all participants has strengthened the research-extension-farmer linkages considerably.

Based on several supervisory visits to the location, it could be concluded that the response to the use of alley cropping technology in Bengkulu was met with a positive response. It was further concluded that some technologies are not being fully adopted by farmers due to a lack of demonstrated benefits of the technology, labour shortage and lack of proper inputs. Strong support from local leaders was needed for improving the role of extension personnel in providing guidance on the adoption of new technology.

Similarly, encouraging results were gathered in the other four provinces. Research needs were identified, and approaches to improve the transfer of research results were developed.

Section II

CHAPTER

10

REPUBLIC OF KOREA

Yong-Hwa Shin [1] and Jae-Duk Kim [2]

I. Technology assessment for sustainable agriculture

Since the 1960s, Korea's agriculture has become a high-input agriculture, using large quantities of chemical fertilizers and other agricultural chemicals. Trends in the use of fertilizers and other chemicals were as follows:

	1965	1970	1975	1980	1985	1990
Fertilizer (kg/ha) (As fertilizer elements)	113	162	232	285	311	458
Total Agricult. Chemicals (tons) (Active ingredients)	1,287	-	8,642	-	17,758	26,610

Among other things, two factors mainly contributed to the rapid growth in the use of chemical inputs: the rapid migration of rural labour forces to other sectors along with the rapid industrialization, and the steady growth in the per capita consumption of some agricultural produce, particularly vegetables, fruits, and livestock produce. In the recent years, the call for sustainability of agriculture and environmental friendliness of agricultural practices has become louder. The relevance of these issues has been recognized by planners and researchers. However, as yet, the farmers' response has been very slow.

The majority of Korean farmers are still practising high-input agriculture, due to the current socio-economic conditions that do not force them to change their practices. Despite huge imports of cereals, the demand for major cash crops is increasing and rural labour forces continue to decrease. This situation, in fact, encourages the farmers to pursue more labour-productive technologies. Despite this macro-trend, there are some individuals who believe in the philosophy of organic farming. It is estimated that currently about 10,000 farmers are practising organic farming in various manners. Some of them totally eliminate the use of chemical fertilizers and agricultural chemicals, while others try to combine organic and high-input farming. The degrees of success vary widely. The major problem with sustainable agriculture is the absence of a solid definition. Some people equate organic farming with sustainable farming, a questionable notion vis-à-vis the existing need for ever increasing productivity.

The prevailing socio-economic outlook in Korea will not allow to depart from the current practices within the very near future. A fundamental change in consumer demands is needed which is currently based on a "the more, the better" mentality, before high-input technologies can be discarded.

Technological options

As a first step, research efforts in Korea are being strengthened for maximizing efficiency in the use of scarce resources. Following below are some example for current strategies in resource protection:

[1] *Director General, International Technical Cooperation Centre, Rural Development Administration (RDA), Suweon, Korea*

[2] *Research Scientist, International Technical Cooperation Centre, Rural Development Administration (RDA), Suweon, Korea*

i) Improvement of fertilizer use efficiency, through
   - Re-examination of fertilizer application rates for different crops
   - Development of more efficient fertilizers, such as slow-release fertilizers
   - Improvement of fertilizer placement methods
   - Efficient use of plant nutrients accumulated in the soil

ii) Integrated pest management, through
   - Improvement of methods for the monitoring of insects and diseases
   - Improvement of damage evaluation methods
   - Utilization of soil micro-organisms for the control of some soil-born diseases
   - Exploration and use of natural enemies

iii) Strengthening protection of agricultural environments, through
   - Improvement of methods for monitoring of soil, water and air contamination
   - Development of technologies to minimize the damages by various pollutants

iv) Better management of environmental resources, through
   - Protection of soil resources from erosion, degradation, and losses of soil fertility
   - Efficient use of water resources
   - Better use of climatic information

II. Technology transfer

There are two major channels for technology transfer in Korea, the field demonstration and the demonstration farm. Numerous technologies are being transferred in this way, including labour-saving techniques, horticultural techniques, specialized and value-added production, rice, upland and cash crops, and livestock production techniques. Technology transfer is essentially the responsibility of the County Extension Office under supervision of the Provincial Rural Development Administration.

A. Gaps in technology transfer

There are gaps between the yield levels achieved in the research institutes and under practical farming conditions. These gaps, however, are relatively small. For instance, in rice, the yield difference between the demonstration plots' and farm fields is about 1 percent. For maize, barley, pulses, peanut and sesame, the yield gaps are 6 percent, 11 percent, 12 percent, 22 percent and 36 percent, respectively. When yield gaps are large this is mainly due to cultural practices and lagging adaptation of new varieties. Those crops are mostly produced for self-consumption and farmers do not pay full attention to yields.

B. Intervention level and accompanying measures for technology transfer

Agricultural cooperatives, organized under the National Agriculture Cooperative Federation (NACF) due to their mandates in increasing agricultural productivity and enhancing rural welfare, play an essential role in technology transfer, covering such activities as banking and credit input supply, marketing, insurance, warehousing, transportation, processing and related support services, e.g., research. Recently, the cooperatives have become active in economically and politically representing farmers as an interest group.

C. Dissemination strategies and research-extension linkages

The Rural Development Administration (RDA) is the centralized government organization responsible for agricultural research and extension services. It plays a key role in research on the improvement of farming technology and rural development, dissemination of technology to the farmers, and education of farmers. During the last three decades, RDA has emphasized a demand-driven technology development and timely delivery of technology to the farming community. The RDA comprises 15 research institutes having specific objectives and also nine Provincial RDAs conducting both research on location-specific problems and extension work, supervising 176 County Extension Offices. In addition, 10 specialized crop experiment stations have been established under the Provincial RDAs to conduct the research on special crops. In Korea, the linkage between research and extension is very strong, because these two functions are under one administration. There are frequent interactions between the researchers and extension officers to identify and solve the problems occurring in farmers' fields.

Section II

CHAPTER

11

LAO PEOPLE'S DEMOCRATIC REPUBLIC

B. Chounthavong [1/]

I. Technology assessment for varying agro-ecological zones, production systems and resource endowments

A. Government policies

The Fifth Party Congress of March 1991 stated that the Government of the Lao PDR would further stress the role of the market economy and re-emphasized the importance of agriculture and forestry in the economy, referring to the sector as the "number one battlefield". It reiterated that the farm-household is the main unit of agricultural production, and that it needs proper incentives and support (e.g., tax reform, credit, land tenure, land use rights, etc.). It also stressed the necessary role of technology and that the research system should "uphold the orientation of combining the use of traditional and semi-modern instruments and means, and the acquisition of modern techniques and technologies" for the improvement of the performance of the agriculture and forestry sector.

The government has put in place a clear policy to reduce shifting cultivation and replace it with more sustainable agricultural systems. All technical departments within the Ministry of Agriculture and Forestry (MAF) have a clear mandate to work on such sustainable technologies.

Since 1986, with the New Economic Mechanism, the opening of domestic and international agricultural markets is seen as the basis of growth for the economy. Food self-sufficiency is now viewed in national terms, encouraging inter-provincial trade of food commodities, such as rice. As price distortions are eliminated, farmers will have more incentives to produce a more diversified set of commodities for commercial purposes.

B. Major agro-ecological zones and production systems

At present, there exists no classification of agro-ecological zones and agricultural systems in the Lao PDR. A preliminary classification can be based on the major production systems and topography as influenced by the Mekong Watershed.

The lowland areas of alluvial plans are located along the Mekong River and its tributaries. The production systems are rainfed lowland rice-based, providing the staple food requirements. Fish and livestock are raised for protein supply. It is in these areas that the few dry season irrigation facilities are located. For cash income, fruit trees, vegetables, cotton, sugarcane and tobacco are grown. Many farmers in this area consider large animals as a form of wealth which can be liquidated in case of emergency. Much of the nation's food is supplied from the lowland areas.

On the foothills, i.e., the rolling hills and lower mountain slopes, much of the nation's "rotational" shifting cultivation is practised. Upland rice and maize are grown as the main crops, and also livestock plays an important role. The mostly subsistence-oriented people rely heavily upon forests

[1/] *Director, Agricultural Extension Agency, Vientiane, Lao PDR*

for food plants, animal feed, medicinal plants, and wood for fuel and shelter. While bunded paddy land is scarce, it contributes significantly to the overall performance of the agro-ecosystems. Where water resources are available, some farmers have traditional irrigation systems and supplement their protein intake with wild fish.

There are a number of high plateaus in the country (Xiang Khuang, Na Kay, Bolovens) with natural pastures of good quality and farmers traditionally raise animals, especially cattle, for sale. Some of these areas, e.g., Bolovens Plateau, produce also cash crops such as coffee, fruit trees, vegetable, and potatoes. With cash income from the sale of these products, farmers purchase rice and other necessities.

The highlands on or near mountain tops favour production systems which include crops of upland rice, maize, grain legumes, and tubers; small and large animals; and in some cases opium. Sometimes fruit trees are grown, and home gardens are very important. Many of these people practice a ''pioneering'' type of shifting cultivation.

C. Resource endowments

During the last decade, the LAO PDR has undergone a prolonged period of expansion in the use of its land resources in order to increase production and attain rice self-sufficiency at the national level. About 700,000-800,000 ha (3-3.5 percent) of the nation's lands are presently under cultivation out of about 1.9 million ha (8 percent) of potentially arable land. In addition, there are 800,000 ha (3 percent) of pastures and rangelands, which are presently being utilized. The scrub land, which comprises 5 million ha (21 percent) of marginal land, has an undetermined potential for improving watersheds and perhaps for other uses. Once there is an understanding of indigenous wild fish production in the nation's 2,180,000 ha of rivers and lakes, and means of improvement decided upon, fisheries in the Lao PDR can gain its previous status as a key component in farmers livelihood systems (Table 1).

D. Forest resources:

Forests cover about 47 percent of the country's area with an estimated 11,273,000 ha of which 30 percent is evergreen forest, 50 percent mixed deciduous forest, 15 percent deciduous forest and 5 percent other categories, i.e., bamboo, pine, etc.

The total wood volume of all types is about 1,200 million m^3 and the total annually logged volume is estimated at 450,000 m^3. Forest plays an important role in the country: it provides various wood and non-wood products such as food, rattan, bamboo, medicine for the rural people, and it has an important ecological role for the rational exploitation of the country's renewable natural resources. The wood industry is the second major export earner accounting for about 40 percent of total export. Fuelwood is extracted from the forest by about 85 percent of the population of the country to meet their energy needs. Annual fuelwood consumption is about 3 million m^3.

Forest resources represent a significant economic value also in terms of non-wood forest products such as wildlife, food cardamon, benzoin, medicines, fruits, resins, rattan, bamboo and minor building materials.

E. Shifting cultivation:

Shifting cultivation is one of the key development issues in the Lao PDR, due to the controversy over its impact on the environment and since farmers, who practice it, are among the nation's poorest. The reduction of shifting cultivation was recognized as a major objective in the Second Five-Year Plan. According to the latest estimates, there are approximately 337,000 families involved in shifting cultivation, at least part-time. It is estimated that 360,000 ha of secondary forest are used each year. Given the national

TABLE 1. LAND USE IN THE LAO PDR (1988)

Land type	1,000 ha	Percentage
Forest land	11,000	46
Scrub bush	5,000	21
Cultivated cropland	800	3
Lowland rice	379	1.6
Upland rice	215	0.9
Other crops	94	0.4
Pastures and rangelands	800	3
Waterways and lakes	2,180	9
Other (unspecified in statistics)	2,400	10
TOTAL	23,684	100

Source: MAF, 1989 Vientiane

average fallow period of five years, approximately 1.8 million ha are under shifting cultivation. Most of the nation's upland rice, corn, roots and tubers, grain legumes, and oil crops are grown under swidden systems.

F. Crop production:

Rice is the main staple food crop in the country with about 700,000 ha annually cultivated. About 400,000 ha are annually planted to rainfed lowland rice with an average yield of 2.3 t/ha of paddy rice and an annual production of 950,000 tons of paddy. Rainfed lowland rice covers about 60 percent of the total rice area and accounts for about 70 percent of the national rice production. Dry season irrigated rice covers about 11,400 ha which represents about 3 percent of the total rice areas of the country with an annual production of about 33,000 tons of paddy and average yield of 2.9 t/ha of paddy. It is estimated that about 160,000 ha of rainfed lowland rice receive some supplementary irrigation water during the wet season in small-scale gravity irrigation schemes. About 250,000 ha are annually planted to upland rice with an annual production of about 300,000 tons of paddy. Yield averages 1.2 t/ha of paddy. It is mostly grown under shifting cultivation and therefore closely related to forest and soil resource degradation where cropping intensity is high. The average consumption of rice is estimated to be equivalent to 350 kg of paddy rice (213 kg/per year of milled rice with a milling rate of 60 percent).

Maize is the nation's second most important crop after rice with about 30,000 ha most concentrated in the northern provinces. Annual production is estimated at about 40,000 tons and yields are about 1-1.5 t/ha. Grain legumes are grown in small quantities in many parts of the country. About 15,000 ha are annually planted to grain legumes with average yields of 0.6-0.9 t/ha for soybean, 0.3-0.6 t/ha for mungbean and 0.7-0.8 t/ha for groundnut. Roots and tubers are grown in small plots in most of the villages of the country. In 1989, about 27,000 ha were planted to roots and tubers with a total production of about 162,000 tons. About 4,000 ha are annually planted to sugarcane with an estimated production of 111,900 tons of cane and average yield of 28 t/ha. Sugarcane is grown in small plots throughout the country and is mainly used for chewing. Cotton is traditionally grown on small parcels of land with a total planted area of 30,000 ha throughout the country. Annual production is estimated to be 14,000 tons of seed-cotton with yields averaging about 400 kg/ha under traditional cultivation practices.

Coffee is cultivated on about 12,000 ha essentially concentrated on the Bolovens Plateau between 400 and 1,250 metres elevation. Coffee is the number one export crop of the country with an annual production averaging 4,800 tons of green coffee and an average yield of 400 kg/ha. Yield variations are very high from one farmer to another ranging from 200-1,000 kg/ha.

A wide range of fruit tree species is commonly grown near houses in every city and every village of the country. Fruit trees are cultivated on about 5,000 ha with a total production of about 60,000 tons of fruits per year. There are many different vegetables grown in the Lao PDR. Different non-cultivated plants are also exploited as vegetables throughout the country. An estimated 60,000 tons of cultivated vegetables are produced in the country on about 7,000 ha.

G. Livestock production:

Livestock is an integral component of the prevalent low-input farming systems in the Lao PDR with one or two buffaloes for draught and a small number of cattle, which are usually a form of wealth for farmers and can be liquidated to generate cash revenue for the farm family in cases of emergency. These animals are also a source of farmyard manure for gardens and orchards.

The country has about 1 million buffaloes and 700,000 head of cattle owned by some 500,000 small farmers. On average, there are two buffaloes and 1.4 cattle per household. In some regions there are farmers who possess a large number of animals. Chickens, ducks, pigs, and goats all play an important part for subsistence and cash income for farm families.

H. Fisheries:

Fish is an important source of protein in the Lao PDR with an estimated consumption of 7-10 kg per year per person which represents about 30-50 percent of the protein intake of the people. An estimated 20,000 tons of fish is annually produced in the country. Indigenous fish account for more than 95 percent of the total fish production. Indigenous fish species are found in natural waters: Mekong River and its tributaries, reservoirs, swamps and rice fields. An estimated 100 tons of exotic fish are annually produced by the fish farms developed during the last decade by the Government with international cooperation support. From 1980 to 1990 an estimated decline of indigenous fish production has been observed from 27,000 tons to 20,000 tons.

I. Farm-household objectives and constraints

About 85 percent of the total population of the Lao PDR is involved in agricultural production, which accounts for about 60 percent of the GDP. More than 90 percent of farmers are subsistence-oriented and farmer literacy is generally low. The agricultural production sector has been characterized by an opening to a more market-oriented economy during the last two years with a progressive decollectivization of the production units. There are severe constraints to the free flow of information, inputs, and outputs since communications are inadequate in isolated marginal areas.

Needs assessment (diagnosis):

Research of any kind, let alone problem-solving adaptive research, cannot be launched without an understanding of farmers' existing farming system, including its decision-making behaviour, and precise problem identification. Such complex conditions can rarely be diagnosed without research and extension jointly going to the field and analyzing problems, causes, effects, and possible solutions within classified agro-ecological zones and production system domains. Thus, proper diagnosis is needed in research design for both bio-physical and socio-economic research. This can be accomplished within single disciplines or by an interdisciplinary approach: rapid rural appraisals (RRAs), surveys, and special studies. For adaptive research, information is required about the farmers' existing problems, which considers their objectives and strategies; resources; opportunities, constraints, and problems; and desired changes in their livelihood systems.

J. Critical areas and determinants for sustainability

The Lao PDR is a predominantly mountainous country with 30 percent of its total area at elevations between 1,000-3,000 metres and more than 60 percent of the slopes steeper than 30 percent, in particular in the northern and eastern areas of the country. In the upland areas under shifting cultivation in the absence of a permanent vegetation cover, rainwater provokes strong erosion of the soils on the slopes and leaching of nutrients. However, it is recognized that when the population pressure is low, the shifting cultivation system is one of the most appropriate land use systems, especially when soils are acidic. There is also considerable erosion associated with clear-cut logging practices. Obviously, sedimentation is becoming increasingly acute.

An emerging key issue concerning the sustainability of Lao Agriculture is the rapidly increasing population. The low average density of about 17 persons per km^2 does not really reflect the relatively high pressure on arable land.

Land tenure status is uncertain in most areas and is an emerging source of contention in forests, in shifting cultivation areas, and in and around more urban areas. Land tenure issues are crucial to the reduction of shifting cultivation.

In general, the tropical monsoon climate of Lao PDR is conducive to supporting a variety of pests. Pest incidence may become more acute with the introduction and extensive cultivation of new and high yielding crop varieties. For example, downy mildew disease of maize became severe in the lowland areas of Laos following the introduction of new maize varieties. Severe insect pest problems such as the brown plant hopper have followed the spread of new high-yielding rice varieties. Weeds and rats are the most severe problems to shifting cultivators.

K. Objectives and technological requirements for sustainable agriculture

The Ministry of Agriculture and Forestry has sustainable agriculture and forestry policy objectives in the areas of food security, diversification of production for export markets, thus spreading risks, and the reduction of shifting cultivation and conservation of the environment.

Important to the process of development of sustainable technologies is the periodic evaluation of their performance. The results at each stage of the technology development process need to be analyzed and evaluated before planning of future trials or for the preparation of recommendations of mature technologies for extension. Screening requires clearly defined performance evaluation criteria and systematic step-by-step procedures, which combine different disciplinary viewpoints and involve both research and extension. The productivity, stability, sustainability, and equatability characteristics of agro-ecosystems performance are blended into the screening criteria of technical viability, economic feasibility, and social acceptability. At different stages these criteria have different weights and trade-offs.

The technology development process in the Lao PDR is in transition to be more responsive to farmer needs. Interdisciplinary teams composed of biological, physical, and social scientists and extension workers will initiate systematic and rigorous precesses to: determine research themes; select target agro-ecological zones and production system domains; diagnose farmers' circumstances and design trials; execute on-farm research, e.g., trials and special studies; data collection, processing and research monitoring; analyze findings; present results; evaluate and screen technologies; and continue diagnosis and redesign.

The flow of a technology is envisioned as being logically circular in nature, beginning with farmers and ending with a better menu of choices for farmers in similar production environments. Emphasis is placed on the two-way flow of information between research and farmers through extension. Key activities of the systematic technology development process in the Lao PDR which serve as mechanisms for research and extension collaboration are:

- i) agro-ecological zoning;
- ii) needs assessment;
- iii) programming of research and extension;
- iv) on-station testing;
- v) on-farm trials, researcher managed;
- vi) on-farm trials, farmer managed;
- vii) extension programmes: demonstrations, field-days, etc.;
- viii) routine monitoring of farmers adoption practices;
- ix) analysis, evaluation, and screening;
- x) training of trainers;
- xi) technical workshops;
- xii) information systems;
- xiii) publications.

II. Technology transfer

Technology transfer refers to the delivering of technical knowledge from international research institutes (e.g., CGIAR) or from national research programmes to technical personnel either in research or extension of the Lao PDR. The nation depends very much on international relationships. More appropriate methods of technology development and technologies for adaptation are needed in the Lao PDR in: production, post-harvest (e.g., processing, handling, packaging), marketing, etc.

The purpose of an extension system is to provide farmers with technical information (scientific-based or indigenous knowledge-based) by means of a non-formal education process. This information will allow farmers under varying agro-ecological conditions a greater range of choices to improve their income and well-being on a sustainable basis. The MAF is taking initial steps in developing such a system.

Such an extension service aims to be: farmer-client oriented; maintaining a two-way flow of information with farmers and being responsive to their problems and opportunities; flexible; easily accessible to farmers for information in their endeavour to improve their livelihoods; and promoting location-specific tested technologies.

Section II

CHAPTER

12

MALAYSIA

Mohd. Yusof Hashim [1/]

I. Technology assessment for varying agro-ecological zones, production systems and resource endowments

There exist different definitions and interpretations of technology assessment, including feasibility studies, field trials, market research, cost/benefit analysis and impact studies. The term has become more widely accepted, however, and is used here as a systematic examination of the possible effects on society when a technology is introduced, extended or modified. It is a class of policy studies and it allows public policy interventions during the research and development phases of a technology. Technology assessment in agriculture, in rapidly industrializing developing countries, is becoming increasingly important, largely because the sector is undergoing an active phase of transformation and articulation together with the rest of the economy. The direction of technological change during this phase must therefore be managed towards desirable ends.

A. Government policies

Although agriculture's share of the country's economy is declining, the sector still remains an important one. It plays a significant role in meeting the wider national objectives. The two-pronged strategy of the New Economic Policy, *viz.* restructuring of society and poverty eradication, is still prominent in the country's short- and long-term development policies. Agriculture is expected to contribute significantly to increased farmers' incomes, thereby bringing about a more equitable income distribution and regional balance, increased efficiency particularly in resource use, increased food production and food security.

More recently, the concept of sustainability together with renewed enthusiasm in rural development have taken centre stage in agricultural development and issues in agricultural technology development, assessment and transfer in Malaysia must therefore be treated in the context of wider national objectives.

It must be noted that the Government policy on sustainable agriculture and rural development in Malaysia is not formalized but appears in a number of different, though closely related, development policies and plans. Likewise, the Government policy on technology assessment for sustainable agriculture and rural development is not explicit but implied in those other polices and plans. The main thrust in sustainable agriculture is that the course of agricultural development must be managed in a way that optimizes the utilization of resources to foster stable biological production and to allow trans-generational equity, while ensuring economic, political and environmental stability (Aziz A. Rahman 1991).

It is recognized that the issue of sustainable agriculture is more serious in developing countries in the process of catching up with the socio-economically more advanced countries. This process, if improperly managed, can lead to serious problems, inter-alia the depletion of natural resources, erosion of biodiversity, and global warming, to name a few.

[1/] *Director-General, Malaysian Agricultural Research and Development Institute (MARDI), Kuala Lumpur, Malaysia*

Sustainable agriculture in Malaysia may be achievable through a number of strategies that foster stable biological production, prudent management of natural resources and stability in the ecosystem. Stability in these respects must be gained alongside a balanced regional development to achieve overall stability. Renewed enthusiasm in rural development is one of the most promising strategies towards a regional balance. The basic strategy to expand and modernize the predominantly rural agricultural sector is to integrate agriculture and manufacturing not only to broaden the industrial production base but also to maximize the inter-sectoral growth and developmental stimulus arising from the linkages. This is possible through the synergistic two-way demand and supply process between the two sectors to be driven largely by market factors with increasing initiatives by the private sector. One of the benefits arising from this linkage is the growth and expansion of downstream manufacturing activities particularly for import substitution with greater use of local raw materials. The growth and expansion of the agro-based industries expected is irrespective of the size of establishments. However, small- and medium-scale ones are seen to be helpful in realizing the policy on rural development.

Greater emphasis is to be placed on *in-situ* development rather than on the opening up of new areas for agricultural or rural development. This development strategy which is designed to generate higher productivity in rural areas and the farming community as a whole entails a new social organization of production which allows for a greater receptivity of improved technologies.

At the outset, technology is seen as a vital input for the agricultural sector to play its role in the years to come. Indigenous research and development, as well as technology importations, are important sources of improved and new technologies in this context. Thus, the assessment of potential technologies developed, adapted and extended to agriculture, must be undertaken against the roles that the sector is expected to play.

As implied earlier, the concept of technology evaluation in Malaysian agriculture, or by its institutions including MARDI, has been used for as long as records show. However, the use of the term assessment is rather recent. A close examination of what actually takes place in research and technology evaluations would reveal that the two terminologies could be used interchangeably.

The procedures for technology assessment reflect closely what actually takes place within the organizations and those linked to them. There are notable variations between individual organizations but the approach they take is fairly similar. The differences between them are largely attributable to the range of crops under their purview, the clientele system they serve and the industrial or market priorities they pursue. The experience of MARDI is discussed in greater detail here for the simple reason that MARDI handles a wide range of agricultural commodities, serving a heterogeneous clientele system and is faced with a mammoth challenge to increase and upgrade production of the food crop sector. MARDI's rich experience may prove useful in the overall discussion about technology assessment in agriculture.

Figure 1 represents the relationship between the main activities undertaken by MARDI in the overall process of

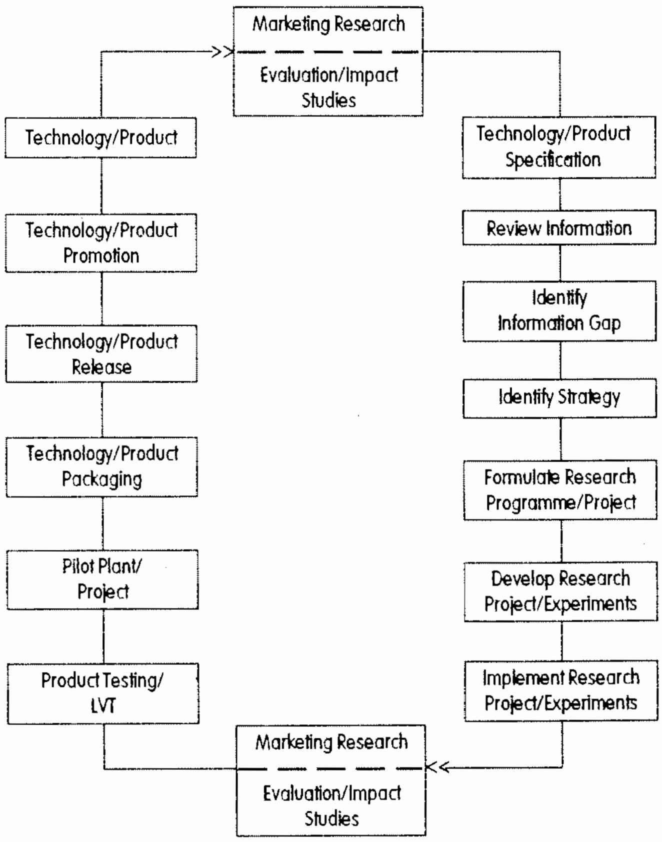

FIGURE 1. TECHNOLOGY DEVELOPMENT AND TRANSFER PROCESS IN MARDI

technology assessment. It must be noted that in reality the flow of information from one activity to another does not necessary follow the sequence suggested in the diagram.

B. Recognition of the problem

Technology development in MARDI, for purposes of convenience in our discussion, begins with the formulation of research proposals. There are many elements in these proposals. In accordance with the market approach that MARDI adopts for technology development and transfer, the starting point in mot research proposals highlights the market needs and opportunities for which the research is intended. The next major element is the identification of beneficiaries that are directly or indirectly involved with the potential technology to be generated. A thorough understanding of the market and the beneficiaries should clearly reveal the information gaps which provide the basis for conduct of a study or a group of studies.

At the initial stages, research proposals undergo peer review from within the institute itself, particularly by close associates with related disciplines. In this exercise, the research objectives, methods, financial and personnel requirements are being discussed. The expected contributions to wider socio-economic objectives are often discussed.

These proposals are then submitted to the respective panels (Agricultural, Industry, Medical, Strategic and Social Science) under the Intensification of Research in Priority Areas (IRPA) mechanism coordinated by the Ministry of Science, Technology and the Environment. Each respective panel, consisting of representatives from the various research institutions, universities and government agencies ascertains the merits of the proposals and decides on their financing.

C. Technology generation

MARDI's experience is that, more often than not, research has a better chance of producing a more "complete" technology when it is generated in a multi- or inter-disciplinary mode. In MARDI, this mode is very closely adhered to at least during the technology generation phase. Assuming the development of a technology is being initiated in the laboratory, then the subsequent test activities are being conducted outside the laboratory environment. MARDI operates some 30 research stations which are actively evaluating technology for different crops, varieties and other specific variables under observation. These stations are selectively located in different agro-ecological zones of the Peninsular. Further observations, tests and modifications would be done at this stage in response to the interaction exhibited between the technology and the environment. This process will continue until a certain degree of performance stability is achieved.

The technical feasibility of the technology up to this stage has been evaluated under research conditions and high management levels. The prospective technology will now have to be evaluated in farmers' plots to capture a realistic production environment. These local verification trials (LVTs), as they are called in MARDI, are conducted across the country but divided into groups within the agro-ecological zones that they are supposed to represent. These LVTs are powerful means of technology assessment in terms of technical feasibility, social acceptability and, to a lesser extent, economic viability. However, assessing economic viability from these trials is not satisfactory as there are many limitations. For example, the management of such technology and the output so derived on a scale economically desirable under the present context of marketing cannot be captured or fully understood from these trials. One of the procedures to overcome these limitations is to conduct pilot scale testing. This test is designed to enumerate the actual production situation and is thus capable of exhibiting most, if not all, of the problems likely to be encountered on a commercial scale.

A technology is considered ready for transfer or dissemination after it has undergone the various assessment procedures. The mechanisms adopted vary and include the conduct of field days, seminars and conferences, mass media announcements, publications, training courses, extension in the case of food processing technology, and providing advisory and consultancy services. These mechanisms will be further elaborated in the section on technology transfer.

D. Major agro-ecological zones

Agricultural planning in Peninsular Malaysia takes into consideration not only socio economic but also climatic and soil factors. These are important considerations because all too often the technologies developed are merely guided by market signals and social preferences, assuming that the country is fairly uniform in terms of climatic and soil factors.

Subsequently, technology adoption rates do not live up to expectations.

There are at least six major agro-ecological zones proposed for Peninsular Malaysia (Nieuwolt, et al., undated). Two of the regions refer to highlands 300 m and more above sea level. The remaining four were differentiated on the basis of differences in rainfall patterns and the predominance of histosols (Figure 2).

The various agro-ecological zones identified in Peninsular Malaysia allow for a more exacting agricultural planning in terms of technology to be developed, modified or disseminated. This is particularly so in terms of crop selection, level of farm management, nutrient requirement and water management.

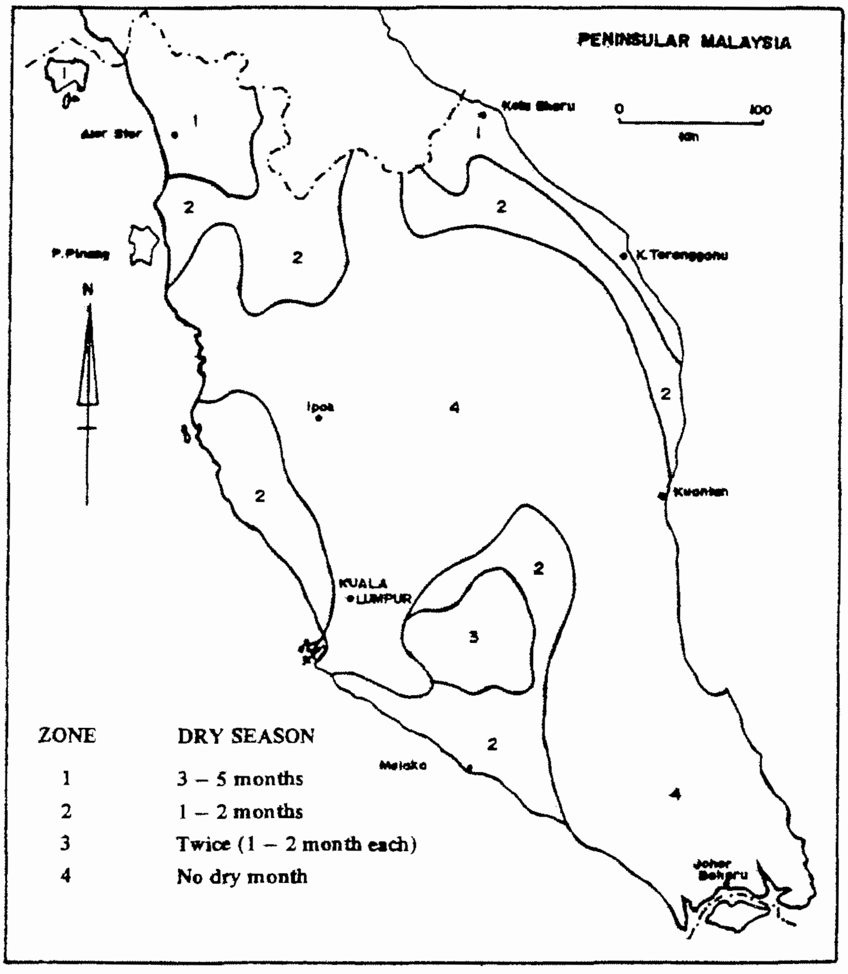

FIGURE 2. AGRO-ECOLOGICAL REGIONS OF PENINSULAR MALAYSIA

Source: Business Proposal Series No. 3 44 pp 19, Ministry of Agriculture, Malaysia, 1986

E. Major production systems

The agricultural sector of Malaysia is dualistic in character with respect to size, management and performance. The larger plantation sector is well organized with centralized management and accounts for almost 50 percent of agricultural output, even though units are smaller in number. Smallholders are far more numerous but less organized and less productive.

The modernization of the agricultural sector, especially the rural smallholders, has to concentrate on increased farm incomes and poverty eradication, improvement of product quality to satisfy both domestic and international markets, creation of a competitive advantage and above all integration of agriculture with the rest of the economy, particularly with the manufacturing sector. These are the major guiding principles in the design of the corporate and action plan for research and development in MARDI.

In Malaysia, new technologies are being developed with a view to their suitability for different production systems. The assessment of such technologies, therefore, must be undertaken on farms representing those systems. Experience suggests that most of the technologies developed (i.e., new clones or varieties, pest-control measures) are scale-neutral and are well received irrespective of the production systems. However, technology transfer mechanisms have to be adjusted as decision making processes are different among the production systems.

F. Resource endowments

The relationship between technology and resource use is becoming important in the overall assessment of technology. Although 45 percent of Malaysia's land area is suitable for agriculture, much of it has to compete with other uses. That means that pressure exists to develop agriculture on marginal and problem soils like peat, bris, tin-tailings and acid sulphate.

Agricultural land use patterns have changed markedly over the years. There is a significant switch of land under rubber to oil palm although the decline of land under rubber has been halted by the late 1980s. There is also a slight reduction in land acreage for rice, the country's staple food, but this is unlikely to be reduced further since rice production is part of the food security strategy of the country. There is a definite increase in land acreage for other crops like oil palm, fruits and vegetables.

However, increasing acreage under cultivation cannot be accompanied by an increase in labour force. This is so because the demand for labour in the rapidly expanding manufacturing and service sectors is more acute than that in agricultural production. The downward trend of total employment in agriculture is expected to continue in the future from 31.3 percent in 1985 to only 23.5 by 1995. Therefore, technology development and assessment must be undertaken against the scenario of resource endowments of the country discussed above. The challenge in Malaysia really is to continue to develop and adopt land-substituting technologies, for example, high yielding varieties, over and above what possibly had been achieved under conventional plant breeding techniques where there are serious limitations in gene combination and fixation. This will ease the pressure to invest heavily on problem soils or on opening new land to increase production. Technologies to reduce post-harvest losses will have to be equally emphasized. At the same time, technologies should also be labour saving.

G. Critical areas for sustainability

Both the public and the private sectors are paying greater attention to the environmental problems such as soil erosion, pollution, loss of bio-diversity, global warming, destruction of the ozone layer and carbon monoxide emissions, to name a few. Some of these are causing direct and immediate problems to the community but others have longer term and global implications.

Many of these problems are observed to be closely associated with the way "development" is being pursued. For example, rapid urban housing developments have adverse implications for the cities' underground sewage and drainage systems and also for the public transport system. The practice of open burning of forests for new agricultural land or for replanting has been under constant attack by all parties.

A number of positive measures are being introduced to minimize or control these problems. Integrated Pest Management (IPM) technologies minimize the indiscriminate use of chemicals against pests and diseases. Golden Hope Malaysia, a planation-based establishment, has developed and practised a technique to conduct clearing and replanting without resorting to open burning in the attempt to preserve the environment.

Besides the development and use of "environment-friendly" techniques, the country upholds certain rules and regulations to preserve the environment. An important one is the effluent disposal regulation pertinent to the production and primary processing of palm oil and rubber in Malaysia. Many of the major development projects are required to undergo an Environmental Impact Assessment (EIA) before they are implemented, a preventive procedure being adopted.

II. Technology transfer

The concept of technology transfer has rarely been clearly defined. Different authors seem to employ different definitions leading to different conflicting conclusions. Here, technology transfer refers to the process whereby technical information originating in one institutional setting is adopted for use in another institutional setting.

In general, there is a marked distinction between research and technology transfer agencies as depicted in Figure 3. Both the public and private sectors and universities are actively involved in research and development in agriculture. The public sector agencies such as RRIM and PORIM deal with single commodities while MARDI deals with multiple commodities. The private sector usually deals with single commodities and research results are mainly for own use.

Technology transfer agencies are mainly public agencies which cater for the smallholder sector. These agencies include DOA, FELCRA, FELDA, KADA and MADA. They have specific roles to play in the agricultural development of the country. FELCRA is involved in *in-situ* development and FELDA is involved in opening of new lands for the resettlement of the rural population. Both agencies are mainly engaged in the development of perennial crops, namely rubber, cocoa and oil palm. They are therefore closely linked with research agencies for those crops. KADA and MADA on the other hand are regional development agencies involved in the development of paddy areas. DOA however deals with multi-crops and therefore has a bigger role to play in the transfer of technology.

Commodities	Research Agencies	Extension Agencies	Clientele System
All crops (exept rubber and oil palm) Livestock	MARDI	DOA MPIB DVS NTB DOF FAMA	Rice farmers Veg. gardeners Fruit growers Livestock rearers Tobacco growers Pineapple growers
Rubber	RRIM	RISDA FELDA FELCRA	Rubber smallholders Land settlers Fringe & Alienation Scheme farmers
Oil palm	PORIM	FELDA FELCRA	Land settlers Fringe & Alienation Scheme farmers Oil palm smallholders

Source: Mohd. Yusof Hashim and Chin Fatt 1984

FIGURE 3. RESEARCH AND EXTENSION LINKAGES IN MALAYSIA

Recent emphasis on exploiting the international market potential has had an influence on the technology transfer process. The market situation has highest priority in order to gain the competitive edge. This trend has been very much manifested in the various agencies involved in agricultural development. More emphasis has been given towards transferring technologies that are market-driven over those that are farmer-driven. In this process, technology transfer has become a more challenging area in the overall development of the agricultural sector. On realizing this, the research agencies are to some extent more committed towards the technologies generated, and more involved in the process of technology transfer, in order to ensure that technologies generated are appropriate and adopted by users. At the same time, technology transfer agencies are more peculiar and selective about the technologies to be adopted by their respective clientele groups.

The clientele system for research outputs has also changed. Generalizations of the clientele system thus far overlooked the complexities of the end users of research results. In reality, they are diverse in nature, characterized by different needs, wants, agro-ecological and socio-economic environments and technological profiles (Tasir 1991).

A. Technology profile

With the passage of time, remarkable changes have occurred in the technology profiles of the various crops in the country, especially in some of the more important commodities. Indigenous farm practices have given way to modern technologies. Most remarkable changes occurred in paddy where high yielding varieties (HYV) replaced the traditional varieties. Subsequent changes in farm practices followed to meet the different needs of HYV. At the initial stage of transformation, indigenous technologies existed together with modern technologies especially in field preparation, transplanting and harvesting. Currently, however, it is hard to find paddy farmers using buffaloes for ploughing their fields and manual labour for harvesting. These two operations have been fully mechanized. However, the indigenous practice of transplanting manually still exists even though it is slowly being replaced by transplanting machines or direct seeding techniques.

Parallel changes also occur in the social aspects of production. Farmers no longer rely on family or reciprocal labour but on tractors and combined harvesters. The rural institution of "gotong royong" (reciprocal relationship among farmers to perform some farm practices especially in transplanting and harvesting) is no longer in existence. It has been replaced by hired labour and machines.

The changes in the paddy cultivation practices are necessitated by the agricultural labour shortage and the need to reduce the drudgery in paddy production. The changes in other commodities, however, are made with a view to achieving efficiency in production as well as to produce better quality products. Such changes are necessary especially for export commodities such as cocoa, rubber and oil palm in order to remain competitive in the world market. The use of high-yielding clones/varieties and other new technologies for rubber, oil-palm and cocoa has enabled the country to become an efficient producer of these commodities.

The current emphasis on the development of downstream activities to give value-added to the agricultural commodities has spurred the generation of processing technologies especially for food and, to a lesser extent, non-food products. This development would further strengthen the research capabilities of the country to face the changing technological needs of the agricultural sector in the future.

B. Gaps in technology transfer

It has been recognized that with the complexity of agricultural technologies generated and transferred, disparities exist between experiment station yields and those obtained on the ground and between smallholders and estates. These differences are due to environmental differences and biological and socio-economic constraints (Figure 4). On station research is conducted under controlled conditions which a minimum interaction of constraints, except technical and biological factors. Farmers on the other hand are beset with many constraints of biological, technical and socio-economic nature. They have to develop skills in order to utilize the technologies and at the same time have to deal with pests and diseases, soil and environmental factors that are different from those at the experimental stations. Structural problems such as small farm size, credit and input availability will affect their technology adoption. Furthermore, modern farming requires besides purely technical also business skills, i.e., the optimization of output for those commodities which bring the highest return in the market.

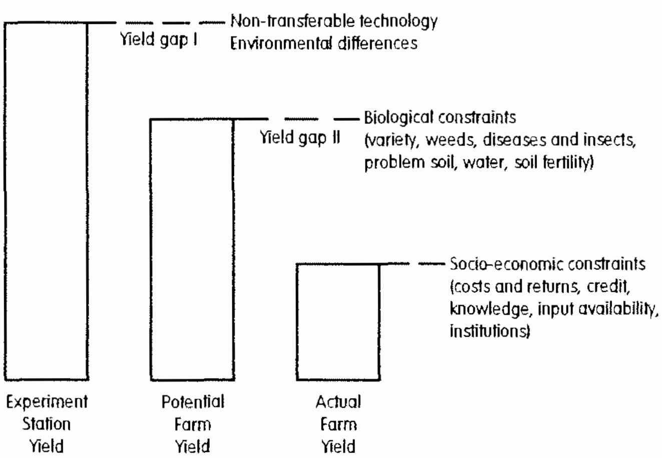

FIGURE 4. REPRESENTATION OF YIELD GAPS

Source: IRRI 1977

The yield gap between experiment stations and farmers' fields can be clearly observed in the case of the different paddy varieties planted locally (Table 1). These differences are mainly attributed to environmental and infrastructural differences, soil management, rate of fertilizer application, management of pests and diseases and field management practices between research and farmers' fields (Supaad and Suhaimi 1991).

TABLE 1. YIELD GAPS OF PADDY VARIETIES

Variety	Average farm yield (t/ha)	Potential farm yield (t/ha)	Experiment station yield (t/ha)
MR27	2.31	4.60	5.00
MR52	3.10	4.40	5.00
MR71	3.40	4.70	5.50
MR73	3.70	4.20	5.50

In the case of rubber, the estates achieve higher yields than the smallholders. In 1989, the average yield of rubber on estates was about 1,379 kg/ha per year. This contrasting performance occurred as a result of different management practices in the smallholder and estate sectors. However, research results for some clones exceed 2,000 kg/ha per year (RRIM 1989).

Steps are taken to reduce the yield gap firstly through intensification of services for the clientele groups. These services include training of extension agents and farmers on the usage of technologies to be adopted, providing credit facilities and ensuring the availability and accessibility of inputs. Secondly, the farmers are organized into groups for efficient management of their farms. Thirdly, intensive trials are carried out on technologies to be transferred. And, finally, constant monitoring of the performance of the transferred technologies and their impacts are also being carried out through impact studies. Such studies are essential in assessing the performance of these technologies at the farmers' level.

C. Accompanying measures for technology transfer

Changes in the agricultural scenario require changes in the nature of policies, services and support for the agricultural sector. More services, institutional support and infrastructure have to be made available in order to accelerate the process of agricultural development. Measures taken in these areas are not only a response to the ever changing economic scenario but as a result of policy-makers' better understanding and appreciation of the position of the agricultural sector domestically and internationally. This is reflected in the country's National Agriculture Policy (NAP). Guided by this policy the relevant agricultural development agencies make the necessary changes in their approach towards accelerating agricultural development. Furthermore, the role of science and technology is given greater emphasis in the development of the agricultural sector in order to remain competitive in both domestic and international markets.

Given the prospects that agricultural technologies would increase productivity and at the same time require more modern inputs and supporting services for effective adoption, the government embarked on a programme of technology adoption through (i) mobilization of resources toward research and experimentation; (ii) development of the infrastructural framework and institutions responsible for supplying modern inputs (e.g., planting material, fertilizer, water, credit, etc.) and services (e.g., market outlet and information, extension, etc); and (iii) organization of the producers for improving receptivity (e.g., farmers' organizations, group farming, mini-estates, etc.).

While efforts are made to provide support services for improving the productivity of agriculture, concerted efforts are also made to develop the agro-based industries. This is in view of their potential in the creation of off-farm jobs, expanding market outlets, increasing value-added to the agricultural produce and the provision of overall stimulus to growth through further intersectoral integration. At the same time, they would also provide additional leverage for technology transfer not only by providing markets for the increased agricultural production, but also by creating opportunities for private sector investment in the agricultural sector. Such development has been observed especially in latex-based products, processed palm oil, and food processing.

With the increasing involvement of the private sector, the need for direct transfer of technology has become crucial. This is achieved through close collaboration between the research institutions and the private investors in R&D activities.

D. Technology transfer mechanisms and dissemination strategies

The means by which a technology is transferred form its source to the end users depends on the types of clients and the degree of sophistication and complexity of the technology involved. Accordingly, some technologies require a much higher degree of supervision than others.

Transfer mechanisms can be divided into two categories: packaged or formal and unpackaged or informal. Packaged or formal mechanisms include both the technologies and the support services essential for the successful application of the technologies. On the other hand, unpackaged or informal mechanisms involve a wide range of transfer activities that do not include any other services. Publication, training and discussions are some of the activities involved here (Tasir 1991).

As stated earlier, agricultural research and development are undertaken by various private and public agencies and universities in the country. Technology transfer mechanisms, however, are very similar. For some agencies, however, their clientele is specific to a particular farming community, such as rubber smallholders and estates for RRIM and oil palm smallholders and estates for PORIM.

Among the agencies that are involved int he technology transfer, MARDI plays the most important role since it serves a broader range of agricultural activities, including food processing. Mechanisms of technology transfer adopted by MARDI have undergone changes over the years. MARDI extended most of its research findings to DOA. Later, farmers' organizations were also actively involved. These agencies in turn disseminate research findings to the farmers.

Conditions of agricultural production, however, have changed significantly over time. Current emphasis is not only on the production of paddy and tree crops but include a wide range of other crops such as fruits and vegetables, and processed food for export. These changes create opportunities for commercial producers to invest in the agricultural sector. These commercial producers require different transfer mechanism. Hence new technology transfer mechanisms have been devised by MARDI over the years to cater for this clientele group.

During the early years, technology transfer took place mainly through publications and seminars. In the later 1970s and early 1980s, training programmes and promotional activities were added. The technology promotion activities include the provision of advisory and consultancy services, conducting pilot projects, organizing technology exhibitions and conducting dialogue sessions with the clientele groups. Currently, establishment of joint-venture companies with equity participation by MARDI is being pursued actively. Another important mechanism is collaborative research with the private sectors agencies.

E. Research and extension linkages

The links between agricultural research and technology transfer agencies are generally recognized as a major bottleneck in agricultural technology systems (Sands 1988). Ideally, a free flow of agricultural information has to occur between agencies involved in the agricultural development process in the country. These include credit and marketing agencies, and farmers' associations. However, a vacuum does exist between these two interfaces which need to be filled or managed for effective technology transfer. In Malaysia, the problem is compounded by different management of these agencies. Thus, the need to develop linkages is a necessity for the betterment of technology transfer.

In Malaysia, the linkages between research and extension have evolved from informal to formal means in the last tow decades. Informal means are based on personal contacts while the formal means are in the form of institutionalized entities or committees with the purpose of better inter-agency coordination of activities at the grassroots level (Mohd. Yusof Hashim and Chin Fatt 1984).

Institutionalized approach:

The Integrated Agricultural Development Project is an example of the institutionalized approach. Component agencies are represented on the Steering Committees whose secretaries are the Project Directors charged with the day-to-day task of mastering and coordinating the efforts of the component agencies in their implementation activities.

The committee approach:

The committee approach seems to be the more acceptable and widely used means for facilitating technology transfer from research to extension and development agencies. The rationale for this approach is to ensure a constant flow of available and up-to-date technologies to the agricultural producers and to obtain feedback on the recommended and needed technologies. Basically, through meetings and consultations, these committees determine which technologies are required and to be transferred.

F. On-farm technology testing

Technologies generated need to be tested, verified and adapted for various locations or agro-climatic zones in the country. Technologies developed at the experimental stations may not be suitable in the different agro-climatic zones or target areas where they are to be applied or disseminated. On-farm technology testing is thus carried out to verify the performance of these technologies in the different locations or zones.

Local Verification Trials (LVTs):

The LVTs are carried out by researchers on a small scale under actual farm conditions. The number of LVTs varies depending on factors such as extent and heterogeneity of the area where the technology will be disseminated. In short, LVTs are carried out to verify the technical capability of the technologies to perform under different environments other than the experimental stations before they are recommended for use by the clientele groups.

The LVTs provide limited information on the suitability of technologies. At the very best, they provide feedback on the technical feasibility of technologies in different locations. Since LVTs are research-managed, the results achieved do not really reflect the expected performance of the technologies under farmer-managed conditions.

Pilot projects:

Pilot projects are carried out for demonstration purposes and to test the commercial viability of technologies. For MARDI, pilot projects are the final test of technologies on a commercial scale at strategic locations before the technologies are released. The choice of locations is based on agro-ecological, economic and social factors. Evaluation of the projects is carried out to determine the weaknesses and appropriateness of the technologies. Technologies will be released only after the weaknesses have been rectified.

Implementation of the pilot project requires the active participation of research agencies and their clientele groups.

REFERENCES

ANON. 1986. "Fifth Malaysia Plan, 1986-1990", Government of Malaysia, Kuala Lumpur.

ANON. 1990. "MARDI 20 Years Achievements", MARDI, Serdang, Selangor.

ANON. 1991. "Sixth Malaysia Plan, 1991-1995", Government of Malaysia, Kuala Lumpur.

RAHMAN, AZIZ A. 1991. Towards Sustainable Agricultural Development? Option Vol 6(1).

IRRI 1977. Constraints to High Yields on Asian Rice Farms: An Interim Report. IRRI, Los Banos, the Philippines.

MOHD. YUSOF HASHIM and CHIN FATT 1984. Research and Extension Linkages in Malaysia, in Improving Extension Strategies for Rural Development, University Pertanian Malaysia Press, 1984, pp 247-258.

MOHD. YUSOF HASHIM 1992. The National Agricultural Research System in Malaysia (to be published by ISNAR).

NIEUWOLT S., M. ZAKI GHAZALI and GOPINATHAN B. 1989. Agro-ecological Regions in Peninsular Malaysia. MARDI, Serdang. RRIM, Planters Bulletin 1989 No. 198.

SANDS, C.M. 1988. The theoretical and empirical basis for analyzing agricultural technology systems, Ph.D thesis. Champaign-Urban: University of Illinois.

SUPAAD, M.A. and SUHAIMI, O 1991. Kemajuan penyelidikan teknologi padi, penerimaan pakai, pengurusan serta peningkatan daya penguluara. Teknol. Padi. MARDI 7: 1-9.

TASIR BIN LOPE PIHIE, AHMAD 1991. Technology transfer from R&D Institution: The Experience of MARDI - A paper presented at the seminar on management for quality research.

ACRONYMS

DOA	Department of Agriculture
DOF	Department of Fisheries
DVS	Department of Veterinary Services
EIA	Environmental Impact Assessment
FAMA	Federal Agricultural Marketing Authority
FELCRA	Federal Land Consolidation and Rehabilitation Authority
FELDA	Federal Land Development Authority
HYV	High-yielding Variety
IPM	Integrated Pest Management
IRPA	Intensification of Research in Priority Areas
IRRI	International Rice Research Institute
KADA	Kemubu Agricultural Development Authority
LVT	Local Verification Trial
MADA	Muda Agricultural Development Authority
MARDI	Malaysian Agriculture Research and Development Institute
MPIB	Malaysian Pineapple Industry Board
NAP	National Agricultural Policy
NTB	National Tobacco Board
PORIM	Palm Oil Research Institute of Malaysia
RISDA	Rubber Industry Smallholders Development Authority
RRIM	Rubber Research Institute of Malaysia

Section II

CHAPTER

13

NEPAL

Purushottam Amatya [1]

I. Technology assessment for varying agro-ecological zones, production systems and resource endowments

Nepal faces the serious challenge of maintaining a rate of food production growth higher than that of population growth. Between 1967/68 and 1988/89, the annual average growth rate in food grains, in fact, significantly lagged behind population growth. Both growth rates, however, were roughly equal during the last decade, with the increases in maize and wheat largely due to expansion in land area under these crops and yield improvements primarily responsible for increases in rice production. Large potential exists for livestock production, accounting for 30% of AgDP and 40% of farm incomes in the mid-hills, but sustainable growth can only be brought about by adjusting animal numbers and feed resources.

A. Government policies

Since 1991, the Government of Nepal has begun to address issues of development strategies and planning in the agriculture sector. FAO has assisted in developing a strategic framework for integrating future development assistance to agriculture, forestry and natural resources. A key consideration in the strategic framework is the need for sustainability, both in terms of administrative and managerial capacity, of the institutions involved, and in terms of sustainability of natural resource exploitation and development.

The draft paper for the Eighth Five Year Plan, published by the National Planning Commission (NPC) in November 1991 calls for priority to be given to agricultural intensification and diversification. More specifically, it recognizes the importance of an effective research system under an autonomous Nepal Agricultural Research Council (NRC). NARC would be charged with developing appropriate agricultural technologies, given the existing resource endowments and market conditions with special attention to the development of technology for rainfed and hill agriculture.

B. Major agro-ecological zones and resource endowments

Nepal comprises 14,748 sq.km of land, which is readily sub-divided into five major physiographic regions: Terai, Siwaliks, Middle Mountains and the High Himalayas. These regions have different soils and land use patterns. Each region differs in geology, climate and hydrological characteristics. The upper limit of cultivation is at 4,500 m, with the majority of cultivation at an elevation of 3,000 m.

The Terai region comprises 14% of the land area of Nepal. Elevations range from 60 to 330 m, with slope gradients of 0.2 to 1%. It is considered the bread basket of Nepal. Soils are stable, water tables are never far from the surface, particularly during monsoon and the natural tendency far water to collect in ponds facilitates rice production. Virtually all land in the Terai region is under cultivation.

The Siwaliks include 1,879 sq.km, or approximately 12.7% of the land area of Nepal. Agriculturally, the most important areas of the Siwaliks are the "Dun" valleys where

[1] *Executive Director, Nepal Agricultural Research Council (NARC), Kathmandu, Nepal*

virtually all of the presently cultivated land is found. All Dun valleys have distinct features, based largely on the characteristics of the watershed that served the prehistoric basins.

The Middle Mountains make up 4,350 sq.km or 29.5% of Nepal's land area. The majority of the Nepalese population traditionally have lived in this region because soils are suited to terracing, the climate in most of the areas permits two crops per year, and the forest was well suited to meet most household needs. The forests of the Middle Mountains are intensively used for fodder, firewood, litter and timber collection. Unfortunately, the management of these forests does not match the generally excellent management of the adjacent agricultural lands. Given the importance of these forests to provide nutrients and energy to operate the agricultural systems of the Middle Mountains, more productive and sustainable use of the forests is a prerequisite to agricultural development.

The High Mountain region comprises roughly 2,899 sq.km or 19% of the country's land area. Due to difficulties in transportation, systems are closely tied to subsistence production. Individual production pockets tend to be self-sufficient, and cash cropping is uncommon. The forests are in a much better condition than in the Middle Mountain region due to less population pressure.

The High Himalaya makes up 3,447 sq.km or 23.7% of the land area. The area has a very low permanent population because of lack of cultivable land and cold winter conditions. Potatoes, millet, and naked barley have been the mainstay of production. With the increasing importance of tourism in these areas, there is a growing interest in horticultural crops.

C. Major production systems

In each major physiographic region, production systems are determined by the following factors:

i) The resource endowments of the individual farmer (holdings of less than one hectare tend to be basically subsistence systems, whereas larger and/or more intensively managed holdings are more apt to be commercially oriented).

ii) The physical environment (Terai, Hills, or Mountains).

iii) The accessibility of production inputs and markets.

These factors are associated. Resource endowments reflect important differences between the Terai with an average farm size of 2.63 ha and about 0.75 ha in the Hills and Mountains. Likewise, accessibility is associated with topography. Thus, in general, farmers in the Terai enjoy a much more favourable access to production inputs and market outlets than their counterparts in the Hills and Mountains.

Production systems in Nepal, although varying in detail from one agro-ecological zone to another, are characterized by the general integration of crop and livestock production, by the use of local forests to provide some farm inputs and by the importance of non-farm activities to generate supplementary cash income.

The principal production systems in the Terai are based on paddy farming on heavy soils, some rainfed and some irrigated. Rainfed farming consists of a monsoon crop of paddy, sometimes followed by a winter crop of potatoes. Under irrigated conditions, the most intensive farming is triple cropping of two crops of paddy followed by a winter cop of wheat. Double cropping is much more common under such conditions. Sugarcane, jute and tobacco are important cash crops in this system. Cattle and buffaloes are principally used for traction (land preparation and transport) and for milk production. A large proportion of feed comes from crop residues. The production system is largely independent of forest and public grazing land, except for the upper Terai which constitutes 8% of the cultivated area and where the use of forests as a source of fuel and fodder is more intensive. Including the upper Terai, the Terai production systems constitute 53% of the total cultivated area of Nepal.

The second major type of production systems is located in the Middle Mountains region. This system is also found in small isolated pockets of lowland which are prevalent in High Mountains region. The system involves three principal land types: valley floors, Tars (raised old river terraces) and hill slopes. Cropping is maize-based in rainfed areas (80%) and rice-based in irrigated areas (20%). A winter crop of wheat generally follows the maize or rice crop. There is little cash cropping. Bullocks are mainly used for land preparation and cows and female buffaloes are milked. Use of forest and public grazing areas is heavy. This system occupies 38% of the cultivated area of the country.

The third major production system is prevalent in the High Mountains and the High Himalaya region. It is essentially a livestock farming system, based on yaks, chauris (yak/cattle crosses), sheep and horses. Livestock provide milk and wool and are also used as pack animals. Pastures are often far from the homestead and the herds move up and down the slopes according to the season. Crop production is accessory to livestock raising and off-farm employment. Forests are a significant source of fuelwood and fodder. This production system occupies about 8% of the total cultivated area.

The 1981/82 agricultural census indicated that almost all agricultural land holdings are family-operated, are run by full-time farmers, employ two to three full-time family members and about one half of them regularly employ off-farm labour. 50% of the farms are smaller than 0.5 ha and 34% are between 0.5 and 2.0 ha. Most farms are composed of many parcels of land (4.3 is the mean); the smaller the holding, the greater the degree of fragmentation.

Most rainfed and many irrigated systems use local unimproved seeds, draft animals, wooden ploughs and other simple implements. Soil fertility is maintained through the use of compost and animal manure. The use of improved seeds and chemical fertilizers is concentrated in the Kathmandu valley and in the Terai. Over the last decade, one third of the supply of chemical fertilizer has been extended to vegetable farming in the Kathmandu valley and to the cultivation of other cash crops such as sugarcane, tobacco, jute, tea and cardamom in specialized areas of the Terai and Hills.

D. Critical areas for sustainable agriculture

Critical areas for sustainable agriculture in Nepal include the following:

i) Maintaining a rate of food production higher than the rate of population growth,

ii) diversifying the production systems to fulfil the requirements of industries and of farmers for cash income,

iii) making hill agriculture more sustainable,

iv) tapping technologies generated elsewhere for the benefit of Nepalese farmers, and

v) rendering the agricultural research system more accountable to the national development needs.

The above can be achieved if the research process becomes need-based. This is feasible only when a bottom-up approach in agricultural research programme planning and implementation is institutionalized so that technologies appropriate to varying agro-ecological needs can be developed. Considering the vast variations in agro-ecological conditions and resource endowments, the potentials and challenges for agricultural research and development in Nepal are enormous. In the Terai, the focus should be on crop diversification and intensification. The Hills have large potential for horticulture, spices and medicinal plants. Agricultural sustainability in this region depends on integration of crops, livestock and agro-forestry.

Specialization in production and trade seems possible as Nepal has an unusually diverse set of resources. The most obvious potential lies in a highly complementary and fully integrated development of the Terai and the Hills and Mountains. The Terai will generate substantial income through the basic staples of cereals, horticulture, intensive livestock production and perhaps in oilseeds, and produce rapidly growing markets and manufacturing centres, while providing staples and other goods for the Hills. Much of the burden will be on yield improvement. This will require investment in the agricultural research system, clear priorities aimed at increasing yields in the major components of agricultural production systems, and, most important of all, a system of accountability for results at the levels of the research station and the individual researcher.

II. Technology transfer

Success in the transfer of technologies is greatly determined by the types of available technologies. Successful examples of technologies that have been transferred and adopted widely by Nepalese farmers are found in cereals, lentils, potatoes, vegetables and fishery. However, research efforts have not been able to benefit the large sections of resource-poor farmers in Nepal that rely on subsistence farming.

The process of technology transfer seems to have got a scientific footing in 1981 when the World Bank supported Agricultural Extension and Research Project (AERP) was launched in four Terai research stations, namely Tarahara, Parwanipur, Bhairahawa and Nepalgunj to strengthen research-extension linkages in technology development, verification and dissemination.

In 1985, the Farming Systems Research and Development Division was created to integrate different components of Nepalese farming systems into the technology transfer process through farming systems research site activities, collectively called Outreach Research Programme (ORP). The strategy of ORP, since then, has been to complement on-station research with adaptive on-farm research carried out with inter-disciplinary/inter-commodity support to identify and package location-specific technologies. Its goal has been to help NARC plan and implement relevant research programmes which are more responsive to clients' needs and priorities.

The newly implemented USAID-assisted Agroenterprise and Technology System Project (ATSP) has a large component on research outreach. It will provide substantial assistance to strengthen ORP of eight major stations under NARC. For the years to come, the outreach research model is envisaged by the NARC as the functional technology transfer process. This model has proved successful if the experiences of Pakharibas Agricultural Research Centre, an ODA-assisted project, are counted. After expanding the activities in 1975, Pakharibas put emphasis on working with resource-poor farmers. The technology generation process at Pakharibas has been a three stage process that begins and ends with the farmer. Stages include (a) on-station research, (b) on-farm research, and (c) outreach research.

Gaps in technology transfer

Transfer gaps, i.e., differences between experiment station and actual yields, can be attributed to several factors:

i) The process of technology generation does not account for the farmers' needs in totality, which comprise interrelated physical, biological and socio-economic components. Intervention in one component would consequently change the others, adversely or favourably.

ii) Very few recommendations are available for resource-poor farmers.

iii) An ineffective technology transfer process might dilute the quality and relevance of technological information.

iv) The present agricultural research system has not been accountable to farmers' needs, particularly due to a top-down approach in research programme implementation.

v) Input delivery and government support services are not very effective.

Strategies to minimize technology transfer gaps have to take into account farmers' goals, i.e., a certain degree of self-reliance, the need for cash income, and the need for economic stability. Furthermore, farmers have land and capital constraints and inputs tend to be expensive, alongside an often uncertain supply. Besides, on-station testing of technologies does not fully reflect the range of bio-physical constraints farmers have to face, i.e., limited and widely variable water supply for at least parts of the year.

Section II

CHAPTER

14

THE PHILIPPINES

C.B. Pérez [1], C.A.E. Magboo [2], B.M. Burgos [3] and A.O. Lapitan [4]

I. The technology development and transfer system

Two basic structures comprise the Philippine agriculture and natural resources research system: a planning and coordinating body which is the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) and a network of research centres and stations, the National Agriculture and Resources Research and Development Network (NARRDN).

The PCARRD, as one of the five sectoral councils of the Department of Science and Technology (DOST), is a planning, coordinating and monitoring council for agriculture and natural resources; a repository of research and development information; and an agency for packaging and dissemination of mature technologies for development.

The centres of NARRDN conduct basic and applied research on one or more commodities across a broad range of disciplines, and also package mature and verified technologies. The NARRDN is composed of R&D centres/stations of the Department of Agriculture (DA), Department of Environment and Natural Resources (DENR), State Colleges and Universities (SCUs), and specialized research agencies.

A. Regional R&D consortia in agriculture, forestry, and natural resources

The regional R&D consortia, within the NARRDN, were established to build up regional capability for research management.

A consortium serves as a mechanism for priority setting, planning, monitoring and evaluation of R&D projects, technology dissemination, and sharing of resources of member agencies at the regional level. There are now 13 regional consortia.

Technology transfer is a major component of the Science and Technology Plan for every sector. Technologies provide the means for improving income and productivity of farmers, private entrepreneurs and other end-users in the rural areas. It is important that technologies for transfer and commercialization undergo critical evaluation. For this purpose, PCARRD has formulated criteria for identifying these technologies. These criteria are:

i) Technical Feasibility/General Adaptability
ii) Economic Viability
iii) Environmental Soundness
iv) Potential Availability of Support Services

[1] *Executive Director, Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), Los Banos, Laguna, The Philippines*

[2] *Acting Director, Technology Outreach and Promotion Division, Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), Los Banos, Laguna, The Philippines*

[3] & [4] *Senior Science Research Specialists, Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), Los Banos, Laguna, The Philippines*

v) Expected Ceiling of Adoption/Social Acceptability

Specific indicators/measures for each criterion are identified in Annex A.

B. Technology development

The technology development process in the Philippines normally undergoes the following stages, the definitions of which are shown in Annex B: (i) Technology Generation (TG), (ii) Technology Adaptation (TA), (iii) Technology Verification (TV), (iv) Technology Pilot Testing (TP), and (v) Technology Dissemination/Commercialization (TD).

The process is viewed as a continuum where research is interfaced with development. As the technology moves downstream into the early stage of piloting and dissemination, research activities diminish, while development/outreach activities increase. Feedback mechanisms are put in place to provide the necessary action on constraints which may appear along the way.

Results of TG researches conducted under optimal environmental conditions existing in research laboratories and on-station experimental fields need to be verified and fine-tuned in different areas of the country and under actual field conditions using farmers' resources. Not all technologies, however, necessarily undergo these stages of technology development. Depending on the nature of the technologies, some find their way directly from TG to commercialization and utilization.

In the Philippines, TG activities are carried out by the national, regional, and specialized research agencies. The TA/TV trials are done mostly in the field stations of the Department of Agriculture (DA) and the Department of Environment and Natural Resources (DENR).

C. Technology transfer networking

Part of the mandates of member-agencies of the R&D network are technology transfer/extension/community services. The regional consortium also provides for a venue where technology transfer and extension efforts of these agencies are coordinated in the region.

The agricultural extension and on-site research services have been recently devolved from the national government (responsibility of the DA) to the local government units. With this development, the consortia have started to establish linkages with the local government units for the technology delivery in the countryside. The consortia, in their efforts to facilitate the utilization/commercialization of appropriate technologies, have also forged linkages with non-government organizations (NGOs), the private sector/farmers' co-operatives, financial/market institutions, and other agencies/ entities providing auxiliary services.

Recognizing the need for more aggressive technology transfer activities that will complement the activities of the extension agencies, PCARRD has adopted a two-pronged strategy for technology transfer and commercialization namely (i) "supply-push" technology delivery programme through action/pilot projects, Comprehensive Technology Transfer and Commercialization (CTTC) programme of DOST, technology business incubators, technology fairs/ investment fora, and other outreach programmes like publication, instructional, broadcast and other communication materials; and (ii) "demand-driven" or "bottom-up" approach to technology delivery based on the concept of rural-based enterprise development. In both strategies, forging linkages with the private sector, NGOs, cooperatives, financial and market institutions, local government units and other agencies involved in technology transfer and commercialization is vital and is being pursued.

II. Technology assessment for varying agro-ecological zones, production systems and resource endowments

One of the priority areas of the system is technology assessment (TA). TA is conducted at various levels of technology development and utilization. Ideally, TA should be undertaken at the earliest possible time, even before R&D on new technologies begins, or at least before a technology can be widely applied.

In the NARRDN, technology assessment is done during the annual Regional Symposium on R&D Highlights (RSRDH). This is an *ex-ante* type of evaluation since technologies are assessed before they are disseminated to or adopted/utilized by the intended users. First conducted in 1989, the RSRDH is an activity whereby technologies are reviewed using set criteria. It focuses on the discussion/

presentation of technologies (TA, TV, TP, TD) and information for dissemination using a prescribed report format. It facilitates the dissemination of research breakthroughs and significant findings to end users by providing the venue to interact and learn about newly developed technologies, and evaluate the potential of emerging technologies. The regional consortia coordinate the activity at the regional level. The "Technology forum" is also organized by the consortia on 2-3 highly commerciable technologies to undertake more in-depth evaluation of the technologies in terms of resource, market, credit and other requirements for technology commercialization. The forum is attended by the technology generators, prospective users, representatives from credit and market institutions, local governments units, and others.

TA is also done during or after the implementation (*ex-post* or impact assessment) of technology transfer and commercialization projects when the technology is already being or has been applied by the beneficiaries. Certain levels of success may have already been achieved by these projects especially if reckoned in terms of increase in income of beneficiaries, increase in hectarage, increase in number of clientele. However, whether or not such increases translated to significant improvement in income and welfare of the farmers should be ascertained. In view of this concern, PCARRD has embarked on the activity "socio-economic evaluation and policy analysis of technology commercialization and development projects in agriculture and natural resources", the objectives of which are to: determine the effects of technology commercialization and development projects on total output, productivity, income and on the socio-economic well-being of target clientele and the community; analyze factors affecting performance of these projects, assess effects of macro-policies on the programmes, recommended strategies to improve the delivery systems for technologies under study; and recommend a policy agenda to enhance technology commercialization and the development of relevant commodity industries. The PCARRD has also tapped researchers in NARRDN to assess various technologies based on their relative importance in the respective regions and the existence of substantial technologies that have been adopted by farmers. An earlier study of some technologies was undertaken, the results of which were published in the book entitled "Technology Assessment for Agriculture in the Philippines".

A. Agricultural land classification

Based on slope, the agricultural areas in the Philippines are divided into three categories:

Category I:

These are areas of 0-8% slope of flat lands, easily irrigable, highly suitable for agriculture, urban, industrial and related uses. Included in this category are Regions I, II, IV, V (all in Luzon) and VI (Western Visayas) where 50% of the areas are flat lands.

Category II:

These are areas with slopes ranging from 8-18% and referred to as upland regions. Land under this category has a wide variety of uses and can be planted to different crops, both seasonal and permanent. Approximately 50% of upland regions are in Mindanao, with Region X (Northern Mindanao) accounting for the biggest area.

Category III:

Areas under this category have slopes of 18-30%. These are hilly to mountainous areas generally considered marginal for most agricultural crops requiring tillage. About 50% of these mountainous areas are found in Regions X, VI, VII (all in Mindanao) where many productive economic trees are found.

The largest area devoted to agriculture under this category is in the Region IV (Southern Luzon) while the biggest portion of productive agricultural land is in Region XII (Central Mindanao). The biggest areas planted to rice are in Regions III (Central Luzon) and VI (Western Visayas) while those planted to corn are in Region XI (Southern Mindanao). Coconut occupies 21% of the total agricultural land area covering 3.3 million ha.

B. Major agro-ecological zones

Geographically, the Philippines has highly diverse climatic and land resources that call for a zonification based on agro-climatic characteristics of the area. The three major development zones identified in the Philippines are the uplands, lowlands and aquatic zones. These zones are further divided into seven sub-zones. The upland sub-zones are the upland plains and the hilly lands/highlands while the lowland sub-zones are the lowland rainfed and lowland irrigated areas. The aquatic sub-zones, on the other hand, are the marine, freshwater and brackishwater zones.

III. Technology transfer

Strategies to promote rural development vary among developing nations due to location-specific problems and variations in social, economic, and cultural factors. However, technology is expected to play a key role in improving the living conditions of farmers and other end-users in the countryside, especially in an agricultural country like the Philippines.

As agriculture is multifaceted, its growth and rural development are affected by the interrelation among biological, technical, economic, social, cultural, political and psychological factors. Since agriculture enterprises encompass a broad spectrum from production to marketing, the strategy for agricultural and rural development should emphasize a much greater understanding of the farmers' goals and motivations.

Technology transfer is an extremely complex and elaborate process. It involves deliberate and systematic networking, liaisoning, brokeraging, communication, persuading, organizing, teaching and training.

Technologies need to undergo pilot testing before commercialization to confirm and demonstrate the importance and feasibility of using improved technologies over relatively large areas involving many farmers/clientele groups. However, there are technologies that by their very nature can immediately proceed to commercialization like post-harvest technologies on cutflowers and fruits.

A. Dissemination strategies

In the Philippines, there are several approaches to technology transfer which have been the subject of a recently completed study (Bonifacio 1992). These approaches are:

i) Farming Systems
ii) Training and Visit
iii) Community Organizing
iv) Legitimacy of New Technology
v) Participatory R&E
vi) Utilization of Multidisciplinary Team

In the above-mentioned approaches, agriculture should be recognized as an organized activity of the community. It is important therefore to fully delineate the factors that would facilitate technology transfer for agriculture and rural development. A summary of some approaches as featured in the study is given below.

Farming Systems (FS)

Farming systems is the most appropriate approach in promoting agriculture and rural development and perhaps the most comprehensive concept developed in agricultural research. However, some are very wary about its full utility and the concept is too global in nature. This is perhaps the main reason why there is now a shift in the conceptual orientation in agriculture from farming systems to sustainability. The attainment of the goals of sustainable agriculture can be facilitated through a farming systems approach as the FS concept readily fits the framework of a unified approach to the multidimensional problems of agriculture.

Training and Visit approach (R and V)

One of the central features of this approach is the contact farmer who will act as a farmer leader, the idea of leadership being vital to development. Leadership, however, is always linked to power and therefore it is political in nature. Two issues with political implications which were not attended to in the T and V approach are: (i) what are the implications of creating a new power base among the farmers?; and (ii) what are its implications to the existing power relations in the community? Corollary to these are two additional issues: (i) is it more advantageous if contact leadership is vested in the existing community leader? (this is a case of cooptation); and (ii) what happens when a different leader is installed? From one point of view, cooptation could be taken as an evolutionary process while the installation of a new leader is revolutionary.

Community organizing

Community organizing involves the creation of a new mode of action which must be accepted by the members of the community and must serve as a new imperative. Community organizing therefore is a process of institutionalization of new patterns of behaviour. The question of institutionalization is often neglected in organizing the farmers. The most difficult part of organizing is the evolution of a new consciousness among the farmers. The eventual success of organizing will depend entirely on creating in the community a new system of legitimation.

Legitimacy of new technology

Technology adoption is associated with innovativeness of the farmers. The less innovative the farmer is, the less likely he will adopt recommended technology. Therefore, levels of innovativeness are important considerations in technology transfer.

The PCARRD has embarked on two major programmes to support technology transfer promotion and commercialization.

Development/Action Programme

In the pilot project strategy, a package of technology is tried in the farmers' field, supported with relevant services such as credit, market, extension, and farmers' training. The PCARRD and NARRDN, through the pilot/action projects, have established linkages with local farmer groups to confirm and demonstrate the technical feasibility, economic viability, and social acceptability of technologies on a semi-commercial scale under actual farming conditions. This action programme offers packages of technology (POT) with accompanying support systems. It also provides a mechanism for determining research gaps and non-researchable problems based on feedback gathered directly form the field.

Applied Communication Programme

This programme produces various publications, instructional, audio-visual, broadcast, and other communication materials to satisfy the information needs of specific target groups. The Applied Communication Programme also develops primers and bulletins on different commodities which are mass produced by the Department of Agriculture and the Department of Environment and Natural Resources and disseminated to farmers and other end users in 13 regions of the country. This programme manages the production of the Technology! series, a publication highlighting selected technologies in agriculture and natural resources. Such publication features the step-by-step technology package and the cost-and-return analysis of a particular technology.

B. Providing the "missing link" to commercialization

The Comprehensive Technology Transfer and Commercialization Programme (CTTC)

The CTTC is an aggressive mode of moving technologies from the generators to the clientele undertaken by agencies of the Department of Science and Technology (DOST) in cooperation with other concerned agencies and sectors. The programme provides an effective and efficient mechanism for technology transfer and commercialization to facilitate modernization of the production sectors, especially agriculture and industry. Appropriate technologies may come from domestic and foreign sources.

For the technologies under the CTTC Programme, information dissemination is strengthened through various channels such as conduct of technology forum, technology fair, field days, training, and production of communication materials like flyers, calendars, comics and videos. These mechanisms of moving technologies to the appropriate clientele fill the information gap and strengthen the likelihood that products of research can find eventual commercialization. Through Memorandum of Agreement (MOA), linkages among the beneficiaries, agencies providing support services (market, credit and extension), local government units and implementing/coordinating agencies are formalized. This MOA ensures the support and commitment to the CTTC project of all agencies/entities concerned.

Rural-based Enterprise Development (RED)

Rural-based Enterprise Development (RED) is a holistic and systematic approach to technology commercialization and enterprise building. It is anchored on the framework of local institution building, the integration of various components of enterprise development, and the facilitating strategies of intervention. In RED, target clientele are encouraged to voluntarily express their needs/problems on the farm, and how they perceive that these could be addressed.

Problem areas are resolved within the local context with technology innovations provided by the rural S&T network. The RED concept also attempts to demonstrate developmental strategies to attain entrepreneurial skills, and to establish rural enterprises which are self-contained and not dependent on dole-outs of subsidies.

The process of enterprise building is viewed as partnerships among R&D institutions, government agencies, the private sector, and the farmers, all of whom are participatory agents of countryside development. Thus, there is commitment to adapt to socio-economic challenges and to share in the responsibilities and risks of enterprise building.

IV. Case study

A. Technology transfer and assessment for small farm reservoir (SFR)

As part of the Comprehensive Technology Transfer and Commercialization Programme (CTTC) of the Department of Science and Technology (DOST) of the Philippines, PCARRD launched the National Programme on Small Farm Reservoir (SFR) in order to boost farm incomes by intensifying land use in rainfed areas through crop, fish and livestock production.

The SFR is essentially an earth dam commonly built by a bulldozer at a rate of 8-12 hours per SFR structure. It traps, harvests and stores rainfall and run-off which can be used to provide supplemental irrigation for rainfed lowland wet season rice, partial irrigation for a dry season crop, fish production and water requirements for livestock and poultry raised on the farm. A typical SFR has an area of about 1,500 m^2 and an embankment hight of not more than 4 m. Compared to other reservoir types, e.g., small water impounding (SWIM), SFRs are smaller and owned/managed by individual farmers.

The SFR system has three basic components, i.e., catchment area, reservoir, and service area. The catchment area is bounded by high points from which run-off drains into the reservoir. Adequate catchment area (without defined stream) is necessary to harvest run-off and fill the reservoir to its capacity. The reservoir is the portion of the farm where water is stored by an earth embankment. Earth embankment is the dam structure which traps the water. It is normally made from soil excavated from the upstream side of the embankment. The reservoir is preferably located in an elevation relatively higher than the farm area for irrigation. The service area is the farm area being irrigated using the stored water from the reservoir. This is usually situated at a lower elevation relative to the reservoir's water level. However, a pump is used in cases where the farm is situated at a higher elevation relative to the water level.

In terms of potential uses, the three SFR components may be used as follows:

i) **Catchment Area**: for forest/fruit tree production, rice or vegetable farming, livestock raising and pasture.

ii) **Embankment and reservoir**: for freshwater aquaculture, vegetables and other cash crop production, livestock raising, duck rasing, recreation (fishing) and erosion control.

iii) **Service Area**: for rice and non-rice crop production, e.g., legumes, cucurbits, vegetables and other cash crops.

B. Technology transfer system for the SFR programme

The technology transfer process for the SFR programme essentially focused on the following strategies:

i) Collection, consolidation and analysis of benchmark information on potential SFR areas. This includes climate, land and water resources, agronomic surveys, socio-economic profiles and other factors considered critical to programme implementation.

ii) Arrangement for financial assistance and provision of technical assistance to farmers who want to adopt the technology. Arrangement is made with credit institutions, e.g., Land Bank of the Philippines (LBP), to enable farmers to obtain low-interest loans to finance the construction of reservoirs. Technical support is provided to deal with farm management problems usually experienced by SFR owners.

iii) Training of SFR survey teams and extension workers. Personnel to be involved in the programme are trained in specific objectives of the programme and equipped with technical skills needed to support the programme. This training focuses on the design, construction and management of SFRs, and in the application of the package of technology (POT) being introduced.

iv) On-site training of farmers in the application of the different POTs. Farmers are trained in the application of the POTs on crop production, fish culture, and on the management of the reservoir and its watershed.

v) Linking up with bulldozer owners/operators (private or government) to pool possible sources of equipment. To ensure the availability of bulldozers for the SFR construction, the programme facilitates the transport of the equipment to the site of construction.

vi) Construction of demonstration reservoirs in newly identified potential areas in preparation for the Phase II activities of the programme. An area may satisfy all the physical requirement for successful reservoir use but farmers may not immediately accept the technology. Hence, the construction of demonstration reservoirs would serve as means of encouraging farmers to adopt the technology. Monitoring and evaluation of these will help modify the package of technology to make it more suitable to the areas.

C. Preliminary assessments and farmers' feedback on the SFR

The first phase of the programme was implemented in selected villages of Regions I and III in 1989. To assess the performance of the programme, a socio-economic evaluation (which is external to the programme) is now under way. However, some initial micro-level evaluations indicate a positive impact of the SFRs on farm productivity. A comparative analysis of pilot adopters and adjacent non-SFR users in Munoz, Nueva Ecija and San Ildefonso, Bulacan indicate that yield and gross margin among SFR users for the crop year 1990-1991 were about twice that of non users.

REFERENCES

BONIFACIO, MANUEL F. 1992. Images of Agriculture: Issues, Problems and Trends in Technology Transfer. Seminar Paper. PCARRD.

ACRONYMS

CTTC	Comprehensive Technology Transfer and Commercialization
DA	Department of Agriculture
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
LBP	Land Bank of the Philippines
NARRDN	National Agriculture and Resources Research and Development Network
PCARRD	Philippine Council for Agriculture, Forestry and Natural Resources Research and Development
POT	Package of Technology
RED	Rural-based Enterprise Development
SCUs	State Colleges and Universities
SFR	Small-farm Reservoir

Annex A

Indicators/measures for commercialization and transfer of technologies:

1. Technical Feasibility/General Adaptability

1.1 Adaptability and stability of technology over a specific range of environmental settings.

1.2 Countryside fit or applicability of technology over wider areas especially at the village level.

1.3 Probability of success in generating the desired product/process and benefits.

2. Economic Viability

2.1 Magnitude of Expected Benefits

- increase in productivity (a) producing more for the same level of input, (b) producing the same level of output for lesser inputs, or (c) producing more with lesser inputs,
- higher value added as a result of performing post production services,
- increase in net income,
- more employment opportunities,
- higher foreign exchange earnings,
- increase in resource savings (sum total of the values of resources saved or cost foregone as a result of the technology), and
- increase in the proportion of the local component utilization (in terms of gross value added) as a result of technology commercialization.

2.2 Likelihood that the proposed technical administrative, and institutional arrangements can be implemented at a cost commensurate with the expected benefits.

2.3 Presence of adequate price incentive to producers and marketability of expected additional outputs.

2.4 Financially sound ROI or IRR or BCR (e.g., a technology is profitable if ROI is at least equal to the prevailing rate of interest on loans from formal financial institutions; if IRR is greater than or equal to the relevant discount rate (NEDA's prescribed reference is 15%); and BCR of greater than or equal to 1).

3. Environmental Soundness

3.1 Adherence to environmental laws, directives and policies.

3.2 Relevance to (or conformity with) the goals of sustainable development.

3.3 Reduced if not total absence of any harmful environmental consequences.

4. Potential Availability of Support Services

4.1 Availability of competent and appropriate manpower and support services (market, credit, extension service, technology, post-harvest facilities, and others).

5. Expected Ceiling Level of Adoption/Social Acceptability

5.1 Farmer retention: Ratio of farmers currently using the technology over the number of farmers who initially adopted the technology.

5.2 Degree of adoption: Ratio of the number of component practices in POT adopted by the farmers over the total number of recommended practices in POT.

5.3 Extent of adoption: This can be either the ratio of the number of hectarage following POT over the total hectarage (area basis) and the ratio of the number of farmers following the POT over the total number of farmers in the area.

5.4 Effectiveness of technology in meeting the needs of target end users.

5.5 Compatibility of technology with ability, capacity, and available resources of target end users.

5.6 Conformity with the norms/values in target communities.

5.7 Relevance to existing government thrusts/programmes.

5.8 Absorptive capacity of local manpower in terms of technology utilization.

Annex B

Stages of Technology Development

Technology Generation (TG): basic research activities. These activities are commonly done in the confine of research centres/laboratories under direct supervision of scientists or skilled researchers.

Technology Adaptation (TA): TA trials determine the performance and suitability of technologies and are conducted either in farmers' fields or research stations and managed by researchers. These trials further test the economic feasibility of technologies. A technology is classified as TA if it meets the following criteria:

- It has been tested in technology generation (TG) research for at least one season.
- It has shown good potential for economic feasibility as based on TG research.
- It has a good potential for acceptance by farmers and commercial producers.

Technology for Verification (TV): TV tests a combination of factors (representing improved technologies) which are incorporated in the major farming systems in specific localities. The TV trials are conducted to identify the most appropriate technologies for specific locations by comparing the most promising technologies with existing farmers practices. A technology is classified as TV if it can be incorporated in a package of technology that has good potential for improving existing farmers' practices. Specifically, it should satisfy the following:

- It has been tested for two seasons in TG trials.
- It has shown economic and technical feasibility in TG trials. Its computed return based on TG trials is better than that of farmers' practice as shown by marginal rate of return (MRR).
- It is perceived to be socially acceptable and environmentally safe.

Technology for Piloting (TP): is designed to assess the average performance of improved packages of technologies when applied or used by a large number of farmers: uses a whole community or portion thereof as the basic unit of evaluation; also seeks to gauge users' reaction to the introduction of new technologies; and determines major constraints to its adoption.

In the adoption of technology through farmers are given support services like credit/market and technical supervision by extension workers.

A technology is ready for piloting if its TV shows a minimum Marginal benefit Cost Ratio (MBCR) of 2.

Technology for Dissemination (TD): a technology that consistently shows outstanding performance in TG or TV may be immediately judged ready for TD if it meets all the following criteria:

- It must have general adaptability. The technology should be replicable outside the research station, that is, under field conditions of producers/entrepreneurs.
- The technology must be economically profitable. A technology is profitable if its percent profitability is at least equal to the prevailing rate of interest on loans of formal financial institutions.
- The technology must have social acceptability. This means that the technology should not pose any serious contradiction to existing social norms and values prevailing in the community.
- It must be environmentally safe. The technology should have no obvious deleterious environmental consequences both in the short run and long run.
- The support system (e.g., provision of seeds) can be made available for the technology to be adopted.

Section II

CHAPTER

15

THAILAND

V. Benjasil [1]

I. Technology assessment for varying agro-ecological zones, production systems and resource endowments

Under the seventh plan for national socio-economic development, the government has emphasized the improvement of the quality of the environment through reduced utilization of agro-chemicals and promotion of biological agriculture. Under the Department of Agriculture, substantial research has been undertaken as regards biological control measures for crop pests and diseases. Research results are being transferred to farmers through the Department of Agricultural Extension but there are still shortcomings in the commercial production of organic pesticides and fertilizers.

A. Major agro-ecological zones and production systems

Cultivated land in Thailand is divided into four major categories. Paddy covers about 12 million, field crops about 4 million, fruit crops about 2 million, and vegetables are planted to 36,000 hectares. Paddy land is normally lowland with adequate or surplus rainfall during the cropping season. Field crops are mainly grown on upland with adequate or variable rainfall and soil moisture. Fruit crops are distributed in the central plain, the eastern and the southern parts of the country. Vegetables are grown mostly in the irrigated area of the central plain and the northern part of Thailand.

Cropping systems practised in Thailand vary between the regions but cereals and legumes are always among the first choices. Rice, the staple food, is the main crop. In the northern area. In the northern region, farmers cultivate two crops per year in irrigated areas. Cropping patterns include rice followed by rice, tobacco, garlic/onion, soybean, chili, and vegetables. Few farmers raise three crops with rice followed by tomato and rice, garlic and vegetables, tobacco and vegetables, and legumes and vegetables. In the north-eastern region, farmers usually grow cowpea, groundnut, vegetables, cucumber or water-melon after rice. Cropping patterns in the central region include rice followed by corn and mungbean/peanut, groundnut and corn, mungbean and vegetables, and also mungbean-rice-mungbean.In the southern region, upland rice is intercropped with rubber or fruit trees. Pineapple intercropped with rubber or fruit trees can be found in upland areas.

In non-irrigated areas, rice is grown in the lowlands during the wet season. Sugarcane, cassava, maize, sorghum, etc. are grown in uplands during the rainy season. Only one crop per year is possible in this area.

B. Farm-household objectives and constraints

Smallholders in Thailand mainly practice subsistence agriculture. The medium to large size farms also produce for the market. Most farmers, however, depend on the climatic conditions. Credit availability is generally insufficient. Local money lenders fill in the gap at high interest rates which often leads to the loss of the farm by the owners. Existing

[1] *Deputy Director General, Department of Agriculture, Bangkok, Thailand*

government policies address these problems through the expansion of the irrigated area, the promotion of multiple cropping, the provision of more credit to farmers for the purchase of inputs, and through the subsidization of economically important crops.

C. Unsustainability indicators

In the northern region, erosion is the most pressing problem. Erosion control is practised by means of terracing, cover crops, and strip crops using vetiver grass.

Waterlogging is generally not a serious problem. It does occur in some rice cultivating areas where deep water rice varieties are used.

Salinization occurs in the northeast and in the coastal areas. In the northeast, there are almost 2.5 million ha of saline soils. During the wet season, however, only the deeper soil layers are affected and rice can be grown in these areas. The problem is most serious during the dry season when salt accumulates on the surface. The Land Development Department has been charged with the task to undertake research in this area. e.g., the identification and promotion of salt tolerant crops.

Crop pests have become a considerable problem with the introduction of high yielding varieties. In 1989, the brown planthopper (*Nilaparvata lugens*) destroyed more than 0.13 million ha of rice. The outbreak was most severe in the central region where the variety Suphan Buri 60 and RD 7 were planted. In 1990-1991, farmers were advised to use a new rice variety, i.e., Suphan Buri 90, and a further outbreak could be prevented.

Negative yield trends are a further unsustainability indicator in rice production. During the 1992 cropping season, some farmers turned back to the Suphan Buri 60 variety because of its superior quality and yield, despite a newly detected outbreak of brown planthopper.

D. Critical areas and determinants for sustainability

Thailand has a low population growth rate but the quantities of food required to feed the existing population serve to underline the importance of agricultural productivity. Sustainable agricultural practices are perceived as being rather limited in their potential to produce enough food. However, there is strong governmental support for research in biological agriculture. The application of existing technologies in this area, however, is severely limited as there is no commercial production of organic pesticides and fertilizers and the costs of such products are prohibitively high due to transportation and storage needs.

E. Objectives and technological requirements for sustainable agriculture

Sustainable agriculture should maintain long-term production capacities vis-a-vis limiting factors such as acid/alkaline soils, waterlogging, droughts, pests, etc.

Modern production technology requires land clearing, tillage, puddling, high yielding varieties, fertilizers and pesticides. These factors tend to bring about soil erosion, environmental pollution, pest and disease outbreaks, reduction of forests, and limited genetic variety.

Sustainable agriculture would require diversity of species, complexity and interaction of ecosystem and natural selection. Diversity results in natural competition, thus controlling the numbers of certain species and leading to integrated pest control.

Technologies that fulfil such requirements include the following:

i) Multiple cropping including intercropping, relay cropping, sequential cropping, multi-story cropping and ratoon cropping.

ii) Farm diversification, i.e., the parallel production of crops, livestock, aquaculture and forestry.

iii) Soil amendment through organic matter application, leading top better physical/chemical soil conditions, providing plant nutrients and increasing nutrient availability, reducing soil erosion, percolation and evaporation, and controlling certain plant diseases.

iv) Application of bio-fertilizers in order to promote microbial activities in the soil such as decomposition of organic matter, biological nitrogen fixation and phosphate solubilizing microorganisms.

v) No-tillage or minimum tillage which can reduce erosion and detachment of soil.

vi) Biological control of insect pest for which numerous examples exist.

II. Technology transfer

Gaps in technology transfer

Yields under experiment station conditions exceed actual farm yields by approximately 20-30%. Reasons for this include:

i) The environmental variation in farmers' fields

ii) Farmers' management does not follow strictly the recommendations

iii) The released technology may not be suitable for a specific area

iv) Farmers cannot afford/do not have access to the necessary inputs

It follows from this analysis that bottom-up planning, considering farmers' actual conditions and constraints, is essential to successful technology transfer. Furthermore, the development of low-input technologies should receive more emphasis, given the farmers' frequent inability to avail of production inputs, due to a multitude of factors, e.g., unavailability or inaccessibility of credit. Strengthened extension services also play a key role in the adoption of technologies by end-users.

For some field crops, particularly soybean, a yield gap analysis concluded that the costs of production should be reduced as the new technology had not been proven to be more profitable than the farmers' traditional technology. Some farmers regularly achieve high yields. Analyses should aim to identify factors behind farmers' achievements and this knowledge should be made available to other farmers.

Section II

CHAPTER

16

VIETNAM

Nguyen Huu Nghia [1] *and Ngo The Dan* [2]

I. Technology assessment for varying agro-ecological zones, production systems and resource endowments

A. Major agro-ecological zones and production systems

Vietnam is divided into eight zones: northern mountainous zone, northern midlands, Hong River delta, fourth zone, coastal midlands, highland Taynguyen, east of southland, and Cuulong River delta, with the most fertile zones being the Hong delta (17,432 km^2) and the Cuulong delta (39,000 Km^2).

At present, research centres and institutes carry out studies on agricultural production systems in these zones to identify their constraints and to find solutions in order to reach the objectives of these systems: yield increases, higher incomes and employment.

In the rainfed mountainous areas, farmers practice mainly the slash-and-burn system. The most widespread cropping systems are upland rice, upland rice and maize intercropped, or cassava. Buffaloes, pigs and goats mostly roam about freely. In many places, agroforestry systems, reforestation, raw material trees or high value trees are well developed. In the valleys and terraced fields, farmers plant one or two crops per year depending on the availability of irrigation water. Some farmers stock fish in paddy fields at the start of the cultivation period and harvest at the end of the growth cycle.

In the hilly land or midlands, agroforestry systems are prevalent, where agricultural crops and trees are intercropped during the first 3-4 years and then cattle are grazed. Fruit-tree garden systems exist in the Cuulong delta and in some places of the Hong delta. Home gardens, however, are most widespread in the north. Agroforestry-cattle-fish farming systems are prevalent in coastal and highland areas. There are some typical cropping systems in deepwater rice areas in the Hong delta and floating rice areas in the Cuulong delta. In irrigated areas, cropping systems are almost exclusively rice-based with 3-4 crops per year.

The diversity of the cropping systems currently supports substantial increases in agricultural production. The area planted to rice, however, constitutes 74-85% of the total arable land area, indicating the importance of rice in the country. Animals mainly provide draft power and manure. Animals generally utilize by-products and natural vegetation.

B. Resource endowments

Vietnam's climatic conditions are favourable for year-long cropping. It is estimated that about 2.8 million ha of potential cultivated land can be used in agricultural production, with 1 million ha having potential for irrigation. Vietnam has a coastline of 3,200 km and 2,860 km of rivers. The

---

[1] *Deputy Director, Vietnam Agricultural Science Institute, Hanoi, Vietnam*

[2] *Vice Minister, Ministry of Agriculture and Food Industry, Hanoi, Vietnam*

hydroelectric potential is estimated to be 17 times higher than the presently available hydroelectric energy. The forest area is estimated at 7 million ha. Vietnam's labour force are skilful and have a high level of education in comparison with other countries in the region with the same level of income: more than 80% of its population is literate.

C. Farm-household objectives and constraints

Vietnamese farmers have the same objectives as the other farmers in Asia: provision of food, contributions to the community, increased household incomes, and raised moral values. At present, with the mechanism of a market-oriented economy, Vietnamese farmers face some difficulties in production and delivery of their products. Return to labour, livestock and crop yields, and product quality are still low. Investment policies, credit for agriculture, and rural infrastructure still are limited.

D. Critical areas and determinants for sustainability

Climatic conditions in Vietnam sometimes adversely affect agricultural production. Cold winters in the north decrease the spring rice yield. In summer, storms, floods and sometimes droughts influence rice production. The humid weather supports the spread of pests and diseases. High rainfall and deforestation contribute to soil erosion and degradation. About 3 million ha of cultivated land in the deltas are influenced by salinity or acidity. The Fourth central coast zone faces difficulties in increasing the cropping intensity because of storms, sand invasion and salt water intrusion. In some places, farmers grow only one rice crop per year. In the Cuulong delta, there are 1-1.2 million ha of land inundated during 2-4 months per year, 0.1-0.15 million ha of arable land are inundated in the Hong delta when rainfall is over 300 mm per day.

Because of unequal population pressure (50 persons/km^2 in mountainous areas, 300-500 persons/km^2 in the Hong and Cuulong deltas) the government had resettled about 3.5 million people.

To increase cropping intensity and crop yields, agricultural inputs need to be supplied on time and adequately. Irrigation and drainage systems in the Hong delta are old and degraded. The pumping station systems have to be restored.

E. Objectives and technological requirements for sustainable agriculture

In 1995, food production will reach an estimated 25 million tonnes, out of which rice should account for 20.5 million tonnes. Besides rice, the Vietnamese government also supports increased production of other food crops such as maize and potatoes as well as livestock. A more all-round food strategy, which takes into account the interactions among ecologically sound agricultural and industrial development is projected. Export products such as coffee, tea and rubber also should be on the increase. In order to fulfil these objectives, policy options concentrate on improved technologies, i.e., new crop varieties, good quality livestock, quality feeds for livestock, increased supply of production inputs, improved irrigation and drainage systems and better production implements are envisaged. Furthermore, a rural banking system is being developed to support farmers in the purchase of required production inputs. Technical personnel need to master the organization and development of small-sized farms.

F. Technological options

In Vietnam, technological choices are mainly made by the farmers. After the agrarian reform in 1988, farmers have signed land use contracts with cooperative leaders (for 10-15 years) and exchange their products for production inputs and other services such as research and technology transfer, and receive 40-50% of the total production. The government programmes such as agro-product processing, rural development, credit, irrigation, etc., promote farmers' adoption of new technology, with productivity and total production depending on farmers' decisions.

The agricultural research institutes in Vietnam continuously develop and evaluate new technologies for transfer into production, for example:

i) Rice and other crop variety systems for different agro-ecological zones. In some areas, hybrid rice varieties are evaluated. Maize varieties suitable for the winter crop are determined, and hybrid maize varieties are tested. Potato varieties which are high-yielding, resistant to major pests, and have high tuber quality are selected and recommended for production. Technology packages for groundnut and legumes have been developed successfully and are widely applied in farmers' fields.

ii) Systems of tuber crop processing, oil plant pressing and fodder production at farm level are installed in rural areas.

iii) Methods of tissue culture, rapid propagation of potato varieties by sprout cutting and production of small potato tubers are applied in potato production.

iv) F_1 hybrid pigs are widely kept in the country. Addition of micro-elements to the ration, use of hormones to increase reproductive performance in buffaloes contributed significantly to improved animal production.

II. TECHNOLOGY TRANSFER

A. Technologies in operation in farmers' fields

With the development of irrigation systems, the use of modern crop varieties, mineral fertilizers, pesticides and efficient crop management techniques, farmers have changed their traditional cropping patterns of one or two crops per year to practice multiple cropping with two or four crops per year. However, in some areas indigenous cropping patterns are still practised such as upland rice varieties in agroforestry and hill areas, floating rice in the Cuulong delta and local rice varieties frown in saline and acid sulphate soil. In animal production, F_1 hybrid prigs and hybrid ducks are raised by most of the farmers. Some farmers raise dairy cows and produce chicken commercially.

B. Gaps in technology transfer

In Vietnam, crop yields in farmers' fields are 30-40% lower than those in research stations, in animal production this gap is around 25-45%. In the deltas, crop and animal yields are always higher than in the midland and mountainous areas and in the villages yields differ between farms. Reasons for yield gaps can be divided into two groups: environmental and socio-economic. Differences in ecological conditions account for sub-optimum crop yields and incidence of insect pests. On the other hand, most farmers cannot apply high input levels as much as is the case in research stations, and farmers' technical knowledge is limited. In order to overcome these yield gaps, the Vietnamese government conducts extension programmes, farming systems research and development in the whole country with the participation of local management organizations, cooperative leaders, researchers and other farmers' organizations.

C. Accompanying measurers for technology transfer

Farmers' organizations play an important role in the process of technology transfer. Together with researchers they organize on-farm trials and spread the trial results. District rural banks offer credit for farmers to invest into production, district agricultural departments give information on new technologies to farmers and organize markets for input service and agro-products.

D. Intervention level

NGOs also participate in rural development through their rural development projects. The NGOs organize the extension programmes in mountainous areas and support some irrigation constructions in the midlands and highlands. The private sector actively participates in the circulation of agricultural inputs and agro-products, but the government still plays a main role in the provision of production inputs and consumption of agro-products.

E. Dissemination strategies

Agricultural research institutes in Vietnam continuously cooperate with local extension organizations to conduct on-farm trials, to get feedback from farmers, and to train local extension technicians and farmers. Mass information media (television, radio, leaflets) are used to inform farmers about new technology and successful trials. Many on-farm trials are conducted in typical agro-ecological zones. The results of these trials are then diffused for suitable areas through mass media and the local market.

Section II

CHAPTER

17

SOUTH PACIFIC ISLAND COUNTRIES

M. Umar [1] *and A. de S. Liyanage* [2]

I. Introduction

Agriculture is the main stay of the South Pacific countries. It accounts for 24 to 50% of the total Gross Domestic Product in most of the Pacific Island countries and provides livelihood for millions of people.

There are some seventeen island countries in the South Pacific out of which 12 countries fall within the ambit of IRETA's activities, i.e., applied research, advanced non-formal training, dissemination of agricultural information and carrying out of rural development programmes. Some selected indicators of these nations are given in Table 1. The size and population of these countries vary considerably and the arable land permanently cropped is rather limited. The national agricultural research and extension systems are small and there is a dearth of qualified personnel. Except in some larger nations of the region, the budgetary allocation for research and extension is small. Therefore, many of these countries are highly dependent on external sources of funds for research and expatriate staff to implement research programmes. However, limited funds are allocated for extension activities.

The 12 countries which are served by the USP/IRETA can be broadly classified into two groups: atoll countries and volcanic islands.

TABLE 1. SELECTED INDICATORS OF SIZE OF SOME OF THE SOUTH PACIFIC ISLANDS

Country	Surface land area (km^2)	Arable land permanently cropped land (km^2)	Population 1986 ('000)
Papua New Guinea	426,243	-	3,605
Fiji	18,274	2,000	703
Solomon Islands	28,446	530	279
Vanuatu	14,763	950	147
Western Samoa	2,842	1,220	165
Kiribati	724	360	65
Tonga	669	540	112
Cook Islands	236	60	22
Tokelau	10	-	1
Tuvalu	158	-	8
Niue	258	-	9
Nauru	21	-	21

Unsustainability issues

There exists a variety of unsustainability issues in the countries of the South Pacific:

[1] *Director, Institute for Research, Extension and Training in Agriculture (IRETA), University of the South Pacific (USP), Apia, Western Samoa*

[2] *Associate Director (Research), Institute for Research, Extension and Training in Agriculture (IRETA), University of the South Pacific (USP), Apia, Western Samoa*

Availability of inputs

In the island nations availability of inputs such as seeds, fertilizer and agrochemicals is often a problem for the farmers. Sometimes they are unable to obtain the type of input they want both in quantity and quality.

Dissemination of information

The main problem is the lack of resources, both in terms of manpower and funds for transfer of technology. Sometimes the package of recommendations given to the farmers are too technical for them to clearly understand and implement them properly. Another problem is the misinterpretation of the recommendations by the extension officer in the process of transfer of technology.

Seasonality of production

There are no proper facilities in many countries in the Pacific for processing of food and storage. This has resulted in waste of agricultural produce during periods of glut.

Population pressure

Many of the island nations still have the extended family system, where caring and sharing is of paramount importance. The land tenure systems that operate in these countries ensure that each person has sufficient land for cultivation to meet their own needs as well as those of the extended family. Further, many of the people receive foreign remittances from relatives living abroad. Therefore there is no necessity and pressure to cultivate the land.

Culture

In the Pacific region people do not utilize and value time in the same way as those in other countries, where there is heavy pressure to utilize land and other resources.

Women

They play an important role in many agricultural activities in addition to their normal household chores. However, women get second hand information on recommendations issued by the extension staff. This is because many of the male extension officers do not come directly into contact with the women, for cultural reasons.

Markets

Although farmers produce a variety of agricultural products there is only a limited export market. Most of what is produced is usually sold in the local market at low prices.

Narrow expert commodity base

Many countries still rely on one or two of traditional crops for export to earn foreign exchange. This heavy dependency has often led to problems in the balance of payments, especially when prices for such commodities are depressed in the world market. Therefore, farmers in many countries have realized the need to diversity.

Inadequate basic infrastructure

This has been one of the major problems for optimum production in the agriculture sector, especially in the smaller nations in the Pacific.

Lack of manpower

There is a dearth of trained manpower skilled in agriculture and communication in many of the countries.

II. Sustainable agriculture in the Atolls

This paper discusses the methods of technology assessment and transfer with special reference to the Pacific Regional Agricultural Project (PRAP) funded by the European Community (EC) and the South Pacific Regional Agricultural Development (SPRAD) and the Commercial Agricultural Development (CAD) project funded by USAID in the countries served by the USP/IRETA.

The project is aimed at developing sustainable systems of food crop production for the primarily subsistence farmers of the atoll islands of the South Pacific region. Key activities of the project include the following: The visual demonstration of the feasibility of sustaining fertility and yields, and protecting the aquifer from pollution by artificial fertilizer; the development of sustainable agro-ecosystems that are environmentally sound and economically productive; and improvement of health and nutrition of the people and reduction of their dependence on imported food stuffs.

The soil and environmental problems of crop production on atolls are two-fold, arising from the nature of the soil which is very free draining, largely coralline sand and rock with very high pH. Because of the free draining nature of coralline sands only perennial crops with deep roots to tap the aquifer, e.g., coconut, breadfruit, and pandanus can be reliably grown without irrigation. Short-term vegetable crops require some simple system of irrigation to overcome this problem.

The lack of plant nutrients in the coralline sands together with the effect that the high pH has upon fixing soluble phosphate and other minerals results in very poor mineral availability for plant growth, particulary in the leached upper horizons of the soil. The use of artificial fertilizers to overcome this deficiency is limited by the rapid fixation of phosphate and the dangers of contaminating the aquifer which also serves as the reservoirs for drinking water.

Traditionally, these two problems were overcome by growing food crops in pits dug down into the aquifer and by using leaf mulches and composts to provide slow release nutrients required by the growing crop. These systems based on traditional knowledge developed over thousands of years of relative isolation from the rest of the world have proven to be productive and ecologically stable, given locally available resources (both human and natural), and are also well integrated both socially and culturally. However, as development pressure has increased and the islands have become more oriented towards cash economy, there has been a steady decline in traditional agriculture. Many farming practices with possible negative environmental effects, including the use of imported fertilizers and pesticides, are being adopted by farmers, mainly for the production of commercial commodities. A good example is the production of sweet potato in Tuvalu under a mono-culture system after removal of coconuts with very high inputs of inorganic fertilizers (2,299 kg/ha). This dependence on expensive imported inputs for crop production has made agriculture increasingly unsustainable in the atolls and eventually led to a decline in overall food production, increased possibility of environmental degradation and increased imports of less nutritious foods (which are easily obtained, cooked and stored).

There is scope for the adoption of sustainable agricultural technologies as most of the producers in the atolls are small-scale, part-time and produce mainly for subsistence, the use of local inputs is widespread, and traditional knowledge of agriculture and the environment is still somewhat practised.

The research programme emphasizes sustainable agriculture, blending both traditional and new technologies in agricultural systems in order to develop improved, productive and sustainable agro-ecosystems for the atolls in the region. The programme concentrated on the identification of compost media ratios, simple and reliable production methods, and the suitability of various vegetables, roots and fruit crops as well as some other plants (e.g., nitrogen fixing trees) to the atoll environment, all as mono-cultures. Work was also initiated on investigating an integrated farming system incorporating food crops and animals in a coconut plantation at Temaku, Kiribati. Most of the research was on Tarawa and it is now planned to carry out much on-farm research on the outer islands.

Coconut is the main crop species in all the atoll countries and the daily existence of the dwellers revolves around it. There is a need to investigate in greater detail various agroforestry and mixed cropping approaches to food crop production, in association with the ever-present coconut, incorporating the traditional sustainable technologies, improved varieties and crops and their methods of production, local fertilizers (compost and manure) with minimum inputs of inorganic fertilizers as well as local livestock feeds for the animal component (goats, ducks) of the integrated farming system. The adoption of this approach will ensure the development of sustainable agro-ecosystems that are environmentally sound and economically productive in the atoll countries of the region.

The development of the sustainable food cropping system with improvement in production methods and the use of new exotic crops/varieties which have been identified will contribute to increasing food production and food security, improved nutrition and the greater availability of other materials from agricultural activities for the people's needs. Promoting greater output in agriculture will contribute to greater import substitution, a swing back to production and consumption of traditional crops in greater quantities, and possibly higher exports (copra, sweet potato, taro), which will contribute to the countries' goal of increasing self-reliance.

The coralline atoll soils are unsuitable for many crops. Therefore, development of suitable compost media (25% sand or black soils plus 25% rotten coconut logs plus 25% leaves plus 25% pig or chicken manure) suitable for crop growth with limited input of inorganic fertilizer was defined as a priority area. Fertilizer application could be reduced from 2,200 kg/ha to 380 kg/ha, thus reducing the risk of pollution. Recommended food crop production methods include the growing of plants in compost placed in small polythene bags, half drum containers trenches with or without a plastic lining, and individual pits.

There is an acute deficiency in vitamins, especially vitamin A, in the diet of atoll dwellers. Therefore, several vegetable crops and varieties were screened to select those suitable for atoll conditions. The production of green leafy crops high in vitamin A especially drumstick (*Moringa oleifera*) and bele was actively promoted.

In an attempt to widen the staple food base of breadfruit and swamp taro, attempts are being made to evaluate sweet potato, cassava and *Alocasia* and *Xanthosomataro* cultivars for dryland conditions. So far, three cultivars of sweet potato (L329, TIB2 and Funafuti White) and two cultivars of taro (Intelpelyar and Tausala ni muu) which perform well have been identified.

There are only a few varieties of fruits in the atolls and several potential useful improved varieties were introduced. They include banana, bilimbi, carambola, citrus, guava, mango, pawpaw, passion fruit, grape sapodilla, Tahitian chestnut, tamarind, custard apple and cut nut Bavingtonia sp.

Another development that has wide application is the model *Cyrtosperma* pit, where swamp taro, kangkong and azolla are grown in the pit, shallow rooted crops (vegetables and fruits) in the inner terrace and deep rooted crops in the outer terrace.

The development of technologies appropriate to the atolls have helped to widen the scope of activities as well as improve the nutritional quality of the diets and the project's findings are already being disseminated to the outer islands of Kiribati as well as to the other atoll countries such a Tuvalu, Marshall Islands, Pohnpei and Niue.

III. Sustainable food cropping for the Volcanic Islands

In volcanic sites, the project aims at visually demonstrating the benefits of sustaining fertility and yields and the prevention of physical soil erosion through sustainable systems of farming.

Taro is the staple crop in many Polynesian countries. Apart from this, other root crops such as cassava, yams and sweet potatoes are also popular, especially in Tonga, Fiji and Solomon Islands.

The primary objective of this programme is to develop and demonstrate food crop production systems which will maintain fertility and sustain yields, while being ecologically sound and economically attractive to subsistence farmers.

In parts of the volcanic islands the population pressure on the traditional system of food crop production as part of shifting cultivation across regenerating secondary forests has led to a reduction in the fallow period and the cultivation of steeper slopes. Both trends lead to physical erosion of the soil, declining fertility and a reduction of food crop yields. A further noticeable effect of this and of the introduction of cash cropping has been to distance food gardens even further from the village. Physical erosion can be observed on the hills in many of the Pacific countries, leading to increased flooding in the valleys and town, silting of the rivers, town drains and harbours, and killing even larger areas of the reef.

In many areas of the dry and humid tropics alley cropping, the planting of food crops between rows of nitrogen fixing trees grown to tap nutrients from the deeper layers of soil and cycle them via leaf drop and mulching with the coppiced branches to the shallower rooted food crops, has been found to sustain food crop yields. In the South Pacific region there is a need to continue the development of alley cropping systems to sustain the food crop yields of subsistence farmers, supply firewood and arrest physical erosion.

Most systems of shifting cultivation are based upon partial clearing of the forest, often with burning and two, rarely three years of food cropping before the area is allowed to revert to forest. Longer periods of cropping are rarely possible on the predominantly acid volcanic soils with very low cation exchange capacity due to the intensive leaching as a result of excessive rainfall in the humid tropics. The increased incidence of weeds, pests and diseases further contributes to declining yields. However, it is assumed that declining fertility is the major cause of yield reduction and the project aims at demonstrating this fact and establishing the extent to which alley cropping systems can be used to sustain yields.

In Western Samoa, agroforestry is being tested as an alternative land use practice to rotational natural fallow with the objective of reducing pressure for land clearance on the more fragile steep lands. The target is to improve productivity and sustainability of taro production in coastal areas and under-utilized coconut lands close to the main dwellings. Initial work has concentrated on using fast growing legume trees to fix nitrogen and recycle soil nutrients. Prunings from the trees are being applied as mulch to inter-cropped taro with the objectives of maintaining soil fertility and reducing weed growth. Short-term green manure crops such as *Dolchios lablab* are also being tested in the system. The main objective of the alley cropping studies is to assess the long-term effects of inter-cropping leguminous trees with taro on sustainability of crop yields, weed control and economic viability.

Long-term data from the alley trials now in the sixth cropping year indicate that improvements in soil properties take three to four years to become evident. Taro alley plots showed no yield advantage over controls in the first four years of the trial, but in year five the tree plots out-yielded controls through a small basal addition of NPK fertilizer (equivalent to 30 kg N, 12.5 kg P, 30 kg K per ha). Control plots continued to decline and did not respond to the fertilizer application.

Studies carried out to improve the shade management in agroforestry systems for taro cropping indicate that weed growth can be reduced in tree shade plots without reducing corm production. Indeed, higher crop biomass was obtained when taro was grown under 50% shade compared to full sunlight. Furthermore, there is a shade-cultivar interaction which indicates the need to select cultivars appropriate to the shade levels found in farmers' fields.

Tree shade in agroforestry plots provide a pleasant environment to carry out heavy tasks such as crop planting and weeding, possibly improving labour productivity.

Work is also done on the development of *Erythrina* based agroforestry systems for taro cropping, to control weeds, maintain fertility and also for fallow enrichment.

In Tonga and Fiji soil fertility is maintained by using rotations. These practices have proved that they enhance soil fertility and reduce the incidence of pests and diseases.

These practices of using multipurpose nitrogen fixing trees and shrubs in agroforesty for growing food crops as well as rotation practices are now being accepted as low input sustainable measures.

IV. Tissue culture

The island states of the region have strict and justified plant quarantine regulations to prevent the spread of pests and diseases. Few countries can sustain the effort to breed improved cultivars for their own country and are therefore dependent upon regional selection and breeding programmes or on the introduction of cultivars from outside the region to widen the narrow genetic base. For many of these cultivars produced by vegetative propagation, only tissue culture together with virus disease indexing can be used to introduce new cultivars or disseminate improved cultivars developed within the region or disease free material when this is required to replace diseased material.

Therefore, the objectives of this project are to introduce tissue culture techniques for crops important for the region (root crops, banana, vanilla, fruit crops, spice crops, etc.), provide germplasm storage for improved cultivars in the region, multiply the improved cultivars bred in or introduced to the region and collaborate with metropolitan laboratories in the elimination of virus diseases in improved cultivars to allow their safe dissemination in the region (root crops, spice crops, coconut embryos, etc.).

The collection at the IRETA Tissue Culture Laboratory has increased and now holds the following pathogen-tested material: 127 taro, 125 sweet potato, 23 cassava, 10 banana, 5 yam and 3 vanilla accessions.

Pathogen-tested material has been distributed to many countries in the region, which are within and outside the USP member countries. This programme has helped these countries, who lack the facilities and expertise in this area, to obtain promising cultivars for testing and evaluation. Finally, it would permit these countries to select cultivars adapted to their environments.

Both the project itself and the implementation of its outputs will contribute to the reduction of the spread of pests and diseases in the region and the increased availability of introduced and improved crop cultivars.

V. Mechanisms of transfer of technology

A. Print Media Unit (PMU)

The role of the PMU is to disseminate agricultural development information through its monthly newsletter called the South Pacific Agriculture News (SPAN). Information on research carried out in the region is reported through the Journal of the South Pacific Agriculture, on agricultural teaching materials through manuals; and on workshops and training through proceedings. The identification and publication of extension materials is largely guided by the needs and priorities identified by the regional countries. In addition, the results of research undertaken at Alafua Campus and in the national collaborative trials carried out in the countries are also published and disseminated through the IRETA annual research reports and Agro-facts. The production of public actions in response to country-specific needs is also undertaken by IRETA to provide continuing support to national ministries.

The information officer heading the PMU also operates the Technical Centre for Agricultural and Rural Cooperation (CTA) Regional Branch Office (RBP). Among others, the functions of the CTA-RBP are to assess and promote new information technology in the region and help spread information inside and outside the region.

B. Electronic Media Unit (EMU)

The EMU which includes satellite, radio and video helps to strengthen and further support agricultural extension, education and training activities through effective communication in the region.

The USP Alafua went on line with PEACESAT's new satellite connection, the Geostationary Operation Environmental Satellite (GOES). The performance of the new system far exceeds that of NASA's old ATS-3, which still operates in the PEACESAT network. The "footprint" or range of the satellite is far greater, as are its communication capabilities.

Terminals have been installed at the PEACESAT base at the University of Hawaii - Manoa; Wellington, New Zealand; Cook Islands; American Samoa; USP Alafua and Malifa, Western Samoa; Honiara, Solomon Islands; Guam; Saipan; Fiji; New Caledonia; Tonga; Yap; Pohnpei; Bonape; Majouro; Kosrae; Papua New Guinea (PNG); and Palau.

Additional terminals in PNG and Kiribati will come on line soon. When the terminals are fully equipped, PEACESAT, through GOES, will provide electronic messaging, bulletin boards, interactive data base access, slow scan and video phone, all of which will assist the communication process.

The satellite communications system (PEACESAT) helps to:

i) Maintain links with Agricultural Liaison Officers (ALOs), national agricultural ministries and educational institutions throughout the Pacific;

ii) Enable point to point and round-table exchange between research scientists, agriculturists and staff of national departments of agriculture and relevant regional organizations;

iii) Receive and respond to agricultural Information Network (AIN) requests.

The IRETA/CTA video library now has cover 170 titles. Acquisition of new materials continues. An upgraded catalogue was produced during 1991 and loan procedures have been simplified to encourage clients to use the service.

The EMU has an educational video library with over 171 titles in agriculture for loan and distribution to USP member countries and others.

C. Outreach Programme - ALO network

The ALO network is IRETA's outreach arm in-country. The ALOs link IRETA's activities with the national governments. The salaries and operating budget are paid by IRETA through the funds provided by USAID. With the conclusion of the project South Pacific Regional Agricultural Development (SPRAD), some member countries have agreed to pay the salaries of ALOs, with operating budget provided by IRETA. All nine ALOs are in place and prospects for the continuation of the ALO network are good. Some strengths of the ALO network are as follows:

i) The ALO network is unique and the most effective network in the region.

ii) It provides a very important link between IRETA and the regional countries in coordinating the research, extension, training and more recently the rural development activities of IRETA. Their presence in-country is a major strength for IRETA in implementing its programmes.

iii) It identifies commercial and subsistence agricultural research needs for the University of the South Pacific (USP) staff and students, and disseminates research finding to commercial enterprises and subsistence farmers.

iv) It disseminates marketing information and quality control manuals in the networking countries.

v) It assists in organizing commercial agriculture training programmes.

vi) It maintains a paid IRETA presence in-country to promote information exchange.

vii) It helps to coordinate national and regional workshops in-country including those related to CAD, national collaborative work on regional research efforts by IRETA, and the distribution of various IRETA publications to specific target groups.

viii) It improves access and facilities responses through the AIN Centre to information requests by regional agriculturists, commercial producers, exporters and others involved with commercial agriculture.

ix) It helps to provide footage for relevant educational videos in-country.

x) It helps to organize weekly satellite meetings with in-country agriculturists and other target groups to discuss problems and issues affecting and of interest to regional researchers, extensionists and commercial producers.

D. Agricultural Information Network (AIN)

Begun in 1988, the AIN links the ALOs to Alafua, regional and worldwide information resources. The centre contains over 3,000 documents, computer disks and CD-ROM access to AGRICOLA.KIT, CABI, AGRIS and other worldwide agricultural indices. The AIN Centre is also the regional (Pacific) input centre for FAO and the FADINAP documentation system for GRIS and CARIS projects.

The AIN Centre continuously played its role in providing information services to support the work of agriculturists in the Pacific region. The ALOs in each country are the first source of answers and they continue to answer many requests from their own files. The number of requests answered by ALOs is not reflected in AIN statistics. Questions which are unable to be answered in-country are sent to the AIN Centre.

The AIN Centre provides materials and referrals to all the South Pacific countries served by IRETA. Countries provide publications and information about agricultural research. Current training of national agricultural librarians focuses on teaching the skills necessary for setting up and maintaining agricultural libraries.

E. Training unit

IRETA is the only regional organization in the Pacific which is well equipped with training facilities and management skills to undertake any form of non-formal training to satisfy specific needs of the regional countries. Clients include growers, exporters, quarantine officers, extension officers, researchers and others. The training activities are to benefit participants in projects they are directly involved with. IRETA also provides training in specialized areas such as livestock, tissue culture and plant protection. Some areas covered in workshops include methodology, communications, sustainable agriculture systems of food production, vegetable production on atolls and other environments, tissue culture, statistical services, plant protection and quarantine areas. The duration of workshops varies between one to two weeks depending on the type and scope of the subject matter and the needs of the trainees.

IRETA works in collaboration with several donor agencies to seek funding support for the workshops it conducts. It has a very well-developed infrastructure to support training at national, regional or international levels. It has accommodation facilities for male and female trainees, together with administrative support facilities to coordinate, organize and conduct training. IRETA is blessed with the largest pool of agricultural scientists in the region next to its training centre - the SOA. The other distinct advantage IRETA has if its training experience in organizing workshops.

F. Demonstrations

On-farm research and field demonstrations are carried out to show improved methods of crop production. Often field days are conducted by the extension staff together with the farmers where demonstration plots have been established. These have shown to be quite useful in disseminating the information to other farmers.

Section III

Conclusions and recommendations

Section III

CHAPTER 18

CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations reported here essentially reflect those arrived at on the occasion of the Expert Consultation organized by FAO and MARDI in Kuala Lumpur, Malaysia, in December 1992. Their legitimation as to their relevance for the Asia-Pacific Region is based on the consensus reached by the twenty-four participants from the region and various international institutions (Australia, Bangladesh, China, Fiji, Indonesia, Iran, Laos, Malaysia, Nepal, Papua New Guinea, Republic of Korea, Thailand, Vietnam, AIT, ESCAP, FAO, IDRC, IRETA, SEARCA, and UNDP).

I. Major trends in Asian agriculture and technology development

The Asia-Pacific Region has been on the forefront of generation and transfer of modern agricultural technologies, recording the highest agricultural production growth rate (about 4 percent) during the past two decades. The "Green Revolution", ushered in through the development and adoption of HYVs of rice and wheat, more than doubled the productivity of these crops. Besides, advances in soil and water management, integrated pest management, post-harvest handling and other related disciplines have synergistically contributed to the increased productivity. Similar developments have been recorded in the livestock and fisheries sectors. The Region is also using modern biotechnologies to produce genetically modified plants, animals and microbes resulting in superior-quality products, increased productivity and resistance to biotic and abiotic stresses.

However, the above gains were linked with negative influences. The Green Revolution has generally by-passed rainfed dryland, lowland and upland areas, including the arid tropics, and also highland ecosystems and resource-poor farmers, thus exacerbating inequity. Production of some of the poor man's crops, viz. pulses, coarse grains, roots and tubers remained stagnant or even declined. The irrigation-associated problems of salinization and waterlogging have greatly negated the positive impact of expansion of irrigation. Increased genetic vulnerability, incidence of pests and diseases, excessive application of agrochemicals and environmental pollution are other serious adverse impacts and have aggravated the unsustainability problem.

II. Major challenges for sustainable agriculture in the Asia-Pacific region

It is generally agreed upon that major challenges include deforestation, soil erosion, land degradation, land scarcity and population pressure (reflected in the low land/man ratio), poverty, declining incomes, and the rural agricultural and non-agricultural employment situation. Land pressure emerges as a common denominator of agricultural sustainability in the region, requiring the intensification of production systems in ways that do not further undermine but enhance the resource base and preserve the environment.

III. Definition of the major concepts

Some of the major concepts involved that require a definition are: *technology assessment*, *technology transfer*, *appropriate technology* and *sustainability*. *Technology assessment* for sustainable agriculture and rural development is defined as a comprehensive approach to examine the actual or potential impact of technology applications on certain sustainability issues and second order consequences and to facilitate the development and use of technological interventions according to location-specific constraints and objectives. To render the somewhat elusive concept of sustainability applicable to problem-solving, a methodological approach was suggested that builds on the description of agro-ecological zones, production systems, resource endowments and their management, and socio-economic environments with special reference to rural development. The conceptualization, collection and collation of unsustainability indicators and critical areas shall eventually lead to definable objectives and technological needs and options. It is well recognized that the development of technology assessment capacities may imply a considerable demand for institution-building and establishment of sectoral linkages (public and private sector as well as intra-sector linkages) in order to make use of technology assessments and to allow for transfer and appropriate use of technologies for sustainable development.

Technology transfer refers to a system under which various interrelated components of technology, namely, ''hardware'' (materials such as a variety), ''software'' (technique, know-how, information), knowledge, institutions (organizational, management aspects) and the final product (including marketing) are rendered accessible to the end-users (farmers). The system also includes institutional capacity for technology adoption, adaptation or rejection, constituting a matrix of technology component and institutional capacities for absorbing technologies (Table 1). Thus, technology transfer has both functional and institutional meanings. A technology transfer programme would be considered effective when there is minimal or no gap between the potential and realised impacts of the technology. It means that monitoring of the adoption or adaptation of technologies is an integral part of the technology transfer system. Transfer of technology must therefore be preceded and succeeded by technology assessment, reasserting that technology transfer and assessment are complementary processes.

One of the prerequisites for effective technology transfer is the appropriateness of the technology. *Appropriate technology* refers to a technology package which must be technically feasible, economically viable, socially acceptable, environment-friendly, consistent with household endowments, and relevant to the needs of farmers. The concept is a dynamic one and the elements of appropriateness will vary over time and space. Thus technologies are subject to adjustment, change and evolution.

As regards *sustainability*, the underlying definition is the one adopted by the FAO Council in 1988: *Sustainable*

TABLE 1. TECHNOLOGY TRANSFER AND ADAPTATION MATRIX FOR SUSTAINABLE INCREASED PRODUCTIVITY IN CROP-ANIMAL SYSTEMS IN ASIA

Institutional Capacity for technology	Technology components				
	Hardware, Tangibles	Techniques, Software	Knowledge, "Humanware"	Organization, Management	Product, Commercialization
Choice, Identification					
Acquisition, Negotiation and Transfer					
Generation, Upgrading, Adaptation, Invention					
Reproduction, Capital goods, Manufacture					
Application, Maintenance					

development is the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable. It is understood that the definition of sustainability varies between countries. A common denominator should be, however, not to compromise increased productivity.

IV. Operationalizing the concepts

The methodological approach to technology assessment suggested above, again, involves several sub-concepts that need definition and have to be agreed upon in order to share information among countries/regions/subregions. It will be necessary to generate much of this information in the course of pilot programmes, since the knowledge of the factors determining sustainability and the associated indicators is limited. The approach is to serve, eventually, the delineation of homologous zones for technology transfer and development of appropriate technologies in a sustainability context.

A. Agro-ecosystems, production systems, unsustainability indicators and sustainability determinants

There are several approaches to the agro-ecological classification of environments, both within and outside the international agricultural research system. Agro-ecological zones are commonly described by a combination of climatic and soils characteristics, with spatial and temporal variability, e.g. specific biotic or abiotic stresses, only partially accounted for. On the other hand, the *recommendation domains* of Farming Systems Research closely define climate, land type and socio-economic conditions. Keeping in mind *major* land use patterns and resource potentials in the Asia-Pacific region without complicating the concept to an extent that renders it unmanageable, *major* agro-ecological zones and production systems/commodities and related unsustain-ability indicators can be identified and agreed upon (Table 2). Indicators were to meet the following requirements: unambiguous, affordable, convenient, consistent, and repeatable.

Minimum data sets for the characterization of AEZs and resource endowments (bio-physical and socio-economic), i.e. the environment under which a technology is supposed to operate, were defined as follows:

- **AEZ**
  - **Climate data**
    - Rainfall means and distribution
    - Temperature
    - Solar radiation and day length
    - Length of growing period
  - **Topography**
  - **Altitude**
- **RESOURCE ENDOWMENT**
  - **Soil data**
    - Soil type
    - Water holding capacity
    - Underground water
    - Fertility
      - high
      - low
  - **Biodiversity (flora and fauna)**
    - Farm enterprise (crops and animals)
    - Species (indigenous spp.)
  - **Socio-economic factors**
    - Population, density
    - Type of agriculture practised
      - permanent
      - shifting
      - nature of enterprise
        - commercial
        - semi-commercial
        - subsistence
    - Infrastructure
    - Information system
    - Access to land
    - Access to credit
    - Access to markets
    - Access to other support services
    - Access to water
    - Access to inputs

TABLE 2. AEZs, PRODUCTION SYSTEMS AND RELATED UNSUSTAINABILITY INDICATORS IN THE ASIA-PACIFIC REGION

AEZ	Prod. Systems/Commodities	Unsustainability Issues	Unsustainability Indicators
Drylands:		**(Arid & semi-arid)**	
Arid (<500 mm)	Ruminants/pastures Coarse grains Short season legumes	• Soil degradation • Water conservation and use • Overgrazing • Biomass production	• Low soil fertility • Low soil org. matter • Soil erosion/desertification • Soil cover/biomass loss • Water quality/stress • Yield fluctuations • Poverty • Cropping of sub-marginal lands • Changes of herd composition
Semi-arid (500-1000 mm)	Ruminants Food grains Pulses Peanuts Fruit trees Sugarcane Agroforestry		see arid lands • Pests
Irrigated lands:	Rice-based Wheat-based Sugarcane Tobacco Horticulture Animals Aquaculture	• Input use • Irrigation management	• Weeds, pests & diseases • Salinity & waterlogging • (Micro)-nutrient leaching & imbalances • Reduced organic matter • Excessive use of agrochemicals • Lowered water tables • Floods • Uncertain water availability • Methane & nitrous oxide emissions • On-farm water management capacity • Plateauing/declining yield levels
Humid lands:		**(Humid & subhumid)**	
Sub-humid (1000-1500 mm)	Food grains (rice) Cash crops Animals (incl. monogastrics) Fruit trees Roots & tubers Vegetables Aquaculture Silviculture Integrated systems	• Input use • Focus on cereals • Inadequate integration of systems • Lack of market development • Availability & management of water resources	• Reduced ground cover/soil erosion • Nutrient leaching • Acidification/alkalinity • Pests & diseases • Flooding • High input use • Soil & water pollution • Prices & incomes
Humid (>1500 mm)	Plantation crops Rice Fruits Spices Roots & tubers Vegetables Animals		see sub-humid lands • Drainage • Loss of biodiversity

TABLE 2. CONT'D

AEZ	Prod. Systems/Commodities	Unsustainability Issues	Unsustainability Indicators
Highlands:		**(both sub-zones)**	
Average temp. <20°C	Potato Maize Barley Medicinal plants Livestock (yak & sheep) Pasture Horticulture	• Land tenure • Accessibility & marketing • Fragility • Limited technological choice • Deforestation	• Loss of forest cover • Run-off/soil erosion • Reduced water retention capacity • Soil acidity • Loss of biodiversity • Downstream flooding & sedimentation • Poverty
Average temp. >20°C	Plantation crops Spices Roots & tubers Horticulture, vegetables Rice, Wheat Dairy cattle Agroforestry Coffee, tea Ornamental plants Shifting cultivation		see (temp. <20°C) • Incidence of shifting cultivation
Coastal lands:	Rice-based Horticulture Cash crops Aquaculture Mangroves Integrated tree/animal systems (coconut-based)	• Monocropping • Lack of technologies • Inadequately integrated systems • Competition for land (mangrove vs. shrimps) • Natural disasters	• Salt water intrusion/salinization • Rising sea levels • Crop damages • Pests & diseases • Reduced organic matter • Reduction in mangrove cover • Erosion
Islands: *(Volcanic & atoll)*	• Fruit trees Roots & tubers Integrated coconut/ ruminant systems Aquaculture •	• Natural disasters • Soil fertility • Global warming • Lack & feasibility of technologies • Remoteness & accessibility Population pressure	see coastal areas • Emigration

B. Definition of objectives for sustainable agriculture and identification of available and needed technological options (information/ management-based and material) to achieve these objectives

The definition of objectives is essentially a management tool. Quantified location-specific goals are necessary to measure the degree of success in sustainability-enhancing interventions. Overall objectives of technological interventions for sustainable agriculture can be summarized as food security and risk resilience, environmental compatibility, economic viability, and social acceptability. Different AEZs and production systems, however, require location-specific and tailored solutions. In *drylands*, objectives of technological interventions include diversification of production and bio-diversity conservation, soil and water conservation, crop/ livestock/tree integration, and, where necessary, area rehabilitation. Where possible, a rather drastic intervention is irrigation and thus a change of the agro-ecological zone. Irrigation, however, requires proper management of water supply and drainage to counteract soil salinization.

In *subhumid and humid areas*, besides soil and biodiversity conservation, a major objective should be the management of soil acidity and phosphorus fixation. There appears to be scope for the expansion of irrigation in Asia to reduce pressure on upland areas with considerable migration, but the financial implications of irrigation expansion are becoming highly severe.

Irrigated lands are prone to salinization and objectives should be water use efficiency and water resource protection. The decline in yields must be arrested and even reversed through integrated management of nutrients, soil, water and biotic stresses under intensive production systems. It is recognized that these and assured rainfall lowlands provide the bulk of the food and agricultural products.

In *highlands*, the risk of erosion needs to be checked through conservation measures and afforestation. Of particular interest are second order consequences that may occur at some distance from the production systems, e.g. downstream flooding and sedimentation.

Coastal areas and islands face particular problems of rising sea levels/salt water intrusion and objectives can be defined at the level of global changes, e.g. reduction of greenhouse gas emissions.

Based on the analysis above, several available and needed generic technologies for the AEZs and unsustainability problems agreed upon can be identified, keeping in mind the distinction between information/management-based and material/input-based technologies (Table 3). The distinction between information- and material-based tech-

TABLE 3. AVAILABLE AND NEEDED TECHNOLOGIES FOR SUSTAINABILITY OBJECTIVES*

AEZ	Available Technologies		Needed Technologies
	info-based	material	
Drylands	• Knowledge of IPM and IPNS • Management capabilities • Agroforestry • Water conservation • Rangeland management • Animal health care	• Drought & disease resistant species and varieties • Short duration varieties • Forage banks, fodder conservation	• Coarse grain post-production technology • Efficient water-extraction technology • Heat-tolerant animals
Irrigated lands	• Knowledge of IPM and IPNS • Knowledge of Biocontrol • Integrated rice-fish-livestock systems • Processing • Animal health care • Water management	• Appropriate varieties and breeds • Processing • Soil amendments • Rehabilitation of conveyance & drainage systems	• Biofertilizer • Transgenics • Tolerance to abiotic stress
Humid & subhumid lands	• Animal health care • Agroforestry • Integrated systems • IPM, IPNS • Green manure	• Soil amendment • Pest & disease resistance • Resistance to abiotic stress • Legume fodder banks • Sown pastures/fodders • High-biomass crops	• Biotechnology applications • Amplified hydroponic syst.
Highlands	• Agro-sylvo-past./agrofor. • Watershed management • Rangeland management • Hedgerows • Grass strips • Terracing	• Low-volume high-value crops • Reforestation	• Small-scale value-added • Labour-saving technology
Coastal lands & islands	• Watershed management • Integrated systems (animal prod./ forage under trees) • IPM, IPNS • Animal health care • Agroforestry	• Animal/plant quarantine • Resistance to salinity/toxicity • Sanddune forestation • Pest/disease resistance	• Increased genetic base for swamp grown plants

* *Available technologies are not listed in order of priority nor are they exhaustive.*

nologies is useful in order to emphasize adoption constraints specific to the respective technology category: the former is hampered chiefly by possibly higher labour requirements, the latter by associated risks. Assessment of relevant technology has to consider preeminently the given resource endowment. Appropriate technology can be found in either category.

C. Choice of qualitative and/or quantitative criteria and indicators for priority technologies

Quantified objectives are, besides providing performance standards for interventions, useful for a prioritization of projects or programmes. Ideally, a quantification of technological effects would enable assessments to be based on cost/benefit analyses. It is recognized that research into cause-effect relationships is necessary to support such analyses. The underlying principle of research priority setting is the expected economic return to investments. Therefore, the economic significance of a commodity tends to determine its ranking on the research agenda. Technology for sustainability is somewhat more difficult to value: neither the costs nor the long-term returns (sustainability, by definition, implies rather long-term than short-term returns) of specific technological interventions can be sufficiently quantified at the moment. Against this back-drop, a set of criteria applicable to the prioritization of technology interventions could be identified.

Interventions should:

- i) address (a) serious problem(s) with research and development relevance;
- ii) contribute to sustainability and sustainable development;
- iii) address both production and post-production aspects;
- iv) make use of locally available resources and recognizes traditional systems and indigenous knowledge in developing new technologies;
- v) contribute to increased food production and food security;
- vi) generate increased income and contribute to increasea equity and improved livelihoods for small-farmers;
- vii) have a capacity building element and potential for replicable technology transfer within and between regions and subregions;
- viii) include community participation;
- ix) involve interdisciplinary and wide inter-sectoral participation;
- x) be innovative;
- xi) have received limited research and development support, especially orphan commodities;
- xii) have potential for commercialization;
- xiii) have an impact on rural development;
- xiv) address gender issues.

V. Recommendations for technology assessment and transfer

Based on the criteria listed above, a number of recommendations for technology assessment and transfer could be derived and follow-up action was urged upon FAO, donor agencies and national programmes. The paramount constraint to effective technology assessment is a dearth of information. Another major handicap is the paucity of trained manpower to conceptualize the theme, develop methodologies and indicators and use them in technology assessment, development and transfer. The problem is severest in the case of remote countries (e.g. Pacific islands) and also Indo-China. Most countries in the Asia-Pacific Region, and indeed the world, do not have explicit policies in place to conduct technology assessments. This situation is aggravated by a lack of suitable holistic methodologies for monitoring and evaluating agricultural systems which results in a limited understanding of sustainability trends. The development of assessment capacities encompasses both local as well as regional/global issues as there are often second order consequences occurring at some distance from the site of production.

- i) It is emphasized that there is a hand and glove relationship between agriculture and environment. Besides, economic, social and political factors intimately impact agriculture. The increasingly complex world of agriculture thus calls for an integrated approach to be efficiently productive, equitable and sustainable. Governments should develop policy settings to meet this demand. Technology assessment should become an important intervention for research and technology development geared to sustainable agricultural and rural development. It was noted that most of the countries lack the capacity for formulation of appropriate policies and the Consultation recommended that FAO should assist the countries in this regard by sensitizing and enhancing the capacities of policy makers through training/seminars and increasing access to information. Policy issues such as intellectual property rights, biosafety, technology standards, incentive structures, trade and pricing, institutional support, and environmental accounting should be addressed to.

ii) To close the gap of information on and to develop desired human resources and institutional systems for sustainable agriculture in the Region, it is recommended that FAO, in close collaboration with other international and national programmes, organize training programmes, workshops and information exchange to sensitize and train extensionists, researchers and farmers to further develop and apply guidelines, methodologies and indicators leading to sustainable agricultural production.

iii) There are, however, considerable technological capacities available in the Region. Some mature NARS and the CGIAR and other international Centres in the Region offer, through regional co-operation and networking, substantial scope for synergies, considering that the Asia-Pacific countries share many of the AEZs, production systems and resource endowments. Given the diversity of development stages in the Region, there are numerous on-the-shelf technologies awaiting assessment for use in other countries.

iv) National capabilities in technology assessment and transfer are critical. The development of such capabilities should be supported initially by FAO and NARS through case studies to generate inventories of resource endowments and unsustainability indicators for (a) given AEZ(s). Of particular interest would be agricultural systems associated with deforestation, besides other basic questions of land use (e.g. agriculture versus in-situ conservation of biodiversity and agriculture in marginal lands). A suitable methodology should be developed to assess trends in sustainability of such competing land use systems and to identify technologies appropriate for monitoring the trends and for promoting sustainable agriculture.

v) A complementary effort to the case study approach should be made by FAO to develop and establish inventories of available technologies relevant to productivity and sustainability in agriculture. Initial activities should concentrate on pilot projects, focused on selected technologies representing the range of generic technologies. The information required from inventories should pertain to sources of technology, method(s) of application, environmental friendliness and risks, and broad terms under which technology may be acquired. Attention should be given to intellectual property rights and technologies ready for commercialization. The accessibility and utility of inventories should be monitored by individual countries by a survey of inventory users. Assistance should be provided by FAO and other donors for adaptive trials to support technology adoption.

vi) The majority of the farm holdings in the Asian countries are small and technologies for them should be information-based, encompassing low use of purchased inputs, improved efficiency of manual labours, especially women, and integrated farming systems. Appropriate policy interventions to improve receiving and delivery capacity of small farmers are essential for adoption of new technologies. Appropriate land-tenure systems, such as land-to-tiller, would enhance adoption of technology for increased sustainability. Recognizing that, in several countries of the region, specific programmes focused on technology transfer to small farmers have been in vogue, such experiences should be critically analyzed and shared with other countries.

vii) Rainfed/dryland, highlands, coastal lowlands and islands are generally endowed with fragile resource bases, have low productivity and the majority of the inhabitants are resource-poor and are obliged to eke out an existence in harsh biophysical and socio-economic environments. The task of resource management is very complex and the risk taking capacity of such areas and their people is very low. Therefore, sustainability matters assume very high, if not higher, importance than productivity per se. Risk-resilience and linkage mechanisms specifically designed for resource-poor farmers in harsh environments should be a prime consideration while developing and transferring technologies for such settings.

viii) In order to address unsustainability problems in agriculture in humid and sub-humid lands, the development, evaluation and adoption of new and available technologies should focus on the promotion of integrated agro-economic or market-driven systems. Such integration should consider crop production, horticulture, vegetables, use of ponds, aquaculture, ruminant and non-ruminant livestock, marketable products, and the stability of market outlets.

xi) Post-harvest technologies are a priority area for sustainable agricultural production and growth. It is recommended that the development of post-harvest technologies focus on:
  - providing a wider range and diversity of processing technologies so that more agricultural end products reach markets, giving greater returns to farmers and having more consumer appeal
  - enriching post-harvest technologies with such value added processes as packaging and bioprocessing
  - technologies for handling of perishables but not neglecting other products
  - linkages between research, technology development and commercialisation.

xii) On-farm conservation of biodiversity should be addressed, including the use of indigenous knowledge. A project should be developed in resource-poor highlands or rainfed drylands, in an appropriate area with richness of biodiversity. Through the project, a strategy should be developed for conservation and economic implications of appropriate interventions (e.g. compensation to the farmer for loss of land).

xiii) It is emphasized that, given the complex multidisciplinary and intersectoral nature of technology development and transfer, effective linkages among concerned sectors and players should be strengthened/ established and managed for attaining sustainable agricultural and rural development. Although different types of links will be required for different types of technology, the most important linkages envisaged are: research-extension-farmer, private-public, regulatory agencies-policy-R&D and agriculture-industry-environment. It is recommended that, based on informed judgement, regulatory agencies in individual countries should develop mechanisms and national guidelines and procedures to procure need-based technologies and to use them safely. FAO and other international agencies should establish mechanisms to help recipient countries to obtain protected technologies and to develop harmonized international biosafety standards for safe introduction or development and release of genetically engineered organisms.

xiv) Technology transfer approaches vary according to technology packages and target groups. Recognizing that there are serious gaps in technology transfer under certain systems, there is a need to re-evaluate the technology transfer approach. The transfer of technology (TOT) approach and the training and visit (T&V) method were based on extension of knowledge and "know-how" and were effective only under simplistic, predictable and controlled settings. Under complex and veritable settings of rainfed agriculture, these straight-jacket approaches were rather unsuccessful, and farming systems and participatory approaches should be followed under such settings. The Beyond Farmer First approach is the latest paradigm of technology transfer. Under this approach, farmers' needs and priorities are put first and farmers participate in research and extension. The shift in the approach calls for professional, institutional and policy-related changes and, for the approach to succeed, human resources development should be strengthened and attitudinal and behaviourial barriers would have to be removed. The approach emphasizes learning and skill development rather than knowledge and technology *per se* which are generally contextual in time and space, hence limited in their transferability.

xv) To facilitate the establishment of joint ventures and partnerships of various kinds, it may be expedient to foster regional/sub-regional technology assessment capacity through (a) regional or sub-regional clearing-house or technology assessment centre(s). Existing capacities, such as the Asia-Pacific Association of Agricultural Research Institutions (APAARI) and other networks and institutions, indeed abundant in the region, could be pooled. The suggested regional network, involving sub-regional networks and linking with other networks in the region, would promote co-operation and information exchange, and primarily address sustainability problems, food production and alleviation of poverty. The structure of the network should ensure strong linkages between disciplines and sectors.

ACRONYMS

AEZ	Agro-ecological Zone
AIT	Asian Institute of Technology, Bangkok
APAARI	Asia-Pacific Association of Agricultural Research Institutions

CGIAR	Consultative Group on International Agricultural Research
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
IDRC	International Development Research Centre (Canada)
IPM	Integrated Pest Management
IPNS	Integrated Plant Nutrition System
IRETA	Institute for Research, Extension and Training (Alafua, Western Samoa)
MARDI	Malaysian Agricultural Research and Development Institute
NARS	National Agricultural Research System
SEARCA	Southeast Asian Regional Centre for Graduate Study and Research in Agriculture
TOT	Transfer of Technology
T&V	Training and Visit System
UNDP	United Nations Development Programme