Proceedings of the Global Forum on Salinization and Climate Change (GFSCC2010)

Valencia, 25–29 October 2010

Edited by
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The work provided by Dr. Clemencia Licona Manzur, ex-Soil Reclamation and Development Officer, FAO, to organize the Forum, raise funds and provide a vision for the Forum.

It is expected that this Global Forum and its Proceedings can further facilitate work on salinization associated with climate change and establish the basis for more research and field applications to adapt ecosystems to climate change.

The Organizing Committee

Part 1
Executive summary

RATIONALE OF THE GLOBAL FORUM ON SALINIZATION AND CLIMATE CHANGE (GFSCC2010)

Several international organizations and scienctific societies have been addressing the problems in food production due to the salinization of soil and irrigation water for several years. The Food and Agriculture Organization of the United Nations (FAO) created the Global Network on Salinization Prevention and Productive Use of Salt-Affected Habitats (SPUSH) that has organized seven thematic meetings (Manila 1995, Cairo 1997, Manila 1999, Izmir 1999, Bangkok 2000, Valencia 2001, and Dubai 2007) addressing different aspects of salinity, its regional distribution and quantification of affected areas, in order to obtain a global picture of the extent of the problem.

The relevance of the possible impact of climate change in many productive areas prompted the organization of a meeting considering the possible effects of climate change on cultivated lands, coastal areas and other areas under risk of salinization. This constituted a new approach to the prevention of the risk of salinization, and an attempt to develop strategies for early action at regional and global scale. The GFSCC2010 was the first forum of global participation on this subject.

Soil salinization is one of the more subtle and progressive causes of soil degradation, threatening some of the most productive lands currently under irrigated agriculture. It is also an increasing environmental concern for those areas for which suggested climate change scenarios predict aridity increase and/or sea level rise. Salinity is also a natural inherent condition of many ecosystems contributing to global biodiversity supporting halophytes.

Salinization is a problem that has long being associated with agriculture, both as a constraint and as the result of inappropriate practices. In addition, agriculture intensification, as well as changes in temperature and precipitation patterns expected from climate change, are likely to further affect the salt-water balance of fragile ecosystems.

Information on the relationship between climate change, salt-affected habitats and salinization processes is scarce. There is a need to establish a better picture of the most affected or vulnerable areas and to promote practices that can be used to adapt agricultural production in areas susceptible to climate change. This will contribute to food security and reduce stress on ecosystems.

The forum constituted an opportunity to discuss, from a multi-disciplinary perspective, the problems associated with salinization and climate change and strengthened the dialogue between policy makers, scientists and field experts.

OBJECTIVES OF THE GFSCC2010

The objectives of the Global Forum on Salinization and Climate Change were:

- to discuss, from a multi-disciplinary perspective, the problems associated with salinization and climate change;
- to exchange experiences of study cases of monitoring and measuring of soil and water salinity, plant response and plant adaptation to adverse conditions;
- to discuss strategies for early prevention of the risk of salinization in sensitive areas;
- to strengthen the dialogue between policy makers, scientists and field experts;

- to formulate proposals of action intended to provide more information on the development of salinization under climate change threats; to determine vulnerable areas; to identify successful experiences to prevent or control salinization or increase productivity of already salinized areas; and to identify reasons why some technologies are not taken up by farmers.

FORMAT OF THE FORUM

The forum had a mixed format. The scientific basis for different thematic areas was presented and discussed during dedicated sessions and additional sessions for general discussion were held at the end of each day.

The contributions of the participants were classified by sessions, distributed over five days (from Monday 25 to Friday 29), including keynotes, oral communications, poster sessions and a technical seminar. The following topics were covered:

- Identifying systems vulnerable to salinization, including agroecosystems (irrigated and rainfed), soils, water bodies, biodiversity and fragile ecosystems and available tools and information systems to assess and monitor the evolution of salinization.
- Preventing and managing salinization under climate change threats: learning from past experiences, introducing new technologies and facilitating the exchange of knowledge.
- Alternative land use systems/ecosystem services in salt-affected habitats.
- Evaluating the effects of climate change on coastal areas, lagoons and wetlands, including economical, social and environmental aspects.
- Analysis of the effects of increased salinization on food security at national, regional and global levels.

FORUM ATTENDANCE

The organizers received more than 100 abstracts from interested parties. Eighty participants, both funded and self-funded, attended the forum, including soil, plant and water scientists, experts representing authorities, national institutes and universities, members of the FAO SPUSH and other networks, from a total of 33 countries from Africa, the Americas, Asia and Europe.

Participants shared their expertise during the forum sessions as oral and poster presentations, as well as during the general discussions. Officers representative of the Food and Agriculture Organization of the United Nations (FAO), the Joint Programme of FAO-International Agency of Atomic Energy (FAO/IAEA), the International Union of Soil Sciences (IUSS), the International Center for Biosaline Agriculture (ICBA/INBA) and the representative of the COST European Network on Halophytes, promoted wide discussion of topics and offered the support of their organizations for further collaboration, beyond GFSCC2010.

ORGANISING COMMITTEE

The GFSCC2010 was organized by:

- Dr. Clemencia Licona Manzur, Soil reclamation and Development Officer, Plant Production and Protection Division, FAO, Rome, Italy.
- Prof. Dr. Jorge Batlle-Sales, Secretary of the Commission of Salt-affected Soils, International Union of Soil Sciences, Universidad de Valencia, Spain.
- Dr. Freddy Nachtergaele, Senior Officer, Land and Water Division, FAO, Rome, Italy.
- Dr. Minh-Long Nguyen, Section Head, Soil and Water Management & Crop Nutrition, Joint FAO/IEAE Programme, Vienna, Austria.

SCIENTIFIC COMMITTEE

The Scientific Committee consisted of:

- Prof. Dr. Jorge Batlle-Sales, Universidad de Valencia. Spain. President of the Scientific Committee.
- Dr. Minh-Long Nguyen, Joint FAO/IEAE Programme, Austria.
- Prof. Dr. Donald L. Suarez, U.S. Salinity Laboratory USDA-ARS, USA.
- Prof. Dr. Faisal K Taha, ICBA. Dubai, United Arab Emirates.
- Prof. Dr. Shoaib Ismail, ICBA. Dubai, United Arab Emirates.
- Prof. Dr. Jingsong Yang, Institute of Soil Science, Chinese Academy of Sciences. China.
- Prof. Dr. Ignacio Morell Evangelista, Universitat Jaume I, Castellón, Valencia, Spain.
- Prof. Dr. Helena Freitas, University of Coimbra, Portugal.
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- Prof. Dr. Amparo Roca Zamora, Universidad de Valencia, Spain.
- Prof. Dr. Samran Sombatpanit, WASWAC, Thailand.
- Prof. Dr. J. D. Etchevers, Colegio de Postgraduados de Chapingo/Montecillo, Mexico.
- Prof. Dr. Juan Gallardo Lancho, CSIC, Salamanca, Spain.

OPENING AND CLOSING CEREMONIES

The opening ceremony was held on Monday 25 October at 10:00 am in the Sala Darwin of the Universidad de Valencia. It was presided over by the Excelentísimo y Magnífico Rector of the Universidad de Valencia, Professor Dr. Esteban Morcillo Sánchez, accompanied by the Ilustrísimo Sr. Jorge Lamparero Lázaro, Director General for Climate Change of the Regional Government (Generalitat Valenciana), Miss Maria Angeles Ramon-Llin, Vice Mayor the City of Valencia, Dr. Clemencia Licona Manzur, Soil Reclamation and Development Officer, Plant Production and Protection Division, FAO, and Dr. Minh-Long Nguyen, Section Head, Soil and Water Management and Crop Production, Joint FAO/IEAE Programme. Professor Jorge Batlle-Sales acted as host for the ceremony.

The authorities' representatives welcomed the participants, highlighting the opportunity of the GFSCC2010 for addressing the problem of salinization in a new comprehensive approach, and expressing the importance of the work of the forum at both regional and global scale. All participants were encouraged to actively interact, exchange their knowledge, experience and perspectives. Finally, special thanks and acknowledgement were given to the organizing institutions, sponsors and committees for the works of preparation of the GFSCC2010. Participants were invited to a welcome mixer.

The closing ceremony was held on Friday 29 November at 1:00 pm. It was chaired (on behalf of the Vice Rector of the Universidad de Valencia) by Prof. Dr. Jorge Batlle-Sales, accompanied by Dr. Clemencia Licona Manzur, Dr. Minh-Long Nguyen, Dr. Ismail Shoaib (on behalf INBA/ICBA) and by Prof. Dr. Timothy Flowers (as Head of the EU COST Research Network FA0901).

The members of the Presidium congratulated the participants on their input during the forum, for their interesting case studies and the very valuable conclusions and recommendations. Special thanks were given to the organizations, institutions, sponsors, committees and people that made the GFSCC2010 possible. Before leaving, participants shared their last lunch together in a very friendly atmosphere.

Technical seminar

A short technical seminar was delivered for interested experts, parallel to the sessions of the GFSCC2010 in a second conference room at the Universidad de Valencia, courtesy of the DECAGON and LABFERRER companies. The seminar, entitled "Monitoring soil moisture and electrical conductivity (EC) with sensors" was delivered by Dr. Francesc Ferrer-Alegre and Dr. Francisco Fonseca Salcedo, LabFerrer/Universitat de Lleida.

The following topics were discussed:

- Monitoring of water content in the soil with capacitance (TDR and FDR) probes
- Monitoring of electrical conductivity (EC) of the soil with sensors (electrode arrays)
- Using wetting front detectors for tracing water and salinity signatures
- Calculation of salt balances with a spreadsheet for assessing leaching practices in an irrigated field
- Constructing a dash-board with a spreadsheet to assess irrigation and salinity management practices

The seminar presented the principles of measurement with different devices, including practice with sensors on soil columns, presenting the best field implementation plan and assessment of on-farm management practices of soil moisture and EC. The seminar consisted of short theoretical explanations, followed by discussion of participants' experiences, hands-on practice with the instruments and laboratory spreadsheets.

FINDINGS AND CONCLUSIONS OF THE SESSIONS.

Distribution of presentations by topics

The objectives of the GFSCC2010 included five topics, with wide scope, to be considered by the participants as the main framework for their presentations, distributed over several sessions.

- Session I. Identifying systems vulnerable to salinization, including agroecoystems (irrigated and rainfed), soils, water bodies, biodiversity and fragile ecosystems and available tools and information systems to assess and monitor the evolution of salinization.
- Session II. Preventing and managing salinization under climate change threats: learning from past experiences, introducing new technologies and facilitating the exchange of knowledge.
- Session III. Alternative land use systems/ecosystem services in salt-affected habitats.
- Session IV. Evaluating the effects of climate change on coastal areas, lagoons and wetlands, including economical, social and environmental aspects.
- Session V. Analysis of the effects of increased salinization on food security at national, regional and global levels.

The findings for each topic can be found on the enclosed CD-ROM.

CONCLUSIONS

- Global warming is reputed to be responsible for climate changes in many areas around the world. Although the evidences of average global warming are evident, there exist still great uncertainty about the magnitude and the extent of the regional and local variations in temperature and water availability. Some areas will be affected in a complex way by rainfall variation, temperature increase, with parallel evapotranspiration increase and sea level rise.

- Water quality of aquifers, rivers and lakes can be affected by the variation in precipitation, due to that its ionic content depends on the dissolution/ precipitation of minerals, the dilution factor by rainfall and the litology of the area of origin of the water.
- Biological activity variation according to the changes in temperature and precipitation are likely to affect, among others, the biological cycles of pollinating insects, possibly leading to future changes in crops and natural vegetation.
- There is a need of close cooperation of soil and plant scientists with climatologists to draw possible scenarios of climate change and develop preventive and remedial strategies, for avoiding yield reduction or loss of crops due to the development of soil salinity.
- Halophytes are a global resource as an alternative crop in salinized areas, providing food for livestock, fibre, oil and energy.
- Medium and long-term effects should be carefully considered in projects dealing with biosaline agriculture. There is a concern for long term irrigation effects in arid areas with highly saline waters because of the massive salt mobilization that can promote aquifer salinity increase and decrease in the piezometric level of aquifers.
- There is a need for the development of new mechanistic models capable of accurately representing the atmosphere/soil/water/plant/aquifer system, for exploring the consequences of different management practices, including the optimization the water use and the crop yield, avoiding the soil and aquifers salinization, for its sustainable productive use.
- Further research on the soil physics/chemistry/hydraulics, on the plant mechanisms of response to combined salinity/drought stress, on biochemistry and plant physiology research, will provide refinements to the existing models, based on processes.
- The concepts of "virtual water" and of "water footprint" should be incorporated in food production planning, for better evaluating the environmental costs and impacts of irrigation in areas under risk of salinization. This would also help to soundly distribute the food production on the basis of regional optimal use of resources and for fixing the market prices, including the "externalities".
- New conceptual models are to be developed, including the social factors.
- Soil and water salinization risk assessment can be approached by the Pressure-State-Response methodology, using indicators.
- A set of indicators for the risk assessment are to be established for pressures, effects (change of state) and efficiency of remedial actions.
- Dissemination of the information to farmers is a key issue.
- Further efforts should be made for analysis of the effects of increased salinization on food security. This requires the collaboration of soil, water and plant scientists with other specialists, including climatologists, economists and sociologists, coordinated with national authorities and policy makers.
- At regional and global levels, the international organizations should have a key role in the design of policies and trade fluxes, to alleviate the adverse effects or possible food scarcity.
- Convergence of efforts of scientists, international organization, research institutions, policy makers, governments and other agents is needed to prevent or mitigate the adverse effects of the decrease in water availability and water quality, development or increase in salinity in coastal and inland areas, as consequence of climate change.

PROPOSALS OF ACTIONS AS A RESULT OF THE GLOBAL FORUM ON SALINIZATION AND CLIMATE CHANGE

As a result of the discussions and suggestions presented at the GFSCC2010, a number of proposals for action were made. These are intended to provide more information on the development of salinization under climate change threats; to determine vulnerable areas; to identify successful cases of upscaling that could contribute to prevent or control salinization, or increase productivity of already salinized areas; and to identify reasons why some technologies are not taken up by farmers.

The exchange of information during the GFSCC2010 has evidenced the need of joint-research and continuous collaboration among the experts, their institutions, existing organizations and research networks. Several international organizations are concerned with the problems associated with soil and water salinization, the use of halophytes and the possibilities of biotechnology for overcoming the possible effects of future climate changes, at local, regional and global scale. A convergence of these efforts is needed.

The large number of international participants in the GFSCC2010 constituted a critical mass of experts dealing with different aspects related to salinity problems, providing the basis for continued collaboration through voluntary participation in working groups.

Two work packages are proposed:

- Work package 1: Determination of the zones most vulnerable to salinization under potential climate change scenarios and the establishment of regional monitoring groups.
- Work package 2: Documentation of experiences of scaling up technologies in participating countries and analysis of reasons for their success or failure.

They are intended to be activities that promote the collaboration between national, regional and international institutions and to exchange information at different levels, and above all, to capitalise on the long term work on salinization to provide ideas/technology for adapting agriculture to climate change.

Participants were encouraged to discuss with their institutions and with their national authorities to determine if they would be interested in participation in these exercises. At the time of writing interest from several organizations had been expressed.

INFORMATION ON THE NETWORKS AND ASSOCIATIONS PARTICIPATING IN THE GFSCC2010

The FAO Global Network on Salinization Prevention and Productive Use of Salt-affected Habitats (SPUSH)

The FAO SPUSH Network is a neutral forum to connect research institutions, land users and policy makers. The Network aims at disseminating and exchanging information; facilitating the application of technology; contributing to the design of relevant policies and promoting focused scientific research.

The Joint FAO/IAEA Programme

The Joint FAO/IAEA Programme assists Member Countries of FAO and IAEA to use nuclear techniques and related biotechnologies for developing improved strategies for sustainable food security.

The International Union of Soil Sciences Commission 3.6 on Salt-affected Soils

The society was founded as the International Society of Soil Science (ISSS) on 19th May 1924. The IUSS has been a scientific union member of ICSU since 1993. The

scientific activities of IUSS are undertaken through four Divisions that are integrated by Commissions. Commission 3.6 addresses the scientific aspects related to salt-affected soils, under Division 3 Soil Use and Management.

The COST Food and Agriculture Action FA0901 Network

COST is an intergovernmental framework for European Cooperation in Science and Technology, allowing the coordination of nationally-funded research on a European level. COST contributes to reducing the fragmentation in European research investments and opening the European Research Area to cooperation worldwide. This research initiative makes it possible for the various national facilities, institutes, universities and private industry to work jointly on a wide range of research and development activities.

The Inter-Islamic Network on Biosaline Agriculture (INBA)

The Inter-Islamic Network on Biosaline Agriculture (INBA) is a non-political, non-profit, independent and autonomous body promoting biosaline agriculture under the auspices of the Organization of the Islamic Conference (OIC) Ministerial Committee on Scientific and Technological Cooperation (COMSTECH). It was established in 2002 at the 10th General Assembly meeting of COMSTECH.

Part 2

Abstracts according to the programme

TOPIC I. IDENTIFYING SYSTEMS VULNERABLE TO SALINIZATION, INCLUDING AGRO-ECOSYSTEMS (IRRIGATED AND RAINFED), SOILS, WATER BODIES, BIODIVERSITY AND FRAGILE ECOSYSTEMS AND AVAILABLE TOOLS AND INFORMATION SYSTEMS TO ASSESS AND MONITOR THE EVOLUTION OF SALINIZATION.

Salinization: An environmental concern under climate change scenarios

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Soil salinity can be described as a high concentration of ions in the soil solution, a condition that is very restrictive for plant growth, due to the high osmotic potential of the solution that inhibits plant water uptake and the toxicity of specific ions. This definition of soil salinity centred on the plant differs from that used in soil classification, which is more focused on features permanently recognizable in a profile. Salinization is a progressive soil and water degradation process, human-caused, affecting aquifers and the most productive agro-ecosystems under irrigation in arid and semi-arid regions, representing an increasing environmental concern.

Evidence of global mean temperature increase has been presented by the Intergovernmental Panel on Climate Change (IPCC) and by many authors in the last few years. All sources recognize a large uncertainty in the magnitude and geographical distribution of climate change, as well as uncertainty in the response of plants and ecosystems to climate change.

For assessing the risk of salinization, defined scenarios should be analysed. The risk of salinization will affect the soils at different latitudes in different ways. In the Mediterranean area increasing temperatures, higher evapotranspiration rates and higher evaporation from water bodies are expected, combined with rainfall diminution (less water availability, reduction in water in reservoirs). Changes in precipitation patterns are also expected, with more irregular distribution than at present that will provoke increased runoff versus infiltration and difficulties for caudal regulation and water storage.

Under this scenario the water availability will be reduced, and there will be a need for resource optimization through the adoption of adaptation strategies that counteract the possible worsening in irrigation water quality due to an increasing demand that will force the use of alternative water sources. Special effort will be required for the maintenance of crop production under salinization risk and for the expansion of irrigated areas.

The correct analysis and prevention measures require scientific background provided by a critical mass of scientists, an increased effort in research and measurement, development of new conceptual models and the analysis of scenarios under different hypotheses. This will allow the design of new technical and policy approaches.

Soil salinity in the southern Pre-Caspian lowland as related to climate peculiarity and anthropogenic effects

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The main objective was to assess the modern state of soil cover and soil salinity in the region, namely the Western Ilmen region of deltaic-marine origin occupied by Baer's mounds, and the Volga Delta region.

Soils subjected to natural salinization were crusty Solonchack, brown semi-desert soil, meadow and swampy meadow soils with the different degrees of salinization. Soils subjected to secondary salinization were also studied. They were alluvial meadow soils with different degrees of salinization located in former irrigated lands, at present withdrawn from agriculture. The results of our investigations were: a) accumulation and redistribution of salts in the soils of the studied region are complex processes and depend on periodical change in the Caspian Sea level and on anthropogenic loads; b) primary (initial) soil salinity has only remained in the Western Ilmen region; c) in the Volga Delta, the salt-affected soils have extremely variegated composition of salts. Soils which were irrigated have a specific salt profile where the upper part of soils is free from salts and sulfates prevail; d) the cessation of irrigation on many plots changed the hydrological regime of the soils and initiated the development of secondary soil salinization; and e) micromorphological studies identified trends in the salinization-desalinization processes and enabled the differentiation of the salt and gypsic neoformations according to their age.

Salt-affected Palaeosols buried under a rampart in the Dry Steppe Zone of the Lower Volga Region as indicators of climate change in the past 300 years

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The Dry Steppe Zone in the European part of Russia is one of the best studied territories with regard to the history of interactions between human society and the environment. In recent decades, one of the key factors affecting the character of pedogenesis on the East European Plain in the Holocene is climate change, which has been studied in this area by Russian and European scientists with the use of the pedo-archaeological methods. In essence, it consists of a comparative study of background surface soils and palaeosols buried under archaeological monuments of different ages with known dates of their construction.

Cyclic changes in the climate of Europe during the past millennium have already been confirmed by palaeosol data. In particular, changes in the degree of climatic humidity of semi-arid territories are reflected in some labile soil properties, such as the degree and character of soil salinity. In relation to the increased interest in the dynamics of the climate in recent centuries and their impact on the environment and on the economic activity of humans, it is a challenge to search for any kind of evidence for the pattern of climate change.

In this context, ground fortification embankments (ramparts) and the palaeosols buried under them are of great interest. In the Dry Steppe Zone of Russia, such ramparts were created to protect Russian borders from invasions by Steppe Nomads in the late medieval period and in the 16th–18th centuries. Often, their length reaches tens of km. Archaeological data and written historical documents make it possible to determine the year of their construction. Palaeosols buried under such ramparts are unique objects to trace the history of pedogenesis and the environment in previous centuries.

Soil Salinization as Affected by the Cryoarid Climate in the Permafrost Zone of Yakutia

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The genesis and geography of salt-affected soils in the permafrost zone of Yakutia are discussed. These soils are found in three different types of landscapes: in the coastal area of the Arctic Ocean, in river valleys and in thermokarst depressions (alases) within the ancient alluvial plain in Central Yakutia. The chemical composition and genesis of salinization are quite different in these regions. Salt sources and mechanisms responsible for salinization are also different. The geography and genesis of salt-affected soils in Yakutia are highly dependent on local cryoarid climatic, palaeohydrological, lithological and geomorphic conditions, affected by the Arctic Ocean and the presence of permafrost.

River salt loads as influenced by irrigation development in the Bardenas Irrigation Scheme (Spain)

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This work used non-parametric methods to assess the trends in monthly flows, salt concentrations and salt loads in the irrigation water, the upstream inflows to—and the outputs from—the Bardenas Irrigation Scheme (BIS, ca. 80 000 ha) in the Ebro River Basin (NE Spain) from the records of the Ebro Basin Authority (CHE) from 1973 to 2004.

The flow decreased and salt concentration increased at all stations. The decrease in flow/increase in concentration was significantly greater in the downstream stations collecting the irrigation return flows (IRF) from BIS (Arba River at Gallur, ARBGAL and Aragón River at Caparroso, ARACAP) than in the upstream stations (Aragón River at Yesa dam, where irrigation water is diverted, and Irati River at Liédena). The increase in concentration was overridden by the decrease in flow causing an overall decrease in the salt loads. The potential uses of IRF in ARBGAL and ARACAP are being impaired by their increasing salinity, but the overall effect of the BIS on the salinity of the receiving Ebro River is decreasing due to the decrease in export loads.

The salt-land soil system placement (taxonomy) in relation to global changes and challenges

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The development of new concepts for the improved utilization of soil that best meet the demands of diverse social, economical and environmental needs is the challenge facing scientists and decision makers today.

Global demand for food and fibre to ensure the survival of the increasing population and desired higher standards of living create challenges and may require utilization of scarce soil resources. Food production will need to increase 38% by 2025 and 57% by 2050 if the current global food supply is to be maintained. Nearly all of the most suitable soils are currently in cultivation and this increased demand will require expansion into new areas and reclamation of degraded lands.

In addition to increasing the area of land under cultivation, there is an urgent need to increase the yield per unit area. However, an estimated 15% of the total land area of the world has been degraded by soil salinization and erosion. Productivity must become more efficient as an ever increasing arable area succumbs to degradation.

World Soil Resources (FAO/UNESCO) and other data report that climatic variations are the basis for determining global distribution of saline and sodic soils (>900 Mha). Despite prevailing focus on arid and semi-arid areas, most climo-ecological regions in the world are not free from salinization.

The worldwide soil system is multifunctional, including serving as a source and sink for CO_2 to combat climate change. This system is expected to alter with the warming climatic trend and changing distribution of rainfall. These changes will affect soil dynamics through intensity of weathering, transformation and translocation of minerals, rates of biological activities and chemical reactions. A unique systematic classification and correlation network is required to evaluate these changes, enhance food security, reduce stress on fragile ecosystems and most importantly, monitor the evolution of salinization worldwide.

The FAO/UN and US Soil Taxonomy systems and several others as Remote sensing, GIS, Land sat data, have been applied worldwide for classification/ characterization of saline soils on smaller scales.

However, on the basis of this author's global experiences in teaching, research and mapping soils, sustainable restoration/ reclamation of salt-affected soils may not be achieved without development of a unique and "Integrated Classification System". Therefore, it is suggested a new order "SALSODOSOLS" should be created that will be utilized for classifying saline/sodic soils globally. This classification would place soils uniquely to the level of mapping/farmland Units on a global and larger/workable scale.

Utilization of such a system then would allow soil scientists to correlate and harmonize similar mapping units located in unique agro-ecological/physiographic zones under one name, resulting in an effective transfer of knowledge worldwide, enhancing reclamation/ management practices, and improving decision making relative to land use to enhance productivity and meet the demands of growing population.

Chernozem and chestnut soils of South Russia long-term vulnerability to irrigation and salinization (learning from past experiences)

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A long-term study of irrigated Chernozem and chestnut soils and corresponding rainfed soils of South of Russia was carried out. In the Chernozems, an increase in oozy particles in the arable horizon due to the process of clay formation, profile distribution of silt is observed. In the arable horizon of the Chernozems, humus losses of 15% (stale water from river Don) and 22–23% (mineralized water from Veselovsky storage lake, Manych river) were observed. In chestnut complexes of soils, the geochemical scope of a landscape is up to 4–10 times greater. The total soil salinization increases sharply. Irrigation of Chernozems and chestnut soils results in local hydromorphic formation. The structure of soil cover variability strengthens. Exception of laterally stereotyped vertical convection-diffusion water salt transfer in soil at watering and washing out of a soil continuum is proposed.

Salt-affected soils and climate change in the Valle del Cauca, Colombia

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This study provides an overview of the evolution of soil salinity and the salinity programmess in the Cauca River Valley in the period 1980–2009. A description of the environmental conditions in the region studied and the programmes that have been followed for monitoring and control of salinization of soils are presented.

In order to assess the evolution of salinity, pilot projects in areas delimited by rivers flowing into the river Cauca were initiated. The study shows that of the 41 200 ha monitored, 20 830 ha still have some degree of salinity. According to the spatial and temporal assessment of soil salinity in the Cauca River valley, the process of salinization of the sector in general has remained constant, as much in the affected areas and also in the degree of salinity during the period of study. Some local areas showed a slight decrease in saline condition during the study period. It has been found that the region is very sensitive to climate variation events, such as those associated with the El Niño Southern Oscillation (ENSO), which suggests the sensitivity of the region to a change of climate. Among the environmental effects for the study area there is expected to be an impact on soil moisture balance. Several recommendations are given for both the monitoring process of salinization and to promote extension programmess for adaptability to climate change impacts.

Genesis of soils with petrocalcic horizons and alkaline soils in a volcanic landscape: Analysis of climate change scenarios on soil use

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Diverse types of soils are present in the volcanic watershed of Libres-Oriental, situated in the centre part of the Neo-volcanic Mexican Axe, providing different environmental services according to their properties that can be described, as a whole, under the concept of soil quality. The objective of this work is describing the major types of soils present in a part of the watershed where can be recognized the existing topographical relations that drives the salinization-alkalinization processes appearing in the bottom part of the watershed, discussing their quality in terms of environmental services and making an evaluation of the possible impact of climate change on soil use.

Emerging challenges of climate change on salt-induced land degradation and water quality deterioration in peri-urban areas

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The scarcity of fresh water has driven farmers in water scarce countries and regions to use alternative water supplies for irrigation. In peri-urban areas, urban wastewater is often used to irrigate a range of crops in support of urban markets as well as the livelihoods of farming communities. As in many developing countries wastewater treatment is insufficient and the water may contain different types and levels of undesirable constituents. Long-term irrigation with untreated, partly-treated, or diluted wastewater may pose potential health and environmental risks. Emerging events of climate change under such conditions are expected to trigger environmental degradation—extremely low rainfall providing insufficient water to leach salts and other constituents from wastewater-irrigated soils, while high-intensity showers leading to surface runoff and transport of salts and contaminants to nearby good soils irrigated with fresh water or rain-fed. The same applies to surface and groundwater quality.

Environmental impact assessment of peri-urban areas reveals build-up of undesirable constituents in wastewater-irrigated soils and groundwater as a result of changes in rainfall pattern. Salt, nitrate, metal, and metalloid concentrations were found in excess of the critical limits in certain areas as a result of rainfall distribution patterns stemming from climate change events. Therefore, monitoring of water and soil quality in wastewater irrigation schemes is important, particularly where groundwater is used for drinking purposes. In addition, there is a need to develop pertinent models that can predict changes in water and soil quality and to develop management strategies minimizing soil and water quality deterioration in peri-urban areas as a result of climate change.

Temporal changes in the micromorphology of reclaimed Solonetzes in the south-east of European Russia

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Modern trends of soil processes in reclaimed salic Solonetzes sampled with an interval of 20 years were estimated with the use of micromorphology. Salt pedofeatures and their microfabrics proved to be sensitive indicators of processes taking place at the interface between the soil matrix and pore space. In 20 years of reclamation of the Solonetzes, an increase in the degree of homogeneity of the plough horizon and its biogeneity, a decrease in the number and diversity of calcareous and gypsiferous pedofeatures, and a general intensification of ameliorative processes took place.

An ecological approach for proposing and describing a new type of soil salinization

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At present, soil science describes two major types of soil salinization: primary (native) and secondary (anthropic). While the first type is developed due to natural geological, hydrological and pedological processes, the second refers to human-caused factors, mainly as a consequence of improper irrigation management. But sometimes using an ecological-anatomical approach in understanding the interrelations at the level of rhizosphere could reveal new and interesting aspects. For instance, it may be possible that plants induce soil salinization due to a set of anatomical adaptations, allowing them to absorb, conduct and excrete saline solutions. *Tamarix ramosissima* shows the "ideal" example of a plant able to produce soil salinization. This is a halophyte species, being also a phreatophyte, meaning that he has specialised roots that can draw water from deep underground. In addition, the leaves of *Tamarix* posses specialised salt glands, which exude high amount of salts, raising the salt content of the soil, leading to loss of saline-intolerant native plants and pasture. It may be assumed that species with no deep root system, which are not exploiting the salt water table, are exposed to a salinity "provided" by secretory activity of *Tamarix* species. In this way, non-tolerant salt plants are eliminated by the incremental salinity in the rhizosphere. Since salinity occurred as a result of whole plant activity (*Tamarix*) and affecting other species with no salt-copying mechanisms, we suggest that this new type of salinization be called *phyto-salinization*. The place and the relevance of this new proposal in soil science would be specified by further considerations.

Monitoring soil moisture and electrical conductivity (EC) with sensors

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Management of irrigation requires building a picture about how water, nutrients and salts move and accumulate in the soil. This understanding has to be integrated into a more complex farm management scheme, where strategic (slow processes, long term and watershed scale) and tactical (faster processes, short term and plot scale) decisions have to be assessed and made. In a global scenario of increasing food and fibre demands, with important soil degradation problems, and the scarcity of fresh water for irrigation, there is a need for on-farm practical tools for managing water, salt and nutrients in the root zone. Monitoring soil moisture and salts provides an important part of the picture. Relatively new sensors and techniques are available to monitor such variables, such as combined FDR and EC probes and a wetting front detector (WFD). This work shows some basic laboratory exercises done with two commercial products, the 5TE capacitance probe from Decagon devices (Pullman, WA, USA) and the Fullstop® WFD (CSIRO, Australia). These practicum examples may help understanding how these types of instruments work and how to act on the information they provide.

Soil salinity mapping using electromagnetic induction and geostatistics: Case study of Tadla plain, Morocco

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The effective control of soil salinity requires the knowledge of its magnitude and its spatial and temporal variability. Soil salinity is determined by measuring electrical conductivity of a saturated paste extract (ECe). Since it is variable, numerous samples are necessary, which makes the conventional procedure laborious and expensive. Alternatively, soil apparent electrical conductivity (ECa) can be measured in field using electromagnetic induction (EMI). The study area covers 2 060 ha in the irrigation district of Tadla, central Morocco. Twelve samples were taken for determination of ECe while 112 ECa measurements were done using the EM38 instrument (Geonics). The calibration equation ECa-ECe was used to convert ECa into ECe. Geostatistics was used for modelling its spatial variability using the variogram and by interpolating to non-sampled locations by kriging. The results showed that the study area presents various degrees of salinity. In conclusion, combined use of ECe, EMI and geostatistics allowed establishing a reliable soil salinity map. This could serve as a basis for any rehabilitation effort of salt-affected soils according to their actual degree of salinity.

Monitoring temporal stability and/or change of spatial patterns of soil salinity in the context of a changing climate

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Soil salinization is accentuated by climate change, mainly due to spatial and temporal changes in temperature and precipitation. Soil electrical conductivity, obtained from a 1:2.5 soil/water extract ($EC_{2.5}$), was analysed to check temporal stability/change of spatial salinity patterns using Spearman rank correlation and relative differences. Sampling of 20 locations (25 ha) was repeated 19 times (1994–2001). Soil salinity showed strong temporal stability. Rank correlation confirmed persistence of ranking of locations. Using relative differences, three classes of soil salinity were identified: low saline locations which were the most time stable and are associated with waterlogging and/or salt leaching zones; high saline locations which were the least time stable and located exclusively in salt accumulation zone; and locations representative of average field soil salinity which had temporal stability similar to low saline locations and were found in all three zones. Using only two locations, average soil salinity was adequately estimated. The methodology can easily be applied to longer time period and at larger spatial scale for different ecosystems to identify the impact of climate change on soil salinization and select specific locations for monitoring soil salinity with time.

Indicators of impact of climate change on salinity distribution and land-use in Sudan

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As a result of climate changes, there is a negative impact on many countries including Sudan**.** Climate change in some states of the Sudan appears evident from variability in both annual rainfall and distribution with time. This is also reflected in temperature variation. Sudan's economy, like many developing countries, is dependant on agriculture and associated industries, which are contributed to a high extent in the rural development of major farmers groups, who depend on rain-fed agriculture and natural pasture and range. This study is concentrated on the negative impact of climate which leads to drought and consequently to land deterioration which resulted in secondary salinization and vegetation cover degradation. Six locations were selected to represent the effect of climate change on different zones of Sudan: Dongla, Khartoum, Gezira, El-Obeid, Gedarif and Kassala.

Increasing temperatures may result in high evaporative conditions that may activate the capillary rise of salts leading to soil salinization. The results of this study showed a significant increase in salinity in Dongla area in the north where the annual rainfall is the lowest compared to the others in the south, Khartoum and Gezira. Fluctuation and erratic distribution of rainfall together with increase in temperature have an impact on the fertility of soils in the study area and this consequently leads to a reduction in crop productivity and decrease in biodiversity. These factors lead to more degradation of natural resources and displacement of rural people to urban areas. Studies have shown that heat stress, drought and floods have negative impact on animal breeding by reduction of weight gain, food intake and milk production. Sudden heavy rains in different parts of the country including Khartoum, Gezira and El Obeid have caused floods and heavy losses in livestock. A conclusion has to be drawn towards identification of some important research areas aiming at adaptation and mitigation to climate change in Sudan.

Evaluation of the spatial variability of soil salinity patterns by using geo-pedological approach: A case study in arid and semi-arid regions

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The spatial prediction of soil salinity patterns in arid and semi-arid regions has a special importance in the understanding of heterogeneity in landscape, the investigation of the causal processes, and the protection of the potentially vulnerable areas from more degradation. The aim of this study was to develop a multifarious exploration into spatial structure of saline soils to deal with different aspects of salinization, forming factors, distribution in landscape, and vertical variability in soil profiles in a GIS environment in Kermanshah, Iran.

The geo-pedological approach developed by Zinck (1998) was implemented to delineate the boundaries between different geomorphic surfaces. Salinity indicator attribute maps (EC, pH, SAR, ESP) were prepared to evaluate their variation in geo-pedological units. The geo-pedological units were distinguished by interpretation of aerial photos, Google earth image along with DEM. The piedmont landscape of the study area consists of apical, medial and distal landforms. According to the salinity heterogeneity, a grid sampling scheme was designed at three depths. Based on fieldwork and obtained laboratory results, the geo-pedological map was prepared and its corresponding legend was constructed.

The ANOVA results indicated that there were great differences in soil properties (EC, pH, SAR, ESP) and clay percentage between different landforms. The average values of EC, SAR, ESP and their extent were raised from apical to distal. Vertical soil salinity decreased in soil profile from topsoil to subsoil, especially in distal part, due to the capillary action of groundwater and water evaporation from the soil surface. The variation of EC, SAR, and ESP in the surface layer (0–20 cm) was significant while the variation of pH was not significant. The distal part was highly affected by salinity due to its location on the lower part of fan, draining the excess irrigation water from upper farms, and soil properties. The apical and medial soil types were classified in Entisols, while the soil of the distal part was under Aridisols order, which approves the effect of geo-pedological processes on soil types. In fact, the salinization process origins from both natural landscape processes (catena model) and anthropogenic sources. The distribution of soil salinity classes was: saline-alkaline (42.7%) and alkaline (0.8%) in surface layer, non-saline-alkaline (31.2%) and saline-alkaline (19.7%) in subsurface layer, and non-saline-alkaline (33.7%) and alkaline (2.1%) in subsoil layer.

According to these results, the pattern analysis in the prediction of soil salinity by using geo-pedological approach can be considered as an appropriate tool to assist decision makers and authorities in environmental management and large scale planning.

Salinization of soils and aquifers: The case of the Yaqui Valley, Sonora, Mexico

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The Yaqui Valley is predominently an agricultural region with an irrigated area of the order of 233 000 ha, where as much surface waters as groundwaters are used for irrigation. The average annual extraction from the system of dams in the Yaqui River is 2 300 million m^3 and that of the regional coastal aquifer is 270 million m^3. The objective of this paper was to analyse the problem of salinized groundwater in the valley and to determine the causes. In periods of drought, when the volume of the water in dams is lower than average, extraction from the aquifer is increased, being on some occasions more than the recharge rate, which corresponds to 450 million m^3/yr. This situation increases the risk of saline intrusion of the coastal aquifer. Also, at times of high precipitation, infiltration from agricultural land may reach the aquifer, elevating phreatic levels towards the surface. Climatic conditions also increase the risk of salinization of waters and soils, since the potential evaporation in this region is of the order of the 2 000 mm/year. This situation induces direct phreatic evapotranspiration, increasing the salinity of the water and of the soils. The salinity distribution of the aquifer identifies an area of saline intrusion (>5 000 mg/l of TDS), which was not generated by encroachment of the hydraulic gradient on the phreatic levels during periods of higher extraction than recharge, but by infiltration of sea water from ponds of shrimp farms on the coast. The aquifer areas of the continental interior that contain brackish water (between 1 000 and 5 000 mg/l of TDS) have their origin in the dissolution of evaporites or from leaking sandy loam strata. The identification of the causes of the problem of salinity in the valley will facilitate the strategies of prevention and remediation of the salinity of the water and soils of the valley. The construction of 2 350 km of agricultural drainage with the complement of other actions has already enabled the recovery of 28 000 ha affected by salts.

Assessing the relationship between the soil dielectric constant and electrical conductivity using 5TE sensors in the field conditions

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A theoretical model to describe a linear relationship between bulk electric conductivity and dielectric constant is frequently used in the litreature. Some authors recommend an offset of that linear relationship of 4.1 for most soils. In our preliminary field experiments (loamy sand soil) two 5TE probes (measuring water content, temperature, and bulk EC) were used to show that the calculated offset of a linear model including bulk electrical conductivity and dielectric constant, differs according to the water content.

Climate change, salinity and irrigation in southern Italy

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The climatic changes induced by global warming are expected to modify agricultural activity and consequently the other social and economical sectors. In this paper, a three-year Project, funded by three Italian Ministries (University, Agriculture and Environment) and involving Italian Research Institutions of Agricultural National Council is described. After presenting the different types of methodologies that we are applying, the results will be presented with particular reference to the first workpackage (WP). The objective is to characterize two areas in the southern part of Italy subjected to intensive agricultural activity. The characterization of the two areas is based on spatially distributed data concerning the soil, the climate and soil use. Several techniques of data spatialization, clustering, geostatistical analysis and GIS are utilized in order to achieve homogeneous areas. Informative layers of GIS about land use, soil properties and climate are produced to describe the two areas.

TOPIC II. PREVENTING AND MANAGING SALINIZATION UNDER CLIMATE CHANGE THREATS: LEARNING FROM PAST EXPERIENCES, INTRODUCING NEW TECHNOLOGIES AND FACILITATING THE EXCHANGE OF KNOWLEDGE

The effect of salinization and climate change on the biomes of South Africa

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South Africa is both a climatically sensitive and water-stressed country. Much of the country is arid or semi-arid and is subject to droughts and floods. Any variation in the salinity, rainfall or temperatures would thus exacerbate the already stressed environment. Through the whole debate about climate change the underlying view is that the world's climate should stay exactly as it is. The soil and geological records tell us that this is a vain and naïve hope. Instead, it tells us that dramatic change is to be anticipated. Long-term global trends in late Cenozoic climate/oceanographic/sea level evolution are mediated by fundamental geological processes such as the changing configuration of landmasses. However, the underlying forces driving some major trends remain obscure.

There is considerable evidence for several humid cycles, with intervening arid episodes, during the latter part of the Pliocene and the Pleistocene. It was during such humid cycles that pedogenesis and bioturbation occurred within older colluvial or aeolian sediments to form transported sandy soils of mixed origin over large areas of South Africa. Lower winter rainfall conditions in the western part of South Africa are of fairly recent origin. These changes are partially preserved in deep weathering profiles, often capped by paleo-features that are out of phase with present day conditions, such as silcretes or ferricretes in the western arid regions of South Africa. Salinity is in some areas clearly not solely a function of present day climate, therefore the prediction of future salinity conditions in a biome or region is problematic.

Effects of an alternative water source and combined agronomic practices on soil salinity and irrigated cotton in coastal saline soils in China

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The ongoing experiment for cotton crop (*Gossypium hirsutum L.*) was conducted at the Zhongjie Farm, Huanghua city of Hebei province in the coastal salinity-affected areas in North China Plain, to determine the effects of an alternative of irrigation water sources/methods and agronomic practices on the changes in soil water-salt contents and soil pH during cotton growth stages, and also on seedling emergence and yields of cotton. The experiment was set-up using split-plot design with two water sources as main treatments (well water/desalinized sea-ice water); two irrigation methods (+PAM (Polyacrylamide) /-PAM); and four fertilization modes: check (CK), mineral fertilizer (F), mineral+organic fertilizer (FM), and mineral fertilizer+gypsum (FG).

The 10-cm top-soil salt contents at seeding decreased by about 18%, 32%, 34% and 55% with F, FM, FG and PAM under well-water irrigation, respectively, and by about 40%, 23%, 23% and 58% with F, FM, FG and PAM under sea-ice water irrigation, respectively, as compared with PAM-untreated CK. Using PAM-treated irrigation, the 10 cm top-soil salinity significantly decreased to about 2.3–3.9 g/kg from 4.6–8.6 g/kg (PAM-untreated). The top-soil salt contents at seeding stage also adversely affected seedling emergence ($r = -0.71^{**}$), and resulted in yield reduction ($r = -0.50^{**}$). PAM-treated irrigation, either using well-water or desalinized sea-ice, in combination with gypsum, shows the best practice for soil desalinization, and hence seedling emergence and cotton yields, and could be acceptable for crop irrigation in the coastal saline areas.

Molecular characterization of shoots and roots protein contents of salt-stressed barley seedlings inoculated with *Azospirillum brasilense* NO40

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The present work was performed to study the effect of inoculation with *Azospirillum brasilense* NO40 on the protein pattern of shoots and roots of the seedlings of two barley cultivars (Giza 123 and Giza 2000) which are known for their different tolerance to salt stress. A greenhouse experiment was conducted to evaluate the effect of this inoculation on the molecular masses of the protein contents of both studied barley cultivars cultivated under 350 mM NaCl through the determination of SDS-PAGE protein profile of shoots and roots. The results showed that the salt stress, bacterial inoculation and the interaction between them resulted in noticed change in the protein patterns of the shoots and roots in all treatments.

Data mining on soil salinity analysis

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Soil salinity is considered as one of the most serious environmental problems in arid and semi-arid regions which limit sustainable development. For this reason, the development of early warning systems for monitoring and reducing salinity impacts is an important global issue. The lack of up-to-date and available ground observations necessitated the use of remote sensing images for monitoring. The human mind cannot deal with considering each image individually, analyzing it and understanding its relationships with other images at various time steps. Hence, for solving such problems, issues of processing large sets of remotely sensed data using automatic techniques become important. But the understanding of salinity and the use of appropriate methods for extracting information from available remote sensing data is very important in the processes of automated salinity monitoring. In this study, the main objective was to develop a framework that applies image mining techniques for monitoring soil salinity automatically.

In the developed framework a soil salinity indicator (EC) was used to identify soil salinization from remote sensing data. As the central part of Iran is highly affected by the salinity, this area was selected as a case study during the period of 1989 to 2003. To achieve the objective, freely Landsat ETM+ in dry season (from Jun to September) were acquired between the mentioned time periods. 72 soil surface samples as a representation of the Kavir-Lout plain were collected to measure the surface soil salinity. The high correlation between the collected field data (measured EC) and the remotely sensed data (ETM+ band 3) was expressed by an exponential equation ($y = 0.0021 \exp(0.049x+0.04)$) with the correlation coefficient of $R^2=0.63$.

For validation thirty soil samples were used to assess the accuracy of the created soil salinity map. The overall accuracy of soil salinity map was 85% with the Kappa index of 53% which is an acceptable accuracy for this classification. Fuzzy set implemented to overcome the low accuracy of prepared map. For evaluation of the spatio-temporal changes of soil salinity, the obtained equation was applied to band 3 of each Landsat image to create soil salinity maps of different years. To characterize the spatial soil salinity, the identified membership function based on measured EC was applied on the series of TM images. In extraction process, the tracking of salinity objects was facilitated depends on salinity object definition. In this study the definition was kept at pixel-level object. An algorithm has been automated to extract all possible salinity objects from the images. To perform the spatio-temporal analysis of salinity, the salinity objects were traced based on two criteria; intensity and temporal continuity at locations. The consideration of these two criteria in salinity analysis helps to delineate the severity of salinity not only based on intensity but also on duration.

EC by itself does not indicate saline or non-saline soil surface, in the process of understanding salinity from the images the deviation values was calculated to identify the severity of salinity on soil surface as the deviation of current EC values from their corresponding long-term mean EC values. For each location, this deviation was calculated. For validation of the developed algorithm, the outputs were compared with the reports describing salinity on the region and the previous prepared soil salinity maps. The result revealed the proposed framework can be considered as cost and time effective tool in large scale planning for assessment of the spatio-temporal characteristics of soil salinity. The software used in the study were ILWIS 3.3, ArcGIS and PYTHON.

Global Response to soil and water salinization in agricultural landscapes

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The global population is projected to exceed 9.1 billion by 2050 and the food production will need to increase by more than 50% to feed the increased population. As land becomes increasingly scarce, the additional food needs to be produced through crop intensification. In arid and semi-arid regions sustainable management of land and water resources is of concern as a result of crop intensification. Poor irrigation and land management causes widespread soil and water salinity across regions of South Asia, Central Asia, Arabian Peninsula and North Africa and reduced crop productivity and livelihood of rural population. Recent estimates suggest that up to 50% of irrigated land became saline in some of these regions.

This paper focuses on the extent of and response options to soil and water salinization in arid and semi-arid regions. The response options discussed in this paper include integrated soil, water and crop management to prevent further salinization (mitigation) and sustainable use of salt-affected soils and saline water for crop and forage production (adaptation), and principles and practices for using salt-affected soils and saline waters.

Progress towards DSS-SALTIRSOIL: monthly calculation of soil salinity, sodicity and alkalinity in irrigated, well-drained lands

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The development of a decision support system (DSS) based on SALTIRSOIL for the precise management of irrigation water, crop and soil in agricultural lands under risk of salinization, sodification and alkalinization needed SALTIRSOIL to be able to calculate soil salinity, sodicity and alkalinity at monthly intervals. The new monthly SALTIRSOIL model has been developed and validated in three citrus orchards in the Almenara irrigitation area in Valencia (Spain). Comparison of simulations and measurements of electrical conductivity and sodium adsorption ratio in the saturation extract and pH in the saturated paste indicated the SALTIRSOIL is able to give reliable predictions of soil salinity, sodicity and alkalinity when the soil drainage is not impeded. Furthermore, the SALTIRSOIL model gives these reliable predictions in a cost-effective way because only a few basic water quality, climate, soil, crop and irrigation management information data are required to run the model.

GIS-SALTIRSOIL: a new tool to evaluate and modelling soil salinity at regional scale; an application to evaluate the climate change effect in an irrigated salinity risk area

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Soil salinization in irrigated areas is a soil degradation process that affects both crop productivity and environment. It is predicted that climate change could affect the precipitation pattern and/or increase the average temperature at the Mediterranean region. This new scenario can be simulated with the SALTIRSOIL model to know the effect of climate change in soil salinization. This model was fully integrated within a Geographical Information System (GIS) framework to extend its applicability to the whole irrigation area of Segura and Vinalopo lowland (Spain). Three scenarios were simulated to evaluate the climate change effect in soil salinity: i) non-climate change ii) with climate change iii) same conditions as scenario ii but with an increase of 20% in irrigation rates. A total increase of 28% in soil salinity was simulated when comparing the current climatic conditions with the climate change scenario. An increase of 50 hm^3 of irrigation water could practically offset the effect of climate change in soil salinity.

Floodplain rehabilitation model in Hortobágy-Sárrét

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The biggest unbroken floodzone network of the Carpathian Basin before 19th century river controls lay in Hortobágy-Sárrét (9 331 km², between 46° 48' N and 47° 35' N, and 20° 55' E and 22° 04' E). As a result of the Carpathian Basin being uniquely enclosed in Alföld, at its deepest part, significant material accumulation processes take place. Due to persistant human destruction its indigenous vegetation has almost completely disappeared and 63% of the area characterized as agricultural is involved in cropland farming. The constant lability of the relationship between people and nature is signalled by the dramatic deterioration of social and natural conditions due to secondary salinization. By IPCC, EUN and numerous climatic model impacts of climate change will be negative (decreasing precipitation in growing period, increasing evaporation) in the Great Hungarian Plain (Alföld). The present form of landscape management (almost exclusive monocultural cropland farming) is unsustainable from the point of view of society, economy and ecology. It can be seen that the water management system of the Tisza Valley is incapable of managing floods, drainage water, salinization processes and intensifying aridity.

Our research into environmental history warns us to pay particular attention to forests, i.e. final associations of various floodzone successions. Of all the impacts that floodzone forests have on water circulation, the most examined is their bility to act as an aquifer and to reduce runoff water. We have highlighted the landscape degrading effect of salination so we may point out that the war on salinization in Hungary, as a result of unsustainable and destructive landscape management, has proved unsuccessful and, to date, 25% of the Alföld (ca. 12 000 km²) has fallen victim to salinization. As a result of the intensive water utilization of forests the root zone of trees pump up groundwater lying under them, stabilizing the groundwater levels at a lower level lower than elsewhere in the environment.

If groundwater level sinks below level C of three-phase soil, the streaming of salty groundwater in capillaries and the precipitation of salt in the upper layers of soil also comes to a halt. As a consequence of the geomorphological character of Hortobágy-Sárrét water inundating floodzones nearly every year streamed slowly down the landscape southwards from the north dissolving water-soluble substances, including salts accumulated either on the surface or near to it. Another impact of water coverage is that the saturation of soil with water stops capillary effect and leads to the infiltration of water from above. The only feasible solution against the phenomenon of the flow anomalies in salt-affected soils characterized by almost zero infiltration coefficient is to slacken the structure of salinated soils in the root zone. If the impact of rehabilitated floodzone forests on groundwater and soil structure continues together with the rinsing effect of inundations the process of salinization may be reversed.

Disaster risk reduction efforts and factors affecting flood disaster management: A case study of Katakwi district—Olupe and Ngariam camps

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The objective of the study was to establish factors that affected flood disaster management in Katakwi district. The study focused on 238 randomly selected internally displaced camp residents. Key informant interviews were conducted and data qualitatively analysed to assess issues that impeded successful mitigation of flood disasters.

Continued degradation of wetlands for crop cultivation and cattle over grazing were partly responsible for increased flooding during rainy seasons and drought during dry seasons. The absence of accessible micro finance credit schemes to support recovery efforts of the communities' drastically undermined measures to reduce the impact of flood disasters. The district was reported to have lacked contingency plans to show the risks and likelihood of related disasters occurring with potential effects at the community level hence impeding disaster management and preparedness. Both the government of Uganda and the local government of Katakwi district had not practically earmarked emergency funds for disaster response. The affected communities had no storage facilities for emergency relief items like medicine and food. The idea of having community level food stores and granaries died out and this amplified the flood disaster with famine making disaster management difficult. The poor nature of the community's temporary mud bricks and wattle roofed huts exacerbated the impact of the floods since many huts were just washed down prompting more relief items like tents straining the relief efforts.

A lack of awareness at the community level and alternative means of livelihood that do not constrain non-renewable resources have persistently provoked natural disasters in the district.

Utilization of brackish/saline water and salinization risk in centre of Tunisia

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In Kairouan and Mahdia area (Centre of Tunisia), the irrigated sectors represent about 20% of 400 000 ha irrigated in Tunisia. Most of these areas are irrigated by pumping groundwater from wells. In many cases, water has a high salinity of more than 4 g of salt per litre (between 4 and 6.5 dS/m). The over exploitation of groundwater resources induces a decrease of the aquifer's piezometric level and the degradation of its quality by saline water intrusion from the sea or sebkhats (salt flats). In some farms, irrigation is a new practice and the farmers have not enough experience to use water efficiently and to manage soil, water and plants under saline conditions. After some years, problems related to salinity are observed and decrease in yield is noticed. Studies show the feasibility of using saline water for irrigation in some cases. With regard to soil salinity evolution and salinity risks, soil salinity increases under irrigation until the equilibrium with the irrigation water is reached at about 6 dS/m. Many tonnes of salts are added to the soil but a large proportion is leached to deep layers. In the short term, soil salinity increases with irrigation and decreases with rain. In the long term, salinization of the aquifer may occur. In terms of the crop response, a large decrease in yield is observed, the amount varying with region, farmer and land parcel. This decrease is greater for summer and greenhouse crops than for winter crops.

TOPIC III. ALTERNATIVE LAND USE SYSTEMS/ECOSYSTEM SERVICES IN SALT-AFFECTED HABITATS

Plant based management of saline environments

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During the last few decades, net agricultural production has suffered a significant drop, though productivity per unit area has increased. This is mainly due to loss of productive agricultural areas by secondary salinization, among other factors. The three major approaches used to tackle the problem include soil management (mainly reclamation), water management, and plant based approaches. However, none of these approaches can be effective both technically and economically, unless worked out as an integrated measure.

A management strategy is needed to look at soil, water and plant based systems related to salinity conditions, whether on-farm, or at irrigation district or higher levels. A different approach needs to be taken at regional level, based on water quality/quantity, edaphic characteristics, climatic conditions, type of production systems, markets, etc.

Plant based approaches to use salt-affected lands and/or saline water, in economical and environmentally safe ways depend on the salinity ranges of soil, water (and groundwater) and other associated factors. The selected production system(s) not only help in halting further deterioration of the marginal lands, but also have direct commercial uses for food, forage/fodder, livestock industry, medicinal use, wood, etc. In addition to primary products, the use of marginal resources may also provide many secondary and indirect benefits, including bioenergy, carbon sequestration, phytoremediation, etc.

This paper will discuss the different approaches taken by the International Center for Biosaline Agriculture (ICBA) working in different countries and regions that have specific salinity problems. It will describe the salinity problem in the context of the overall water management issue and will focus on different management systems related to production. Case studies will be described from different regions of the world (especially from developing countries) to use marginal and saline resources for different types of agricultural production systems. The paper will also describe the economic and environmental benefits highlighted by the case studies.

Sustainable restoration of salt-affected soil through revegetation of *Leptochloa fusca* and *Sporobolus virginicus*

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Land degradation is a major global issue because of its adverse impact on agricultural productivity and sustainability. Population pressure along with the demand for more food, fodder and fuel has generated a chain of interrelated economic, social and environmental issues associated with land degradation, especially in developing countries in arid and semi-arid regions.

Restoring the productivity of saline lands through improving soil conditions, reducing desertification and raising the fertility of soils is one of the most important tasks. The biological restoration of saline lands by the use of halophytes could achieve this. Halophytes are geologically, physiologically and biochemically specialised plants which are able to function and produce in the conditions of saline soils. Domestication of halophytes will make a promising solution for increasing fodder supply and utilization of the abandoned salt-affected soils, and offers a low-cost approach to reclaiming and rehabilitating saline habitats. For this purpose, two pot experiments were carried out in the halophytic greenhouse of the National Research Centre, Dokki, Giza to study the mutual influence of soil salinity on growth, physiological aspects and some cations content as well as biomass production of *Leptochloa fusca* and *Sporobolus virginicus* plants.

The results showed improvement in the growth characteristics as well as biomass production of both species in the second season due to improvement of the soil salinity. Meanwhile, leaf/stem ratio increased with increasing soil salinity in both seasons. Increasing soil salinity significantly increased Na^+, soluble carbohydrates and proline concentration in the plant tissues. On the other hand K^+, K^+/Na^+ ratio and Ca^{2+} content decreased very slightly compared with the control. No clear effects were recorded for Mg^{2+}.

As for the effect of successive growing of *Leptochloa fusca* and *Sporobolus virginicus* on the soil quality, all cations, anions (except for HCO^{3-}), SAR, and electrical conductivity decreased in the soil by the end of the first season and reached its lowest values by the end of the second season. This may be due to leaching and the accumulation of salts into the leaves' vacuoles followed by excretion through the salt glands. *Leptochloa fusca* showed a greater effect on improving soil quality than *Sporobolus virginicus.*

What is stress? Concepts, definitions and implications for plant growth in saline environments

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Salinity imposes "stress" on plants, affecting plant reproduction and productivity, and hence, agriculture and biodiversity. However, there is no clear consensus on what plant stress is, and how to diagnose and assess its severity. Here, we build upon concepts from physics, medicine and psychology to formulate a novel plant stress concept, considering "eustresses" that enhance function, and "distresses" that have harmful effects. Taking the "General Adaptation Syndrome", a tri-phasic biomedical stress concept from 1936, to the molecular level, the "alarm" phase is defined by post-translational modifications and stress signalling involving cross-talk between hormones and reactive oxygen species, resulting in modifications to the transcriptome. Protection, repair, acclimation and adaptation are viewed as the building blocks of the "resistance" phase. The failure of protection and repair mechanisms, depending on dose and time of exposure to stress, results in "exhaustion", comprising cell and plant death. Implications for salt-tolerant and salt-sensitive plants are discussed.

Maximize the outcome of saline agriculture by integrating fish culture with field crops

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In achieving a more effective use of saline water, farmers could make an important contribution to agricultural industries in arid regions, particularly by maximizing farm production without increasing water consumption. Integrating aquaculture with agriculture has become a channel for increasing the use of limited water resources, decreasing dependence on chemical fertilizers and providing a greater economic return per unit of water. The aim of our study was to use an integrated system that would allow us to determine the effects of fish effluent irrigations on the growth and yield of field crops in an arid region. Our primary site was a tilapia (Oreochromis niloticus) fish farm in Oman that used effluent (EC = 3 and 6 dS/m) from the farm to irrigate tomato plants grown in soil-less culture. When tilapia were cultured intensively in tank systems, with low daily water exchange, some dissolved nutrients including magnesium, calcium, sulphur and boron accumulated to approach levels suitable for fertilizing vegetable crops. However, some key nutrients, including nitrogen, potassium and phosphorus were deficient.

There was a significant difference in growth rate of tomato receiving effluent compared to plants receiving fresh water. However, the effluent treated plants did grow significantly larger than plants that received only fresh water with no fertilizer added. Plant growth decreased linearly with increasing salinity of the effluent. The decrease in plant parameters with salinity was mostly due to a linear decrease in water and nutrient absorption.

In a preliminary trial, low-salinity, tilapia effluent was shown to support the early growth of tomato plants in a hydroponic culture system. Integrative methods used in this study may achieve nutrient recycling of otherwise unused waste materials, as well as nutrient and energy recovery; better sanitation; increased natural resource efficiency; low environmental loading; and low dependence on fossil energy inputs.

Combating salt stress in citrus orchards under semi-arid condition in the Negev desert of Israel

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Citrus is well known as a salt sensitive crop (due to their sensitivity to osmotic and toxic effects of salinity). About 37% (7 400 ha) of the Israeli citrus orchards are located within the Negev desert (a semi-arid climate with average precipitation of 280 mm per year) and exposed to salt stress. The origin of the salt is irrigation water (reclaimed waste water containing about 300 mg chloride per litre). While leaf chloride concentration until 1999 averaged 0.3%, it increased to about 0.5% in 2001 (this increase was associated with about 17% reduction in yield).

In the short term programme, a protocol for a soil analysis that allows growers to monitor their soil EC status under field conditions was developed. Additionally, the use of plastic mulch agro-technique proved effective for the reduction of salt accumulation in trees in young orchards (1–3 years old). For the long term programme, we characterized the link between rootstock salt sensitivity and carbohydrate status (a parameter that is strongly affected by scion characteristics and girdling treatment). A salinity/rootstock experiment and a protocol for early detection of salt stress using remote sensing technology are being developed. Different aspects of the various methods developed and their projected usage will be discussed.

An American legume, ***Prosopis strombulifera***, as a new model for understanding extreme salt tolerance

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The shrub *Prosopis strombulifera* (Lam) Benth is distributed from the Arizona desert (U.S.A) to Patagonia (Argentina) and is especially abundant in the salinized areas of central Argentina. This species showed a halophytic response to NaCl surviving up to 1M NaCl in *in vitro* experiments, but a strong growth inhibition at lower Na_2SO_4 concentrations. These differential responses to the most abundant salts present in most salinized soils make this species an excellent model to study salt-tolerance mechanisms in halophytic plants. This work provides an overview of different salt tolerance mechanisms in the native halophyte *Prosopis strombulifera*, which may be considered a useful new tool to improve crop salt tolerance through two biotechnological strategies: considering *P. strombulifera* as a natural gene donor to improve genetic salt tolerance of low tolerant crops, and considering this species and its rhizosphere as a natural source of Plant Stress Homeostasis-regulating Rhizobacteria (PSHR) capable of improving salt tolerance in crops.

TOPIC IV. EVALUATING HE EFFECTS OF CLIMATE CHANGE ON COASTAL AREAS, LAGOONS AND WETLANDS, INCLUDING ECONOMICAL, SOCIAL AND ENVIRONMENTAL ASPECTS

Salinity issues in Portugal: Coastal aquifers

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Salt accumulation in soils is a serious environmental problem threatening plant physiological processes and soil fertility. Whenever osmotic potential reaches certain levels, as a consequence of high concentrations of salts in the soil solution, plant development becomes limited since they experience many difficulties in absorbing all the nutrients and water they need. Salinity also affects the metabolism of soil microorganisms, and alters soil structure, reducing its fertility. This problem is often associated with irrigation in areas where low rainfall, high evapotranspiration rates or soils with poor drainage impede the washing out of the salts. The regular use of water with an excess of salts in irrigation will, in the short-term, may cause or aggravate soil salinization, putting stress on and limiting agriculture.

In Portugal's coastal areas, as in many other areas around the world, poor water management has impacts on aquifers of the region, which end up with salinization. Salinity problems can be related to over-exploitation of groundwater induced by the expansion of human populations, associated industry, and agricultural practices. These pressures, along with pollution events and climate change, are likely to combine to produce a severe decline of suitable water as well as to accelerate salinization.

Excessive water extraction, increase in the population, contamination and salinization of the coastal aquifers will reduce the safe yield of the water that can be supplied. Such a scenario makes water quality and sustainable use of groundwater resources major challenges to the scientific community, managers and stakeholders. In the scope of the Water Framework Directive (2000) and the Groundwater Directive (2006), a good ecological status of groundwater must be guaranteed by 2015. To achieve this goal, we need to develop a better understanding of the prevalence and significance of aquifers through the integration of multi-disciplinary approaches, identify the risks associated with poor management and develop sustainable management strategies to prevent the deterioration of these water bodies and to ensure compliance with the established legal framework.

Integrated management practices for increased crop production: Introducing salt-tolerant crop varieties in the coastal areas of Bangladesh

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Bangladesh is a deltaic country with total area of 147 570 km^2. The major part of the country (80%) consists of alluvial sediments deposited by rivers, e.g. Meghna, Ganges, Brahmaputra, Tista, Jamuna and their tributaries. Terraces with an altitude of 20–30 m cover about 8% of the country, while hilly areas with an altitude of 10–1000 m occur in the southern and northern parts. The coastal region covers almost 29 000 km^2 or about 20% of the country. The coastal areas of Bangladesh account for more than 30% of the cultivable lands of the country. About 53% of the coastal areas are affected by different degrees of salinity (4.0–25.0 dS/m).

Agricultural land use in the coastal area is very poor, much lower, (62–144% less) than the country's average cropping intensity (175–180%). Salinity causes an unfavourable environmental and hydrological situation that restricts normal crop production throughout the year. The coastal area receives huge amounts of fresh alluvial deposits every year. The land becomes saline as it comes in contact with sea water and continues to be inundated during high tides.

The factors which contribute significantly to the development of saline soil are: tidal flooding during the wet season (July–October); direct inundation by saline or brackish water; and upward or lateral movement of saline groundwater during the dry season (November–June). Salinity problems will be exacerbated by climate change and sea-level rise; decrease of upstream flow due to Farakka Barrage in the upstream of the Ganges River; horizontal expansion of shrimp firms; and due to construction of the coastal embankment. The severity of the salinity problem in Bangladesh increases with the desiccation of the soil. The effect on crops depends on the degree of salinity at critical stages of growth, which may reduce yield and in severe cases causes total yield loss.

Soil reaction values (pH) range from 6.0–8.4 in the coastal region. The organic matter content of the soils is also low (1.0–1.5%). Nutrient deficiencies of N and P are quite dominant in saline soils. Micro-nutrients deficiency such as Cu and Zn are widespread. During the wet monsoon, the severity of salt injury is reduced due to dilution of the salt in the root zone of the standing crop. The dominant crop grown in the saline areas (July–October) is local transplanted rice with low yields. The cropping patterns followed in the coastal areas are mainly fallow–fallow–transplanted rice. The salinity problem in Bangladesh has received very little attention in the past.

Due to increased demand for food crops by an increasing population, it has become imperative to explore the potential of these lands for food security. High potentials of the area for increased crop production can be achieved by introducing salt-tolerant crop varieties and intensifying cropping through salinity control, improved irrigation and drainage systems and better soil and water management practices. Mutation breeding for evolution of salt-tolerant crop varieties coupled with biotechnology in laboratory and field level studies has provided an opportunity to develop salt-tolerant rice and other crop varieties. Isotopic tracer and nuclear techniques have provided the

potential for exploiting the saline soil for better fertilizer, soil and water management practices in the coastal area. The findings of this research are that there is a potential for future exploitation of the saline areas to reduce food scarcity and poverty, increasing food security.

Soil water and salinity modelling aimed at sustainable agriculture

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Evapotranspiration by crops and bare soil increases salinity in soils, in particular when irrigation water and groundwater is of poor quality. Critical conditions are defined by threshold values defined in terms of sodicity, above which soil structure is destroyed and thresholds defined in terms of salinity, above which crop yield starts to be reduced. Numerous models for salt and water transport are available and approaches range from steady state to transient process descriptions which are mathematically complex and numerically intensive. Descriptions of crop growth as dependent on salinity are rather more limited in physiological detail. When striving for soil-vegetation models which are balanced in terms of detail, quantitative descriptions of crop physiological responses seem to be limiting the approaches available.

In this presentation, we will give an overview of some currently actual issues in the scientific debate, on water availability from the perspective of the soil physicist and hydrologist. These issues involve whether or not the stresses from water availability and soil water salinity (osmotic effects) should be conceived as additive or multiplicative. This debate is illustrated with detailed mechanistic modelling. Furthermore, we show the effects of soil salinity on the water balance of the rootzone, in a stochastic ecohydrological systems analysis approach, results of which are used to indicate currently unresolved issues in soil water salinity research.

Impacts of climate change and sea level rise on wetlands agriculture: a case study from India

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Coastal wetlands face challenges from the changing climate and rising sea level, in addition to increasing anthropogenic activites. The issue is serious in developing countries like India where wetlands agriculture is vital in maintaining food security and where adaptation strategies are not well developed and not properly implemented. The Vembanad-Kol coastal agricultural wetland in India now faces environmental problems affecting the ecosystem and the livelihood of thousands of wetland dependent communities.

The Vembanad-Kol (also called Kuttanad) wetlands, the largest designated wetland in India lying in the south-western coastal state of Kerala, are rich in biodiversity, provide hydrological and ecological services and also support the livelihoods of thousands of rural people. It acts as a mechanism for flood control and pollution abatement. It provides income through fisheries, lime shell collection, rice and banana cultivation, duck farming, navigation, port facilities, tourism and the coir (natural fibre extracted from coconut husk) industry. It is a complex wetland system comprising of backwaters, marshes, lagoons, mangrove forests, reclaimed land and an intricate network of natural and man-made canals. The wetland system covers an area of over 1 512 km^2, of which 500 km^2 are 0.6 to 2.2 m below sea level. About 30% of its inhabited area was recovered from water. The northern region is more urbanized and industrialized. The five rivers—Pumba, Achenkovil, Meenachil, Manimala and Muvattupuzha—flow through the wetland to join the Arabian Sea. From these rivers, 10 000 Mm^3 water flows into the wetland in a year. In extreme years it can be as much as 15 000 Mm^3. Steep slopes in the eastern hills, the Western Ghats where the rivers originate cause fast flow of water in rainy season and results in flooding in the wetland. This acts as a natural flushing system that removes the wastes and wastewater in the wetlands into the Arabian Sea and minimises saline water mixing. The wetland is of high conservation priority owing to vanishing mangrove patches and declining diversity and population of fishes and other aquatic species and migratory waterfowl. It was declared as a Ramsar site by the Convention on Wetlands in November 2002.

Evaluating the effects of climate change on coastal areas, lagoons and wetlands, including economic, social and environmental aspects: A case study from Turkey

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The coastal zone is expected to be home to nearly 75% of the world's population by 2025. Nearly half the world's major cities are located within 50 km of the coast and coastal population densities are 2.6 times greater than those of inland areas. Heavy urbanization, demographic and industrial developments around this zone have worsened the situation. The coastal sprawl is highly affected by increases in tourism. In less than one generation, entire swathes of the coast have disappeared under concrete, causing irreversible damage to landscapes and loss of habitat and biodiversity. The effects of a drop in natural sediment input from rivers, illegal extraction of sand and inappropriate construction on the coast are combining to intensify coastal erosion, the economic consequences of which can pose a major threat. Demands on coastal zones are ever increasing leading to severe socio-economic and environmental problems in these fragile ecosystems. Despite growing awareness sustainable coastal management policies remain insufficient. The relative share of protected coastal areas remains low despite a six-fold increase over 25 years.

Climate is one of the two most important physical factors (the other being topography) determining the survival and nature of all living beings, from individuals and communities to populations and entire species, by heavily influencing the coastal ecosystems. This presentation gives a general account of the coastal zone ecology of Turkey and potential impacts of climate change on this zone.

Vulnerability of a coastal plain of Mexico to climate change

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The Pacific Coastal Plain of north-western Mexico comprises 445 Mha in Nayarit State. The origin of the coastal plain is related to marine transgressions and regressions which occurred in Pleistocene and Holocene times and controlled the formation of deltas at river outflows and beach ridges that enclose wetlands currently connected to the Pacific Ocean through coastal lagoons and tidal channels. Soil formation occurs under a warm sub-humid climate with tropical forests and mangroves, where Fluvisols, Feozems, Cambisols, Solonchaks and Arenosols are the dominant soil types.

The actual processes of change in the above-mentioned soils are post-Holocene desalinization, net carbon loss and tidal-driven saline intrusion in free aquifers. The future vulnerability of the coastal plain ecosystems and soils will be related to the tendency of sea level rise of 1.9 a 3.3 mm/year, a slight increase in precipitation concentrated over a shorter period, a mean increase of 1 °C on the maximum and minimum temperatures every 30 years, together with the change of regime of river flows due to the potential construction of infrastructure.

Application of a new seawater intrusion index: SITE method

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One of the main objectives of the Directives 2000/60/EC and 2006/118/EC is to achieve accurate quantitative and chemical status of groundwater bodies by 2015, therefore some work has been focused on selecting and designing methodologies to determine the state of groundwater bodies. In coastal aquifers, seawater intrusion processes lead to a large variation in groundwater quality. Consequently, in most cases only methodologies based on very simple approaches and elemental criteria can provide practical and universal results. In addition, these methods must meet two basic requirements: 1) ease of elaboration from simple and readily available data and 2) ability to provide realistic, discriminatory and understandable information. With these aims the SITE method, designed from the initial bases proposed by Ballesteros (2008), is presented. It allows characterization of the seawater intrusion suffered by a coastal aquifer from four basic parameters obtained quickly and easily: S = Spatial extent, I = Intensity of salinization, T = Temporal variability or seasonality and E = Evolution to medium-long term. Each parameter is determined by specific calculations based exclusively on chloride ion content within the groundwater body. The key output of the method is an index and typological values, which are easy to conceptualize and provide qualitative information and quantitative values for the most representative factors, i.e. extent, intensity and evolution of the intrusive process. This information will help to objectively determine the real condition of coastal groundwater bodies, allowing them to be compared with each other and to improve their management.

Part of the work described is included within an agreement between the Ministry of the Environment and Rural and Marine Affairs of Spain (Directorate General for Water) and the Geological Survey of Spain (IGME). As a result from its application to three Spanish coastal aquifers, the way for the estimation of factors has been redefined and the procedure for obtaining the SITE index has been outlined.

Pilot study of water quality control in the wetland plots of Valencia's Albufera (Spain)

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The Albufera of Valencia is one of the most important wetlands in Spain. Its ecological conservation status is preserved by regional and local governments that attempt to reverse, as far as possible, the degradation that it is has suffered.

Historically, the binomial nature-human action has remained a constant balance in the environment, but at the present time, human action and changing environmental conditions (less input of water, poor quality of these, etc.) has produced a rapid degradation of the environment.

This research study, which involves the installation of piezometers in several rice plots, was initiated to investigate the existence of salinization problems and the low yield of rice in some areas of the park. With the intention of finding out why these situations occur, we have temporally and spatially analysed groundwater and surface water.

Opportunities for sustainable utilization of salt-affected lands and poor quality waters for livelihood security and mitigating climate change through agroforestry systems

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Vast tracts of arid and semi-arid areas of the world are salt-affected (nearly 1 billion ha) and remain barren due to salinity or water scarcity. From the FAO/UNESCO Soil Map of the World, the total area of saline soils is 397 Mha, while for sodic soils it is 434 Mha. In India about 6.73 Mha land is salt-affected. These lands constrain plant growth owing to the osmotic effects of salt, poor physical conditions leading to poor aeration, nutrition imbalances and toxicities. Besides this large areas in arid and semi-arid regions of the world are underlain by saline groundwater aquifers and fresh water for agricultural use is a scarcity. The requirement of irrigation is more in the inland semi-arid to arid areas and the coastal belts, while the waterlogged areas need more drainage applications in conjunction with limited irrigation facilities.

Meeting the requirements of food and other agricultural commodities for the burgeoning population is a big challenge for the agricultural community. With the increasing demand for good quality land and water for urbanization and development projects, agriculture will be pushed more and more to the marginal lands and use of poor quality water for irrigation is inevitable.

With use of appropriate planting techniques and salt-tolerant species the salt-affected lands can be brought under viable vegetation cover. Further, in most of the arid and semi-arid regions the groundwater aquifers are saline. Cultivation of conventional arable crops with saline irrigation has not been sustainable. Concerted research efforts have shown that by applying appropriate planting and other management techniques (e.g. sub-surface planting and furrow irrigation), the degraded lands (including calcareous) can be put to alternative uses, where salt-tolerant forest and fruit trees, forage grasses, medicinal and aromatic and other high value crops can be equally remunerative.

Agricultural biosaline research and development in Oman

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Salinity is an ever-increasing problem in agriculture worldwide, especially in Arabian Gulf Countries. Improved genotypes that are well adapted to saline conditions are needed to enhance and sustain production in these areas. The Sultanate of Oman, the third largest country in the Arabian Peninsula, has about 72 588 ha currently under cultivation, of which fruits occupy as high as 58%, followed by perennial fodder crops (24.5%), vegetables (9.35%) and annual grain crops (8.20%). The Sultanate is categorized as an arid country with low rainfall and high evapo-transpiration (ET). Annual rainfall varies from less than 50 mm in Central Oman to more than 300 mm in the mountains. Groundwater is the main source of water for both domestic and agricultural use. Until the mid-seventies, water demand and supply were relatively well balanced. Subsequently high water demand has led to over pumping and prolonged lack of rains has reduced the extent of recharge. These situations have progressively deteriorated the quality of both water and soil towards salinity. The affected areas are mostly the farms near the coast, which have abundant but saline water.

Plant growth and yields are decreased by salinity, drought and other environmental stress conditions. The combined effects of aridity and soil salinity limit the range of crops that can be grown in Oman. In the Ministry of Agriculture, biosaline agriculture in terms of development and introduction of new crops and salt-tolerant varieties of existing crops has been given priority, along with the water focused solutions. Although the soil salinity problem has been consistently highlighted and emphasized in various surveys and integrated studies conducted in the country, soil and water salinity research has been inadequate in relation to the extent and severity of this threat. Severe deficiencies were observed in the salinity knowledge base. Therefore lack of relevant information and data is felt seriously at present. There is considerable government support for research in salinity tolerance in crop plants. In addition, the present practice of using fresh water to irrigate in Oman is limited and hence, research efforts on the use of brackish and saline water for irrigation required. In view of these facts, the Directorate General of Agricultural and Livestock Research has conducted several projects in the past two decades to select and promote salt-tolerant plants and technologies for using saline water. This paper describes significant findings of research in biosaline agriculture in Oman undertaken over the last 20 years, giving examples of successes in translating techniques from the laboratory to the farming community.

Salinity intrusion: Periodical monitoring results in the Sultanate of Oman

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The Sultanate of Oman is situated in the south-eastern part of the Middle East. The northern part of Oman is mostly mountainous, parallel to the coast and separates the fertile plain from the Interior region. The highest peak of this magnificent mountain range is Jabal Shams, whose altitude reaches more than 3 000 m above sea level. The central plateau of Oman is a flat table of carbonates sediments with occasional scattered sand dunes. The extensive sand desert of Rub Al Khali and Rymal AsSharqiyah, and widespread gravel plain covering large areas of the country are extremely arid. A second mountain belt is located in the southern part of the country. The Dhofar Mountains are up to 1 800 m high, and near Salalah they frame a small but important coastal plain.

Oman has an arid and semi-arid climate, generally hot and dry in the summer and mild in the winter, with the exception of Dhofar Governorate, which affected by the monsoon. The Sultanate is characterized by the lowest rate of rainfall and the highest rate of evaporation in the world. Rain is the main source of fresh water in Oman. The average rainfall in the Sultanate is about 100 mm per year and that rate varies between less than 50 mm in the centre of the country to about 300 mm in the mountains. The annual evaporation rate is estimated at between 3 000 mm in interior areas, 2 100 mm in the north and 1 700 mm in the south. There is a high rate of evaporation due to high temperatures and low humidity.

There has been rapid development of the water resources of Oman during the past forty years. The growing economy has brought an increase in urbanization with a demand for high levels of service and quality for water supplies. The challenges faced for water resources in Oman are increased water demand, low agriculture returns compared with the amount of water used and groundwater pollution .

The increase in groundwater use over the last thirty years, mainly as a result of uncontrolled extraction, particularly during the 1970s and 1990s has led to groundwater quality deterioration in some areas and to the inland flow of saline groundwater in coastal areas.

The government has sought to develop management plans and water resources development and these plans rely on a database and available hydrological information. So it established a hydrometric monitoring network covering all regions of the Sultanate. The strategy of water resources monitoring on several axes are to provide data for all water hydrological basins through periodic monitoring and modernize in an integrated database and, in addition, to identify areas that are exposed to a deficiency or pollution in water resources and to find quick solutions to cope with such problems. The hydrometric monitoring network in the Sultanate consists of 4 636 control points (rain, Wadi, Falaj, wells, water salinity, and dams) distributed throughout the Sultanate.

This paper reviews the monitoring activities of groundwater quality in the coastal plains of Oman for the period 1983 to 2010. It is clear that there is an increase in groundwater salinity in most of the coastal areas. This is an indication of aquifer over-exploitation. It is currently monitoring the levels and quality of 1 600 wells. The results of this project and possible solutions to the problem of salinity in Oman are presented.

Effect of climate and land use change to increase salinity impact in North-east Thailand

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Thailand is a country where agriculture has long been important for its socio-economic growth since A.D. 1238. Land area of around 21 Mha is currently under crop, 13 Mha are forests and the remaining 17 Mha comprises urban and public areas, sanitation, swamp land, railroads, highways, real estate and other areas. The climate of Thailand is classified as tropical savannah (the Central Plain, North, North-east and some part of Eastern Thailand), tropical monsoon (west side of Southern and Eastern Thailand) and tropical rainforest (east side of Southern Thailand). The average annual temperature is about 27 °C while the annual rainfall is in the range of 824–5 248 mm. The potential irrigated lands are scattered in every part of the country, with an area of 5 Mha or 23.8% of arable land, of which 46% is located in the Central Plain.

The North-east region of Thailand has a land area of 16.9 Mha or about one-third of the total area of the country. It comprises agricultural land (9.3 Mha), forest (2.5 Mha) and other areas (5.1 Mha). The geomorphological characteristic of this region is a plateau, uplifted from the sea with rolling and undulating topography. An average annual rainfall in this part of the country is below 1 100 mm; it shows irregular distribution, with long drought periods, and is concentrated in summer season, with high potential evapotranspiration rate always exceeding the precipitation, which promotes the upward movement of soil solution and concentration of salts in the surface horizons. Soils are mostly shallow and sandy, with low fertility and deficient in most plant nutrients. Soils in some parts of the region are severely affected by salinization, e.g. in large areas in Khon Kaen and Nakon Ratchasima provinces. The salt-affected areas occur on the lower slope and lowland, where the natural forest has been denuded.

In terms of agriculture, soil and land resources are important factors in agricultural production. However, many land areas in Thailand have changed since 1960 due to the rapidly burgeoning population, land use pattern changes and, in particular, the introduction of modern technologies. The most notable changes were: encroachment on natural forest, using marginal lands and mismanagement of soil and water that resulted in deteriorated soil and water resources, particularly anthropogenic soil salinization.

TOPIC V. ANALYSIS OF THE EFFECTS OF INCREASED SALINIZATION ON FOOD SECURITY AT NATIONAL, REGIONAL AND GLOBAL LEVELS

Facing the food challenge under climate change threats to land resources through increased salinization

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Soil salinity and sodicity problems are common in arid and semi-arid regions, where rainfall is insufficient to leach salts and excess sodium ions out of the rhizosphere. Nearly 6% of the total land surface is affected by either salinity or sodicity. These salt-affected soils are distributed throughout the world. More than 80 Mha of such soils are in Africa, 50 Mha in Europe, 357 Mha in Australasia and 147 Mha in Central, North and South America. Similarly, a large bulk of about 320 Mha of land in South and South-east Asia is under the grip of salinity.

Pakistan's agricultural system is predominately irrigated as irrigation water is the major driver of food production. Of the total area of Pakistan (80.0 Mha), 19.3 Mha are available for farming. Of these, irrigated agriculture is practiced on about 16 Mha (about 80%). The irrigated agriculture consumes about 90% of fresh water resources and contributes 80% to national production. Additionally, Pakistan's economy is heavily dependent on the export of agricultural goods and the textile sector depends on the cotton crop. Thanks to the elaborate irrigation network in Pakistan, farmers have obtained quite stable crop productivity. But ironically, soil salinity has emerged as one of the major factors responsible for low crop production after the introduction of canal irrigation system in the Indo-Pak subcontinent. It is an important problem affecting irrigated agriculture of Pakistan. Improper irrigation practices and lack of drainage have generally led to accumulation of salts in the soil, which are harmful to the crops. There is a major imbalance in the amount of salt entering and leaving the soil in Pakistan. This situation is very alarming especially for the Punjab region which is producing a major share of crops for the whole country. Intensive and continuous use of surface irrigation has altered the hydrological balance of the irrigated areas, especially the Indus basin. During the last years, various agricultural regions have significantly lost their productivity potential due to soil salinity. The substantial rise in the water table has caused development of salinity and waterlogging in large areas of Sindh, Punjab, Khyber Pakhtoonkha and Balochistan. Waterlogging is caused by high water table from canal seepage and impeded drainage. Salinity is caused by residual salt accumulation on land surface as a result of evaporation or due to high salt concentration of irrigation water. This paper discusses the possible benefits of using saline agriculture.

Effects of climate change on salinization in China

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The current research hot spot of climate change is focused on global warming. Global warming is the increase in the average temperature of Earth's near-surface air and oceans since the mid-20th century and its projected continuation. According to the 2007 Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC), global surface temperature increased 0.74 ± 0.18 °C during the 20th century. Most of the observed temperature increase since the mid-20th century was caused by increasing concentrations of greenhouse gases, which results from human activity such as the burning of fossil fuel and deforestation. Global dimming, as a result of increasing concentrations of atmospheric aerosols that block sunlight from reaching the surface, has partially countered the effects of greenhouse gas induced warming.

The IPCC report indicated that the global surface temperature is likely to rise a further 1.1 to 6.4 °C during the 21st century. An increase in global temperature will cause sea levels to rise and will change the amount and pattern of precipitation, probably including expansion of subtropical deserts. Warming is expected to be strongest in the Arctic and would be associated with continuing retreat of glaciers, permafrost and sea ice. Other likely effects include changes in the frequency and intensity of extreme weather events, species extinctions, ocean acidification and changes in agricultural yields. Warming and related changes will vary from region to region around the globe, though the nature of these regional variations is uncertain. In China, climate change has caused many different effects. One of the most significant effects on agriculture is the impact on soil salinization in different regions in China.

The impact of climate change on human mobility in West Africa

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Migration is a way of life in West Africa and for centuries people have migrated in response to population pressure, environmental disasters, poor economic conditions, conflicts, and adverse effects of macroeconomic restructuring. These migrants include temporary cross-border workers, seasonal migrants, clandestine workers, refugees and professionals. Cross-border movements involve farm labourers, unskilled workers, female traders and nomads.

The purpose of this research is to briefly explore the nexus between environmental change and human mobility; the implications of environmental change on human mobility; the connection between environmental vulnerability, migration, peace and stability in areas most vulnerable to environmental change, with a focus on human mobility; how climate change could work as a threat-multiplier from a human security point of view, breeding grounds for conflicts over resources and large population movements; the connections between climate change and forced migration; and managing the resulting environmental issues at local level.

Biodiversity, climate change and desertification issues affecting the indigenous communities of Africa: A case study of the Sahel and the Horn

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This Sahel environment stretches all the way from Senegal to Somalia cutting across over ten African countries bordering the Sahara desert in the north and the Sudan savannah in the south. With an annual rainfall of less than 50 cm per annum, it has good agricultural production as well as large grazing fields for pastoral activities and is a home for many indigenous communities like the Mbororo (Cameroon and Chad), Tuareg (Niger) and the Kanuris (Nigeria, Niger, Chad and Cameroon), who depend on pastoral activities, fishing, irrigation farming and mineral extraction as their main activities of livelihoods.

Desertification is a primary issue faced by these Sahelian communities. Indigenous communities are continuously losing their grazing fields, farmlands, and even villages to the encroaching desert from the north. Indigenous communities in the Sahelian region are currently trying their best in control of the desert encroachment through tree planting campaigns, small or local forestation projects and other programmes using traditional knowledge on their own, but yet the desert keeps expanding invading grazing fields, farms and even villages and towns. Loss of biodiversity, decreases in agricultural output and unemployment are putting food security under threat, leading to hunger, poverty and social insecurity.

POSTER PRESENTATIONS. SESSION 1

Climate change, evapotranspiration and salinization: A case study from Iran

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This research investigates the potential effect of vegetation cover evapotranspiration on the concentration or dilution of soil water and therefore, acceleration or alleviation of soil salinity for the next three decades in a region with shallow saline groundwater. The reference, potential and actual evapotranspiration (ET) were simulated for the time period 2010–2039 by integration of the surface energy balance algorithm for land (SEBAL), remotely sensed satellite images and General Circulation Model (GCM) derived data. This research indicates that the role of vegetative surfaces in a global changing climate would be paramount in alleviation of soil salinity. In other words, acceleration of soil salinization rate would be probable under low vegetation cover conditions, especially when the groundwater is saline and shallow.

Old landfills as emergent vulnerable ecosystems to salinization: Soil characteristics and response of the plant species to increasing Na and anion contents

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The anion contents of soil samples taken from the discharge and slope areas of landfills are considerably elevated with respect to soils collected from ecosystems surrounding these landfills. In this study, greatest concentrations were observed for the more soluble ions Cl^-, NO_3^- and SO_4^{2-} and lowest concentrations for F^- and PO_4^{3-}.

Species such as *Bromus tectorum, Desmazeria rigida*, *Trifolium tomentosum*, *Anacyclus clavatus*, *Carduus tenuiflorus*, and *Diplotaxis virgata* showed a preference for soils containing appreciable amounts of chlorides, sulfates, and sodium, and high electrical conductivities (EC). Of the species listed in the four ecological profile tables provided, *Hordeum murinum*, *Bromus rubens*, *B. tectorum*, *Hirschfeldia incana* and *Polygonum aviculare*, also showed a preference for soils with high values of these four factors and were followed by *B. hordeaceus*, *Juncus bufonius*, *Spergularia rubra, Trifolium cernuum, Medicago polymorpha*, *Crepis vesicaria*, *Plantago coronopus* and *Reseda lutea*.

Trifolium tomentosum and *Crepis capillaris* predominantly grew in soils with "certain levels" of chlorides and sodium. *Carduus tenuiflorus* was most often found in high sodium soils with high conductivity. *Diplotaxis virgata* preferred soils with high contents of sulfates and sodium. Finally, *Desmazeria rigida* only grew in soils with a high EC.

The species listed comprise the plants that are currently revegetating the steep slopes, "saline" soils and discharge zones of many landfills. These species are helping to reduce the pollutant leachates that eventually reach nearby streams, marshes and pastures.

Centrifugation affects salt content and ionic composition in the 1:5 water extracts of calcareous soils

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The 1:5 soil water extracts are frequently used for salinity appraisal because they are easier to obtain than saturation extracts. The experimental conditions for obtaining the 1:5 extracts should guarantee that the equilibrium status of the solution regarding calcite, gypsum and CO_2 has been attained and preserved in order to use them instead of saturation extracts for salinity diagnosis and also model validation.

A laboratory experiment was conducted in order to determine the time that calcareous soil samples need for attaining equilibrium with calcite, gypsum and CO_2 in 1:5 soil to water suspensions. Once this time was known, the effect of the centrifugation extraction on the thermodynamic parameters of the 1:5 extracts was studied. This was done comparing the ionic activity products of calcium carbonate of 1:5 extracts obtained by centrifugation with those not obtained by centrifugation. According to the results the centrifugation affects the ionic composition of the extracts and also the equilibrium parameters. However, for some measured parameters it was not possible to identify significant differences between centrifuged and non-centrifuged extracts. The study of the equilibrium parameters of 1:5 extracts obtained from soils with calcite and gypsum should continue before they can be reliably used instead of saturation extracts.

Rain effect on salts dynamic in the semi-arid region of Bou Hajla (Central Tunisia): Characterisation and long-term simulation

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Rainy events are rare and a characteristic of semi-arid regions. They play a regulatory role on the leaching of salts from topsoil to deeper layers which increase the risk of aquifers salinization. For this purpose, parcel in the region of Bou Hajla (Central Tunisia) was selected. Samples of soil were collected at 4 m depth from 26/12/2006 until 22/07/2008. Water and salt profiles highlight the role of a silty clay layer in the infiltration of water and salt transfer. This layer reduces salt's training but do not stop it which increases the risk of the aquifer salinization. The simulation was carried out by Hydrus-1d. The hydrodynamic parameters were determined by inverse modelling. The simulation allowed the analysis of two scenarios; the first being the effect of a very rainy event (> 50 mm/d) on the dynamics of salts. This type of event allows leaching of the accumulated salts in the topsoil which promotes their burial in depth. The second scenario is the long-term evolution of the saline profile in 25 years, which showed the cyclical nature of salts leaching in the topsoil and a continuous leaching in the deeper layers, increasing groundwater contamination.

Ecosystem's fragility under continuous methods of irrigation (learning from modern experiences)

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A long-term investigation of subsoil irrigated and drop irrigated soils in South Russia has been carried out over the last 6 years. Under the subsoil and drop methods of water delivery a non-uniform watering pattern is achieved, e.g. subsoil 0.5–1.0 m (the distance between subsoil outlets), drop 0.2–0.6 m (distance between droppers). The inefficiency of subsoil and drop watering is reflected by superfluous continuous watering and consequent local waterlogging of the soil and loss of irrigation water to groundwaters. A defect of the present-day irrigation concept is its imitating approach—a technical reproduction of a natural mode of water inflow into the ground from above or from below by means of a gravitation field or capillary forces. Development of a discrete artificial mode of applying water to a soil is required in order to achieve even watering.

The method of intrasoil discrete plant watering (introducing new technologies)

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The method of intrasoil pulse discrete watering of plants is proposed. It includes water delivery on an irrigation site and its distribution, provides water delivery inside the ground by means of injector element in consecutive step-by-step pulse injection under pressure in discrete portions immersing the bottom end of an injector element into ground at a depth of 0.05–0.15 m, step-by-step along a direction of movement of the chassis through 0.1–0.15 m. With the method of watering proposed there is no longer the necessity to protect the landscape from irrigation. The amount of water consumption for irrigation is 2–3 times less than with standard irrigation methods. This method minimises the use of fresh water resources, which are under threat globally due to climate change.

The management of soils with salinization risk from experimental field Lacu Sarat, Braila

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The management of saline soils requires a combination of agricultural practices depending of the careful investigations of soil characteristics, water quality and local conditions including climate, crops, economical, social, political, and cultural conditions, as well as the existing farm systems.

The research was carried out in the eastern part of the Romanian Plain (Braila Plain) in a depressionary area, on a slightly to moderately salinized Chernozem. Taking into account the natural conditions of the experimental field, an improvement scheme on an eight ha area was established, with multiple variants of ameliorative treatment.

The results presented in this paper were obtained between 1998 and 2004 at the Lacu Sarat trial plot in natural conditions in the frame of the ameliorative field scheme and also the crops structure. The results presented here are compared with the benchmark variant = 100, identified as the variant with the minimum ameliorative practices, due to the lack of a real benchmark variant.

Water quality and irrigation system affects salt accumulation and distribution in the soil profile of citrus orchards: A case study in Almenara (Valencia, Spain)

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The citrus crops cultivated in the Mediterranean area of Almenara (Spain) are threatened by soil salinization. Three citrus orchards representative in the area were sampled at monthly intervals at 10, 30, and 60 cm depth during the irrigation period and analysed for soil salinity parameters in the saturation extract: electrical conductivity, pH, alkalinity and major ions. One of the plots was drip-fertirrigated with water of low salinity and the two others were surface-irrigated with more saline water.

Samples grouped by plot and depth were statistically treated by Discriminant Analysis (DA) in order to disentangle the soil salinity parameters discriminating among the groups. A function explaining 51% of variance separated the plots by the quality of irrigation water, with chloride and sodium in the soil saturation extract as the main variables separating plots. Another function explaining 33% of variance separated shallow from deep soil layers, with nitrites and potassium as the main variables discriminating among depths. Samples at 30 and 60 cm depth in the surface-irrigated plots had similar salt composition. In the drip-fertirrigated plot, nutrients decreased beyond 30 cm depth. This suggests an efficient use of water and nutrients by plants that decrease salt accumulation in the profile, compared to the accumulation of salts in the root zone and beyond it in the surface-irrigated plots. Drip irrigation systems should be used in a new scenario of climate change, given the future lack of good quality water resources and the increase of water demand by the crops due to higher temperatures.

Water re-use projects as a solution of salinity problems in scarcity areas

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Recurrent droughts in recent decades have shown that water supply is not always balanced with demand. More than 70% of Europe's population face water stress problems with semi-arid coastal and highly urbanized areas being the most affected. Salinization is a problem that has been known for a long time, which particularly affects the soil in areas where precipitation is scarce. In addition, global climate change will worsen this situation, especially in southern European countries where greater susceptibility to drought can cause serious environmental, social and economic problems.

In this context, wastewater regeneration and re-use is emerging as an important future alternative because it enables water resources to be increased, lessening the pressure on conventional natural resources. It may also help to reduce salinization as the wastewater regeneration process for agricultural purposes includes filtration systems that significantly reduce salt concentrations. In many cases reclaimed water has lower content of salt than water from natural sources. In recent decades significant technological progress has been made in the field of wastewater regeneration and project feasibility is now mainly subject to economic considerations. However, thed economic aspect is perhaps the least studied in the research on wastewater regeneration and re-use. This is because while internal impacts can be easily translated into monetary units, the external effects, such as environmental benefits, are not considered by the market and, therefore are relegated to a series of statements about the advantages of water re-use but without economic valuation. As a result, the true benefits and costs of many projects are not properly evaluated.

With the aim to integrate the economy in the design and implementation of water re-use projects, this work shows a methodology to assess the economic feasibility where not only internal but also external impacts are considered. Using the concepts of distance functions and shadow prices for undesirable outputs, we calculate the value of avoided environmental damage or a proxy to the environmental benefit derived from the water re-use. This is a very important issue especially for the areas affected by salinity problems.

In order to show the usefulness of the proposed methodology, an empirical application has been made with a sample of Spanish wastewater treatment plants that re-use effluent for environmental purposes. In this case study, to obtain an economic viability indicator, the monetary values of internal and environmental benefits have been quantified. Results show that when water re-use projects are analysed taking into account just the internal benefit, some projects are not economically feasible. However, if environmental benefits are incorporated to the analysis, the economic feasible evaluation provides positive results for all of them.

This work shows the importance of the valuation of the environmental benefits derived from water re-use and justifies the use of this kind of projects to solve the salinity problems in certain areas.

Compost application: Effect on soil salinity

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Composting organic residue is an interesting alternative to recycling waste as the compost obtained may be used as organic fertilizer. Nevertheless, the application of compost on soil could affect the quality of soils and plants. The objective of this study were determine the effects of applying different doses of compost, elaborated with rice straw and sewage sludge, on soil salinity and plant development in pot experiments. Sandy (psamment) and clayey (xeralf) soils were amended with different doses (0.0%, 0.2%, 0.8%, 1.5%, 3.0%, 6.0% and 100% for clayey soil, and 0%, 1%, 2%, 4%, 6%, 10%, 20% and 100% for sandy soil) of mature compost and covered with with barley straw in pot experiments, under laboratory conditions. To assess the effects of compost-amended soil on *Hordeum vulgare* L. plants, the root/shoot (R/S) ratio index was determined.

The results showed that doses over 2% in sandy soil and 0.8% in clayey soil considerably increased EC values. It is well known that EC (1:5 w/v soil extracts) values over 0.4 dS/m lead to salinity problems in soils. The variability of the R/S relationship in terms of the compost doses applied to soil indicated that the lowest R/S ratio values were 0.37 for barley grown in sandy soil with doses of 4 and 6%, and 0.45 for barley grown in clayey soil with a dose of 0.8%. These facts, along with the effect of the compost on soils, undoubtedly confirmed that the optimum dose to obtain the best effect on the soil–plant system were 34 Mg/ha for sandy soil and 11 Mg/ha for clayey soil. Under there conditions, the only limiting factor of agronomic compost utilisation was the increased soil salinity. The authors wish to thanks the Generalitat Valenciana (project GV-CAPA00-03), and the Ministry of the Environment (project MMA 4.3-141/2005/3-B) for the financial support.

Problem soils and their amelioration, with emphasis on saline soils

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Thailand has abundant and diverse natural resources. The socio-economic growth of the country is mainly through the agricultural sector, in terms of gross domestic product (GDP), employment and provision of food security. The total land area of the country is approximately 51.4 Mha, comprising of 38% farmland, 25% forests, and the remaining 37% is public area, i.e. sanitary districts, swamp land, railroads, highways, real estate and others.

The climate of Thailand is classified as tropical savannah (the Central Plain, North, North-east and some parts of eastern Thailand), tropical monsoon (west side of the southern and eastern parts) and tropical rainforest (east side of the southern part). The average temperature is about 27 °C, while the annual rainfall is in the range of 824–5 248 mm. The potentially irrigated lands are dispersed over an area of approximately 5 Mha or 23.8% of the country's arable land, of which 46% is allocated in the Central Plain (Center for Agricultural Information, 2005).

In the last decade, land resources have been extensively used to increase agricultural production to provide for the burgeoning population—from 8 million in 1911 to 63 million at present. This has resulted in a constant expansion of land use for agriculture, even into marginal lands and encroachment on national forest reserves. Moreover, many areas are being cultivated with inappropriate methods causing deterioration of the land. This has accelerated degradation, which in turn causes poor production and loss of cultivated land.

The Land Development Department (LDD) is an executive agency responsible for planning, implementation, assessment, monitoring, improvement and rehabilitation of degraded soils for increasing yield and sustainable use of land resources.

Saline water effect on three tomato cultivars under subsurface drip irrigation with three regimes in Tunisia: Yield and fruit quality

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In the investigation of crop salinity tolerance and management, an experiment was carried out on three tomato cultivars (*Solanum lycopersicum*, cv. Río Tinto, Río Grande and Nemador) treated by drip irrigation (DI) and subsurface drip irrigation (SDI). This experiment was done in a silty clay soil using saline water (6.57 dS/m) and applying three irrigation regimes: 100%, 85% and 70% of the tomato plants' water requirement.

In the case of a deficit regime with DI, the results show an increase of soil ECe and a decrease in flower and fruit numbers and yield for all three cultivars. We also observed an increase of titratable acidity (TA) and total soluble solid content (TSS), while there was a decrease in fruit juice pH.

Improving management of saline water irrigation at farm scale: A case from the south of Tunisia

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In this study we followed several agricultures in terms of irrigation management with high salinity level of the irrigation water in three locations in the south of Tunisia. We calculated the crop water requirements of the cultivated crops (especially fodder) using the method described in the FAO56 guideline for computing crop water requirements.

Comparing the calculated crop water requirement with what is actually given by the farmers revealed bad irrigation management by the farmers, mainly in terms of the quantity of water supplied and because the concept of water quality was not included in the irrigation management system.

Effect of proline exogenous application on two tomato varieties irrigated with saline water by subsurface drip system

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An experiment was carried out using saline water (6.57 dS/m) and subsurface drip irrigation (SDI) on two tomato varieties (*Solanum lycopersicum*, cv. Rio Grande and Heinz$_{-2274}$) in a silty clay soil. Exogenous application of proline was done by foliar spray at two concentrations: 10 and 20 mg/l, with a control situation (saline water without proline), during the flowering stage.

The results show an increase in plant growth (leaf area), fruit yield and mineral composition (K and Ca) in the leaves of both varieties accompanied by a significant decrease of Na^+ and blossom-end rot (BER), particularly at the lower concentration used (10 mg/l).

A key role for ABA-GE and atypical LEA protein expression in an American halophyte treated with different sodium salts

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The plant hormone abscisic acid (ABA) plays a major role in plant responses to stress. Although rapid production of ABA in response to salt stress is essential to define ABA as a stress hormone, an equally rapid catabolism of ABA when such stresses are relieved is also essential in that role. Since ABA mediates so many stress responses, the initial perception of dehydration and the subsequent changes in gene expression that lead to rapid ABA biosynthesis constitute the most important stress signal transduction pathway among all the plant responses to stresses. In glycophytes, stress tolerance is increased with high concentrations of ABA, whereas in halophytes the ABA role in not yet known. Thus, endogenous ABA levels in leaves and roots of salinized plants of the halophyte *P. strombulifera* were determined. ABA levels differed with the type of salt, the concentration, the analysed organ and the plant age. A remarkably higher ABA content was found in leaves in comparison with roots, maybe due to its protective role, and a rapid biosynthesis and distribution from roots, where the highest levels were detected at the beginning of the treatments. Leaves from sulfate treated plants showed the highest ABA levels, in coincidence with toxicity symptoms showing up. Dynamics of ABA levels from 6 to 24 h in all treatments would indicate that ABA would act like a triggering signal for adaptive biochemical and molecular mechanisms for plant survival to salinity.

With respect to ABA metabolism, our results showed that both roots and leaves of *P. strombulifera* seedlings accumulated mainly ABA-GE (Glucose conjugated) in relation to PA and DPA which levels were very low. This pattern was especially marked in plants treated with the highest Na_2SO_4 concentration. The greater ABA-GE accumulation recorded in roots under high salt concentrations (Ψo: -2.6 MPa) could be related to ABA transport to the leaves where the highest levels of free ABA were detected. It is noteworthy that in the presence of Na_2SO_4, both roots and leaves showed the highest ABA-GE concentration of as well as free ABA, which correlates with the severe stressful condition imposed by this salt. Northern analysis in *P. strombulifera* revealed the expression of an atypical LEA protein in control roots showing constitutive expression; its over-expression in roots of sulfate-treated plants at Ψo: -1.8 MPa correlates with the beginning of ABA and ABA-GE accumulation.

Soil Doctor: Its significance to the land development programmes in Thailand

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Thailand has abundant and diverse natural resources. As an agrarian country, its economy is dominated by the agricultural sector in terms of gross domestic product (GDP), employment and provision of food security. It is estimated that the agricultural sector accounted for 38% of the population in 2005. The total land area of the country is approximately 51.4 Mha, comprising 38% farmland, 25% forests, with the remaining 37% occupied by public area, sanitary district areas, swamp land, railroads, highways, real estate and othes (Center for Agricultural Information, 2005).

The use to which the land is put has always been dynamic, depending on various factors, such as rapid increase of population, change of cropping pattern and emergence of new technologies. Prior to the mid-1950s the agriculture system was characterized by mono cropping, with rice cultivation as the major crop. In 1960 rice cultivation covered almost 60% of total cultivated land, compared to 12% for upland crops and 16% for tree crops. The upland crops increased substantially in the period 1960–1984 from 12–23%, reaching almost 25% by 1993, while forested areas decreased sharply from 54% in 1960 to 26% in 1993 (Charrupat, 1998).

Soil resources are being used to increase agricultural production to provide for the increasing population, growing from 8 million in 1911 (Office of National Statistics, 1958) to 63 million in 2008. This has resulted in constant expansion of land use for agriculture, even into marginal lands and encroachment on national forest. Moreover, many areas are usually cultivated without proper use of chemical inputs, due to lack of basic knowledge and inappropriate land use. This situation led to the accelerated degradation of land resources, causing fertility decline of soils. This is a major cause of poor production and loss of cultivated land.

Degradation of soils and mismanagement of land and water resources are the major causes that limit agricultural productivity. This problem has increased while the number of officials in the Land Development Department (LDD) has declined. To solve the problems, the LDD has planned several programmes including Soil Doctor Programme. The Soil Doctor Programme was initiated to be a part of non-governmental support. This paper covers the achievement of Soil Doctor volunteers and their activities.

Response of photosynthesis, water relations and root growth of two tomato varieties (Lycopersion esculentum Mill.) to irrigation water salinity under arid conditions

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In several arid and semi-arid regions vegetable production is attractive option but dependent upon the availability of large amounts of irrigation water. The Arava Valley in southern Israel is a typical area where vegetable production has increased steadily in recent years. Unfortunately, water resources in the Arava and other arid regions are limited and the salinity of available irrigation water tends to be high. Furthermore, high solar radiation and low air humidity are additional stress factors for plant growth. Tomatoes have been defined as moderately sensitive to soil water salinity.

The effects of salinity and water quantity were investigated for two tomato varieties (5656 and Daniela) in lysimeter and field experiments. Irrigation water was applied by a drip irrigation system. Salinity levels increased from 1 to 11 mS/cm. The irrigation amounts varied between 210 litres (30%) and 760 litres (130%) per plant and growing season. Pre-dawn leaf water potential was measured with a Scholander pressure probe. Maximum stomata opening were measured with a portable porometer CO_2/H_2O system. Diurnal CO_2 gas exchange was determined parallel with the transpiration. Chlorophyll fluorescence was used to determine the effects of salinity and temperature stress on the photosynthesis systems. Increasing salinity effects stomata opening and limits CO_2 uptake and photosynthesis by 40%. Irrigation amounts affecting the leaf gas exchange only at extreme drought stress at 30% relative irrigation. Stomata opening is regulated by the water uptake and therefore a relation between pre-dawn water and leaf conductance could be found. Furthermore, root growth was effected by soil salinity.

Evaluation of soil phytodesalinization capacity of *Sesuvium portulacastrum* L. by a test-culture

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Progressive worldwide salinization is a major environmental threat for crop production, which forces the scientific community to look for suitable solutions for reclaiming degraded lands and to explore new farming systems for the exploitation of saline soils.

The presented work aimed to evaluate the potential use of the obligate halophyte *Sesuvium portulacastrum* for remediation of an experimentally-salinized soil to allow the subsequent growth of a glycophyte test plant. A 189-day period of cultivation of *S. portulacastrum* was effective in reducing EC, SAR and soluble Na^+ content in the upper soil layer, and to increase them in the lower horizon, probably owing to root-assisted solubilization of soil-absorbed ions.

Phytodesalinization by *S. portulacastrum* cultivation ameliorated the percentage of barley germination and allowed a partial recovery of shoot and root growth, accompanied by a decrease of Na^+ and an increase of K^+ concentration in the shoots. It is therefore evident that *S. portulacastrum* cultivation is a promising and effective strategy for phytoreclamation of salt-affected lands.

Aspects of sustainable vineyard management in La Mancha (Central Spain): Potential impact of soil salinity increase in drip irrigated vineyards

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Vineyard irrigation management in La Mancha (Central Spain) has significantly changed over the past two decades. Efficient water management in the vineyards of this region has resulted in the application of lower water quantities, resulting in nearly 100% efficiency of irrigation.

Global warming is a scientific reality which is having an impact, whether good or bad, on vineyard management. The current drought conditions in the region make irrigation a neccessary practice. In recent years the salinity of irrigation water has been high, and an excess of salt may have been added to the soil. The question now is whether this is a long-term sustainable system considering the environmental conditions that will result from global warming.

Many vineyards in the region are now drip irrigation, or they are in process of being converted to drip systems. The potential problem is the presence of salts in soil under drip irrigation and their accumulation due to low water application rate of drip irrigation systems.

In some areas subsurface drip systems are now being tested, which show some interesting results in relation to root zone salinity. In the presented work a study was made to determine the degree of salt accumulation with drip irrigation in some vineyards in La Mancha. Several conclusions can be drawn: 1) Vineyards that were drip irrigated between four and ten years showed no dangerous level of soil salinity in the root zone; 2) It is necessary to adapt the management of water and soil to individual cases depending on environmental factors; and 3) An understanding of the processes of soil salinity and various management options to address these problems is a good basis on which to make recommendations for wine-producing areas in the region.

Detoxication of *Capsicum annuum* L. with zeolites

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The widespread occurrence of pollution is the reason for continuous examination of heavy metals and their impact on physiological processes in plants, diversity and ecology. For that purpose, the world's most developed investigating centres often use methods such as immobilization and phytoremediation. Zeolites are the most often used immobilization minerals, which neutralise heavy metals and change their oxidation structure.

This study examines the changes in the level of pollution in soil when zeolites are added to soil in which pepper plants (*Capsicum annuum* L.) are cultivated. The soil was treated with different concentrations of cadmium (0.1, 0.2, 0.4, 0.8 mg/kg soil), copper (0.5, 1.0, 10.0, 20.0 mg/kg soil) and zinc (1.0, 5.0, 10.0, 20.0 mg/kg soil). Parallel to the physiological metabolism, anatomic changes have been studied. The results confirm the positive effects of zeolites in the process of soil-phytoremediation. In every case studied the zeolite significantly reduced the uptake of cadmium, copper and zinc ions by the pepper plants.

POSTER PRESENTATIONS. SESSION 2

Physiological and morpho-anatomic anomalies in pepper after treatment with cobalt chloride

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The study was carried out at the glasshouse of the Faculty of Natural Sciences and Mathematics, Institute of Biology in Skopje, Republic of Macedonia. The aim of this study was to determinate how cobalt affects growth and metabolism of plants, by treatmenting with four levels of cobalt chloride ($CoCl_2$): 0.25, 1.5, 3.0, 5.0 mg/kg soil. We investigated phytotoxicity and bioavailability of cobalt to the pepper plant by determining the concentration of secondary biomolecules (total and soluble sugars and phenols), biopigment concentration (chloroplast pigments) and the effectiveness of some antioxidants, such as vitamin C and antocyanins, as well as the anatomic-morphological changes by the cytotoxic and phytotoxic activities of cobalt.

The results indicated the activation of plant defense metabolism after intoxication, by increasing the concentration of polyphenols, inhibiting the synthesis of antocyanins and vitamin C as major group of antioxidants as well as inhibiting the differentiation of starch grain. We also concluded that cobalt alters the structure and increases the number of chloroplasts per unit area of leaf. The third and fourth concentrations (3.0 mg/kg and 5.0 mg/kg soil) are the most toxic, causing extreme visible changes in leaf anatomy. The epidermal layer of plants treated with third and fourth concentration is thin and oxalate crystals appear under the palisade row of cells, particularly in plants treated with 3.0 mg/kg soil. All plants treated with higher concentrations have undisintegrated cores and a large number of sclerenchyme fibres.

Possible correlation between soil salinity and proline accumulation in halophytes

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Despite advances in our knowledge on the biology of salt-tolerant plants, mostly derived from experiments performed under controlled laboratory and greenhouse conditions, there are still relatively few data regarding the physiological and biochemical responses of halophytes in their natural stressful environments. Our study focuses on the accumulation of proline in several halophytes (*Sarcocornia fruticosa, Arthrocnemum macrostachyum, Juncus acutus, Juncus maritimus, Inula crithmoides, Limonium sp.*) collected in a coastal salt marsh in the province of Alicante (South-east Spain), from four selected experimental plots with different degrees of soil salinity.

The aim of our work is to establish whether proline biosynthesis could be used as a reliable stress marker in halophytes subjected to salt stress in their natural habitats. Generally speaking, in those species which use proline as the major osmolyte, a positive correlation has been found between the level of salinity in the soil and the content of proline in the plants. However, it is difficult to assert if soil salinity *per se* induces proline biosynthesis in all investigated taxa; at least in some species, the accumulation of this osmolyte could represent a constitutive rather than an inducible mechanism of response to salt. In addition, halophytes in nature are normally subjected simultaneously to different stressful environmental conditions, apart from salt stress, e.g. drought, high or low temperatures, high irradiation, etc., which could also induce osmolyte accumulation. Therefore, the possible use of proline concentration in halophytes as an indicator of soil salinity level must be carefully checked. Further investigations will help to elucidate if, and how, proline biosynthesis in salt-tolerant taxa differs under natural and artificial conditions, and the relative contributions of different abiotic stresses to proline accumulation in the plants.

Can malondialdehyde (MDA) be used as a marker of abiotic stress in halophytes growing in their natural habitats?

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Different abiotic stress conditions, including high soil salinity, cause secondary oxidative stress in plants, by generation of 'reactive oxygen species' (ROS), which in turn leads to membrane lipid peroxidation, among other deleterious effects. Maintenance of cell membrane integrity under salt stress should therefore contribute to salt tolerance, and this could be assessed by determining the levels of malondialdehyade (MDA), the major peroxidation product of polyunsaturated fatty acids in membrane lipids. To our knowledge, all available data on correlations between MDA contents and salt stress responses have been obtained in experiments carried out under artificial greenhouse conditions. The aim of this work was to establish whether MDA could also be used as a reliable biochemical marker of salt stress—and of abiotic stress, in general—in the natural habitats of the plants.

Three 100 m^2 plots have been selected in a salt marsh (*mallada*) in the Natural Park 'La Albufera', 15 km south of the city of Valencia (SE Spain). The plots have different levels of salinity, according to their vegetation and soil electric conductivity. Plant material was collected from 11 different species, in three successive seasons (summer and autumn 2009, spring 2010), and MDA contents were determined as described by Hodges *et al.* (1999). Preliminary results indicate a negative correlation between MDA accumulation and the degree of salt tolerance of different species; for example, *Helianthemum syriacum*, a relatively salt-sensitive plant (present only in the zone of lower soil salinity), has significantly higher MDA levels than several halophytes growing in the same plot. However, no significant differences were found when comparing samples of individual species, collected either from different plots or in different seasons. These data suggest that chemical and enzymatic antioxidant systems efficiently protect the cells from membrane lipid peroxidation, despite temporal or spatial changes in the degree of soil salinity; higher salt concentrations, not found in the natural habitats of the investigated halophytes, will probably be required to overcome these antioxidant systems and affect cellular membranes. Therefore, MDA content does not appear to be a useful biochemical marker of salt stress for halophytes growing in their natural habitats.

Synergic effect of salinity and CO_2 enrichment on growth and photosynthetic responses of the cordgrass Spartina maritima

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Spartina maritima is a C_4 halophytic species that has proved to be an important pioneer and ecosystem engineer in salt marshes on the Atlantic coast of southern Europe. A glasshouse experiment was designed to investigate the synergic effect of 380 and 700 ppm CO_2 for 0, 171 and 510 mM NaCl on the growth and the photosynthetic apparatus of *S. maritima* by measuring chlorophyll fluorescence parameters, gas exchange and photosynthetic pigment concentrations. We also determined total ash, sodium, potassium, calcium and nitrogen concentrations.

Elevated CO_2 stimulated growth of *S. maritima* at all external salinity after 30 days of treatment. This growth enhancement was associated with a greater net photosynthetic rate (A) and improved leaf water relations. Despite the fact that stomatal conductance decreased in response to 700 ppm CO_2, A was not affected.

On the whole, plant nutrient concentrations declined under elevated CO_2, which can be ascribed to the dilution effect caused by an increase in biomass and the higher water content found at 700 ppm CO_2. Finally, CO_2 and salinity had a marked overall effect on the photochemical (PSII) apparatus and the synthesis of photosynthetic pigments.

Potential impacts of climate change on primary soil salinization at Iran's national scale

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Long term meteorological data and the 1:1 000 000 soil salinity map of Iran were used (after excluding agricultural areas and miscellaneous lands) to develop correlations between soil salinity and climatic factors,. Mean soil salinity showed fair correlations with different climatic variables developed as simple and multiple linear regression models (R^2 of 0.56 to 0.72). Since predictors of these regression-based models consisted of different climatic variables, General Circulation Model (GCM) derived data were found suitable to link to the models for projection of salinities in upcoming decades. Data of HadCM3 model that were resulted from IPCC-SRES scenarios of A2 and B2 were used for projection of monthly T_{min}, T_{max}, annual P and ET for the nine next decades. Predicted variables were inserted in the developed regressions to project future status of soil salinity. At a country wide scale results showed that for the upcoming 90 years, mean soil salinity may increase from 1.5 to 4.7 dS/m, in different scenarios and time intervals.

A soil salinization study in a coastal plain of Mexico

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Previous studies (Bojórquez *et al.,* 2006, 2008; Gonzáles *et al.*, 2009) have shown the susceptibility to salinization in the Holocene coastal plain of Nayarit, Mexico. A large area of about 230 000 ha is undergoing this process. With the aim of knowing the dynamics of soil salinity, a study is taking place in a transect of 24 km at 36 stations in the lowlands.

This study pretends to establish salt movement in the soil profile monitoring in two seasons evaluating variables of depth to the water table, EC, pH and texture. The first monitoring indicated salinity variability in the dry season of 0.22–94.8 dS/m, pH 6–8.8 and textures of sand-loam. The lowest EC was observed higher altitudes with sandy texture and were highest towards lower altitudes with loamy texture. In the soil profile higher EC was found towards the surface and near to the water table.

Remote sensing detection in land use change and salinization

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A multi-temporal analysis was made on the land use changes in the marsh of Pego-Oliva (Valencia, Spain). The earliest information of land use was obtained from the ortophotomosaic interpretation (American flight from 1956), which has been georeferenced to projection UTM, Datum ED-50 and from information contained in the topographic sheet 796 (DGIGC and SGE, 1950). The actual parcel boundaries of land use have been consulted in Visor SIG-PAC (2008).

The major changes observed were urban proliferation, mainly in the sand barrier area and an estimated reduction of 41.4% of the wetland by land filling for agriculture. Possible influence of these changes has been analysed in the two saline intrusion wedges identified by Ballesteros *et al.* (2009) in the sandy superficial section of the Pliocuaternary aquifer of Pego-Oliva. By superimposition of EC isolines and the amended cartography it was possible to prove that both wedges coincide with two highly modified zones: 1) Urbanization zone with a golf course—the saline intrusion wedge is attributed to an overexploitation of the aquifer and it retrieves in the wet season with the rise of the piezometry; 2) SE land filled zone—the saline intrusion wedge is attributed to the automatic pumping to lower level, out of range of the plant roots. In the wet season intense pumping provokes an increase in salinization due to a phenomenon of "up-coning" in the superficial aquifer with a drawing effect on the saltier waters from the surrounding calcareous aquifer (Ballesteros *et al.,* 2009).

In order to know the IR radiation reflected by the crops, the Landsat 5 TM (432) from 1988 has been analysed. Citrus crops on land filled zones appear in purple, in contrast with the intense red color indicating strong photosynthetic activity shown by the surrounding citrus crops fields.

Finally, a field test of the health of citrus crops was made in areas affected by salt degradation, using GPS to locate them, finding correspondence with that observed in satellite images.

Climate change and temporal trend of climatic parameters influencing the evapotranspiration: Case of Chatt-Meriem region

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This study concerned the effect of climate change impact on temporal trends of the climatic parameters influencing the evapotranspiration and the crop water requirement, using the Penman–Montheith methodology described in the FAO Irrigation and Drainage Paper No. 56.

Temporal trends of the climatic parameters and the reference evapotranspiration over a period of 33 years have been analysed using the Mann-Kedall trend test. The sensitivity of ETo has been studied in terms of changes of the most significant climatic parameters. The results show that maximum and minimum temperatures do not evolve similarly. A significant temperature trend was detected during the spring and summer period (hot season), especially for maximum temperature. A highly significant trend for the air vapour deficit was detected, which appears especially from May to June. The wind speed shows a significant decrease trend during the year. The sensitivity analysis test showed that the most influential parameters on ETo are net shortwave radiation, actual vapor pressure, long wave radiation and maximum temperature. This temporal trend analysis of the climatic parameters will be used to develop future regional scenario of evapotranspiration and crop water requirement under climate change conditions.

Ecological discharge of the aquifer of Oropesa-Torreblanca (Castellon, Spain) for recovering the seawater/fresh water equilibrium

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Seawater intrusion is normally associated to over exploitation of groundwater. When fresh water discharge is drastically reduced the hydrodynamic equilibrium between fresh and seawater is altered, provoking saltwater intrusion. In order to recover or preserve the natural equilibrium in the coastal aquifers an ecological approach to the discharge should be considered. Is not easy to estimate how large this discharge has to be, but if a consistent conceptual model is reached the implementation of mathematical models can be a good tool to achieve this objective.

The Oropesa-Torreblanca aquifer (Castellon, Spain) is being over exploitated and the seawater intrusion process is affecting it severely. Increasing the ecological discharge of fresh water appears to be the only way to recover the natural water quality.

Both the drastic reduction of the groundwater abstractions and the application of artificial recharge using wastewater are being considered in a mathematical model implemented using the MODFLOW code. The results show that a progressive reduction of the pumping by up to 40% could re-establish the original equilibrium.

Regional flows contributing to the groundwater salinization of coastal aquifer of Castellon, Spain

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The general hydrogeochemical features in the coastal aquifer of Castellon Plain are very complex due to the overlapping of several processes, both natural and anthropogenic. Seawater intrusion and agricultural and industrial pollution lead to the existence of five well differentiated water-types. Water salinization is very intense in the southern part of the aquifer where overexploitation has been recorded since the 1970s.

The major process accompanying seawater/fresh water mixing is inverse ionic exchange (Ca against Na) which does not involve magnesium, even though the saline water is clearly enriched in this ion. Sulfate contents are also larger than expected. If a sulfated member is considered in the fresh water, the ionic excess of sulfate and magnessium is fully justified. The sulfate water-type has around 16 meq/l of SO_4^{2-} and 7 meq/l of Mg^{2+}.

Significant amounts of boron, lithium and strontium are also involved in this regional flow.

Determining agronomic crop tolerance to salinity: Citrus as a case study

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For the last 50 years, the world has been continuously drifting into a water crisis. Currently about 20% of the world's irrigated areas have become salinazed. As a result, determining a crop's tolerance to salinity is a key factor in evaluating its economic potential.

Citrus is an important crop worldwide that is known for its sensitivity to salinity. Its salt tolerance has been studied for more than 60 years. As a result, citrus salinity research can be used as a case study for evaluation of crop tolerance to salinity. Initially, the citrus salinity research was focused on the osmotic effects of salinity, and the effect of the soil-water electric conductivity on yield reduction was determined. Then the toxicity aspects of salinity (mainly chloride toxicity) were taken into account. The research focused on the mechanism behind chloride uptake, as well as on the effects of the rootstock on chloride uptake (including ranking rootstocks for their tolerance to chloride). Yet, after all these years, the data is relatively inconsistent and we still have difficulties with estimating the effects of salinity on citrus yield reduction. For example, the rootstock of Sour Orange appears in some papers as salt-tolerant while in others as salt-sensitive.

The effects of experimental design, measuring methods, and scion characteristics on citrus tolerance to salinity will be discussed. Furthermore, a new citrus salt-tolerance model that considers both the osmotic effects and toxicity effects of salinity will be described.

Improving the calculation of crops' virtual water content in a context of climate change and salinization risk

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Increased water scarcity and increasing intersectoral competition for water are important reasons to look at the way water is managed on our planet. The water requirements for food are by far the largest and this is why the concept of virtual water is so important when discussing food production and consumption. One of the fundamentals of management is the ability to measure fluxes and volumes. For that we need standardized measurement tools and methodologies, since improved information on virtual water is going to be pertinent for the water management debate. In this regard, recent assessment approaches, such as water footprint calculations (Hoeckstra, Chapagain *et al.*, 2009. *Water footprint manual, state of the art.*) are an important step forward, but some shortcomings and methodological problems need to be properly addressed. Three additional dimensions in particular that should be included when estimating virtual water contents and total water availability are highlighted:

1. The water generated from salinization plants (*witty water*), which is an increasingly important water source in arid and semi-arid regions, in addition to the "green" and "blue" water usually considered in virtual water calculations.
2. The quality of "blue" (irrigation) water matters and therefore the use of water of poor quality for irrigation purposes *(salty water*). In many semi-arid regions the available water is of low quality and the irrigation practices should avoid the development of adverse soil conditions due to the appearance of soil salinity that decreases crop yield through osmotic and toxicity stress effect on plants.
3. Last but not least, it is essential to refine the calculations of water crop requirements, by means of taking into account the differences in soil composition and the complexity of soil processes. Recent papers (Aldaya and Llamas 2008), (Chapagain and Orr 2008), although very valuable, assume an oversimplification of the transient soil water processes (runoff, infiltration, storage) that can lead to a significant bias in the calculations.

Effects of long-term saline irrigation on soil properties and vegetable crops

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Salinity is one of the major environmental constraints that limit crop productivity and quality. The United Nations Food and Agriculture Organization (FAO) has estimated that approximately 20% of irrigated lands are affected by increasing salinity. The competition for fresh water in agricultural, domestic and industrial uses, mostly due to the growing population and climate change, is exacerbating the spread of salinization. Arid and semi-arid regions are more exposed to this phenomenon since in these climatic zones high evapotranspiration rates, irrigation and reduced rainfall all contribute to salt accumulation in the uppermost soil layers, where root development mostly occurs. Salinization does not pertain only to extreme environments and/or southern regions of the world. In Europe, 26 countries have reported cases of salinization with a higher frequency in Mediterranean coastal areas. Although soil salinization could be delayed through proper irrigation management, it cannot be avoided. Consequently the progression of salinization is increasingly jeopardizing productions of irrigated lands, the most active agricultural areas of the world.

In Mediterranean areas, the diversity of agricultural systems underlies the existence of different salinities, whose effects on crop yield and quality should be analysed in an agronomic context. The Department of Agricultural Engineering and Agronomy at the University of Naples Federico II has been engaged since 1988 in a long-term research activity aimed at elucidating the complexity of crop-salinity interactions in specific agricultural contexts. During the dry season (Spring–Summer), the effects of drip irrigation with saline water were studied on growth, yield and market quality of some vegetable crops (broad bean, broccoli, carrot, cauliflower, endive, fennel, lettuce, pea) and on soil properties. The treatments consisted of 5 levels of water salinity (0%, 0.125%, 0.25%, 0.5% and 1%) obtained by adding commercial sea salt to good quality canal water (0% treatment). Electrical conductivities at 25 °C (EC_w) of the 5 irrigation waters were 0.5, 2.3, 4.4, 8.5 and 15.7 dS/m, respectively. Furthermore, a non-irrigated control was also included. After equilibrium levels of soil salinity were reached, the effects of the variably lower soil salinities were studied on plant growth, yield and market quality of fall-winter vegetable crops (cabbage, celery, pepper, eggplant, snap bean, tomato for processing) under a rainfed regime. Sustained irrigation in summer time with saline waters induces salt accumulation and increase of sodium in soil with constraints resulting in reduced crop yields even during the fall-winter season. Soil physical and chemical conditions have been altered by long-term irrigation with saline water: the soil of 1% treatment assumed typical characteristics of alkaline-saline soil with decreased structure index and water infiltration rate, higher water content, surface crusting, pH ≥8.0 and consequently poor aeration in the root zone. Exchangeable sodium percentage (ESP) was much higher in salinized soil. The soil water infiltration rate varied between 12 mmh^{-1} (treatment 0%) and less than 1 mmh^{-1} (treatment 1%), which may be caused by the sodium dominance on the adsorption complex that would determine deflocculation or puddling of the clay particles. The index of stability of the aggregates in water (IS) was reduced from >50% to 12% with irrigation at 1% NaCl. In this paper we summarize some of the results achieved and highlight future research needs.

Use of an aboveground electromagnetic induction meter for detecting salinity gradients and indurated soil layers in a volcanic landscape

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In some volcanic landscapes salts accumulation can appear in the bottom parts of the relief as a consequence of the downward transport of the solutes resulting from rock alteration. Such geochemical process can originate the appearance of mineral-zonation belts according to their relative solubility.

Electromagnetic induction (EM) is a non-invasive technique that can help in quick surveying of landscapes, producing a primary magnetic field than induces a secondary magnetic field if some conductors are present into the soil. The measurement integrates the induced secondary magnetic field from a volume of soil that depends of the sensor geometry. Using the Geonics EM38 sensor, the effective depth of measurement extends to 2 m that is appropriate for soil survey and agriculture applications. The instrument allows two geometry configurations, vertical and horizontal mode that integrate soil and geologic materials response from different depths.

In a conceptual model, the EM signal response can be described as a complex function of geologic materials conductance, soil solution conductivity, soil volumetric moisture, temperature, texture and type of clay, among other factors, each layer contributing unevenly to total signal response.

An andesitic hill in Central Mexico is surrounded by rings of entisols, calcids, salids and argids arranged in the downhill sense. A bottom-top longitudinal survey has been performed measuring with a Geonics EM38 meter, both in vertical and horizontal model, as well as surface temperature with an infrared thermometer, at 95 points along a distance of 762 m, positioning each measurement with a WAAS enabled GPS (HDOP <3 m). Several soil samples were taken to relate the bulk EM ECa with ECe of the saturated paste.

Three distinct zones were clearly discriminated through the analysis of the EM38 raw signals and soil surface temperature: a first area of saline-alkaline soils with halophytes and cactacea; a second area of non-saline soils with petrocalcic horizon where halophytes are absent; and a third area of shallow, less-developed soils with moderate slope at the bottom part of the hill. The measurements provided data for the bulk soil conductivity at every point, showing salinity gradients, area heterogeneity, detecting the appeareance of petrocalcic horizon and computing if salinity is in the topsoil or the bottom soil.

Assessing the relationship between soil salinity and plant distribution using electromagnetic induction

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Salinity distribution in natural or managed ecosystems can follow a complex pattern due to differences in soil texture, permeability, drainage, topographic position, microclimate and vegetation activity, among other factors. Direct sampling of soil profile and water, and subsequent laboratory analysis of ion concentrations and minerals present, is the most informative study approach at point scale, providing detailed data for soil salinity type and magnitude, but is time and effort consuming, only point representative and difficult to perform several times to keep track of landscape time-changing conditions.

Electromagnetic induction (EM) is a useful, low cost technique for quick measurement of bulk soil electrical conductivity, being non-invasive, non-disturbing and can provide very useful information about soil conditions (salts concentration, soil moisture and texture). The measurement integrates the induced secondary magnetic field from a volume of soil.

In a conceptual model, the EM signal response can be described as a complex function of soil solution conductivity, soil moisture, temperature and amount and type of clay, among other factors, each soil depth contributing unevenly to total signal response. The EM apparent soil electrical conductivity (ECa) signal response can be related to ECe of the soil saturation paste extract at particular depths, through statistical calibration.

This study focuses on the relations between topography/soil salinity/vegetation in a low-energy coastal environment at the Western Mediterranean Sea (Valencia, Spain). A seashore–inland longitudinal survey along seashore (origin), sand dunes, salt-affected depressions, sand barriers with trees and bushes and a salt marsh, has been performed measuring bulk ECa with a Geonics EM38 meter, both in vertical and horizontal mode, at 5 m interval, along a distance of 420 m, positioning each measurement with WAAS enabled GPS (HDOP <3 m) and a topofil meter. Each measurement was triplicated and the values averaged.

Signal analysis allowed discrimination of 4 sub-environments, provided data of the actual bulk soil conductivity at every point measured, showed slight salinity gradients, computed if salinity is concentrated in topsoil or in the bottom soil and was useful to relate vegetation present to soil salinity conditions.

ANNEX 1
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