SUSTAINABLE AGRICULTURE depends on maintaining an appropriate balance between the use and conservation of soil nutrients and water resources for crop and livestock production systems and environmental protection. The Soil and Water Management and Crop Nutrition (SWMCN) Subprogramme assists Member States in the use of nuclear techniques to develop improved and integrated soil-nutrient-water management practices for sustainable intensification of agricultural production systems as well as conservation of natural resources.

Soil and Water – the basic resources in agriculture for food security

- Approximately 75-80% of worldwide fresh water use is consumed by irrigated agriculture. This level of consumption is not sustainable because of the increasing competition for water from other sectors and the variation in rainfall patterns and global warming as a result of climate changes.
- Water use efficiency is intrinsically linked to nutrient utilization efficiency by crops. Thus an integrated approach to water-soil-nutrient management is vital to sustainable agriculture.
- Poor agricultural management practices or intensification of agriculture without due regard to the sustainability of natural resources can lead to land degradation. Land degradation including soil erosion affects around 70% of the world’s rangeland, 40% of rainfed agricultural land and 30% of irrigated land.

Nuclear and isotopic techniques in soil-nutrient-plant-water management

Nuclear techniques, which include stable and radioactive isotopes and radiation sources (neutron and gamma density probes), are used to:

- Measure rates of uptake, storage and cycling of water and nutrients in soil-plant and soil-plant-animal systems.
- Quantify soil erosion/sedimentation rates as influenced by land management practices.
- Investigate changes in soil productivity and quantify soil organic matter turnover as influenced by farming systems and practices.
- Trace water movement and agricultural pollutant pathways and to quantify off-site losses of nutrients and water.
- Assist in the selection of crop genotypes with superior resource use efficiency and tolerance to abiotic stress.
- Quantify biological nitrogen fixation (BNF) of legumes in cropping systems.

Integrated soil fertility management

Isotopes such as nitrogen-15 ($^{15}\text{N}$), phosphorus-32 ($^{32}\text{P}$) and carbon-13 ($^{13}\text{C}$) are used as tracers to identify the most efficient management practices of locally available nutrient inputs (e.g., fertilizers, organic nutrient sources, biological nitrogen fixation and phosphate rocks), tailored to specific cropping systems and environmental conditions for optimum crop production. Results from these activities include:

- A publication on “Guidelines on Nitrogen Management in Agricultural Systems”.
- A joint FAO/IAEA bulletin (FAO Fertilizer and Plant Nutrition Bulletin No. 13) on “Use of phosphate rocks for sustainable agriculture”.
- An IAEA-TECDOC publication on “Nutrient and water management practices for increasing production in rainfed arid/semiarid areas”.

Arresting land degradation

Nuclear techniques have been employed to investigate management practices that mitigate land degradation (e.g. soil erosion, soil acidification and soil salinization) and enhance soil productivity. Outputs from these activities include:

- Incorporation of P-efficient crop species into cropping systems and amelioration of soil acidity and P infertility with lime and reactive phosphate rocks enhanced productivity of tropical acid soils.
- $^{32}\text{P}$ isotopic techniques were successfully used to identify crop genotypes that are efficient in scavenging tightly-held soil phosphorus and to assess the agronomic effectiveness of indigenous phosphate rock sources.
- Biological N, fixation (BNF) capacity, as determined by $^{15}\text{N}$, of grain legumes (cowpea, common bean and soybean) commonly grown in the acid savannah soils of West Africa could be improved through rhizobial strain selection and plant genetic improvement.
- $^{13}\text{C}$ was successfully used to estimate residence times of soil C derived from native vegetation and cultivated crops.
- The publication of a “Handbook for the Assessment of Soil Erosion and Sedimentation Using Environmental Radionuclides”.
- Soil erosion rates, as measured by fallout radionuclide ($^{137}\text{Cs}$ and $^{17}\text{Be}$) techniques, ranged from 0.4 to 120 t ha$^{-1}$ yr$^{-1}$, depending on factors such as rainfall intensity, soil characteristics, site topography, vegetation cover and land management practices.
- Soil conservation technologies such as no-till, grass strips and terracing in Morocco, Romania and Vietnam reduced soil losses by 55-89% as measured by fallout radionuclide techniques.

Changes in land uses substantially reduced soil losses by 79% in Chile (with a change from crop land to grassland) and 81% in China (with a change from over-harvesting of timber to the restoration of the damaged watershed).

To date, some 40 Member States now have the capacity to use fallout-radiouclide techniques to estimate the beneficial effects of conservation measures on soil erosion/ sedimentation.
Crop varieties with high tolerance to harsh environments and with superior resource use efficiency

One way of enhancing food security is to identify crop varieties that adapt to specific environments. The SWMCN subprogramme collaborates with the Plant Breeding and Genetics Subprogramme in identifying plants that are tolerant to abiotic stress (drought and salinity). The SWMCN Subprogramme is also concerned with the issues of low inherent soil nutrient status, in particular severe nitrogen (N) and phosphorus (P) deficiencies, which are the most common nutritional stresses for agricultural production in many regions of the developing world. Some specific activities include:

- Developing and validating screening protocols for plant traits that enhance N and P acquisition and utilization in major food cereal and legume crops grown in low fertility soils
- Facilitating the selection of drought-tolerant wheat and salinity-tolerant rice using $^{13}$C discrimination techniques
- Facilitating the selection of crops for efficient phosphorus utilization by using $^{32}$P isotopic techniques.

$^{13}$C is being used to identify wheat with high water use efficiency (WUE): Less discrimination against $^{13}$C (less difference between $^{13}$C and $^{12}$C), the higher the WUE.

Water Management in Agriculture

Improving water use efficiency in agriculture will require an increase in crop-water productivity through the use of novel irrigation technologies and an improvement in water management practices and soil moisture conservation measures at both farm and catchment levels. The measurement of natural variations in the abundance of $^{18}$O, $^2$H, $^{13}$C and $^{15}$N can be used for tracking and quantifying water and nutrient fluxes through and beyond the plant rooting zone. An accurate measurement of soil moisture content using nuclear (soil moisture neutron probe) and non-nuclear methods is essential for establishing the optimal soil-water balance for irrigation scheduling under different irrigation systems and soil management practices. Results from these activities include:

- Publication of “A manual on the use of soil moisture neutron and gamma density probes in agriculture”
- Publication of: “Practical guideline to field assessment of soil water content” (In press)
- Improving yield and revenue by 25-50% while reducing water use by the same extent in Chile, Jordan, Syria and Uzbekistan
- Publication of a book on “Crop Yield Response to Deficit Irrigation” and a joint FAO-IAEA publication (FAO Water Reports Series 22) on “Deficit Irrigation Practices”.

Sustainable use and management of land and water:
A must in sustainable agriculture

Conventional tillage with limited cover

Nuclear and isotopic techniques play an important role in developing efficient water and soil nutrient management strategies for improving crop production, conserving natural resources and enhancing environmental protection.