Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture
Sub-programme on Soil and Water Management & Crop Nutrition Section

General Information on the Soil and Water & Crop Nutrition Sub-programme

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Introduction

The present world population of 6 billion is expected to reach 8 billion by the year 2025. Most of the increase in population will occur in developing countries where nearly 1 billion people suffer from chronic malnutrition. Most increases in food production will have to be achieved by obtaining higher yields from land that is already being farmed (Doos, 1994; Alexandratos, 1995). Many developing countries face major challenges to achieve food security in a sustainable manner, considering available per capita land area, severe scarcity of fresh water resources and particular socio-economic conditions.

It is known that agricultural intensification can have negative effects at different scales, such as increased soil erosion, soil fertility decline and reduced biodiversity at the local level; depletion and pollution of groundwater and eutrophication of surface waters at the regional level; and changes in atmospheric composition and climate on a global scale (Lal and Pierce, 1991; UNCED, 1992, UNEP, 2000; 2004). Enhancing sustainable food production will require integrated strategies for the use of land and water resources: a) agricultural intensification on the best arable land, b) rational utilization of marginal lands for agriculture, and c) prevention and restoration of soil degradation (Lal, 2000).

To achieve sustainable intensification of agricultural production systems that support productivity gains and income generation, novel, soil- and crop-specific technologies will have to be developed, pilot-tested and transferred in a relatively short time frame (FAO, 1995). Issues such as exploiting genotypic differences in nutrient and water use efficiency and adaptation to particular environments, increasing fertilizer use efficiency and nutrient recycling, soil and water conservation, development of efficient methods of irrigation, water harvesting and recycling, all need to be addressed.

For preventing and restoring soil degradation, the main issues will be controlling soil erosion and sedimentation with the associated risks of eutrophication of surface water and contamination of groundwater, combating desertification and enhancing soil carbon sequestration to improve soil quality/productivity and mitigate the greenhouse effect (UNCED, 1992; UNCCD, 1995; Biswas, 1994; Lal, 2000, 2001).

Within this context, the objective, strategies and main activities of the SWMCN sub-programme are described, with particular emphasis on the role of isotope and nuclear-based techniques in the development of integrated soil, water and nutrient management practices for the sustainable intensification of agricultural production systems.

The Soil and Water Management & Crop Nutrition Sub-programme

In 1964, two United Nations Organizations, the Food and Agriculture Organization (FAO) and the International Atomic Energy Agency (IAEA) established the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture at the IAEA Headquarters in Vienna, Austria. The mission was to strengthen capacity for using nuclear methods to improve technologies for sustainable food security and to disseminate these through international co-operation in research, training and other outreach activities in Member States of FAO and IAEA (IAEA, 1996). The Division has five Sections, namely Soil and Water Management & Crop Nutrition, Plant Breeding and Genetics, Animal Production and Health, Insect Pest Control, and Food and Environmental Protection. The Sections, together with their counterpart Units at the FAO/IAEA Agriculture and Biotechnology Laboratory, Seibersdorf, Austria (IAEA, 1999) comprise the five sub-programmes within the Food and Agriculture Programme (IAEA, 1996; http://www.iaea.org/programmes/nafa; http://www.fao.org).

Strategic objective and the role of nuclear techniques

The strategic objective of the SWMCN sub-programme is to develop and promote the adoption of nuclear-based technologies for optimising soil, water and nutrient management practices, which support intensification of crop production and the preservation of natural resources (http://www.iaea.org/programmes/nafa/d1). Nuclear-based techniques (stable and radioactive isotopes, neutron and gamma density probes) provide unique and quantitative data on nutrient and water dynamics in the soil-plant system, and therefore provide information essential both for proper definition of the constraints and for assessing the value of the interventions designed to alleviate them with the ultimate goal of enhancing sustainable intensification of agricultural production (IAEA, 1998; Dargie, 2000). For detailed examination on the use of nuclear-based techniques in the sub-programme, please see separate document in PDF format.

The underlying philosophy in developing strategies for the sub-programme is to address issues of major concern and relevance in soil fertility and sustainable crop production. The following main problems of global relevance have been identified. One or more problems may co-exist in a given situation:

- Accelerated rates of soil and landscape degradation (erosion, acidification, compaction, desertification)
- Scarcity of water for agriculture (competition for a finite resource) and sub-optimal use of available water
- Drought and salinity, particularly in arid and semi-arid environments
- Deteriorating quality of ground and surface waters (salinity, eutrophication)
- Widespread and serious depletion of soil organic matter (continuous cereal cropping, conventional cultivation, removal of crop residues and manure)
- Widespread N deficiency in continuously cropped soils (low soil organic matter)
- Widespread P deficiency, especially in acid soils of the tropics and sub-tropics

The strategy is to work within well-defined cropping systems or agro-ecological zones (FAO, 1996) adopting an integrated approach to soil, water and nutrient management. It is necessary to understand and quantify nutrient and water pools and fluxes in a given system in order to formulate knowledge-based agronomic practices for sustainable crop production.

Significant advances have been made during the past decade in the development and application of isotopic techniques to assess the dynamics of nutrients and water in the soil-plant system. The measurement of natural variations in the abundance of stable isotopes (deuterium, ^{13}C, ^{15}N, ^{18}O, ^{34}S) in components of the agro-ecosystem (soil organic matter, standing biomass, ground and surface water, atmospheric gases) can provide unique information on fluxes of carbon, nutrients

and water. For example, natural variations in the abundance of the stable isotope of carbon (^{13}C) have been used to estimate residence times of soil carbon derived from native vegetation and introduced crop species. Similarly the use of variations in the natural abundance of the stable isotopes of oxygen (^{18}O) and hydrogen (^{2}H) permit the identification of sources of water transpired by trees, and estimation of changes in rates of oxygen and water diffusion due to soil structural changes under different tillage practices. These developments have been possible due to the increased sensitivity of continuous flow isotope-ratio mass spectrometers for analysis of the isotopic composition of plant, water, soil and gas samples.

Intensification of agricultural production will require more refined management of external inputs of water, and an increased need to monitor soil water status and water balance in both rainfed and irrigated agriculture. Nuclear (neutron probe) and non-nuclear (time domain reflectometry and capacitance probes) methods will be required to evaluate water-conservation technologies and the performance of drip or sub-surface irrigation systems that can deliver both nutrients and water simultaneously. The development of an integrated nutrient management package (manufactured fertilizers and natural sources of nutrients such as rock phosphates, biological nitrogen fixation, animal and green manures, etc.) along with recycling of crop residues will result in a greater demand for the use of ^{13}C, ^{15}N and ^{32}P isotopes as tracers to develop efficient agronomic practices tailored to the specific cropping systems and local conditions.

Isotope techniques, which assist in the identification of germplasm with tolerance to abiotic stress factors, will become more widely applied in breeding programmes. Major stress factors include drought, salinity, Al toxicity and nutrient deficiencies, especially phosphorus. For example, ^{13}C isotope discrimination can be used to identify in C-3 plant genotypes with high agronomic water use efficiency and drought tolerance. Genotypes that are efficient in scavenging P in infertile acid tropical soils and the mechanisms of tolerance to P deficiency may be identified using ^{32}P isotopic techniques. Thus an interdisciplinary effort between mutation breeders and soil and water management specialists is required to identify and evaluate the performance of elite germplasm and to understand mechanisms of stress tolerance.

A major challenge will be to control soil and water degradation due to erosion processes. Substantial progress has been made using fallout radionuclides, e.g. ^{137}Cs and ^{210}Pb to estimate soil redistribution and hence erosion at the watershed scale. Considerable scope remains for the wider application of these techniques as well as other shorter-lived radionuclides to identify practical and cost-effective soil conservation measures at both farm and catchment scales.

Operational strategy

To achieve the strategic objective of the sub-programme the following activities are implemented in collaboration with FAO's Land and Water Development Division (AGL):

- Develop and validate nuclear and related methodologies to determine pools and fluxes of nutrients and water in defined cropping systems and agro-ecological zones in order to optimise management of external inputs and natural resources. Implement research activities at the Soil Science Unit, Seibersdorf, and at National Agricultural Research Systems (NARS) in Member States of IAEA and FAO through the Agency's Research Contract Programme that supports global and regional thematic Research Networks.
- Assist Member States through the Agency's Technical Co-operation Projects (TC) to formulate and implement national, regional and interregional TC projects that build infrastructure and use nuclear-based technologies to find solutions to problems of sustainable agricultural development.

- Assist Member States through the TC and Regular Programmes to develop human resources through provision at Seibersdorf and elsewhere of training courses, workshops, fellowships, scientific visits and training materials.
- Provide analytical services and External Quality Assurance through the Soil Science Unit, Seibersdorf, to assist research and develop analytical excellence in Member States, and identify regional laboratories that can provide training and quality-assured analytical services to other institutions in the region.
- Enhance the effectiveness and impact of research and outreach activities by creating linkages to existing projects and partnerships with relevant International Agricultural Research Centres (IARCs) of the CGIAR system and Advanced Research Institutes.
- Synthesize and disseminate information from sub-programme research activities through publications and databases, and exchange information through newsletters, web pages, etc.
- Promote the dissemination of nuclear technologies to the scientific community through the organization of international/regional symposia, seminars and expert consultations.
- Assist Member States to identify and adopt mechanisms to transfer technological packages to end-beneficiaries.

Conclusions

The mission of the Joint FAO/IAEA Programme is to strengthen capacities for using nuclear-based methods to develop technologies for sustainable food security and to disseminate these through international co-operation in research, training and other outreach activities in Member States of FAO and IAEA. The strategic objective of the SWMCN sub-programme is to develop and promote the adoption of nuclear-based technologies for optimising soil, water and nutrient management practices, which support intensification of crop production and the preservation of natural resources Nuclear-based techniques offer great potential in the development of integrated soil, water and nutrient management practices for sustainable intensification of agricultural production and conservation of the natural resource base. Their application requires scientific staff with adequate skills and expertise, and functional laboratory facilities to perform the isotope measurements. These techniques are widely used in essentially all developed and in an increasing number of developing countries in agronomic, ecological and environmental research.

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