by Louise Potterton

No Rain, No Food

How Nuclear Techniques can Support Agriculture in Dry Conditions

In many parts of the world, either too much or too little rain falls, often at the wrong time, leading to water scarcity, droughts and crop failure.
(Photo: P. Pavlicek/IAEA)

Access to sufficient water supplies is essential for successful and sustainable farming. Without water, crops die, farmers lose their income and people go hungry.

There are two types of cropping systems namely irrigated and rain-fed.

Agriculture that depends upon rainwater represents about 80 % of the total area under cultivation and produces the majority, or about 60%, of global food.

In many parts of the world, either too much or too little rain falls, often at the wrong time, leading to water scarcity, droughts and crop failure.

The IAEA's Soil and Water Management and Crop Nutrition section is using nuclear and nuclear-related techniques to help farmers in the developing world to conserve water and cope better under dry conditions.

Louise Potterton spoke to IAEA soil and water expert, Karuppan Sakadevan.

What are the major challenges to rain-fed agriculture and how is it different from irrigated agriculture?

Rain-fed agriculture is a low-input system. Depending on total annual rainfall and its distribution as well as the type of soils, productivity can vary greatly from moderate to low.

Agriculture that depends on rain is more risky with the possibility of crop failures in drier areas due to erratic and unpredictable rains. Rain-fed agriculture is generally more successful on soils that can store a lot of rainfall (i.e. loamy and clayey soils).

On the other hand, irrigated agriculture can be highly productive with low risk but at a high input cost (i.e. irrigation equipment, energy)

How can the IAEA help farmers who practice rain-fed agriculture conserve and manage water?

The IAEA through its Research and Technical Cooperation Programmes has implemented 30 water conservation projects in rain-fed agriculture in IAEA Member States in Asia, Africa and Latin America. These projects focus on practises such as minimum tillage, crop residue retention and crop rotation.

On average, 65% of rainwater is lost and not available to crops in rain-fed agriculture. Farmers need to capture and store water so they can use it during the dry period.

Conservation or minimum tillage is a farming practice in which crops are grown with minimum soil disturbance. It reduces the breakdown of soil organic matter and therefore increases the water holding capacity of the soil. This tillage practice along with crop residue incorporation into the soil reduces water loss through evaporation and the impact of rainfall on soil erosion.

Another example of addressing water scarcity is water harvesting. This involves collecting and storing runoff water in natural or man-made farm ponds and wetlands that can be used for supplementary irrigation or drinking water for livestock. We also run programmes that support the selection of drought and salinity-tolerant crops, such as rice and wheat.

What are the nuclear techniques involved?

In order to save every drop of water, we need to know where the water goes. Isotopic techniques can help to trace the movement of water between soil, plant and atmosphere.

In water harvesting, the oxygen isotope (oxygen-18) is used to identify water sources such as surface runoff and seepage flow entering into farm ponds and wetlands. This will allow farmers to design the size and identify best locations for developing these farm ponds and wetlands.

Since oxygen is a major element of water, the use of oxygen-18 isotope can help to separate the water loss from soil by evaporation and plant uptake. This helps in developing management practices such as tillage, residue retention, plant density and crop rotation for reducing soil evaporation losses.

A crop's ability to capture every drop of water depends on its health. That is why it is important to know whether a nutrient such as nitrogen, a major building block of crop growth, is sufficiently available. Nitrogen-15, a stable isotope of nitrogen can be used to measure the efficient use of applied fertilizer nitrogen to crops under different management practices and thus determine the efficient use of water by crops.

Since carbon is another major component in plant growth, the amount of carbon stable isotopes in light (carbon-12) and heavy (carbon-13) fractions can help us to identify crops that are tolerant to drought.

We also use the neutron probe, an instrument used to measure the amount of water stored in the soil and to assess the effect of different management practices such as tillage and crop residue retention on soil moisture holding capacity.

Can you give me more details about water harvesting?

Water harvesting and storage is gaining increasing importance in arid and semi-arid regions throughout the world as water becomes increasingly scarce, due to changing climatic conditions, erratic weather events or the unsustainable use of existing water. With this technique, rain water is captured, usually in a pond on a farm.

Water harvesting acts as a buffer against drought, providing water for livestock and a limited capacity for irrigation and fire protection.

Can you give me an example of an IAEA project where these practices are working?

IAEA has implemented water harvesting technology in China, Estonia, Iran, Lesotho, Nigeria, Romania, Tunisia and Uganda to increase the productivity of rice, wheat and vegetable crops through a network of coordinated research projects.

Through both Technical Cooperation projects and coordinated research projects, conservation agriculture practices have been implemented in Argentina, Brazil, Chile, India, Kenya, Morocco, Mexico, Niger, Pakistan, Turkey, Uganda and Uzbekistan to increase water availability for crops during the growing period. And our projects have achieved good results. In Niger, cowpea production increased nine-fold by using crop rotation with millet and crop residue retention. In Pakistan, crop residue retention and crop rotation increased wheat yield by 18%.

What about extreme drought situations — how can nuclear techniques help here?

Extreme drought situations arise when a region receives below average or no rain for months or years. During prolonged droughts, losses in crop and livestock production can reach 50% or more. The projects we operate that support water conservation and harvesting are useful in these conditions, since water stored in farm ponds and wetlands can be helpful for irrigating crops for one or two growing seasons.

Also we have projects that use nuclear-based research to support the cultivation of drought-tolerant crops. For example, pigeon pea and cowpea are tolerant to drought as they develop deep roots and extract water from depths up to two meters below the soil surface.

The IAEA also develops soil management techniques. Does soil play an important role in water management?

It certainly does. Soil is different all over the world. Certain crops thrive better in certain soils and different soils can hold varying amounts of water.

The physical properties of the soil, such as particle sizes and the proportions of clay, silt and sand, its chemical properties and its mineralogy can determine how much water the soil holds, for how long and to what depth.

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The amount of water that is retained within the root zone for crop use also depends on the activity of soil organisms and earthworms that influence water runoff along the soil surface or water movement and retention within the soil. So technologies that help to improve the physical, chemical, and biological properties of soils are vital to improving agricultural water management.

Which nuclear techniques are used to improve soil fertility?

Stable isotopes of nitrogen and carbon are used. These techniques are not used directly to improve soil fertility, but help us to identify on-farm management factors that influence the extent of the movement of nutrient of added organic matter between soil and plant across agricultural landscapes.

This information is useful to provide advice on the best soil and nutrient management practices that enhances soil fertility and reduce soil degradation.

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