FINDINGS OF THE SESSIONS

FINDINGS FOR TOPIC 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:

- Soil salinity can be described as a high concentration of ions in the soil solution, a condition that is very restrictive for plant's growth, due to the high osmotic potential of the solution that difficults the plant water uptake, and also due to the plant toxicity produced by specific ions.
- The definition of soil salinity centered in the plant differs from the used in soil classifications that are more exigent in 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 semiarid regions, representing an increasingly environmental concern.
- Among the causes of salinity and salinization are marine intrusion, irrigation with low quality waters, deforestation that make rise the groundwater table by decrease in deep pumping by transpiration, remobilization of salts by irrigation of salt-bearing sediments of marine origin, salts accumulation in lower parts by impossibility of drainage, and marine spray in coastal zones.
- Evidences of the tendency to global mean temperature increase have been presented by the International Panel on Climate Change and by many authors during the past years.
- There is a great uncertainty associated to the projections of rainfall by the various climate models, frequently differing in both sign and magnitude for a given regions. The phenomenon is complex because the temperature affects the soil evaporation, plant transpiration, cloud characteristics, storm intensity, etc. Consequently, some regions can expect an increase in the amount of precipitation. In other areas, especially where the water deficit has been already experienced, the forecasted decrease of rainfall will substantially affect the quantity and/or the quality of the water resources for the agricultural activity.
- For assessing the risk of salinization, defined scenarios should be analyzed. The risk of salinization will affect the soils of different latitudes in a different way.
- Special effort will be required for the maintenance of crops productivity under salinization risk and for the expansion of irrigated areas.
- The correct analysis and the preventing measures need of scientific background provided by a critical mass of scientists, an increased effort in research and measurement, the development of new conceptual models and the analysis of scenarios under different hypothesis. This will allow the design of new technical and policy approaches.
- The accumulation of soluble salts and their distribution in soils of some deltas depend on many factors, including fluctuations in the sea level and the anthropogenic loads on soils.
- Sea level rise is accompanied by the groundwater rise in coastal zones, so that soil salinization due to the ascending migration and evaporation of the groundwater becomes more active.
- In many soil subjected to long-term irrigation, soluble salts were washed from the upper soil layer, changing the initial soluble salts type of salinity by the gypsum in this layer.
- The cessation of irrigation on many plots can change the hydrological regime of the soils and initiated the development of secondary soil salinization.
- Micromorphological studies permit to specify the trend of salinization-desalinization processes and to differentiate the salt and gypsum pedofeatures according to their age.

- Cyclic changes in the climate of Europe during the past millennium have already been confirmed by paleosol data. In particular, changes in the degree of climatic humidity for semiarid territories are reflected in some labile soil properties, such as the degree and character of soil salinity.
- Salt-affected soils are found not only in arid and semiarid areas, but also in the tundra and taiga zones. Seawater salts are the major factor of soil salinization in coastal areas within the tundra. In the taiga zone, salt-affected soils are formed on the floodplains and low terraces of river valleys and in thermokarst depressions. Low precipitation and permafrost hampering natural drainage of the territory are essential factors favoring salinization in the taiga zone
- Sustainable irrigation may help farmers to benefit from warmer climate and longer growing seasons as well as to cope with irregular precipitations, all three foreseeable effects of climate change for some regions.
- An increase in irrigated surface can be expected in semi-arid areas as long as water resources remain available. The higher consumptive water use by irrigated crops will reduce available water resources and increase their salinity, an increase further enhanced by natural soil-subsoil salinity. Therefore, the understanding of the relationship between irrigation development and salinity of rivers and groundwater is necessary to establish how climate change will affect the salinity of water courses.
- It could be desirable consider not only the limitations, but also the environmental services provided by salt-affected soils to be incorporated as classifying criteria of lands.
- There is a need for theoretical and technical development of new irrigation methods addressed to optimize the water availability and the favourable condition around the root zone. The use of robotics is possible nowadays in high-tech agriculture and will increase dramatically the effectivity of irrigation.
- Soil salinity can show a great spatial and temporal variability. The use of electromagnetic induction (at detailed scale) and of remote sensing (at medium-large scales) can help to better understand the temporal and spatial variation of salinity and the salinity fluxes.
- In some tropical areas there is a very abrupt change in the climatic conditions among different years, that difficult the management of salt-affected soils. For countries affected by the phenomena of "El Niño" and "La Niña" the regular patter of precipitations during mid-term periods is dramatically altered, causing either flooding (with salts remobilization and redistribution), or drought, with associated water quality worsening. Flood control, water storage increase and efficient irrigation management with salts drainage from soils, are conditions for a sustainable management that needs from the cooperation of national authorities and watershed policies.
- The geo-pedological approach is suitable to delineate the boundaries between different geomorphic surfaces, including salt affected areas, using aerial photographs, satellite images, digital elevation models and other usual cartography tools as well as field survey.
- For some cases, soil salinity can be conceptualized as a member of a soils catena. This conceptualization is important, when applicable, due to that a better understanding of transport processes is gained in this way.
- Although salt affected soils usually are not very alpha-biodiverse, contribute to global biodiversity maintenance by the high degree of specialization of organisms adapted to restrictive conditions for living.
- The increased aridity in areas of actual salt-affected soils, especially in endorreic areas formerly flooded, can lead to serious problems of health by wind transport of salt-efflorescences, developing respiratory diseases among the population of

the neighbourhood. Also defective recharge of aquifers will lead to worsening in the quality of the pumped irrigation water.

- There is a need to approach to climate scientists to get the information of the climate change tendencies for the region. With this information can be explored different scenarios for management of areas under risk of salinization, evaluating alternatives and making adjusted recommendations to the farmers.
- The salt and water fluxes are affected by plants activity. In agricultural soils the condition of good water infiltration and drainage is needed. In some salt-affected soils developed in flat areas the platy structure inherited from sedimentation can effectively isolate the upper and lower parts of a soil, and plants take water and solutes from the upper or from the bottom parts.
- Micromorphological studies of long-term reclaimed salt-affected soil profiles can reveal trends of soil properties change, providing very valuable information about the adequacy of the method used for soil reclamation.
- The application of computing to the signals provided by new sensors for greenhouse and for the field, measuring soil salinity and soil moisture, can help in the modeling of water quantity/quality requirements of crops and in the design of optimized automated irrigation with waters of high salinity.
- The reclamation of salt-affected soils benefits from the information of salinity distribution, soil texture and residual soil moisture, parameters that can be measured using electromagnetic induction, combined with geostatistics.
- Measuring soil salinity by the saturated paste method is time and resource consuming if a great number of samples are to be analysed. Measurements of apparent electrical conductivity can be correlated with electrical conductivity of the paste, calibrating the electromagnetic induction apparatus that allows quick measurement and that, in turn, can be used as information of reference for calibration remote sensing images to follow temporal variation of soil salinity.
- The development of areas under irrigation should be accompanied by the establishment of a drainage system, for avoiding the deep infiltration of the excess of irrigation water that could produce a vertical recharge of the underlying aquifers, elevating the phreatic levels of salinized waters.
- Great effort is deal to establish new methods of calibration of soil sensors, for quick measurement of soil salinity and soil moisture.

FINDINGS FOR TOPIC II

Preventing and managing salinization under climate change threats: learning from past experiences, introducing new technologies and facilitating the exchange of knowledge:

- Use of existing information is indispensably for monitoring the risk of salinization in sensitive areas.
- The information should be implemented in "Geographical Information Systems" that allow quick recovery, processing for comparison and detection of trends, as well as for examining the quality and coverage of the existing data, and their suitability for making management recommendations, at different scales.
- At national and regional scale it is recommended to identify the areas under risk of salinization and classify them according to their sensitivity to climate change and anthropogenic loadings.
- The identified hot spots should be used as benchmark for monitoring the effect of climate change on salinization.
- Due to the trend of variation in the climatic conditions, it is expected that sensitive areas will undergo detectable changes that can be quantified. Periodic monitoring of salinization indicators is needed to validate the predictive models.
- Low operation cost and quick measurements tools, like remote sensing, electromagnetic survey and similar are very useful for providing evidence of salinity and soil cover changes along the time, allowing quick reaction to counteract the adverse conditions developed.
- A set of indicators for the risk assessment are to be established, considering pressures, effects and efficiency of actions.
- Inventory studies of the current status of habitats, water resources, and wild animals abundance can allow the comparison with historic data to detect the factors of change.
- Transversal joint research programs are needed to cover gaps in land productivity, animal production and wildlife topics linked to climate change.
- For countries sensitive to climate change due to their water scarcity, there is a risk of droughts and floods by irregular precipitations an underdeveloped infrastructure of water storage. As recognized in many countries, there is a risk of development or increase of salinization under such circumstances.
- Innovative methods of irrigation, as the Polyacrilamide-treated irrigation, either using well-water or desalinized sea-ice, combined with gypsum application, are found to be successfully methods for soil desalinization from top to deep soil layers, improving seedling emergence and crop yields.
- Frequently organisms suffering from stress evidence symptoms of stress of multiple causes. Inoculation with bacteria like *Azospirillum brasilense* which lives in soil close to roots and is involved in nitrogen fixation, can improve the resistance to salinity stress and increase the protein masses of the shoots and roots of the crops.
- The development of early warning systems for monitoring and reducing salinity impacts is an important issue. Processing large sets of remotely sensed data using automatic techniques is possible and has demonstrated its utility using supervised classifications that use simple indicators (LADA) to indicate the possible influence of climate change on salinization.
- Models capable of quantifying the effect of climate change on salinization are needed.
- The use of linked mechanistic models and geographic information systems can be a useful tool to understand and spatially predict the processes that control salinization due to climate change at point, geological unit, and climatic zone on a national, regional and global scale.

- In coastal areas the over exploitation of ground water resources induces a decrease of the aquifer's piezometric level and the degradation of its quality by saline water intrusion from the sea or sebkhas (salt flats).
- For some countries, expansion of irrigation is a new practice and the farmers have not enough experiences to use water efficiently and to manage soil, water and plant under saline conditions. After some years, problems related to salinity are observed and decrease of yield crop is noticed. Farmers should be instructed in the correct management practices, and basic guidelines for operation should be elaborated, adapted to the characteristics of each region.
- Most countries do not have a strategy or policy at national level for assessing and monitoring the effect of climate change on salinization. This development should be recommended by its importance.
- Strategies must be drawn for plant-based solutions to the use of saline areas—including the production of new genotypic material through conventional breeding or biotechnological methods.
- Strategies to reduce soil and water salinization include:
  - Controlling water application through appropriate irrigation technology and accurate scheduling to minimise salt accumulation in the crop rooting zone
  - Raised bed technology to reduce irrigation water requirement and lower the risk of groundwater recharge
  - Developing drainage systems, managing seedbeds and grading fields to reduce salt accumulation in the soil
  - Alternate use of fresh water with saline water to leach excess salt from crop rooting zone
  - Reduced tillage, crop residues, crop rotation, gypsum, fertilizers and growing cover crops
- Among useful adaptation measures can be included:
  - Rehabilitation of saline lands through crop based interventions
  - Introduction of rice for water and salt management
  - Agro-forestry in which trees inter cropped with other salt sensitive crops (productivity increase).
  - Mulching of furrows under saline conditions to reduce evaporation.
- Use of salt affected soils and saline water ensure abandoned land and marginal water used for agriculture.
- Improved technologies and methodologies for the development of salt tolerant plants and testing them in salt affected soils and saline waters is important for food security and poverty alleviation.
- Monitoring soil and water salinity within and beyond crop rooting zone is important for both mitigation and adaptation.
- Isotopic and nuclear techniques play an important role on the use and management of salt affected soils and saline waters.
- Isotopic techniques for the use of salt affected soils and saline waters include:
  - Soil moisture neutron probe for measuring soil water under saline condition for accurate irrigation scheduling and reduce salt accumulation in the soil
  - O-18 and H-2 for evapotranspiration estimation in soil–plant system and its influence on soil and water salinity
  - N-15 and P-32 in combination with O-18 and H-2 to relate crop water use to nutrients uptake under saline conditions for improving soil quality
  - Cl-35 and Cl-37 to study the origin of salinity and salt movement in soil
  - H-3 and He-3 for estimating recharge rates and salt loads to groundwater
  - C-13 as an indicator of crop water use efficiency (tool for evaluating salt tolerant plants).

FINDINGS FOR TOPIC III

Alternative land use systems/ecosystem services in salt-affected habitats:

- 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 to marginal land, mainly due to secondary salinization among the different factors.
- The three major approaches used to tackle the problem include soil management (mainly reclamation); water management; and plant based approaches. However, none of the above can be effective both technically and economically, if not worked out as an integrated measure.
- Plant based approaches to use salt affected lands and/or use of saline water, economically and environmentally safe is based 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 as food, forages/ fodder, livestock industry, medicinal uses, wood and others.
- In addition to primary products, use of these marginal resources also provide many secondary and indirect products, including biofuel and bioenergy, carbon sequestration, phytoremediation.
- 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.
- Many halophytes show different response to the different salts composition, differing in the levels of tolerance for each ionic composition of soil solution. Because of this, in vitro and pot experiments should be performed before making large scale halophytes introduction experiments.
- Medium and long-term effects should carefully considered in the projects dealing with biosaline agriculture. There is a concern for long term irrigation effects in arid areas with high saline waters, because of the massive salt mobilization that can promote aquifers salinity increase, depletion of piezometric level of aquifers, and development of deep drainage impediment by formation of deep petrocalcic crusts, as observed in some areas.
- Halophytes can be considered a new useful tool to improve crop salt tolerance trough two biotechnological strategies: considering them as natural gene donors to improve genetic salt tolerance of low tolerant crops, and considering those species and their rhizosphere as a natural source of PSHR microorganisms capable to improve salt tolerance in crops.
- There is no clear consensus on what plant stress is, and how to diagnose and assess its severity. 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.
- Many crop and water management issues pertain to the entire plant-root system and may include both water and osmotic stress. The challenge is to find a concise set of soil physical and plant physiological parameters which characterize this system and enable us to quantify root water uptake and stomatal conditions.
- The research of the ecosystems of mangroves, marsh areas, inland saline areas, can provide very valuable information in order to get a better understanding of salinity tolerance mechanisms.

- 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. Integration of 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.
- Monitoring soil EC status under field conditions, combined with the use of plastic mulch agro-technique has proved for the reduction of salt accumulation in trees in young orchards.
- The efforts for creating germplasm/gene banks with salt tolerant material should be continued.
- Exchange of genetic material should be enhanced, under international regulations, for research and restoration purposes.
- Patent of genetic material is a rejectable practice.
- Networking represents a *sine qua non* condition in any collaboration dealing with saline agriculture, offering good and reliable examples of successful technology which has been tested and has provided stimulating results; contrarily, unsuccessful stories could also represents good tools for learning and improvement of further strategies.
- Technology transfer to the beneficiary (farmers) should involve governments, commercial companies, and scientific community, as well as extension officers.
- FAO structures could be involved in summarizing and centralizing multi-data in respect with salinity problems.

FINDINGS FOR TOPIC IV

Evaluating the effects of climate change on coastal areas, lagoons and wetlands, including economical, social and environmental aspects:

- Poor water management has impacts on aquifers on coastal aquifers, which end up with salinization. Salinity problems can be related with 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 on suitable water as well as to accelerate salinization.
- Excessive water extractions, increase in the population, contamination, and salinization of the coastal aquifers, will reduced the safe yield of the water that can be supplied. Such scenario makes water quality and sustainable use of groundwater resources major challenges to the scientific community, managers and stakeholders.
- The European Water Framework Directive (2000) and the Groundwater Directive (2006), demands that good ecological status of groundwater must be guaranteed by 2015. Those regulations can be a good example for other countries, to implement their policies.
- To achieve those goals, a better understanding of the prevalence and significance of aquifers through the integration of multi-disciplinary approaches is needed, identifying the risks associated with poor management.
- Also development of sustainable management strategies is needed, to prevent the deterioration of the water bodies and to ensure compliance with the established legal framework.
- Coastal wetlands are rich in biodiversity, provide hydrological and ecological services and also support livelihoods of thousands of rural people. They act as a mechanism for flood control and pollution abatement, providing livelihood through fishery, lime shell collection, rice cultivation, duck farming, navigation, port facility and tourism. Some are complex system comprising of backwaters, marshes, lagoons, mangrove forests, reclaimed land and an intricate network of natural and manmade canals. Disconnection from rivers through the construction of dams can lead to increase their salinization level. Also decrease of rainfall or increase of sea level can lead to increase of salinization.
- Some coastal areas receive huge amount of fresh alluvial deposit every year from upstream. The land becomes saline as it comes in contact with sea water and continues to be inundated during high tides.
- Factors which contribute significantly to the development of saline soil are: tidal flooding during wet season, direct inundation by saline or brackish water, upward or lateral movement of saline groundwater during dry season, salinity to be exacerbated by climate change and sea-level rise, decrease of upstream flow due to barrages, horizontal expansion of shrimp farms and lastly, due to construction of coastal embankments.
- Low-lying deltaic areas are very vulnerable to flooding by storms surges from the ocean and by sea level rise, which will result in coastal flooding both under ambient conditions (given the low elevations of the coast), and even more in the event of storm surges.
- The climate change and sea level rise is likely to affect the fisheries in low coastal areas. Increased water temperature and salinity may not be suitable for many species. Sea level rise, by reducing the fresh water fishing areas, will cause reduction in fish production. Pond culture in the coastal areas will be affected by intrusion of salt water into ponds, unless embankments are made around them.
- Current policies such as the wetland policy, agriculture policy, water policy, environment policy and climate policy and current management strategies are

incapable of protecting the wetland from the challenges. Most of the policies are just guidelines and they lack information on how to implement the suggestions successfully and how to enact the regulations properly.

- Sea level rise will have numerous impacts. Flooding of coasts, estuaries, and river deltas can alter the physical structure of habitats and lower habitat availability and suitability. Increased coastal erosion can reduce or remove beach areas and protective barrier islands and interfere with nearshore currents and their physical transport patterns. Subsequent changes in drainage and irrigation patterns and modifications of fluvial flows can reroute sediment transport nutrient runoff into coastal waters. Saltwater intrusion into coastal wetlands, especially estuaries, can negatively affect these ecosystems and contaminate groundwater and other inland freshwater sources.
- In most cases of marine intrusion of coastal aquifers, methodologies based in simple approaches and elemental criteria can provide practical evaluation of the status and vulnerability of aquifers. Those methods must be easy of elaborate from simple and readily available data and should provide realistic, discriminatory and understandable information. A new index largely contrasted, is proposed.

FINDINGS FOR TOPIC V

Analysis of the effects of increased salinization on food security at national, regional and global levels:

- The climate change can lead to the redistribution of water resource among different regions, which can change the dynamics of surface runoff and underground runoff and water-salt movement.
- In some regions already is evident that climate change has induced temperature increase and rainfall decrease, which has caused decrease of wetland area and development of alkaline desertification.
- Improper irrigation practices and lack of drainage have generally led to accumulation of salts in the soil in concentrations, which are harmful to the crops.
- Various agricultural regions have significantly lost their productivity potential due to soil salinity.
- Saline agriculture almost always involves some compromise on yields as even a very salt tolerant species is bound to suffer some yield losses under the adverse conditions. Over the past few decades, research that has been conducted in some countries on a new concept of Biosaline Agriculture. The concept involves growing of salt tolerant plants in a succession with the highly salt tolerant plants gradually being replaced by relatively less salt tolerant plants and ultimately growing of salt resistant crops.
- Salinity intrusion in the coastal wetlands may create several socio-economic issues in future. Fall in rice production will be a serious threat to food security. Safe water will become a rare and costly commodity that may be unaffordable to the poor.
- Change in salinity level may affect the existence of aquatic life. Mass migration can be expected to the highlands and conflicts are likely to develop over land and water resources and over food allocation. Rural unemployment in the agricultural sector may create unrest in society. Large investment will be required for adaptation and to provide basic necessities and infrastructure.
- As the land is lost due to salinity, total production is affected, and its decrease will create increased food insecurity, at local and regional scale.
- People in some saline area have been facing the hard reality of drinking saline water for decades.
- In some coastal areas the situation has worsened with the introduction of shrimp farming and the consequent intrusion of brackish water far inside the coast. As a result, salinity has seriously affected ground water. Finding no alternative, most people now use bacteriologically unsafe surface water.
- In the salinized coastal areas, there is already loss of biodiversity, e.g. decrease in tree species and freshwater fish.
- Many persons in the saline area could be found to be suffering from one or more saline water-related disease.