Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Agricultural Water Management

Meeting the Challenge

COUNTRY IMPACTS

Agricultural Water Management

Global and regional issues and considerations

- Agriculture accounts for 70% of global freshwater use
- FAO projects a 50% increase in agricultural water needs by 2050 to feed growing population
- An average of 65% of rainwater is lost and unavailable to crops in rain-fed agriculture
- Climate change with an increase in extreme weather events can cause severe droughts and flooding
- Irrigation is practiced on 20% of global agricultural croplands that contribute 40% of world food production
- Global water use efficiency of irrigated agriculture is still below 40%
- Grain yield can be increased 5-fold by eliminating water stress
- On-farm water management can influence soil productivity and soil and water quality degradation
- 90% of sub-Saharan farmers depend on rain-fed agriculture
- 12 of the 15 most water scarce countries (less than 300 mm/year) are located in West Asia and North Africa

People's Democratic Republic of Algeria

Water and soil salinity lays 30% of agricultural lands barren in western Algeria

- → 30% of total arable area of 140,000 hectares considered unsuitable for crop production due to high soil salinity
- → Used SMNP to optimise irrigation schedules and measure soil water status for crop growth
- → Efficiently used saline water (3.3 ppt) to produce 2.5 t/ha salinity-tolerant barley and oat
- → Projected to 42,000 ha, this would generate 105,000 t of grain, equivalent to US $26.3 million in additional earnings to small scale farmers

People's Republic of Bangladesh

2.6 million ha saline, highly fertile coastal soils lie fallow during dry season

- → Used SMNP to optimise irrigation schedules
- → Identified salinity tolerant crops
- → Facilitated 2nd crop in dry season
- → 1 year after project completion technologies already implemented on 13,000 ha
- → Farmer incomes boosted by US $2000/yr
- → Potential value of 2nd crop exceeds US $1.4 billion annually

Republic of Chile

Heavy soil erosion from vineyards threaten water quality

- → Used fallout radionuclide to determine soil erosion and deposition
- → Soil erosion on hillside vineyards covering 90,000 ha is huge at up to 82 t//ha/yr
- → Downstream water quality severely impacted by herbicides and fertiliser-derived nutrients fertilisers
- → Cover crops reduce erosion on 3,200 ha in 13 vineyards

Republic of Chile

Foresting activities end extreme weather events threaten water quality and government efforts to expand this sector

- → Valued at US $5.5 billion in 2008, forestry accounts for 7.3% of Chilean exports
- → Used fallout radionuclides, organic carbon and nitrogen contents of soils and sediments to identify hotspots of erosion and contribution to water quality
- → Found sediment delivery to take place primarily as a result of harvesting and planting activities
- → Currently develops data-based decision making processes to implement enhanced, cost-effective sediment management practices

People's Republic of China

Inefficient use of surface flooding triggers water crises in the North China Plains

- → Water table in NCP is falling at a rate of up to 3 m/yr
- → Used SMNP to optimise irrigation schedules
- → Used water isotopes (^{18}O, ^{2}H) to discriminate crop water uptake versus soil water evaporation
- → Reduced water needs in deficit-irrigated wheat by 33% compared to traditional full-flood irrigation
- → Cut water needs of maize by a full 66% compared to traditional furrow irrigation
- → Project findings used to validate FAO's AquaCrop model for predicting yield response under a range of irrigation and cropping scenarios

Republic of Ghana

Recurrent droughts and water shortages prevent vegetable production and threaten peri-urban farmer livelihoods

- → Smallholders account for 80% of agricultural output
- → Used SMNP to optimise irrigation schedules
- → Increased cabbage yield by 50% using only 40% of water compared to sprinkler irrigation
- → Generated savings to farmers of US $216/ha/yr
- → Drip irrigation adopted by 130 peri-urban farmers within two years of project commencement
- → Full transition from sprinkler to drip irrigation on 6400 ha of current peri-urban farming would bring water savings of 416,000 m^3/yr

Republic of Kenya

Low, erratic rainfall causes frequent crop failures, low food production and unsustainable livelihoods

- → 80% of farmland is arid or semi-arid
- → Used SMNP to optimise irrigation schedules
- → Used ^{15}N labelled fertiliser to measure nitrogen uptake by crops
- → Developed small-scale, low-cost drip irrigation systems for resource-poor farmers
- → Achieved up to 3.3 times the tomato yield with drip irrigation using only 55% water and 50% nitrogen under field conditions
- → Achieved a further 20 times the tomato yield, to 580 t/ha, using drip irrigation in locally produced, low-cost greenhouses
- → Now provides technical expertise and know-how on agricultural water management to 23 African countries

Republic of Kenya

Poor utilisation of scarce rainfall result in meagre harvests and food shortages among rural poor

- → Close to 90% of Kenyan pigeon pea is produced by small-scale farmers
- → Used ^{15}N isotope to determine the efficiency of pigeon pea to capture atmospheric nitrogen for crop production
- → Used pigeon pea to tap scarce water resources up to 2.5 m below ground in dry season
- → Increased pigeon pea yield to generate 6-10 times higher yields per hectare
- → Generated extra farmer incomes of US $2500-3200/ha/yr

Republic of Mali

Poor water management and low yields contribute to food shortages and widespread malnutrition among rural population

- → Agricultural productivity is hampered by less than 40 mm of rainfall during 6-month dry summer seasons
- → Used ^{15}N isotope to determine the efficiency of cowpea to capture atmospheric nitrogen for crop production
- → Used cowpea to tap scarce water resources up to 2.5 m below ground in dry season
- → generated additional farmer incomes of up to US $441/ha/yr
- → Projected to current 520,000 ha land under sorghum, could add up to 470,000 t of sorghum and 126,000 t of cowpea to the annual Malian diet

State of Qatar

Abundant use of saline groundwater causes extensive soil salinization

- → Currently 8000 ha under cultivation; 23% of farmland abandoned because of increasing salinization
- → Used SMNP to optimise drip irrigation schedule with mixture of saline groundwater and treated sewage water
- → Reduced water needs by 20-30% using drip irrigation versus sprinkler and generated annual biomass of 35 t/ha
- → Plans to use 100 million m^3 saline groundwater with 60 million m^3 treated sewage water/yr will add 83,300 ha and increase cultivated lands to ten times the current acreage
- → Treated sewage water delivers 3000 t nitrogen, 600 t phosphorous and 22,000 t organic matter and increases soil quality

Republic of Slovenia

Trebled on-farm water use efficiency in vegetable crops through drip irrigation in Slovenia, allowing a 60% reduction in nitrogen fertiliser use

- → Used ^{15}N labelled nitrogen fertiliser to determine nitrogen use efficiency of vegetable crops under different irrigation and fertiliser practices
- → Increased nitrogen use efficiency of vegetable crops from 45% to 75% of nitrogen applied through drip fertigation
- → Used drip irrigation to reduce water application rates to less than a third compared to sprinkler; corresponding reduction expected in loss of nitrogen fertiliser beyond plant rooting zone
- → Ministry of the Environment and Spatial Planning now anticipates compliance with EU Directive (2000/60/EC) by 2015

Republic of Tajikistan

Chronic water shortage in short summer season is a major threat to food security and sustainable agriculture

- → Inappropriate irrigation and tilling practices erode fertile top soils
- → Used fallout radionuclide ^{137}Cs to quantify soil erosion and deposition rates
- → Measured erosion losses of up to 30-40 t/ha/yr with irrigation furrows placed along 3-4° slopes
- → Effectively controlled soil erosion by placing irrigation furrows along contour lines of slopes of up to 8° and terracing on steeper slopes
- → New farming practices eagerly adapted both by farming community and by local government

United Republic of Tanzania

Recurrent droughts and poor yields jeopardise livelihoods of small-scale tea farmers

- → Fourth-largest African tea producer
- → 80% of tea-producing areas are rain-fed, 19% are sprinkler irrigated
- → Used SMNP to optimise irrigation schedules
- → Generated tea yields of 8500 kg/ha with drip irrigation, 17 times higher than rain-fed yields and twice as high as sprinklers
- → Reduced water consumption with drip irrigation by 75% compared to sprinkler
- → Generated interest of commercial company in low-cost-drip irrigation systems

Republic of Turkey

Excessive sprinkler irrigation with 35% water use efficiency reduces fertiliser efficiency

- → Used SMNP to optimise irrigation schedules
- → Used ^{15}N labelled fertiliser to determine nitrogen uptake by crops
- → Reduced water needs in potato crop by 50% and nitrogen fertiliser by 40% using drip irrigation
- → Transition to drip irrigation costs US $200/ha and saves US $2000/ha/yr
- → Potato drip irrigation up from 500 ha in 2005 to 10,000 ha expected in 2011
- → Regional policy subsidises 50% of costs; additional local subsidies introduced

Socialist Republic of Vietnam

Recurrent droughts and water shortages threaten coffee production of smallholders

- → Second-largest coffee producer in the world
- → Used isotopic signatures of water to assess extent of soil water evaporation
- → Reduced soil water evaporation during dry season from 17% to 5% by covering soil with old branches and leaves
- → Full transition to drip irrigation on all coffee plantations would save $^2/_3$ of water during dry season (Dec. to Jan.), equivalent to 66 million m^3

Socialist Republic of Vietnam

Intensive upland cultivation causes severe soil and nutrient erosion and silts up lowland water reservoirs

- → Used CSSI to assess influence of land use practices on lowland water quality
- → Used CSSI to identify hotspots of land degradation and enable implementation of cost-effective conservation strategies
- → Mulch-based cropping systems reduced soil erosion in uplands by 90% and retained sufficient runoff water for lowland rice production

NOTES

How were these impacts achieved?

Nuclear technologies in Agricultural Water Management

Soil moisture neutron probe (SMNP)

- → ideal for measuring water content of soil surrounding plant root
- → the best sensors for water content of saline soils
- → widely used to calibrate conventional moisture sensors

Water isotopes (^{18}O, ^{2}H)

- → effectively partition water consumption into crop water uptake and evaporation from the soil to accurately determine crop water use efficiency

Carbon isotope (^{13}C)

- → variations in plant tissues identify crop varieties tolerant to drought and salinity
- → variations in plants, plant litter and soil organic matter identify hotspots of land degradation

Nitrogen isotopes (^{15}N)

- → trace the movement of applied nitrogen fertiliser to optimize nitrogen use efficiency
- → are essential for determining water quality in agricultural landscapes

Fallout radionuclides of caesium (^{137}Cs), lead (^{210}Pb), beryllium (^{7}Be)

- → identify soil erosion patterns and rates
- → measure efficiency of soil conservation measures to control soil erosion and protect water quality

Compound-specific stable isotope (CSSI)

- → identify hotspots of land degradation that enable implementation of cost-effective conservation strategies

FAO/IAEA Delivery Mechanisms?

Organisational setting

The Soil and Water Management and Crop Nutrition (SWMCN) Section, with its associated laboratory in Seibersdorf, Austria, is one of five sections of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. It assists member states to develop improved soil and water management practices for sustainable intensification of agricultural production systems. Through the application of nuclear techniques, it focuses on the development of methodologies and cost-effective soil-water technology management packages to: (i) improve soil quality and fertility for crop nutrition and production; (ii) increase on-farm and area-wide water and nutrient use efficiency to combat water scarcity and prevent the inefficient use of applied fertilisers; (iii) minimize the impacts of land use and soil and water management practices on greenhouse gas emissions; and (iv) reduce the effects of climate change on agricultural soil and water resources. It does this by coordinating and supporting research, promoting capacity building and technology transfer, providing technical services and policy advice, and collecting, analysing and disseminating information.

Coordinating and supporting research

The Joint FAO/IAEA Division supports and coordinates research activities of member states through its Coordinated Research Projects (CRPs), one of its main delivery mechanisms. These projects bring together research institutes in both developing and developed member states to solve practical problems of economic significance, and each project typically involves collaboration among 10-30 institutions, including those belonging to the Consultative Group on International Agricultural Research (CGIAR). Institutions in developing countries are normally awarded Research Contracts with nominal financial support, whereas those in more developed countries participate as advisers through Research Agreements that enable their attendance at Research Coordination Meetings. These projects normally last for five years and the results are published and often used for the elaboration of international standards related to food security and trade. Approximately 500-600 research institutions and experimental stations in member states cooperate in about 30-40 on-going CRPs organized by the Joint Division every year.

Providing technical and advisory services through technical cooperation projects

The Joint Division is also responsible for providing scientific and technical support, capacity building and technology transfer to both FAO and IAEA member states through the annual implementation of some 250 national and regional IAEA Technical Cooperation Projects (TCPs), as well as for interregional and regional training courses channelled to recipient countries for the purposes of providing equipment, expert advice and training. Capacity building plays a key role in the Joint Division, with some 50 training courses, workshops and seminars being organized each year for about 500 trainees from developing countries. Most training activities take place in member states, while activities that require special facilities are carried out at the FAO/IAEA Agriculture & Biotechnology Laboratories in Seibersdorf, Austria. IAEA's TC projects in the field of food and agriculture are financed with approximately US $12-13 million per year through the IAEA's Technical Cooperation Fund and through trust funds provided by donor countries and international funding agencies.

Providing laboratory support and training

The FAO/IAEA Agriculture & Biotechnology Laboratories, situated at the village of Seibersdorf 45 km southeast of Vienna, play a key role in the implementation of Joint Division activities. The laboratories specialize in adaptive research, development and transfer of nuclear methods in soil science, plant breeding, animal production and health, entomology and food safety. The laboratories provide a broad range of specialized services and training of scientists through individual fellowships and interregional group training in various disciplines. It also provides guidance on the introduction of analytical quality control and assurance programmes into counterpart laboratories, and training in the maintenance of laboratory equipment and instruments.

Collecting, analysing and disseminating information

In addition to encouraging the direct transfer of skills and technology, the Joint Division provides a variety of information services. These include conferences, symposia, seminars and advisory group panels as well as the publication of technical and public information documents that arise from these and other meetings such as CRPs and TCPs. The Division also maintains contact with member states through the publication of newsletters, periodic reviews and IT databases. It also plays a key role in the elaboration and adoption of standards through three key organizations under World Trade Organization agreements related to plant, animal and human safety (IPPC, OIE, CODEX), as well as in the development of standard operating procedures (SOPs), guidelines and manuals.

For further information please contact:

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