IAEA FACTSHEET

Food and Agriculture

Monitoring Soil–Water–Nutrient Interaction Using Isotope and Nuclear Techniques

What should I know?

Soil, water and nutrients are vital for life and food security.

In the areas of soil and water management and crop nutrition, isotope and nuclear techniques are employed to measure and monitor the interactions between soil, water and nutrients in order to ensure that these are used efficiently in various cropping systems. Such techniques underpin the development of best soil–water–nutrient management practices.

Isotopic technologies play a crucial role in assessing the impacts of climate change and changing weather patterns on soil and on agricultural water resources. The IAEA and the Food and Agriculture Organization of the United Nations (FAO) assist Member States in the use of advanced nuclear and isotopic techniques to measure changes in soil, water and nutrient movement, thereby supporting farming practices that keep the soil healthy, improve water and nutrient use efficiency, and optimize crop yields and soil resilience against the impacts of climate change and variability.

Conserving soil and water and improving farming practices

Land degradation and soil erosion threaten agricultural productivity, food security and environmental sustainability. Erosion carries away the soil's most fertile layer and many of the nutrients, potentially leaving behind land that may no longer be usable for agriculture.

Soil and water scientists from Iraq monitor and track soil-water-nutrient movement during a training course at the Joint FAO/IAEA Laboratories Seibersdorf, Austria.

(Photo: J. Adu-Gyamfi/IAEA)

Land degradation currently affects 1.9 billion hectares globally, or about 65% of global soil resources. Soil erosion accounts for 85% of the degraded surface area and is thus the main contributor to land degradation. Approximately 1.5 billion people — a fifth of the world's population — depend directly on the food produced from degraded land. Approximately 36 billion tonnes of fertile soil are lost to world agricultural systems each year through soil erosion. The economic cost associated with on-farm and off-farm soil erosion is estimated at US $400 billion per year.

Isotopic and nuclear techniques can help to pinpoint precisely the sources and causes of soil erosion, and to adopt appropriate agricultural conservation practices that can be targeted to reduce erosion. These techniques can therefore play a vital role in helping farmers to produce more food with limited natural resources and external inputs and under difficult growing conditions.

Enhancing soil fertility

Soil fertility is the ability of soil to sustain plant growth and optimize crop yield. It can be enhanced through the application of organic and inorganic fertilizers to the soil. Isotopic and nuclear techniques can provide efficient tracing methods that help scientists and farmers to understand the movement of nutrients between soils and plants, and thus make it possible to conserve soil resources and improve soil productivity.

Integrated soil fertility management approaches aim to maximize the efficient use of nutrients and improve crop productivity. One such approach is the use of grain legumes to capture nitrogen directly from the atmosphere and hence improve soil fertility, enabling farmers to save millions of dollars that they would otherwise have had to spend on the purchase of nitrogen fertilizers.

Improving drip irrigation and fertigation

The efficient use of water in agriculture is becoming increasingly important, as water demand rises with the expansion of competing industrial and residential uses and rainfall becomes more erratic. Drip irrigation and fertigation (the addition of fertilizer, soil conditioners or other water-soluble products to irrigation water) can vastly improve water and nutrient use efficiency. Nuclear and isotopic techniques can be used to monitor crop water and nutrient requirements and identify improvements to water and fertilizer management practices.

How do nuclear and isotopic techniques help?

The Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture (Joint Division) helps Member States to strengthen their capacity to use nuclear and isotopic techniques for improving the resilience of farming systems against the impacts of climate change, and hence for enhancing crop production and the preservation of natural resources.

The isotopes nitrogen-15 and phosphorus-32 are effective tracers that can be employed to ascertain and understand the movement of nutrients between soil and plants, and to provide quantitative data on the efficiency of their use by crops. Such information is valuable in the design of improved fertilizer application strategies. The nitrogen-15 tracing technique is also used to quantify the amount of nitrogen capture from the atmosphere through biological nitrogen fixation by leguminous crops — a natural process that enhances soil fertility.

Compound specific stable isotope (CSSI) analysis — based on the measurement of carbon-13 signatures of specific soil organic compounds, such as fatty acids — is used to identify sources of land degradation. By linking fingerprints of land use to the sediment in deposition zones, the CSSI technique is helpful in determining the sources of eroded soil and in identifying areas prone to soil degradation.

Techniques based on fallout radionuclides, such as caesium-137, lead-210 and beryllium-7, are also used to assess short-, medium- and long-term soil erosion and sedimentation processes, and they can often complement or even replace traditional and more time-consuming techniques. These radionuclides are strongly adsorbed by fine soil particles and are not taken up by plants. During erosion and deposition processes, they move with the soil particles and can be used to trace soil redistribution over large areas and extended periods of time.

Farmers in Kenya are learning the importance of how drip irrigation contributes to fruit and vegetable production.
(Photo:IAEA)

Laboratory support, research and knowledge-sharing

The Joint Division's Soil and Water Management and Crop Nutrition Laboratory in Seibersdorf (Austria) assists in the development, adaptation and transfer of nuclear techniques to Member States to optimize soil, water and nutrient management practices and strategies that enhance sustainable agriculture. The laboratory supports a broad range of services, which include:

- Developing and validating isotope and nuclear techniques for use in coordinated research and technical cooperation projects;
- Conducting training for Member States on the use and applications of nuclear and related techniques to develop improved and integrated soil–water–nutrient management practices;
- Performing isotope analyses for Member States that do not have analytical facilities, as well as providing quality assurance services.

Snapshot of achievements

In Kenya, the introduction of low-cost, small-scale irrigation technologies has helped Maasai women to grow vegetables for food security, while the men attend to their cattle herds often long distances from home. Similar successes in irrigation management have also been achieved in the Sudan, Zimbabwe and other countries.

In Benin, 5000 rural farmers received assistance with the identification of high-nitrogen-fixing legumes that are compatible with the dominant cereal-cropping systems and can thus help optimize

crop productivity and soil fertility. Scientists in the country are now able to identify the specific bacteria needed for legume roots to produce the nodules that fix nitrogen, and to use the nitrogen-15 tracing technique to quantify the amount of nitrogen fixed. This has resulted in a 50% increase in maize yields and a 70% reduction in imports of nitrogen fertilizers.

In the mountainous regions of Morocco, the use of fallout radionuclide techniques has helped to identify the most erosion-prone areas and, through the subsequent adoption of appropriate conservation-promoting agricultural practices, soil erosion in the watershed has been reduced by 40% and agricultural productivity optimized.

More Information can be found here:

Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture

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www.iaea.org/about/organizational-structure/department-of-nuclear-sciences-and-applications/joint-fao/iaea-division-of-nuclear-techniques-in-food-and-agriculture

At the Joint FAO/IAEA laboratories in Seibersdorf, Austria, a field trial where methods of drip irrigation and fertigation are being implemented to improve crop production.

(Photo: J. Adu-Gyamfi/IAEA)

Training and technology transfer are important activities at the Joint FAO/IAEA Soil and Water Management and Crop Nutrition Laboratory in Seibersdorf, Austria.

(Photo: IAEA)

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