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Contents

Maasai people are pastoralists by nature. Circumstances have changed them to agro pastoralists

To Our Readers

2011 started at a hectic pace and on a positive note for the team members of the Soil and Water Management & Crop Nutrition (SWMCN) Section and the SWMCN Laboratory following an announcement by the IAEA Director General (DG) that the use of nuclear techniques for water is to be one of the major IAEA focuses for this year. In addition, it will also be a major theme for the IAEA Scientific Forum entitled: *'Water Matters: Making a Difference with Nuclear Techniques'*, which will be held in September (21-22 September 2011) at the Vienna International Centre. This theme encompasses the three pillars of the IAEA's activities which include water resource assessment, agricultural water management, and aquatic pollution control.

From the agricultural water management perspective, the DG's announcement gives both the SWMCN Section and the SWMCN Laboratory an excellent opportunity to promote and disseminate the importance of nuclear techniques to enhance water use efficiency and ensure more crops per drop in both rainfed and irrigated agricultural systems in Member States. Together with input from our counterparts in coordinated research projects (CRPs) and technical cooperation projects (TCPs), we have critically examined the achievements of the IAEA-funded studies on agricultural water management. Some of these studies and their impacts on enhancing water use efficiency and crop productivity in Member States are reported in this issue of the Soils Newsletter in the Impact Reports Section.

IAEA
International Atomic Energy Agency

However, since not all of the **impact reports** can be published in this newsletter, we aim to provide our readers with more stories from other countries in the December 2011 issue and on the SWNCN Webpage at http://www-naweb.iaea.org/nafa/swmn/index.html.

The impact reports in this Soils Newsletter highlight the importance of water management in agriculture and the contribution of nuclear techniques to unravel processes that affect the interactions between soil, water and crops which in turn influence water use efficiency and crop productivity. The importance of water management in agriculture cannot be over-emphasized. With 70% of freshwater usage dedicated to agriculture and 40% of the world food supply produced from irrigated agriculture, the efficient use of every drop of water coming from either irrigation in irrigated agriculture or rainfall under rainfed conditions (60% of the world food supply) is of vital importance if we are to grow enough food to meet the demands of more than 9 billion people by 2050. Besides these demands from the world population, the competition for water with other sectors and the impacts of climate change and variability on water availability are expected to put more pressure on the efficient use of water for sustainable agriculture (both in food production and environmental sustainability).

Since one of the four planned sessions of the IAEA Scientific Forum will be on *'Water matters - Tackling water scarcity and saving water in agriculture with nuclear techniques'*, the SWMCN Subprogramme is planning to use this opportunity to inform Member States and the general public of the importance of nuclear techniques in agricultural water management (AWM) for food security and environmental sustainability. If you have an opportunity to visit Vienna at this time and to attend the Forum, please let me know, so that I can welcome you.

Besides water management, improving soil conditions is increasingly viewed as an important issue to enhance food security and climate change mitigation and adaptation. Even in poorly developed economies, soil is no longer viewed as an academic subject but as a lifelong management art to enhance sustainable economic and social development. Without properly managed soils, crop growth can be limited and soil degradation and erosion can be major constraints for food security and environmental sustainability. With the aim of promoting the exchange of information among the scientific community and policy makers on the importance of soil management in food security in the face of climate change and variability, the SWMCN Subprogramme is also busy planning and organizing the International Symposium on Managing Soils for Food Security and Climate Change Mitigation and Adaptation. As indicated in the previous Soils Newsletter (January 2011), this Symposium will be held at the IAEA in Vienna from 23-26 July 2012, about twelve months from now. Please pencil this exciting event into your diary and I do hope I will be able to meet you in Vienna for this important Symposium.

The interaction between soil and water for crop production does not stop here, since changes in land use, water management and crop production systems can affect energy requirements for sustainable development, taking into account the impacts of climate change and variability on the water and soil resources through which we grow our crops and livestock. Climate-land uses, energy and water nexus will increasingly be major issues of concern in Member States. To address these issues, the SWMCN Subprogramme (Section and Laboratory) will be working through internal and global networks to identify management practices that meet ever increasing food demands in the face of a changing climate, uneven distribution of water rainfall patterns and finite external inputs of phosphatic fertilizers and fossil fuel supplies (Please see the Past Events Section of this Soil Newsletter for recent activity in this area).

I would like to take this opportunity to thank all of our counterparts who helped us to compile Impact Reports and also to thank some of our readers who have sent me suggestions and comments for the planned International Symposium in July 2012. My thanks also to all team members in the SWMCN Section and the SWMCN Laboratory and to the two consultants (Mr. Phillip Chalk and Mr. Erik Busch-Petersen) for the dedication and commitment they have given to AWM activities and to the planning of the FAO/IAEA International Symposium in July 2012. I also would like to take this opportunity to express my appreciation to colleagues from other IAEA Departments who have helped me and my team members to meet the challenges for the forthcoming IAEA Scientific Forum on Water and the 2012 International Symposium in July 2012.

Wishing you all the best,

Long Nguyen
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Staff News

Mr Phillip Chalk, former Section Head (August 1997 to August 2004), joined the section on 15 February 2011 as a consultant on a 6-month contract. During the previous 10 months he was a visiting scientist at EMBRAPA-Soils, Rio de Janeiro, Brazil. He and colleagues at EMBRAPA wrote several review articles on C and N dynamics during composting and in compost-amended soils, with emphasis on the application of ^{13}C and ^{15}N as tracers. Phil's responsibility during his consultancy is to support the section head in all activities, including the formulation and setup of new CRPs and TCPs and to organise the International Symposium 'Managing soils for food security and climate change adaptation and mitigation', July 23-26, 2012, Vienna, Austria.

Mr Erik Busch-Petersen, former Head of the Agriculture & Biotechnology Laboratory (April 2004 to March 2009), joined the Section on 9 March 2011 as a consultant on a 4-month contract. During this period he is re-responsible for a range of activities relating to agricultural water management, including the generation of impact reports, fact sheets and other outreach materials.

Mr Gudni Hardarson, Head of the SWMCN laboratory retired on 31 December 2010 after 29 years of service to the SWMCN Laboratory. Gudni received his B.Sc. from the University of Iceland in 1974 and Ph.D. in soil microbiology from the University College of Wales in 1978. He conducted post-doctoral research for 2 years at the University of Minnesota on alfalfa improvement before joining the Soil Science Unit of the FAO/IAEA Agriculture and Biotechnology Laboratory, Seibersdorf in 1981. In Seibersdorf, Gudni led an internationally recognized team that developed many of the concepts and procedures for the use of the stable isotope ^{15}N to estimate biological nitrogen fixation by legumes. More than 80 scientific papers were published in international journals as a result of this major research endeavour. We wish Gudni a long, happy and productive retirement.

Ms Lee Heng received a Departmental Award on 16 May from the Deputy Director General and Head of the Department of Nuclear Sciences and Applications (Mr Daud Mohamad) for the publication of the IAEA Training Course Series (N^{o} 30) entitled 'Field Estimation of Soil Water Content – A Practical Guide to Methods, Instrumentation and Sensor Technology'. The Practical Guide was judged to be the best publication for 2008-09 within the category 'Technical Report Series/Special issue of a journal or book based explicitly on, and supported by the IAEA programmes – internal publication.'

Ms Rosario Leon de Muellner received an Award on 16 May from the Deputy Director General and Head of the Department of Nuclear Sciences and Applications (Mr Daud Mohamad) for her 20 years of loyal service working at the International Atomic Energy Agency.

Ms Lamia Dool joined the Soil and Water Management and Crop Nutrition (SWMCN) Laboratory on 16 February 2011 in a temporary team assistant position, replacing Ms Elisabeth Swoboda who is currently on a career development reassignment. Lamia completed her Masters degree in diplomatic and strategic studies in Vienna last year. She has also worked with the United Nations in Sudan, Eritrea and Kosovo. We welcome Lamia to the SWMCN Laboratory.

Country Impact Reports

Using saline water in salt affected soils to enhance food productivity and farmer incomes in Bangladesh

The Challenge

Bangladesh is a deltaic country with a total area of 147,570 km^2, agriculture accounting for a major sector of the national economy. The coastal regions that occupy about 20% of the country's land area are very fertile and are used primarily to grow rice. During the rice season from April to the harvest in August river water as well as monsoon rainwater, harvested in large ponds and natural depressions, is used to flood the rice. During the subsequent months of dry season the intrusion of tidal water from the coast causes the soil and water salinity to increase from around 1 ppt (parts of salt per thousand grams of soil or water) in August to 8 ppt or more in April. This natural salinization is a major threat to crop production, so that about 90% of these potentially arable lands remain unused during the dry season.

Highly fertile arable land left uncultivated from August to April due to salinity and drought

Key challenges to increasing the cropping intensity of these fertile lands are to use the collected pond water, consisting during the dry season of a mixture of rainwater and saline ground- and tidal waters, for crop irrigation without aggravating the natural soil and groundwater salinity, and to identify crops that will thrive in these saline conditions. In order to meet these challenges, irrigation must be applied at the right time and in the optimal amount for each type of crop so as to minimise the use of groundwater that would otherwise cause a further ingress of saline seawater and a resultant increase in soil salinity.

The Project

Turning adversity into opportunity: A farmer harvesting mung bean on saline soil

Through an IAEA technical cooperation project[1], the Bangladesh Institute of Nuclear Agriculture identified and assessed crop varieties for their tolerance to salinity and evaluated the use of water from ponds and natural depressions for drip irrigation during the fallow period from August to April at pilot sites in the Noakhali and Satkhira coastal regions. Saline-tolerant varieties of wheat, mung bean, mustard, sesame, chickpea, tomato and groundnuts were identified using the carbon isotope discrimination methodology and made available to participating farmers. Yields obtained by farmers with these varieties at both Noakhali and Satkhira ranged from 1 to 3 tons per hectare. Such a harvested yield, compared with nothing if land were left fallow, would provide a substantial increase in food crop production and a significant economic benefit to resource-poor farmers.

The soil moisture neutron probe (SMNP) was used to measure the soil content in order to ensure optimal irrigation scheduling. The soil salinity observed after the harvest of the crops in March/April averaged 1.5 ppt with drip irrigation, compared to 6.9 ppt on fallow land, hence showing that there is no adverse effect on soil salinity associated with the sustainable and productive use of these fallow lands for additional food production and income generation.

[1] BGD5026 on 'Increasing Agricultural Production in the Coastal Area through Improved Crop, Water and Soil Management', 2007-2010.

The Technology

Two isotopic techniques were used. The carbon isotope discrimination (CID) measures the extent to which plants assimilate carbon for photosynthesis using carbon isotope (^{12}C) compared to the heavier ^{13}C carbon isotope. Using this measure as a surrogate marker of water use efficiency, drought and salt-tolerant varieties were deployed in conjunction with appropriate irrigation scheduling.

The soil moisture neutron probe (SMNP) is an instrument that measures soil water content for crop production. During the measuring process, the probe emits neutrons that collide with hydrogen atoms in soil water. This collision slows down the speed of the neutrons. The change in the speed of the neutrons is detected by the probe and provides a reading that corresponds to the soil water content. The SMNP is currently the most suitable instrument to accurately measure soil moisture under saline conditions

Drip irrigation technology increases water use efficiency by applying water directly to the immediate vicinity of the plant roots through a network of pipes and water emitters. This results in a reduction both in soil water evaporation and in excess water draining away from the roots, so that much less irrigation water is needed. This technology can be easily adapted for use in large-scale fields allowing for automation of the irrigation process, or for small-scale plots using low-cost materials such as buckets, drum kits, etc. It can also be easily adapted for the simultaneous application of water-soluble nitrogen fertilisers, such as e.g. urea.

The Impact

Good yield of sesame from saline land

Improved water management practices through drip irrigation, coupled with the identification of saline-tolerant crop varieties during this project, have enabled farmers in Bangladesh to introduce and harvest a second crop, in addition to the *aman* rice, on potentially up to 2.6 million hectares of highly fertile coastal lands that would otherwise lie fallow. Such a second harvest could potentially add an additional 4 million tonnes of, for example, wheat to the national bread basket of Bangladesh. At a current price on the international commodity market of US $348/t (February 2011), this would be equivalent to US $1.4 billion to the national economy. With high-value vegetables, the economic returns could be even higher.

Such a second crop would also provide a substantial additional income to local farmers and significantly increase food security in Bangladesh whilst also reducing the soil salinity of these fertile lands.

The saline-tolerant crop varieties have been quickly accepted by local farmers. In the 2010/11 season, these varieties were already grown on approximately 13,000 ha, generating additional incomes of about US $2000/ha/year to the farmers.

"I used to leave my family in the village and go to Dhaka in search of a job because I could not grow any crop during August to April because of the high salt content in the soil. Now, I earn about US $2000 per hectare each year from the cultivation of newly introduced groundnuts and wheat".

Mr Abdul Aziz Boat Man
Farmer from Noakhali, Bangladesh

Improving water quality through better soil management in Chilean vineyard plantations

The Challenge

Sixty per cent of arable land in Chile is affected by erosion, the rate having increased by almost 50% during the past 30 years. In Central Chile, a shortage of flat land has increasingly compelled wine growers to plant vineyards on the hillsides. This has resulted in further soil erosion and degradation that already covers 20% of the region, equivalent to 90,500 ha. The sustainability of vineyard operations is further aggravated by the negative impact that this erosion has on downstream water quality, caused by herbicides and nutrients being carried down the hillsides by excess water runoff.

The central region of Chile has therefore placed priority on the challenge to develop and implement appropriate land management practices designed to improve water quality and minimise soil erosion in vineyards.

Location of project vineyards on the valley slopes.

The Project

Downhill planted rows of grape vines with ground cover present only after the rainy season.

Through three consecutive IAEA technical cooperation projects[1,2,3], the Agriculture Section of the Chilean Nuclear Energy Commission, in cooperation with the Faculty of Agricultural Sciences at the University of Chile and the Agriculture and Livestock Service, compared current soil management practices in vineyards in the Apalta valley 200 km south of Santiago de Chile. The fallout radionuclide, Beryllium-7 (^{7}Be), was used as a tracer to estimate short-term (less than a month) soil erosion and deposition across agricultural landscapes. Herbicides labelled with the radioactive carbon-14 (^{14}C) were used to determine the mobility of herbicides during erosion events and hence their influence on water quality. The projects compared planting on terraces with the traditional downslope rows, both with only scarce soil cover during the rainy season. Net annual rates of soil loss from the terraced site (76 t/ha) were only about 7% less than those from the downslope site (82 t/ha), indicating that soil losses were substantial on both terraces and downslopes. The lack of sufficient cover particularly during the first month of the rainy seasons could explain the severity of the observed soil losses.

Using ^{14}C labelled material it was found that glyphosate, the only herbicide applied in vineyard management, is strongly bound to soil particles and hence the main pathway of herbicide transport was associated with the loss of soil particles.

[1] CHI5048 on ‘Integrated watershed management through nuclear techniques for the sustainability of agricultural lands’, 2005-2006.

[2] RLA5050 on ‘Integrated analytical approaches to assess good agricultural practices (GAP)’, 2007-2009.

[3] RLA5053 on ‘Implementation of a diagnosis system to assess the impact of pesticide contamination in food and environmental compartments at a catchment scale in LAC Region’, 2009-2011.

The Technology

Beryllium-7 (^{7}Be) is a naturally occurring radioactive material in the atmosphere. Through rainfall it is deposited on the soil surface. Once deposited it binds strongly to the soil particles. When soil will be redistributed by soil erosion, this radioactive material will move with the soil. This material is therefore a good indicator of soil erosion and provides an accurate measure of the efficiency of soil conservation measures designed to control erosion processes.

Soil sampling for fallout radionuclide analysis

By labelling herbicides with easily measurable radioactive markers, such as carbon-14 (^{14}C), the movement of these herbicides in the soil can be traced. This enables the determination of the capacity of soil to bind herbicides. The stronger the herbicide is bound to the soil, the less herbicide is available that can move to surface waters. However, where extensive soil erosion is taking place, pesticide-bonded soil particles can be transported in runoff to receiving waters where herbicides may then be desorbed into these waters. ^{14}C is therefore a useful tool in determining the mobility of herbicides in agricultural landscapes.

The Impact

The huge erosion of up to 82 t/ha/year of soil from hillside vineyards, and the ensuing movement of herbicides and nutrients to downhill water reservoirs, has shown the untenability of current vineyard management practices. It has also shown that terracing of vines is only likely to reduce soil erosion on these sites by a mere 7%. The Agriculture Section of the Chilean Nuclear Energy Commission, in cooperation with the Faculty of Agricultural Sciences at the University of Chile, is therefore planning to investigate the use of permanent ground cover between vines to effectively minimise soil erosion and water runoff on such slopes and hence to improve the downstream water quality.

Since the start of the project, cover crops have been introduced in 13 vineyards in Apalta, covering 3,200 ha. The speed with which such cover crops are being adopted reflects the importance of close public-private collaborations between research organisations and wine growers.

“The vineyard associations have been open to embrace nuclear research techniques as it has been a win-win relationship for the farmers of the region. The obtained results will help improve soil conservation and water quality at least on our 65 hectares of vineyards.”

Mr. Emilio Sanchez, Representative of the *La Roblería* vineyard, Apalta

Improving agricultural water management through low-cost small-scale irrigation technologies in Kenya

The Challenge

Agriculture is the second largest contributor to Kenya's gross domestic product and accounts for about 24% of GDP and 50% of revenue from exports. About half of Kenya's total agricultural output is subsistence production and farming provides employment to about 70% of the population. Approximately 80% of Kenyan farmland is classified as arid and semi-arid, with low and erratic rainfall, and food production is low with frequent crop failures. In order to ensure food security and sustainable farmer livelihoods there is an urgent need to improve agricultural water management practices that ensure optimal water use efficiency. A promising option is the use of low-cost small-scale irrigation technologies that are affordable for resource poor farmers.

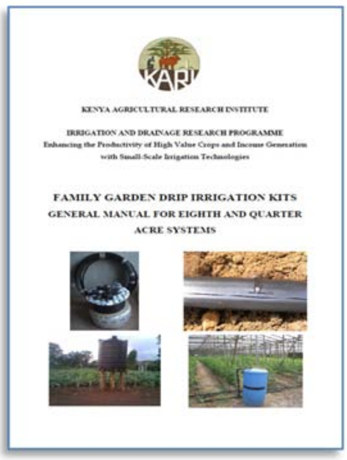
The Project

Through an IAEA technical cooperation project[1], the Kenya Agricultural Research Institute (KARI) has developed low-cost small-scale irrigation technologies to improve water- and nutrient use efficiencies of high-value crops, including cucumber, tomato, kale and lettuce. Yields of these crops were compared under rain-fed conditions, with irrigation using traditional hand-watering method and small-scale drip irrigation. Using the soil moisture neutron probe to determine the soil water content at any time during the growing season and the optimal timing and amount of water to be applied, KARI devised and employed small-scale low-cost drip irrigation technologies and compared yields under a variety of water management applications. Using these technologies, tomato yields of 9.7 t/ha were obtained under rain-fed conditions (with 221 mm of rainfall), 13.0 t/ha with traditional hand watering of 927 mm and 32 t/ha when applying 510 mm of water using small-scale drip irrigation, hence increasing the yield by 3.3 and 2.5 times, compared to rain-fed and hand watering, respectively. In the latter case, this yield increase was obtained despite a 45% reduction in the amount of water applied to the crop.

Small-scale drip irrigation in farmer's field

Results also showed that a total of 580 t/ha of tomatoes can be obtained under the more optimal water and nutrient conditions provided in locally constructed greenhouses, where the ^{15}N stable isotopic tracer was used to determine the fate of nitrogen (N) fertilisers in soils and tomato plants. Information obtained indicates that as much as 50% of the applied nitrogen can be saved when applied through drip irrigation while at the same time tomato yield could be maintained.

A training manual for extension workers on the use of these drip irrigation systems has been developed, and training and dissemination of these technologies have been conducted through farmers' field days and discussion groups.



User manual on small-scale drip irrigation kits

The Technology

Drip irrigation increases water use efficiency by applying water directly to the immediate vicinity of the plant roots through a network of pipes and water emitters. This results in a reduction both in soil water evaporation and in excess water draining away below the roots, so that much less irrigation water is needed. This technology can be easily adapted for use in large-scale fields allowing for automation of the irrigation process, or for small-scale plots using low-cost materials such as buckets, drum kits, etc. It can also be easily adapted for the simultaneous application of water-soluble fertilisers, such as nitrogen.

The soil moisture neutron probe (SMNP) is an instrument that measures soil water content for crop production. During the measuring process, the probe emits neutrons that collide with hydrogen atoms in soil water. This collision slows down the speed of the neutrons. The change in the speed of the neutrons is detected by the probe and provides a reading that corresponds to the soil water content. The SMNP is currently the most suitable instrument to accurately measure soil moisture under

[1] RAF5058 on 'Enhancing the Productivity of High Value Crops and Income Generation with Small-Scale Irrigation Technologies', 2009-2013.

saline conditions. It is also widely used to calibrate other moisture sensors for direct use in farmers' fields.

Nitrogen is a major nutrient for plant growth. Labelling fertilisers with ^{15}N stable isotope tracers can help to determine the fate of applied nitrogen from fertilisers in soils, plants and water and is therefore useful in determining the nitrogen use efficiency of crops.

The Impact

Water use efficiency: A dramatic improvement in water use efficiency obtained with a range of high-value crops through better irrigation scheduling and the use of small-scale drip irrigation technologies highlights the potential to reduce the overall water requirements of field vegetables by up to 45%. This will be of tremendous importance in Kenya's endeavours to ensure the most efficient use of its scarce water resources in arid and semi-arid regions. This improvement also brought about a substantial saving (50%) in nitrogen fertiliser applications hence reducing farmers' fertiliser expenditure.

Small-scale drip irrigation of kale by Maasai farmers at Namanga

Food security: Combined with the substantial increases in yields achieved, the technologies and expertise developed through this project are generating substantial impacts on Kenyan farming both in terms of additional crop yields and in improved and more sustainable farmer incomes. This will be of tremendous importance in Kenya's drive towards food security for its population.

Farmer acceptance: The drip irrigation expertise and technologies perfected by KARI are currently being transferred to resource-poor smallholder farmers to improve agricultural water management and crop productivity. An example is the Maasai farmers at Namanga on the Tanzanian border through collaboration with the Green Belt Movement and the African Medical and Research Foundation (AMREF).

Small-scale drip irrigation for greenhouse tomato

Greenhouse farming: KARI is transferring drip irrigation technologies also for use in greenhouses, which are becoming widespread (covering more than 3000 hectares) due to the high quality, high yields and excellent resource use recovery obtained. As low-cost greenhouses are increasingly being constructed, they are becoming affordable to ordinary Kenyan farmers.

Local expertise: KARI is providing technical assistance and know-how to 23 African countries aiming to improve agricultural water management under rain-fed and irrigated agriculture. It assists the Agency in capacity building by: (i) training more than twenty IAEA fellowship holders, scientists and technicians from other African regions, (ii) backstopping IAEA projects in Africa and (iii) providing laboratory facilities for the analyses of field samples.

Blending of saline groundwater with treated sewage water offers bright future for saline soils in Qatar.

The Challenge

Qatar is one of the ten most water scarce countries in the world. It has an estimated 8,000 hectares of cultivated land, all of which is irrigated with groundwater. As a result groundwater levels have been falling by up to 0.5-1.1 metres per year and the ensuing intrusion of seawater and the movement of saline water from deeper aquifers have led to groundwater salinity of more than 30 grams of salt per litre of water. Also, the soil in Qatar, largely composed of loose sand and gravel, is highly vulnerable to wind erosion.

Current reviews of water management in Qatar show that about 95% of groundwater extraction is used for irrigation with a water use efficiency of less than 45%. This extensive use of saline water has led to an increasing salinization also of the soil, so that about 23% of Qatar farmlands have had to be abandoned. The challenge is therefore to develop and adopt novel agricultural production systems that enhance the productivity of crops and fodders on these salt affected sandy soils.

The Project

Through an IAEA technical cooperation project[1], the Qatar Ministry of Environment set out to develop suitable technologies for improving the productivity of crops and fodders under saline conditions in an integrated approach involving the use of saline (brackish) water sourced from coastal groundwater aquifers and treated sewage water, salt tolerant crops; the optimisation of irrigation scheduling; and the use of drip irrigation technologies that supply water when and where it is needed.

Soil moisture is measured using the soil moisture neutron probe.

This integrated approach was successfully used to grow saline-tolerant vegetables and shrubs for animal fodder in a 12 ha area of saline soils, providing an annual average biomass of 35 tonnes/ha. Accurate irrigation scheduling through drip irrigation was found to save water by 20-30% due to a reduction in water losses from soil evaporation and water movement beyond the reach of plant roots. The blended use of 60% saline groundwater with 40% treated sewage water in this project reduced the overall need for groundwater and resulted in a 50-60% reduction in the amount of salt being added to the soil.

The Technology

Drip irrigation technology increases water use efficiency by applying water directly to the immediate vicinity of the plant roots through a network of pipes and water emitters. This again results in a reduction both in soil water evaporation and in excess water draining away below the roots, so that much less irrigation water is needed.

The soil moisture neutron probe (SMNP) is an instrument that measures soil water content for crop production. During the measuring process, the probe emits neutrons that collide with hydrogen atoms in soil water. This collision slows down the speed of the neutrons. The change in the speed of the neutrons is detected by the probe and provides a reading that corresponds to the soil water content. The SMNP is currently the most suitable instrument to accurately measure soil moisture under saline conditions.

The Impact

As a direct result of information obtained during this project, the Ministry of Environment, Qatar is planning to use about 100 million m^3 of saline groundwater together with about 60 million m^3 of treated sewage water to irrigate 83,300 hectares of highly saline coastal and inland Sabkha lands, currently rated as unsuitable for cultivation, to produce primarily fodder and shrub for livestock. This will essentially increase arable land in Qatar from 8000 ha to 91,000 ha.

[1] QAT/5/002 on 'Developing Biosaline Agriculture in Salt-Affected Areas in Qatar', 2008-2010.

Shrub plants growing in a saline soil irrigated with blended saline groundwater and treated sewage water.

The nutrients contained in 60 million m^3 of treated sewage water (estimated annual additions of 3,000 tonnes of nitrogen and 600 tonnes of phosphorus) will effectively enhance fertility to these nutrient exhausted coastal lands. The soil quality will also be significantly improved through the associated application of more than 22,000 tonnes of organic matter present in the treated sewage water, which binds the soil particles together and provides a healthy environment for vege-vegetation establishment and soil moisture storage. Experience in sandy soils in Iraq, a neighbouring country with similar environmental conditions, has shown that it is possible to reduce soil loss through wind erosion by up to 78% as a result of vegetation coverage of the soil surface.

"This was the worst possible salt-degraded soil site and if we could succeed in growing any useful biomass at this location then there would be no exception for any other site in Qatar".

Mr Yousuf Al Kulaifi, Director, Department of Agricultural Affairs, Ministry of Environment, Qatar.

Improving water and fertiliser use efficiency in potato production: The Turkish way

The Challenge

Turkey is the fifth largest exporter of potatoes, producing around 4.4 million tonnes of potatoes annually on about 154,000 hectares (ha). More than one third of the total production is grown in the Nigde-Nevsehir region, with an average yield of 40 t/ha. This is an arid and semi-arid region with light-textured, loamy sands and production is totally dependent on sprinkler irrigation that relies on residual groundwater provided by spring rainfalls. About 1400-1700 mm of water is required under sprinkler irrigation to achieve marketable potatoes, of which only 35% is taken up by crop roots in the top 90 cm of the soil. The remaining 65% is lost through runoff and downward water movement beyond the plant roots. This excessive use of water also reduces the efficiency of water-soluble nitrogen fertilisers, such as urea or ammonium sulphate, in providing nitrogen for potato production. The main challenges are to increase water and nitrogen fertiliser use efficiency by applying irrigation water mixed with fertilisers, also known as fertigation, to the right place, at the right time and in the appropriate amount.

The Project

Through an IAEA technical cooperation project[1], the Turkish Atomic Energy Agency, in cooperation with the Nigde Potato Research Institute and the Soil and Fertilizer Research Institute, implemented innovative drip fertigation technology to improve water and nitrogen fertiliser use efficiency in potato production in the Nigde-Nevsehir Region. This technology reduced the amount of irrigation water needed by 50% and nitrogen fertiliser use by 40%, from 1000 kg nitrogen/ha to 600 kg nitrogen/ha.

The Technology

Drip fertigation technology increases water and nitrogen use efficiency by applying water and nitrogen directly to the immediate vicinity of the plant roots through a network of pipes and water emitters. This leads to a reduction in soil water evaporation and excess water loss beyond the rooting zone, so that much less irrigation water and nitrogen fertiliser is needed.

Drip fertigation system at Nigde Potato Research Institute supplying water and nutrients to newly planted potato crops

The soil moisture neutron probe (SMNP) is an instrument that measures soil water content at any time for crop production. During the measuring process, the probe emits neutrons that collide with hydrogen atoms of soil water. This collision slows down the speed of the neutrons. The change in neutron speed is detected by the probe and provides a reading that corresponds to soil moisture content. Thus soil moisture measurement using SMNP is important to the effective scheduling of drip fertigation.

Nitrogen is a major nutrient for plant growth. Labelling nitrogen (N) fertilisers with ^{15}N stable isotope tracers help assess how nitrogen fertilisers are taken up by crops and moved down the soil profile beyond the reach of plant roots. This information is necessary to determine the fate of applied nitrogen fertilisers in soils, plants and water, and hence the nitrogen fertiliser use efficiency in crop production systems.

The Impact

Considering the magnitude and importance of potato production in the arid and semi-arid areas of Turkey, the 50% reduction in crop water requirements through drip fertigation is having a major impact on agricultural production and water management strategies in these areas. Likewise, the 40% reduction in nitrogen fertiliser needs is a major step towards reducing farmers' expenditure and potentially improving groundwater quality in these agricultural landscapes.

[1] TUR5024 on 'Improving Crop Productivity through Nuclear and Related Techniques', 2005-2009.

For the farmer, it has been calculated that a transition from sprinkler irrigation to drip fertigation requires an initial one-off investment cost of up to US $200/ha, depending on the sophistication of the drip fertigation system. This investment can be balanced against projected savings in time, energy, fertiliser and labour costs amounting to an estimated US $2,000/ha/year. As a consequence, interest in drip fertigation has been remarkable among potato farmers in the region, so that in only three years the area under drip fertigation has increased from humble beginnings of 500 hectares in 2005 to 4000 ha in 2007 and to nearly 7000 ha in 2010. In efforts to further accelerate this transition, the government, following a request from the Ministry of Agriculture, has developed a regional policy through which it now subsidises 50% of the investment costs for drip irrigation systems. It is expected that the potato-growing area under drip fertigation will climb to 10,000 hectares by the time of planting in June 2011, due to a local financial subsidies promised by the Governors of the Niğde and Nevsehir provinces of the Capadocia Region for the 2011 financial year, in addition to the already implemented central government subsidy policy.

Potato farmers inspecting a drip fertigation system

Improving water quality through better soil management in Vietnamese mountainous uplands

The Challenge

Ploughed upland fields in Chieng Khoi, Vietnam are prone to soil erosion during the typhoon season (Courtesy: University of Hohenheim)

Over the last decade, agricultural practices have been rapidly intensified in the tropical and sub-tropical mountainous areas of Vietnam as a result of demographic pressure, improved market access and increased demand for animal feed. Traditional agriculture, which combined shifting cultivation on steep upland slopes with rain-fed permanent rice cultivation in lowlands, has transformed into a more continuous monocropping system of maize and cassava (cash crops) in the uplands and irrigated rice paddies (staple food) in the lowlands. In particular the high demand for animal feed, due to a change from a vegetable to a more meat based diet, has provided a lucrative earning opportunity for farmers and fuelled rapid deforestation of uplands even on extremely steep slopes (up to 45°). In addition, the traditional moderate soil preparation in combination with maize planting with sticks has been replaced with more intensive cultivation with tillage up to three times per year to provide a weed free and appropriate seed bed for the new hybrid varieties. Such intensive upland cultivation makes these areas prone to erosion, particularly during the early spring season when soils are still bare. Consequently, large amounts of topsoil are eroded annually, also removing soil nutrients and organic matter, thus affecting soil quality in the uplands and hence also water and fertiliser use efficiency. Increasing amounts of fertiliser are therefore needed to counteract the increasing soil degradation in the uplands of Vietnam. However, erosion not only affects uplands, but also simultaneously influences paddy yields in the lowlands by silting up irrigation reservoirs and by delivering often coarse sediments during typhoon events that can smother the rice plants and potentially influence water quality from the whole upland-paddy catchment.

A water flow measuring device and automatic water sampler in a lowland irrigation channel (Courtesy: University of Hohenheim)

The Project

Through an IAEA coordinated research project[1] linked to the German-funded research program (SFB 564) entitled "Sustainable Land Use and Rural Development in Mountainous Regions of Southeast Asia", the IAEA is working with the Center for Agricultural Research and Ecological Studies (CARES) of Hanoi University of Agriculture (Vietnam) and the Institute of Plant Production and Agroecology in the Tropics and Subtropics of the University of Hohenheim, Germany. The project uses stable isotopic techniques to identify hot spots of land degradation in the steep cultivated uplands of Chieng Khoi, Son La Province, in north-western Vietnam. The research consortium traces and quantifies sediment-associated organic carbon and total nitrogen fluxes in runoff water from the uplands, and assesses whether associated sediment deposition alters soil quality and crop performance along paddy rice terraces in the lowlands.

The use of compound-specific stable isotope (CSSI) techniques enabled the identification of the hot spots of land degradation in this region, and showed maize/cassava fields on steep slopes to be the main contributors, with soil erosion rates reaching up to 61 tonnes/ha/year on the steepest slopes. This erosion influenced rice production in the lowlands that was strongly linked to changes in soil fertility due to deposition of sediments delivered by irrigation- and runoff water. Eroded soils from the uplands are also a source of soil carbon and enhanced nitrogen fertility in the topsoil of lowland paddies. However, although the $\delta^{15}N$ signatures in rice plants indicated that this can be a source of nitrogen uptake for rice, grain yields were not always found to be significantly influenced by such nitrogen inputs, probably due

[1] D1.20.11 on 'Improving Crop Productivity through Nuclear and Related Techniques' 2008-2013.

to the smothering effects that the deposition of coarse sand from eroded soils had on the rice plants. The use of ^{13}C sta-stable isotopes showed that grain yields along the cascades of rice paddies were often also influenced by the non-uniform pattern of water availability, with the highest water shortage being located at the bottom of the cascades of paddies.

The Technology

The Compound Specific Stable Isotope (CSSI) technique relies on the individual, naturally abundant isotopic ratio ($\delta^{13}C$) of marker compounds, such as plant derived fatty acids in the soil profile. By comparing the isotopic carbon signal of marker compounds in deposited soil in the lowland with the signal of the same marker compounds from reference soils in the uplands, the contribution of different land use practices in the uplands to sediment deposition in lowland paddies and irrigation reservoirs can be estimated. In addition to providing information on hot spots of land degradation the CSSI technique also allows the characterisation of upland-lowland soil organic carbon dynamics and nutrient flow linkages. The CSSI technique has the advantage of identifying hot spots of land degradation at an area-wide scale by sampling deposited soil in the lowland and reference soils from the upland in one single visit, whereas traditional ways to assess hot spots of land degradation are mostly plot specific, time intensive and costly.

The CSSI technique is supported by natural abundance stable isotope methods, such as ^{15}N and ^{13}C stable isotope compositions of crops to provide comprehensive information on the impacts of integrated land use management on the overall water quantity and quality.

The Impact

This project highlights the importance of linking upland and lowland agricultural practices. Lowland paddy production depends on water runoff from uplands. This runoff, however, must be effectively managed so that losses of top soils and nutrients, that would otherwise reduce upland crop productivity, are controlled. At the same time the lowland paddy rice will benefit from the water and nutrient from uplands without the smothering effects of coarse sands. The project shows that mulch-based no-till farming systems on the uplands can achieve this goal. A similar study in the uplands of Thailand, in the context of SFB 564, proved that, over a period of 3 years, minimum tillage and mulching reduced erosion from 24.5 to 2.5 ton/ha while runoff decreased only moderately from 866 to 427 m³/ha whereas contour hedgerows impeded the flow of water too much, to 187 m³/ha. The application of minimum tillage and mulching therefore shows great potential for the intensification of agriculture in the mountainous regions of Vietnam and of South East Asia in general, as it enables a reduction of erosion without hampering the availability of water so important to downstream rice farmers. The increased interest in animal fodder for ruminants also opens up the opportunity to introduce these crops to the steep upland slopes.

Sediments from uplands smothering rice plants in a paddy field after a rainstorm (Courtesy: University of Hohenheim).

The findings of this project have been used to raise the awareness of farmers and to assist them in adopting strategies to mitigate the impact of typhoons in north-western Vietnam The willingness of farmers to adopt such strategies was influenced by the experienced economic impact of flooding and water management failures at the household level and an understanding of the linkage between upland and lowland agricultural practices. Successful implementation of soil conservation measures will therefore depend on the ability of local policy makers to raise farmer awareness and to provide appropriate incentives.

Feature Articles

Combined Use of Neutron Thermalization and Electromagnetic Sensing in Assessing Soil Water Dynamics

By R.C. Schwartz and S.R. Evett
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Agriculture is by far the largest consumer of available fresh water accounting for 70% of withdrawals worldwide. Meeting increased future demands for food and fibre will, by and large, need to be met by improving the efficient use of both irrigation and precipitation for crop production (FAO, 2002). Field research aimed at evaluating the efficiency of water use by crops invariably requires monitoring changes in soil water with time (e.g. Ibragimov et al., 2011). Such monitoring integrates the irrigation, precipitation, evapotranspiration and deep drainage history that affects the aggregate response of the system, which is manifested as soil water storage. These dynamic processes are important in evaluating the efficiency with which crop cultivars, irrigation strategies, cropping and tillage systems utilize available soil water for grain and biomass production.

The neutron probe has been particularly effective in estimating soil water content because of its large measurement volume and linear response to changes in soil water (Hignett and Evett, 2002). However, neutron thermalization techniques suffer from poor spatial resolution which is problematic near the surface where there are steep soil water content gradients. Data acquisition at sub-daily intervals using the neutron probe is also impractical and restricts measurements to temporal resolutions that are unable to capture highly dynamic hydrological processes. When properly calibrated, automated soil water monitoring with proven electromagnetic (EM) sensors can facilitate measurements at short time scales associated with infiltration and evaporation processes near the surface.

Accurate soil water estimation using EM sensors, including time-domain reflectometry (TDR), usually requires a soil-specific calibration. These sensors respond, in part, to changes in the real permittivity of the soil which is largely governed by changes in soil water content. Difficulties arise from these techniques because all EM sensors are sensitive to both real and imaginary parts of the permittivity with the imaginary part describing signal losses that become more significant at lower frequencies (<100 MHz). An additional difficulty in soils with high clay contents (>250 g kg^{-1}) is that bound water associated with clay surfaces has a much lower real permittivity than bulk water. As a result, measurements using EM sensors are frequency dependent and sensitive to changes in temperature and the bulk electrical conductivity (EC) of the soil. If not accounted for, these effects can lead to large errors in water content (> 0.05 m^3 m^{-3}) and unrealistic changes in soil water content with time (Schwartz et al., 2009a). For sensors that determine the true travel time of an EM pulse such as TDR, ancillary measurements of soil temperature and bulk EC incorporated into physically based soil dielectric models (e.g. Evett et al., 2005; Schwartz et al., 2009b) have led to accurate assessments of soil water content that compare closely to neutron probe measurements in fine-textured soils (Fig. 1). Equivalent success with lower frequency, capacitance-type sensors has been lacking. Fig. 1 shows that soil water estimated with the neutron probe represents a weighted average across a volume that includes shallower soil depths which results in water contents slightly less than TDR estimates at 0.3 m.

Long-term monitoring of soil water with TDR near the surface combined with neutron probe measurements at deeper depths has been proven to be an effective means to partition infiltration and soil water evaporation to evaluate tillage and cropping systems (Schwartz et al., 2010) of agricultural soils. In Bushland, TX, soil water content has been monitored throughout a five year period under sweep-tillage and no-tillage management and through phases of a wheat-sorghum-fallow rotation to examine the temporal dynamics of infiltration and soil water evaporation (Fig. 2). In that study, storage estimated using neutron probe measurements exhibited a similar soil water balance to TDR, but fail to show dynamics associated with infiltration and evaporation.

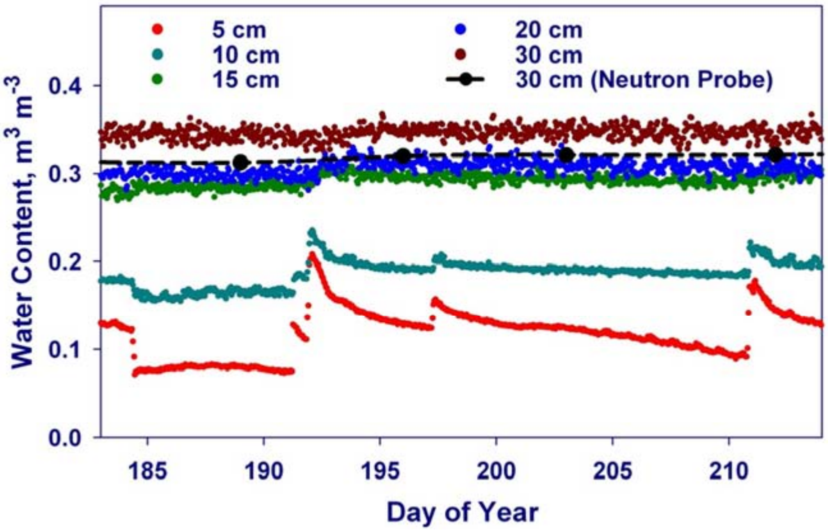

Fig. 1. Water contents estimated with the neutron gauge at 0.3 m depth and with TDR using calibrations of Schwartz et al. (2009b).

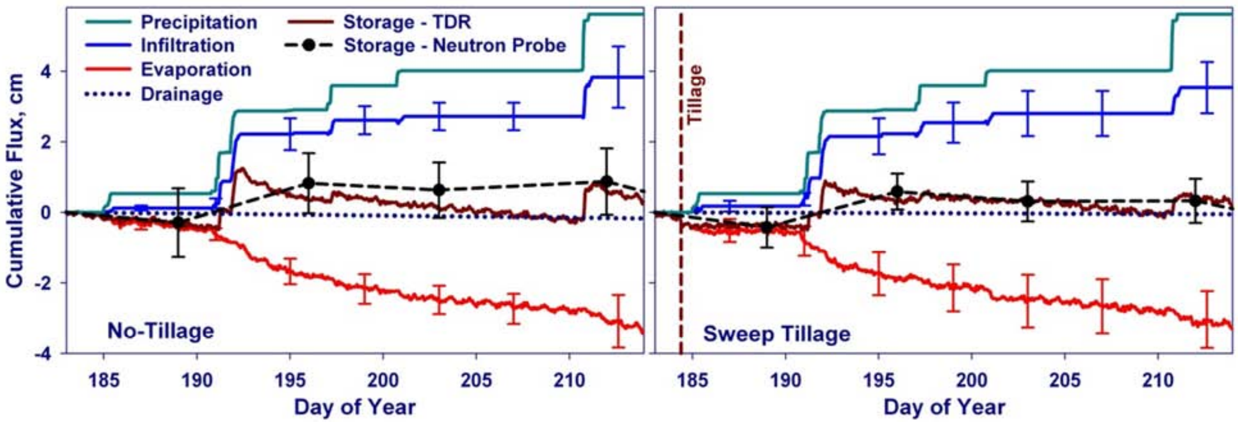

Fig. 2. Mean soil water storage and estimated cumulative fluxes within the 0- to 0.6-m control volume for the no-tillage and sweep tillage plots in July, 2008 during summer fallow following sorghum. Error bars represent the 95% confidence intervals.

References

Evett, S.R., J.A. Tolk, and T.A. Howell. 2005. Time domain reflectometry calibration in travel time, bulk electrical conductivity, and effective frequency. Vadose Zone J. 4:1020–1029.

FAO, 2002 Crops and drops: making the best use of water for agriculture. Rome, Italy: FAO. Information brochure. 28 pp.

Hignett, C. and S.R. Evett. 2001. Neutron Thermalization. Section 3.1.3.10 In Jacob H. Dane and G. Clarke Topp (eds.) Methods of Soil Analysis. Part 4 – Physical Methods. pp. 501–521.

Ibragimov, N., S. Evett, Y. Esanbekov, F. Khasanova, I. Karabaev, L. Mirzaev, and J. Lamers. 2011. Permanent beds vs. conventional tillage in irrigated arid Central Asia. Agron. J. 103:1002–1011.

Schwartz, R.C., S.R. Evett, M.G. Pelletier, and J.M. Bell. 2009a. Complex permittivity model for time domain reflectometry soil water content sensing: I. Theory. Soil Sci. Soc. Am. J. 73:886 –897.

Schwartz, R.C., S.R. Evett, and J.M. Bell. 2009b. Complex permittivity model for time domain reflectometry soil water content sensing: II. Calibration. Soil Sci. Soc. Am. J. 73:898–909.

Schwartz, R.C., R.L. Baumhardt, and S.R. Evett. 2010. Tillage effects on soil water redistribution and bare soil evaporation throughout a season. Soil Tillage Res. 110:221–229.

Soil Sampling Strategy and Geostatistics to Evaluate Soil Quality in Central Italy

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The challenge and the experimental design

The European Framework Directive on soil protection identified soil organic matter (SOM) decline in southern Europe as one of the most serious soil degradation processes among the eight main soil threats (CEC, 2006). SOM affects the chemical, physical and biological properties of the soil, and is a key indicator of soil quality and fertility. Besides providing nutrients and a habitat for soil organisms, organic matter helps to bind soil particles into aggregates, and in improving the soil water holding capacity. However, global warming is expected to accelerate SOM decomposition and increase the atmospheric CO_2 concentrations that contribute to global climate change. As SOM represents the major reservoir for soil organic carbon (C) in the global C cycle, evaluating soil C capture (sequestration), storage and redistribution at various scales is of pressing concern for soil protection and in 'global warming' mitigation strategies. The problem of SOM depletion is of particular concern in central and southern Italy due to high temperature and reduced soil moisture (Mediterranean climatic conditions) that accelerate SOM decomposition.

Using geostatistical (Mabit and Bernard, 2007) and geographic information system (GIS) approaches, the spatial variability of various physical and chemical soil parameters (e.g. particle size distribution, organic carbon content and total nitrogen content) was investigated under Mediterranean climatic conditions in central Italy in the Abruzzo Region (area of 100 km^2). The results of 250 geo-referenced soil sampling points (Fig. 1) were interpolated by means of Ordinary Kriging (OK) to produce contour maps of the distribution of soil texture, SOM content (related to texture) and soil C/N ratios.

Main results

The resulting spatial interpolation of the dataset highlighted the low SOM content in comparison with soil texture in most of the surveyed area (87%) ranging from 1 to 2.2% with an average of 1.6%. A few zones with high values (average 2.6%) are located mainly in the northern part of the study area representing only 0.1% of the total surface area. The low SOM contents are related to soil morphology, especially on hills where erosive processes are exacerbated by intensive agricultural practices. The map presented in Fig. 2 shows the distribution of the soil C/N ratio that can be considered as a proxy indicator of the SOM humification rate and soil N mineralization/immobilization potential, differentiated according to 3 classes based on the USDA classification: C/N < 9, 9 – 12, > 12. At a C/N ratio close to 10, the SOM mineralization and immobilization processes are in equilibrium; soils with a value between 9 and 12 have optimum conditions, with a stable and well humified organic matter. From Fig. 2 about 50% of the surveyed area has an optimum C/N status, while 42% of the area has a C/N ratio lower than 9, indicating that oxidation processes contribute to an accelerated decomposition of SOM. In the remaining 8% of the surveyed area, where the soil C/N ratio is higher than 12, soil nitrogen is not sufficient to ensure an acceptable SOM humification process.

Conclusion and perspectives

Current European research activities on natural resources are firmly set in the context of renewable and non-renewable resources with the emphasis on the setting up of approaches and methods to evaluate the anthropic impact on natural resource management. This study defines the existing SOM status in central Italy and provides a clear warning on SOM management in this region. Conservation agriculture in central Italy should include practices such as conservation tillage or no-tillage (e.g. direct seeding), crop rotations including forage crops and return of crop residues to soil. For agricultural lands in Italy, the average topsoil organic carbon content is around 12 g kg^{-1} equivalent of around 20 g kg^{-1} of SOM. The situation in the Abruzzo region is critical with a mean SOM content of only 16 g kg^{-1}.

The establishment of a baseline reference level and an accurate picture of SOM distribution in central Italy will allow future trends in SOM to be monitored and also the effectiveness of soil conservation measures to enhance soil carbon stocks to be assessed. Soil conservation and management schemes based on robust scientific evidence, and the application of mapping to target soil parameters such as SOM, can influence and support land management policies that can help farmers and to address key challenges facing European soil resources.

References

CEC - Commission of the European Communities. (2006). Thematic Strategy for Soil Protection. Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee, and the Committees of the Region – COM (2006)231 final, September 22, 2006, Brussels, Belgium.

Chiuchiarelli, I., Paolanti, M., Rivieccio, R., Santucci, S. (2006). Soils and Landscapes of Abruzzo – Soil Map of Abruzzo Region. ARSSA Regione Abruzzo (in Italian).

Mabit, L., Bernard, C. (2007). Assessment of spatial distribution of Fallout RadioNuclides through geostatistics concept. *Journal of Environmental Radioactivity* 97: 206-219.

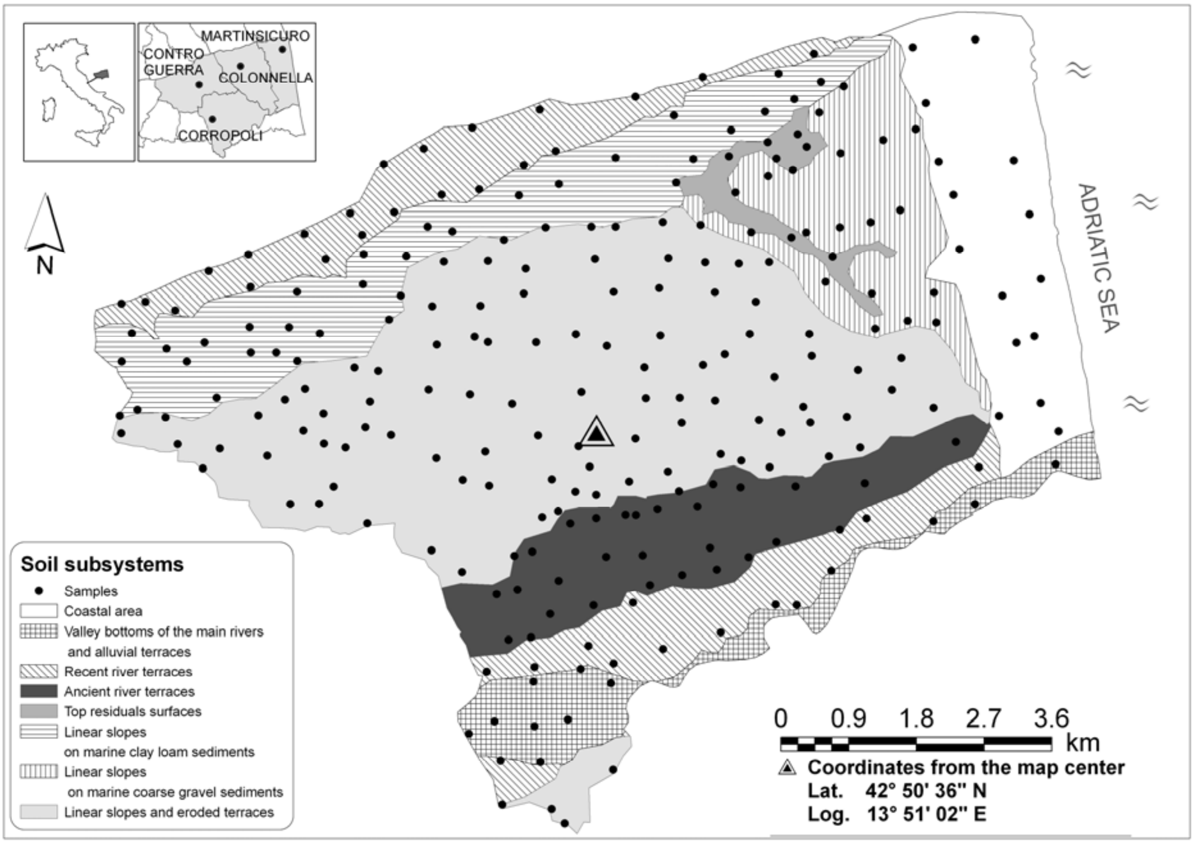

Fig. 1. Soil sampling locations according to soil subsystems of the study area (Adapted from Chiuchiarelli et al., 2006)

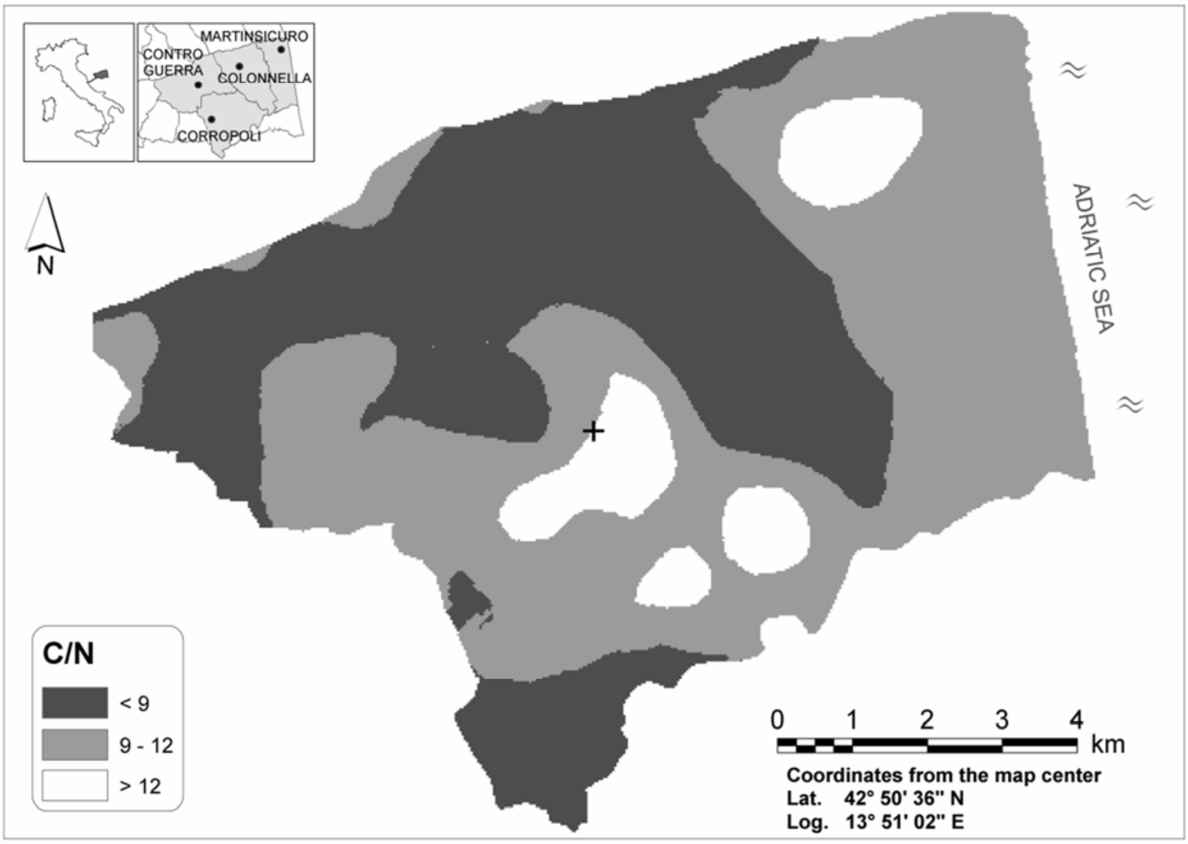

Fig. 2. Spatial representation of C/N ratios in soils

Catchment Science: A Key Element for Sustainable Management of Agricultural Nitrogen

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The Green Revolution of the 20th Century generated unparalleled levels of agricultural productivity based on advances in crop breeding, ample inputs of inexpensive nitrogen (N) fertilizer and irrigation development. Providing food security for a global population that is projected to exceed 9 billion by 2050 is likely to include more intensive use of N fertilizer (UN Population Division, 2007). Such a rapid increase in the use of N fertilizer on agricultural lands of the tropics and subtropics is expected in the future (Beman et al., 2005). Many of these areas are likely to contribute agricultural runoff to coastal waters that are particularly vulnerable to N inputs. Unintended losses of N from production agriculture contribute to increases in algal biomass in estuaries and marine waters, leading to loss of fisheries, spawning habitats, and a multitude of hypoxic 'dead zones' across the globe. In addition, reactive N can undergo transformations that generate nitrous oxide, a potent greenhouse gas. The US National Academy of Engineering declared that managing the N cycle as one of the greatest challenges of the 21st Century.

There is no question that improved crop varieties, cropping systems, precision management and soil and plant testing hold promise for greater N use efficiency at the farm scale (Cassman et al., 2002). However, reactive N is notoriously leaky in many settings suggesting that additional control measures are needed after reactive N leaves the farm and begins to flow through a catchment.

Recent scientific advances provide the capacity for strategic management of N at the catchment scale. These advances emerge from the recognition that certain areas of the landscape can function as sinks for water-borne N (Seitzinger et al., 2006). Landscape N sinks foster denitrification, the conversion of soluble nitrate to N_2 and can also retain N in plant and microbial biomass. Such N sinks include riparian wetlands, lakes, ponds, and lower-order (headwater) stream reaches. These locations are characterized by extended retention times and flow paths that enhance interaction of nitrate-enriched waters with soil within the landscape (Groffman et al., 2009). Studies have shown that these sinks markedly reduce the N delivery from agricultural and rural sources (Smith and Alexander, 2002). Decision makers and landowners need tools that can target source controls to sub-catchments that lack sinks. In catchments where agricultural N runoff is mitigated through natural sinks, approaches are required to identify these critical areas and guide their protection or restoration. For example, wetland sinks that are channelized can lose N removal capacity because of short-circuiting between nitrate-containing water and wetland soils.

A key element underpinning a catchment scale approach for managing N is the identification of flow paths. Flow paths provide insight into the likelihood of sink locations intercepting nitrate-rich agricultural runoff. Physically based models such as SWAT (Neitsch et al., 2005) offer one way to track the transport and fate of agricultural N runoff, but these types of models require extensive catchment data related to climate, soils, cropping systems and topography and should be coupled with calibration and validation studies – making them useful for research applications, but challenging for widespread management applications. For agricultural catchments, we argue that the increasing growth and accessibility of high resolution elevation data (digital elevation models, DEM) can provide the basis for strategic catchment scale management of N. Geographic information systems (GIS) tools, such as ARC Hydro (Maidment, 2002), based solely on digital elevation models, now afford the user with the capacity to manage agricultural N runoff by recognizing the connections of agricultural source areas to potential sinks (Kellogg et al., 2010).

In some situations, edge-of-field N losses can be reduced with artificial sinks, such as compact artificial wetlands (Tanner et al., 2005) or carbon bioreactors – simple, wood-chip filled trenches (Schipper et al., 2010). These artificial sinks are positioned to intercept and promote denitrification in drainage waters or N-rich groundwater. They are being employed in a wide-array of settings and have been found to function for 15 years or more after creation. Of note, the carbon bioreactors are now being incorporated into artificial wetlands, providing opportunities for the production of food or fiber as well as N controls.

A frontier for catchment-scale N management includes tailoring the use of N sinks to the needs of the tropics and subtropics. Much of the work on N sinks has occurred in temperate humid environments. Catchment-scale strategies for locations in the tropics and subtropics - with different physiography, climate and agricultural systems – warrant approaches that consider optimizing the food and fibre opportunities within the wetlands and riparian buffers that capture and transform agricultural N runoff.

Another critical research topic concerns the extent of greenhouse gas emission from N sinks. Because N sinks are hotspots for anaerobic N transformations, they have the potential to generate nitrous oxide and/or methane – gases at the forefront of climate change mitigation efforts. As we gain insights into the factors controlling the hydrology and biogeochemistry of catchment sinks we have the potential to develop management approaches that minimize emissions (Zaman et al., 2008).

Moving forward, a research agenda that recognizes the importance of soil-nutrient-plant interactions and hydrology, coupled with process-level studies (e.g., isotopic techniques) offers considerable promise for a more sustainable approach to N management in agricultural catchments.

References

Beman, J. M., K.R. Arrigo and P.A. Matson. 2005. Agricultural runoff fuels large phytoplankton blooms in vulnerable areas of the ocean. Nature. 434:211-214.

Cassman, K.G., A. Doberman and D. T. Walters. 2002. Agroecosystems, nitrogen-use efficiency and nitrogen management. Ambio 31: 132-140.

Groffman, P.M., K. Butterbach-Bahl, R. W. Fulweiler, A. J. Gold, E.K. Stander, C. Tague, C.Tonitto, and P. Vidon. 2009. Challenges to incorporating spatially and temporally explicit phenomena (hotspots and hot moments) in denitrification models. Biogeochemistry. 93:49-77.

Kellogg, D.Q., Gold, A.J., Cox, S., Addy, K., August, P.V., 2010. A geospatial approach for assessing denitrification sinks within lower-order catchments. Ecol. Eng. 36:1596-160.

Maidment, D.R. (Ed.), 2002. Arc Hydro: GIS for Water Resources. Environmental Systems Research Institute, Inc., Redlands, CA.

Neitsch, S.L., J. G. Arnold, J. R. Kiniry, J. R. Williams. 2005. Soil and Water Assessment Tool theoretical documentation version 2005. Available at http://swatmodel.tamu.edu/documentation.

Schipper, L.A., W.D. Robertson, A.J. Gold, D.B. Jaynes, S.C. Cameron, 2010. Denitrifying bioreactors—An approach for reducing nitrate loads to receiving waters. Ecol. Eng. 36:1532-1543.

Seitzinger, S., J. A. Harrison, J. K. Böhlke, A. F. Bouwman, R.Lowrance, B. Peterson, C. Tobias, and G. Van Drecht. 2006. Denitrification across landscapes and waterscapes. A synthesis.. Ecol. Appl. 16:2064–2090.

Smith, R. A., R. B. Alexander. 2002. Sources of nutrients in the Nation's watersheds, Proceedings of the National Resource, Agriculture, and Engineering Service, A conference for nutrient management consultants, extension educators, and producer advisors, March 28-30, 2000, Camp Hill, Pennsylvania.

Tanner, C. C., **M. L. Nguyen and J. P. S. Sukias.** 2005. Nutrient removal by a constructed wetland treating subsurface drainage from grazed dairy pasture. Agric. Ecosyst. Environ. 105:145-162.

United Nations Population Division, 2007. **World Population Prospects: the 2006 Revision, Executive Summary.**

Zaman, M., M.L. Nguyen, A.J. Gold, P.M. Groffman, D.Q. Kellogg and R.J. Wilcock. 2008. Nitrous oxide generation, denitrification and nitrate removal in a seepage wetland intercepting surface and subsurface flows from a grazed dairy catchment. Aust. J.Soil Res. 46:565-577.

Importance of Near and Instream Zones in Small Agricultural Catchments to Buffer Diffuse Nitrogen Pollution

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A large range of human activities have increased the fluxes of reactive nitrogen (N) to such an extent, that the planet’s carrying capacity or the ‘planet boundary’ has been reached (Rockström et al., 2009). This increase in N fluxes has also affected the C and P cycles, both on land and in the ocean (Gruber and Galloway, 2008). Modern agriculture is considered as one of the most prominent human activities that increased N fluxes in the last 50 years (Howarth, 1998). Omernik et al. (1981) demonstrated positive relationships between agricultural land cover in catchments and nitrate fluxes at their outlets, and more generally between N input and output (Vitousek et al., 1997), which hold for large or medium size catchments (i.e. 100 km^2 and above). However, in small catchments of <10 km^2 and feeding into small streams that are not receiving water from other smaller streams (also known as stream orders 1 and 2), large variations of fluxes were measured despite similar land covers (Burt and Pinay, 2005). These variations decrease as the size of the catchment increases (Lefebvre et al., 2007). Two main non-antagonistic hypotheses can be formulated to explain the pattern of nutrient fluxes along streams : i) instream biogeochemical processes in small streams can recycle and/or remove more N per unit area than larger streams (streams that are part of large or medium size catchments and receive water from smaller streams) entailing larger spatio-temporal variations of fluxes than larger streams; and/or ii) the impact of local land cover or land use on N flux strongly decreases with increasing catchment size (e.g. Strayer et al., 2003). Using a mass balance method, Alexander et al. (2009) determined that large streams were acting as conduits of pollution without significant retention capacity in the stream, i.e. no significant biogeochemical retention or removal. In situ experiments using ^{15}N confirmed the high N uptake and recycling capacity of small streams (Peterson et al., 2001). Lefebvre et al. (2005) also measured high denitrification activity in small streams, with organic C and nitrate being the limiting factors, respectively, in the benthic and hyporheic zones.

The results presented below were undertaken under the IAEA’s Coordinated Research Project on ‘Strategic placement and area-wide evaluation of water conservation zones in agricultural catchments for biomass production, water quality and food security’. They confirm the importance of in- and near-stream N buffering capacity along small agricultural catchment using the natural abundance of sample ^{15}N relative to the natural abundance of standard atmospheric N_2 ($\delta^{15}N$) as a proxy for denitrification activity (Pritchart, 2009).

This study comprised an investigation into the $\delta^{15}N$ variation of aquatic and riparian vegetation within a small English catchment. It was the intention to use measurements to identify nitrate sources within a river environment and monitor areas of denitrification. The aim of the project was to determine whether $\delta^{15}N$ of aquatic and riparian vegetation can be used as an indicator for determining sites of biogeochemical N transformation. The method used involved sampling river water and plant matter during low flow periods (0.6 m^3 sec^{-1}) along a 23 km stretch of the River Tern (drainage basin 92 km^2), located in the vicinity of Market Drayton in Shropshire, approximately 80 km from the University of Birmingham (Fig. 1). Eleven study sites were located on the River Tern with three situated on the longest tributaries. A short transect was also chosen to study N transfer on a smaller spatial scale in order that smaller/ local factors which may influence biogeochemical processes might be identified.

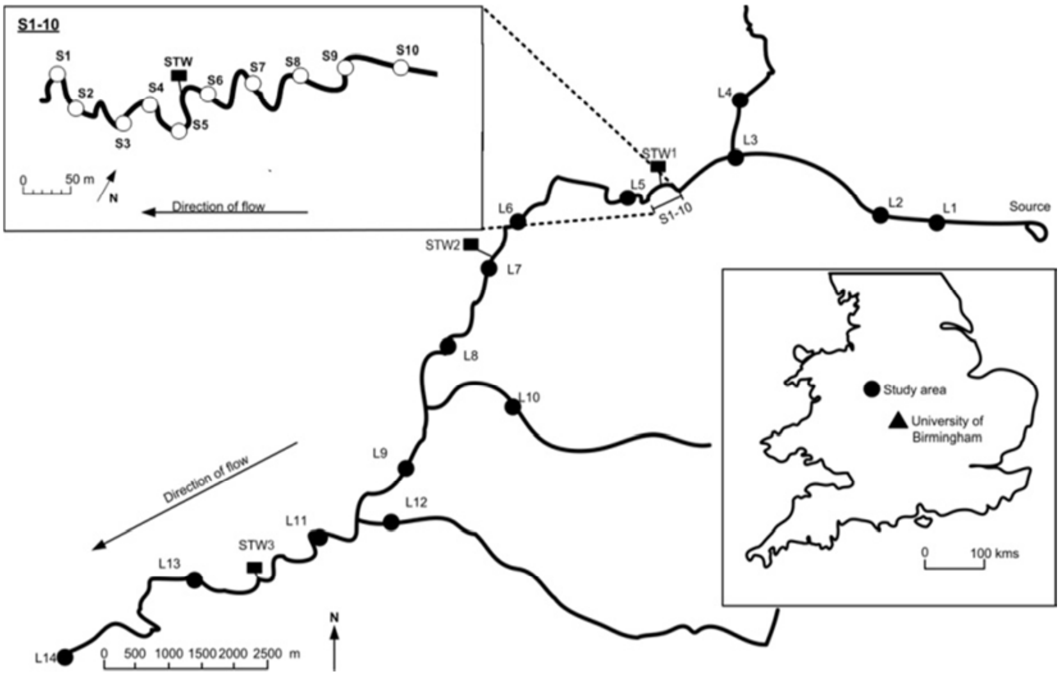

Fig. 1: Study area and sampling location on the Tern River.

In the Tern catchment context most of the nitrate is related to diffuse pollution (Fig. 2). Therefore one should expect that the nitrate load increases with distance. The significant positive linear relationship between distance for the source and NO_3-N fluxes underlines the diffuse context of the nitrate pollution in this catchment (Fig. 2).

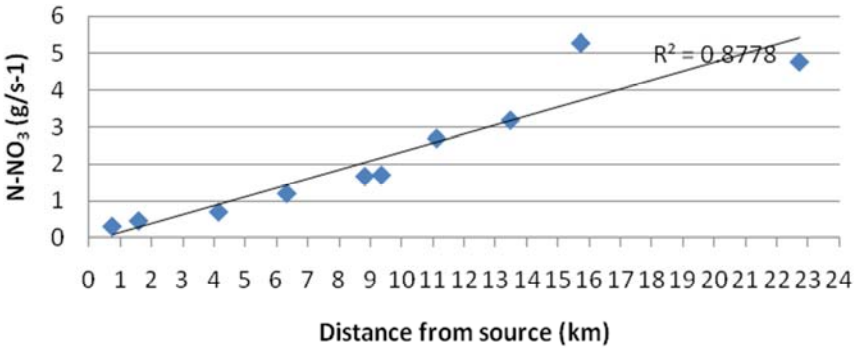

Fig. 2: Relationship between distance from the source and nitrate fluxes.

Two different types of plants were selected to analyse their ^{15}N content. *Salix fragilis* (Crack willow) is a medium-large deciduous tree which grows rapidly to between 10 and 20 m, usually found beside rivers as it prefers a deep, damp soil. It flowers between April to May and prefers a sunny location. *Veronica anagallis-aquatica* (Blue water speedwell) is an herbaceous perennial found in or beside streams, marshes and wetlands and must be in a sunny location. *Salix fragilis* and *Veronica anagallis-aquatica* presented a significant relationship in their δ^{15}N content and the percentage of change of nitrate load per kilometer of stream flow (Fig. 3).

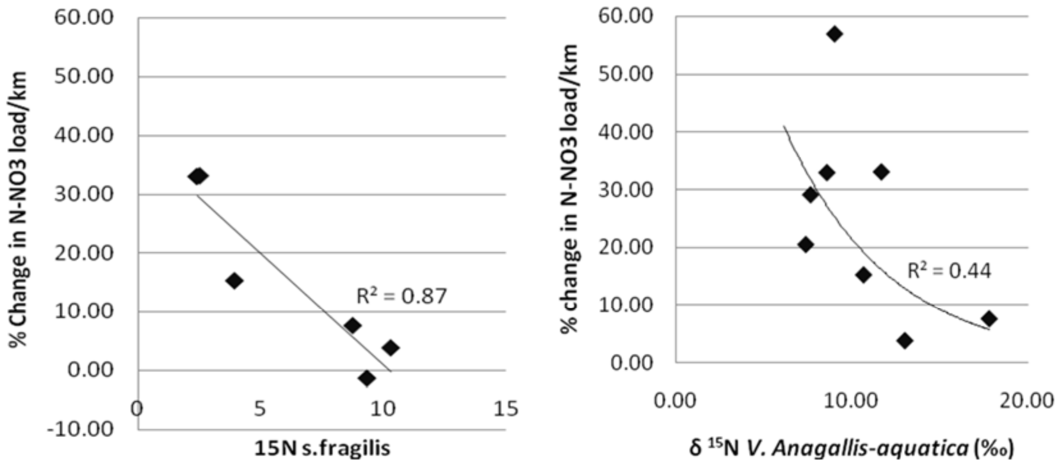

Fig. 3: Relationship between $\delta^{15}N$ in Salix fragilis (3A, left) and in Veronica anagallis-aquatica (3B, right) and percentage of nitrate load change per kilometer of stream.

A reduction of the slope of change, i.e. a decrease of the percentage of change of nitrate load per kilometre, reveals that some nitrate has been removed from the catchment in these particular areas. We used $\delta^{15}N$ signatures of riparian vegetation as a proxy of denitrification. The significant increase of $\delta^{15}N$ in *Salix fragilis*, a typical tree species of the riparian zones, could be attributed to competition with denitrification for nitrate uptake in the riparian sites located in the nitrate load reduction (Fig. 3A). Similarly, the increase of $\delta^{15}N$ in *Veronica anagallis-aquatica* with the decrease in percentage of change of nitrate load reveals that similar competition with denitrification of nitrate uptake occurs also instream (Fig. 3B).

This study emphasises the role of small near and in stream areas in buffering N input from diffuse pollution. However, despite the fact that small streams contribute to the vast majority of drainage in agricultural landscapes they are mostly ignored in national and international water quality monitoring networks such as the European Union Water Framework Directive (WFD, 2000). Indeed, there is a clear need to investigate water quality in small streams because it could be used as an integrated measure of drainage basin nutrient losses. Yet, WFD (2000) only stipulates to monitor water quality in draingae basins of 100 km^2 or more, a size far too large to be useful to decipher the relationship between land cover, land use and N fluxes at the outlet of the catchments.

References

Alexander R.B., Bohlke J.K., Boyer E.W., David M.B., Harvey J.W., Mulholland P.J., Seitzinger S.P., Tobias C.R., Bonitto C. and Wollheim W.M. 2009. Dynamic modeling of nitrogen losses in river networks unravels the coupled effects of hydrological and biogeochemical processes. Biogeochem. 93: 91–116.

Burt T.P. and Pinay G. 2005. Linking hydrology and biogeochemistry in complex landscapes. Prog.Phys. Geogr. 29: 297–316.

Gruber N. and Galloway J.N. 2008. An Earth-system perspective of the global nitrogen cycle. Nature451: 293-295.

Howarth R.W. 1998. An assessment of human influences on fluxes of nitrogen from the terrestrial landscape to the estuaries and continental shelves of the North Atlantic Ocean. Nutr.Cycl. Agrosyst. 52: 213-223.

Lefebvre S., Clément J.C, Pinay G., Thenail C., Durand P. and Marmonier P. 2007. 15N-nitrate signature in low-order streams: a multi-scale integration of land-cover and agricultural practices. Ecol. Appl. 17: 2333–2346.

Lefebvre S., Marmonier P., Pinay G., Bour O., Aquilina L. and Baudry J. 2005. Nutrient dynamics in interstitial habitats of low-order rural streams in different bedrock geology. *Archiv fur* Hydrobiol. 164: 169–191.

Omernik J.M., Abernathy A.R. & Male L.M. 1981. Stream nutrient levels and proximity of agricultural and forest land to streams – Some relationships. J.Soil Water Conserv. 36: 227-231.

Peterson B.J., Wollheim W.M., Mulholland P.J., Webster J.R., Meyer J.L., Tank J.L., Marti E., Bowden W.B., Valett H.M., Hershey A.E., McDowell W.H., Dodds W.K., Hamilton S.K., Gregory S. And Morrall D.D. 2001. Controls of nitrogen export from watersheds by headwater streams. Science 292: 86- 90.

Pritchart J. 2009. Variation in the δ15N of aquatic and riparian vegetation within a small English Catchment - Master Thesis, University of Birmingham, UK

Rockström J., Steffen W., Noone1 K., Persson A., F. Stuart Chapin F.S., Lambin E.F., Lenton T.M., Scheffer M., Folke C., Schellnhuber H.J., Nykvist B., de Wit C.A., Hughes T., van der Leeuw S., Rodhe H., Sörlin S., Snyder P.K., Costanza R., Svedin U., Falkenmark M., Karlberg L., Corell R.W., Fabry V.J., Hansen J., Walker B., Liverman D., RichardsonK., Crutzen P. And Foley J.A. 2009. A safe operating space for humanity. Nature 461: 472-475.

Strayer D.L., Beighley R.E., Thompson L.C., Brooks S., Nilsson C., Pinay G. and Naiman R.J. 2003. Effects of land cover on stream ecosystems: Roles of empirical models and scaling issues. Ecosyst. 6: 407–423.

Vitousek P.M., Mooney H.A., Lubchenco J. and Melillo J.M. 1997. Human domination of Earth’s ecosystems. Science 277: 494–499.

WFD 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

Technical Cooperation Projects

Operational Projects and Technical Officers responsible for implementation

Project Number	Title	Technical Officer
AFG5003	Sustainable Increase in Crop Production in Afghanistan	Nguyen, Minh-Long in collaboration with the Plant Breeding and Genetics Section
ANG5005	Effect of Biofertilizer and Inorganic Fertilizer Uses on the Growth and Yield of Maize and Bean in Ferralitic Soils of Huambo	Adu-Gyamfi, Joseph Jackson
BEN5005	Improving Maize and Yam-Based Cropping Systems and Soil Fertility	Adu-Gyamfi, Joseph Jackson
BKF5007	Improving Voandzou and Sesame Based Cropping Systems Through the Use of Integrated Isotopic and Nuclear Techniques	Sakadevan, Karuppan in collaboration with the Plant Breeding and Genetics Section
ECU5024	Improving Productivity of the African Palm through Better Fertilization and Water Management Practices	Dercon, Gerd
ECU5026	Improving the Efficiency of Irrigation in the Rio Chota Sub-Basin	Sakadevan, Karuppan
ERI5004	Improving Crop Productivity and Combating Desertification	Adu-Gyamfi, Joseph Jackson/ Nguyen, Minh-Long in collaboration with the Plant Breeding and Genetics Section
HAI5003	Enhancing Crop Productivity through the Application of Isotope Nuclear Techniques	Sakadevan, Karuppan in collaboration with the Food and Environmental Protection Section
INS5035	Application of Nuclear Techniques for Screening and Improving Cash Crop Plants in Coastal Saline Lands	Dercon, Gerd in collaboration with the Plant Breeding and Genetics Section
INS5037	Applying Nuclear Techniques for Screening and Improving Cash Crop Plants in Coastal Saline Lands	Sakadevan, Karuppan in collaboration with the Plant Breeding and Genetics Section
IRQ5017	Optimization of Land Productivity through the Application of Nuclear Techniques and Combined Technologies	Nguyen, Minh-Long in collaboration with the Plant Breeding and Genetics Section
IVC5031	Improving Plantain and Cassava Yields through the Use of Legume Cover Crops	Adu-Gyamfi, Joseph Jackson
KEN5030	Assessing Nutrient and Moisture Use in Major Cropping Systems	Heng, Lee Kheng
MAG5015	Optimization of Phosphate Fertilization of Ferralsols (classically deeply weathered red or yellow soils found in humid east Madagascar) in the Highland Areas of Madagascar	Nguyen, Minh-Long / Dercon, Gerd
MAR5017	Investigating the N Dynamics in the Crop-Soil System of a Multiple Cropping System to Optimize Fertilizer Use	Nguyen, Minh-Long
MLI5022	Assessment of Erosion and Sedimentation in the Niger Watershed with the Use of Radioisotopes, Phase-1	Mabit, Lionel
MON5015	Implementation of the Fallout Radionuclide Technique for Erosion Measurement	Dercon, Gerd
MOZ5003	Sustaining the Management of Soil Fertility	Dercon, Gerd
NAM5009	Using Mutation Breeding and Integrated Soil Plant Management Techniques to Develop Sustainable, High Yielding and Drought Resistant Crops	Heng, Lee Kheng in collaboration with Plant Breeding and Genetics Section
NIC8012	Applying Nuclear Techniques for the Development of a Management Plan for the Watershed of the Great Lakes	Dercon, Gerd
QAT5002	Developing Biosaline Agriculture in Salt-affected Areas in Qatar	Nguyen, Minh-Long in collaboration with Plant Breeding and Genetics Section

RAF5058	Enhancing the Productivity of High Value Crops and Income Generation with Small-Scale Irrigation Technologies	Heng, Lee Kheng
RLA5051	Using Environmental Radionuclides as Indicators of Land Degradation in Latin American, Caribbean and Antarctic Ecosystems (ARCAL C)	Dercon, Gerd and IAEA Environment Laboratories
RLA5052	Improving Soil Fertility and Crop Management for Sustainable Food Security and Enhanced Income of Resource-Poor Farmers (ARCAL CI)	Sakadevan, Karuppan
RLA5053	Implementing a Diagnosis System to Assess the Impact of Pesticide Contamination in Food and Environmental Compartments at a Catchment Scale in the Latin American and Caribbean (LAC) Region (ARCAL CII)	Dercon, Gerd in collaboration with Food and Environmental Protection Section
SAU5003	Improving Fertilization under Saline Conditions for Sustainable Crop Production	Nguyen, Minh-Long in collaboration with Plant Breeding and Genetics Section
SEN5030	Integrated Approach to Develop Sustainable Agriculture in Senegal	Dercon, Gerd in collaboration with Plant Breeding and Genetics Section
SEY5004	Developing Improved Nutrient Management Practices Using Nuclear and Related Techniques for Enhancing Sustainable Agricultural Productivity	Heng, Lee Kheng
SIL5008	Contribution of Nitrogen Fixing Legumes to Soil Fertility in Rice-based Cropping Systems	Adu-Gyamfi, Joseph Jackson
SIL5012	Managing Irrigation Water for a Dry Season Sorghum/Legume Intercropping System for Income Generation and Soil Health	Adu-Gyamfi, Joseph Jackson
SRL5040	Study on Nitrogen Balance in Coconut-Based Agroforestry Systems Using Nitrogen-15 Isotope Dilution Technique	Adu-Gyamfi, Joseph Jackson
SUD5030	Increasing Productivity of Selected Crops Using Nuclear Related Techniques	Adu-Gyamfi, Joseph Jackson in collaboration with Plant Breeding and Genetics Section
TAD5002	Assessment of Soil Erosion and Sedimentation for Land Use	Dercon, Gerd
TAD5005	Developing Soil Conservation Strategies for Improved Soil Health	Dercon, Gerd
ZAI5017	Use of Isotope Techniques in Relation with the Nitrogen Dynamic and the Quality of Organic Plant Material in Agricultural Soil Management	Nguyen, Minh-Long/Dercon, Gerd
ZAM5026	Improving Crop Varieties Through Use of Nuclear Techniques	Heng, Lee Kheng in collaboration with Plant Breeding and Genetics Section
ZIM5014	Developing and Promoting Strategies for Improved Crop Production	Heng, Lee Kheng

Forthcoming Events

FAO/IAEA Events

Mid-Term Coordination Meeting for the regional TC project RLA on 'Improving Soil Fertility and Crop Management for Sustainable Food Security and Enhanced Income of Resource-Poor Farmers (ARCAL CI)', 12-16 December 2011, Santo Domingo, Dominican Republic

Technical Officer: Karuppan Sakadevan

The purpose of this coordination meeting is to review the progress of the project activities since the beginning of the project in January 2010. The main activities that will be reviewed include: (1) the progress and results obtained from the field studies on the N use efficiency of by crops of ^{15}N labelled fertilizers and crop residues, (2) enhancement of laboratory facilities, (3) human resource capacity development in the partner institutions on the use of ^{15}N and ^{13}C stable isotopes, and (4) constraints to meeting the project objectives. In addition to reviewing the project progress, the meeting will also discuss and establish country specific action plans and resources required for 2012. It is expected that project participants from Argentina, Bolivia, Brazil, Chile, Cuba, Dominican Republic, El Salvador, Haiti, Mexico, Nicaragua, Paraguay and Venezuela will be attending the meeting.

Mid-Term Coordination Meeting for the regional TC project RLA5051 on 'Using Environmental Radionuclides as Indicators of Land Degradation in Latin American, Caribbean and Antarctic Ecosystems', 22-26 August 2011, Lima, Peru

Technical Officer: Gerd Dercon

The purpose of this coordination meeting is to discuss the progress of the project activities, such as (i) human capacity building in the field of radionuclide use for assessing land degradation by soil erosion, (ii) enhancement of laboratory facilities and (iii) soil erosion monitoring. The meeting will also aim at developing detailed implementation strategies of the second phase (2012-2013) in order to support the future project activities with regard to soil erosion monitoring, soil protection planning and the development of an on-line information and decision support system.

This system includes a geographic information system (GIS) where data are gathered on a regional scale. It should permit user-friendly and cost-effective visualization of the present situation, short and medium term predictions of regional soil degradation, environmental consequence of particular human interventions, and fallout radionuclide inventories in soils on a regional scale and their potential use in assessing soil loss.

It is expected that project participants from fifteen countries from the Latin American and Caribbean region (Argentina, Bolivia, Brazil, Chile, Cuba, Dominican Republic, El Salvador, Guatemala, Haiti, Jamaica, Mexico, Nicaragua, Peru, Uruguay and Venezuela) will be attending the meeting.

Mid-Term Coordination Meeting for the regional TC project RAF5058 on 'Enhancing the Productivity of High Value Crops and Income Generation with Small-Scale Irrigation Technologies', 6-9 December 2011, Quatre-Bornes, Mauritius

Technical Officer: Lee Heng

The purpose of this coordination meeting is to review the progress made in each Member State participating in the project since the First Coordination Meeting held in April 2009. The meeting is intended to evaluate results obtained so far, constraints faced and to reformulate the work plan if necessary, to streamline protocols to achieve the objectives of the project which are to enhance the productivity of high value crops and income generation with small-scale irrigation technologies. Specific objectives of the meeting are: (i) to review and evaluate results, discuss work progress, (ii) to establish country-specific action plans for 2012-13 based on results presented and in line with the objectives set in the project; (iii) to revise, discuss and agree on IAEA inputs for the project implementation in 2012-2013, (iv) to discuss the development of guidelines and practical recommendations on the water and nutrient requirements under small-scale irrigation technologies, and (v) to prepare a draft report giving a summary of achievements.

Project participants from the following countries are expected to attend this meeting: Algeria, Benin, Botswana, Ethiopia, Ghana, Kenya, Libyan Arab Jamahiriya, Mali, Mauritius, Morocco, Nigeria, Sudan, Uganda, United Republic of Tanzania, Zambia and Zimbabwe.

Regional training course for TC project RAF5058 on 'Enhancing the Productivity of High Value Crops and Income Generation with Small-Scale Irrigation Technologies', 10-13 December 2011, Quatre-Bornes, Mauritius

Technical Officer: Lee Heng

The purpose of this training course is to provide training on the use of isotopic and conventional methods for improving water use efficiency to the participants of the TC project RAF5058 subsequent to the coordination meeting. The training will include methods of calculating crop water use, evapotranspiration and its partitioning into soil evaporation and crop transpiration, the two major sources of water losses from agricultural systems. The FAO's AquaCrop model will be used to validate yield performance under this project and to improve irrigation management. Approximately 24 persons will participate in this training course.

Non-FAO/IAEA Events

- Soil Science in a Changing World.
  Dates: 18-22 September 2011; Place: Wageningen, The Netherlands.
  Website:
  http://www.wageningensoilmeeting.wur.nl/UK
- International Congress: Water 2011 - Integrated water resources management in tropical and subtropical drylands.
  Dates: 19-26 September 2011; Place: Mekelle, Ethiopia.
  Website: http://ees.kuleuven.be/water2011
- 5th World Congress of Conservation Agriculture
  Dates: 26-29 September 2011; Place: Brisbane, Australia.
  Website: http://www.wcca2011.org/index.htm
- International Congress on Irrigation and Drainage (ICID).
  Date: 15-23 October 2011; Place: Tehran, Islamic Republic of Iran. Theme: Water productivity towards food security.
  Website: http://www.icid2011.org
- WaterMed 2011.
  Date: 19 to 21 October 2011; Place: Milan, Italy.
  Website:
  http://www.watermed.com/en_wtm/index_wtm.asp
- Challenges and Opportunities for Agricultural Intensification of the Humid Highland Systems of Sub-Saharan Africa.
  Dates: 24-28 October 2011; Place: Kigali, Rwanda.
  Website: http://www.cialca.org

The Fifth International Scientific Conference BALWOIS 2012

Date: 28th May to 2nd June 2012; Place: Ohrid, Former Yugoslav Republic of Macedonia.
Website: http://www.balwois.com/2012/

Past Events

Duty Travel

Vietnam: for the Third Research Coordination Meeting (RCM) of the Coordinated Research Project (CRP D1.20.09) on 'Managing Irrigation Water to Enhance Crop Productivity under Water-Limiting Conditions: a Role for Isotopic Techniques' (6–10 December 2010)

Technical Officer: Lee Heng

Lee Heng travelled to Hanoi, Vietnam, from 6–10 December 2010 to act as Scientific Secretary for the third RCM of the CRP D1.20.09. The main objectives of the meeting were to review research results obtained in accordance with the project workplan, to assess overall progress in project implementation and to draw up an activity plan for completion of the project, in particular in the formulation of strategies for summarizing and publishing the results. Eight contract holders (Malawi, Morocco, China (2 participants), Pakistan, Turkey, Vietnam and Zambia), four agreement holders (Universität für Bodenkultur, Vienna, Austria), Spain (University of Cordoba) and USA (University of California-Davis, and University of Wyoming-Laramie), an observer Dr Daozhi Gong from China and an engineer from Picarro Inc, USA, Dr Gregor Hsiao, participated in the RCM. Drs Hai Sinh Duong, Institute for Water Resources Research of Vietnam and Nhan Dang, Institute for Nuclear Science and Technology at the Vietnam Atomic Energy Commission in Hanoi were the local organizers.

The meeting was opened by Dr Vu The Hai, the Director of the Institute for Water and Environment (IWE), Vietnam Academy for Water Resources. Together with Dr Nguyen Thi Nguyet, Head of the Department of International Cooperation and Training of IWE, they welcomed the participants of the RCM.

The results obtained so far showed that it is possible to use isotopic data (oxygen-18 and deuterium) in the soil, plant and in the water vapour around the plants to partition crop transpiration and soil evaporation from the total water lost through evapotranspiration (ET). This can be done using the isotopic mass balance or the Keeling plot approaches. Several participants also used the AquaCrop model and the conventional water balance approaches to determine the proportion of E and T over the growing period of their crops. The combination of isotopic techniques with crop simulation modelling is a novel approach to assess water productivity and irrigation management at various spatial scales. This approach allows the water productivity gap between potential and actual water productivity values to be identified, and to formulate recommendations (e.g. increasing planting density, reducing the amount of irrigation applied, enhancing soil fertility) to bridge the gap.

Finally, dissemination of the results was discussed. The group will summarise results from maize and wheat, the two major crops studied across the CRP in terms of the apportionment of E and T across the different agroecological zones using isotopic and conventional methods. The summarized results will be presented at the final RCM in Vienna, July 23-26 2012, planned to coincide with the FAO/IAEA International Symposium on 'Managing Soils for Food Security and Climate Change Adaptation and Mitigation'.

A field demonstration was carried out as part of the third RCM to determine the difference in the isotopic composition (oxygen-18 and deuterium) of water surrounding the canopies of actively growing and senescent soybean crops using laser spectroscopy (cavity ring down spectroscopy) in an experimental field belonging to the Vietnamese Institute for Ecological and Biological Resources.

The laser analyser in the middle of young and senesced soybean field in Hanoi

Italy: for the Workshop on Coping with Climate Change and Variability through Minimizing Soil Evaporation Wastage and Enhancing More Crops per Drop (9–13 May 2011)

Technical Officers: Lee Heng and Minh-Long Nguyen

Lee Heng conducted a workshop on Coping with Climate Change and Variability through Minimizing Soil Evaporation Wastage and Enhancing More Crops per Drop, jointly organized by the Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy and the SWMCN Subprogramme. Prof Theodore Hsiao from University of California-Davis and Leo Mayr from Soil Science Laboratory in Seibersdorf were also involved in the workshop. The purpose of the Workshop is to provide training and information exchange on the use of nuclear and conventional techniques for enhancing more crops per drop. Sixteen scientists from various parts of the world participated in this training workshop. The following topics were covered: (1) soil water balance, basic principles of evapotranspiration and crop water use, (2) methods for partitioning evapotranspiration into soil evaporation (E) and crop transpiration (T), and (3) AquaCrop model for predicting yield response to water availability under both rainfed and irrigated production systems. A quantitative framework for improving water use efficiency from field to area-wide scale was discussed. A one-day field demonstration of sampling of the isotopic composition of water vapour (oxygen-18 and H-2) using a laser optical analyser and the extraction of soil and plant samples was also carried out for the estimation of E and T.

Field demonstration of laser analyser for the sampling of water vapour oxygen-18 and H-2 composition at the ICTP campus

Italy: for the Workshop on Uncovering Sustainable Development CLEWS; Modelling Climate, Land-use, Energy and Water (CLEW) Interactions (30 May-3 June)

Technical Officer: Minh-Long Nguyen

The Workshop was jointly organized by the Abdus Salam International Centre for Theoretical Physics (ICTP) and the IAEA in Trieste, Italy. The objective of this workshop is to present 'CLEW assessment methods' for analysing the interaction of climate (C), land (L), energy (E) and water (W) resources and services as well as showing the implications of these interactions on the socio-economic development of society via case studies. The analysis of individual CLEW components (and their related services) is routinely undertaken using modelling tools. However these models often lack the functionality required to conduct the integrated analysis required in developing climate-impact, land-, energy- and water-use related policies. The development of an integrated tool linking the above components would help policy makers assess different technologies, estimate the impact of different development scenarios, coordinate policy and planning activities related to water, energy, land and climate and analyze and evaluate policies.

The main organizer of this workshop was the Planning and Economic Studies Section of the IAEA Department of Nuclear Energy (Mark Howell, and Hans-Holger Rogner) with the involvement of the Isotope Hydrology Section (Brent Newman) and the SWMCN Subprogramme (Long Nguyen). In addition, other speakers at the workshop included Pasquale Steduto from the FAO-Land and Water Division, Guenther Fischer of the International Institute for Applied Systems Analysis (IIASA), Charles Young of the Stockholm Environment Institute, Marie Langlois an independent economist from Austria, and Sebastian Hermann and Manuel Welsch of KTH, Royal Institute of Technology, Department of Energy Technology, Sweden. Amongst 38 participants, I was pleased to meet Ms. Ramma from Mauritius and Mr. Halitligil from Turkey, our counterparts from TC or CRP projects. They both are now actively contributing their inputs and knowledge gained from these IAEA-funded projects in land and water management into the CLEW case studies.

Japan: for a Joint FAO/IAEA Division Food Safety Assessment Team in Fukushima (25 March–1 April 2011)

Technical Officer: Lionel Mabit

From 25 March – 1 April 2011, a joint FAO/IAEA Division Food Safety Assessment Team (FSAT) (Andrew Cannavan, FSAT team leader and Head of the Joint IAEA/FAO Division's Food & Environmental Protection Laboratory, Lionel Mabit, FSAT team member and soil scientist of the Joint IAEA/FAO Division's SWMCN Laboratory, Jean-Michel Poirson from FAO and FSAT team member) went to Japan to provide advice and technical support to face the agro-environmental consequence of the Nuclear Power Plant (NPP) accident of Fukushima Daiichi.

For further information please consult the following link:

http://www.fao.org/audiocatalogue/index.jsp?lang=EN

Chile and Peru for Regional TC project RLA/5/051 on Using Environmental Radionuclides as indicators of Land Degradation in Latin American, Caribbean and Antarctic Ecosystems, 15–19 November 2010

Technical Officer: Gerd Dercon

Peru (15 November)

Mr Gerd Dercon visited the Instituto Peruano de Energía Nuclear (IPEN), Lima, the main project counterpart of Peru in the RLA/5/051 project that aims to enhance soil conservation in the region to ensure sustainable agricultural production and reduce the on- and off-site impacts of land degradation. Mr Dercon gave seminars on the use of isotopic and related tools to enhance the cost-effectiveness of soil conservation strategies. Several new fields of application were identified such as the use of compound specific isotope analysis for the identification of hot spots of land degradation in the agricultural landscape. Further, at the Ministry of Environment Mr Dercon established contacts with personnel from the National Commission for the Control of Desertification, who showed interest in the technologies disseminated under RLA/5/051 for improv-improving soil conservation strategies.

<u>Chile (16–19 November)</u>

Mr Dercon participated in the second Regional Training Course on 'The Use of Fallout Radionuclides (FRN) for Estimating Soil Erosion and Assessing the Effectiveness of Soil Conservation Measures' during the last week of the course, which was conducted in Valdivia, Chile, from 8 to 19 November 2010 to provide basic knowledge and skills to participants on the use of Fallout Radionuclide (Caesium-137, Lead-210 and Beryllium-7) techniques.

The course focused on the use of (i) models to convert environmental radionuclides (Be-7 and Cs-137) measurements into soil redistribution rates in the first week, and (ii) data visualization tools for soil related parameters, such as fallout radionuclide data, in the second week. The participants were directly involved in RLA/5/051 project activities. In total, 26 participants from Argentina, Bolivia, Brazil, Chile, Cuba, El Salvador, Haiti, Jamaica, Mexico, Nicaragua, Peru, the Dominican Republic, Uruguay and Venezuela attended the training course.

Mr Dercon also met with local stakeholders from Valdivia involved in the forestry sector, which has become a driving force in the national economy, with forest exports increasing from approximately US$ 40 million in 1970 to US$ 5.5 billion in 2008. Strong interest was expressed by the stakeholders in the dissemination of the project results through their network of forest managers in the private and public sectors.

Pine plantations on steep slopes in south-central Chile

Participants of the second training course of the regional project RLA/5/051 on the use of radionuclides for assessing land degradation

Regional Training Course on 'Linking Soil and Pesticide Behaviour at a Landscape Scale' under the Regional TC project RLA/5/053 on 'Implementing a Diagnosis System to Assess the Impact of Pesticide Contamination in Food and Environmental Compartments at a Catchment Scale in the Latin American and Caribbean (LAC) Region', 15 November–3 December 2010, Vienna, Austria

Technical Officers: Gerd Dercon and Lionel Mabit

The Regional Training Course was conducted at the IAEA, Vienna, Austria, from 15 November to 3 December 2010, in collaboration with the Food and Environmental Protection Subprogramme, to provide participants with an understanding of the link between soil and pesticide behaviour.

Participants of the second training course of the regional project RLA/5/053 on Linking Soil and Pesticide Behaviour at a Landscape Scale

The course provided practical training on the analytical approaches to characterize soil parameters that describe pesticide behaviour in the soil and highlighted the role of soil properties (mineralogy, soil organic matter and aggregate stability) and related characteristics (e.g. topography, soil erosion, and soil moisture conditions) on the fate of pesticides in the soil at a landscape scale. The training also focused on how land management practices (e.g., conservation agriculture) influence pesticide behaviour and how these practices can help reduce pesticide impact in the environment. Finally, the principles of spatial variability in soil organic matter, clay content and cation exchange capacity and how this variability can be monitored and analysed were explained. A total of 10 participants from Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, and Uruguay attended the training course. Technical officers from both subprogrammes and three experts from Canada, Colombia and Ecuador conducted the course.

The regional Technical Cooperation Project RLA/5/053 aims to apply a diagnosis and assessment system for evaluating the impact of pesticide contamination in food and environmental compartments in Latin American and Caribbean countries in order to ensure sustainable agricultural production and reduce on- and off-site impacts of pesticide use. A total of 17 countries are participating in this regional project (Argentina, Bolivia, Brazil, Chile, Colombia, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Jamaica, Nicaragua, Paraguay, Peru, Uruguay and Venezuela).

Support to the Incident and Emergency Centre in relation to the Fukushima Nuclear Accident

Technical Officer: Gerd Dercon

The Incident and Emergency Centre (IEC) of the International Atomic Emergency Agency is the global focal point for the preparedness and responses to nuclear and radiological incidents and emergencies irrespective of their cause. Its activities include event reporting and information exchange.

Subsequent to the Fukushima Nuclear Accident that occurred on 11 March 2011, the Soil and Water Management & Crop Nutrition Section, the Food and Environmental Protection Section and the Animal Production and Health Section of the FAO/IAEA Joint Division (NAFA) are supporting the IEC with the compilation of agricultural data from the affected areas in Japan reported by the Japanese authorities to ensure a comprehensive exchange of information to the Member States.

For more information on the Incident and Emergency Centre, please visit the website http://www-ns.iaea.org/tech-areas/emergency/incident-emergency-centre.asp?s=1

Non FAO/IAEA Events

Visitors

- Prof Marnik Vanclooster from the Université catholique de Louvain, Louvain-la-Neuve, Belgium (6 April): The expertise and working experience of Prof. Vanclooster and his team in developing countries will be highly useful for the forthcoming TC projects on agricultural water management.

- Dr Robert Schwartz, Soil Scientist from Soil and Water Management Research Unit, USDA-ARS, Bushland, TX, USA visited the SWMCN Subprogramme (VIC and Soil Science Laboratory) on 6 April 2011. Dr Schwartz has been working on soil and water related topics (e.g. soil water measuring techniques, conservation agriculture) both within the USA and in developing countries.

- Dr Bert Quin General Manager of Quin Environmentals (NZ) Ltd., a privately owned international fertiliser, soil fertility and environmental consultancy company, visited the Soil and Water Management & Crop Nutrition Section on 16 May to discuss various research aspects relating to nitrogen cycling and soil fertility. Quin Environmentals (NZ) Ltd is the scientific advisor to Group ONE (ONE stands for Optimise Nutrient Efficiency), a New Zealand Association of individual fertiliser spreaders, fertiliser and lime suppliers and consultants that aims to optimise nutrient efficiency and maintain the productivity and biological health of New Zealand soils, while protecting the environment. Dr. Quin was previously General Manager of Summit Quinphos (1995-2005), a major fertiliser company in New Zealand. Prior to this, he was a senior soil fertility scientist (1974-1984) with the Agricultural Research Division (ARD) of the New Zealand Ministry of Agriculture and Fisheries (MAF), the predecessor of AgResearch (one of the Crown Research Institutes in New Zealand) and then Chief Scientist (1984-1987) for the Soil Fertility Group at the internationally-known Ruakura Research Centre of the MAF-ARD.

- Emeritus Professor Craig Atkins, School of Plant Biology, The University of Western Australia, visited the Soil Water Management & Crop Nutrition Section from 30 to 31 May to discuss the compilation of the outputs from the CRP on ‘Selection and evaluation of food crop genotypes to low nitrogen and phosphorus soils through the use of isotopic and nuclear related techniques' into an IAEA Technical Document (IAEA TECDOC) during the final RCM in Vienna in November 2011. During his visit, Mr Atkins met with Mr Joseph Adu-Gyamfi to discuss a proposal to summarize and publish the results from this CRP in a 'Special Issue' of the journal Plant and Soil following the publication of the IAEA TECDOC.

Status of Coordinated Research Projects (CRPs)

Managing Irrigation Water to Enhance Crop Productivity under Water-Limiting Conditions: a Role for Isotopic Techniques (D1.20.09)

Technical Officers: Lee Heng and Minh-Long Nguyen

This CRP has entered its final phase after the third RCM in Hanoi, Vietnam from 10-14 December 2010. The final RCM will be held in Vienna, to coincide with the FAO/IAEA International Symposium 'Managing Soils for Food Security and Climate Change Adaptation and Mitigation', 23 - 26 July 2012.

The overall objective of this CRP is to improve crop water productivity (production per unit of water input) under water-limiting conditions. The specific research objectives are: 1) Quantify, and develop means to manage soil evaporative losses to maximise the beneficial use of water - the transpirational component of evapotranspiration, 2) Quantify, and develop means to improve the amount of biomass produced per unit of transpiration, 3) Devise irrigation and related management techniques to enhance the yield component of biomass production (Harvest Index).

Stable isotopes of water ($\delta^{18}O$ and $\delta^{2}H$), the soil moisture neutron probe (SMNP) and conventional approaches (e.g. micro-lysimetry, sap flow) were being used to quantify soil evaporation and transpiration fluxes in different crops, stages of canopy development and soil surface wetness. FAO's Aquacrop model was used to validate data generated for improving irrigation scheduling and agronomic practices for efficient agricultural water use and conservation.

Key outputs:

- Significant amounts of water were lost through soil evaporation, ranging from 15 to 85% of the total water from rainfall and irrigation for annual (maize, winter wheat, pepper) and perennial crops (coffee and orange trees). These losses occurred mainly immediately after irrigation or rainfall events, as well as during early seedling and at senescence stages. By mulching the soil surface with maize straw, evaporation was reduced by 50 mm out of the total of 400 mm of water loss in China, and water use efficiency (WUE) improved from 1.30 to 1.48 kg m^{-3}. Similarly, regulated deficit irrigation reduced water loss through evaporation by 70 mm in winter wheat compared to full irrigation, while yield was maintained (7.6 tonnes ha^{-1}) and WUE improved from 1.7 to 2.1 kg m^{-3}.
- In Malawi, adequate soil fertility and irrigation were both needed to increase maize yield and WUE in the semi-arid southern part of the country. Grain yield was less than 0.25 tonnes ha^{-1} under rainfed cultivation (seasonal rainfall 247 mm) irrespective of N application; the proportion of water lost through evaporation was approximately 70% of total water use. However when 240 mm of irrigation and 50 kg N ha^{-1} were added, 2.7 t ha^{-1} of grain yield was obtained and the proportion of evaporation losses was cut by 20%.
- Mulching during bud development and flowering stages for a 12-15 year-old coffee stand in Vietnam effectively reduced evaporation by 10% compared to trees without mulching.
- Data generated in the CRP are being used to validate FAO's AquaCrop model, which is being used in Member States to develop soil and water management recommendations for water productivity improvements.

Strategic Placement and Area-Wide Evaluation of Water Conservation Zones in Agricultural Catchments for Biomass Production, Water Quality and Food Security (D1.20.10)

Technical Officers: Karuppan Sakadevan and Lee Heng

This CRP is now in its third year and approaching its mid-term review in October 2011. The CRP is expected to be completed by the end of 2013 and the third RCM will be held in Vienna in July 2012 to coincide with the FAO/IAEA's International Symposium on 'Managing Soils for Food Security and Climate Change Adaptation and Mitigation'.

The overall objective of this CRP is to assess and enhance services provided by water conservation zones (farm ponds, wetlands and riparian buffer zones) for optimizing water and nutrients storage, biomass production and food security within agricultural catchments. The specific objectives of the project are: (1) to optimize water storage in water conservation zones for downstream irrigation use, (2) to regulate nutrient cycling in water conservation zones to improve bio-fuel crops and fuel wood production and (3) to optimize the use of water conservation zones for crop production.

Key outputs:

- Riparian buffer zones with woody biomass in Estonia improved stream water quality by removing up to 250 kg N ha^{-1} yr^{-1} coming from 380 ha agricultural catchment as runoff. These riparian zones which occupy less than 3% of the catchment can be used to produce up to 6 tonnes ha^{-1} yr^{-1} of biomass which is used for bioenergy
- Biomass production and C and N storage capacity in riparian buffer zones in Romania were higher (108 tonnes biomass ha^{-1}, 53.7 tonnes C ha^{-1} and 2.4 tonnes N ha^{-1}) in mixed forest compared with pastures (7.4 tonnes biomass ha^{-1}, 3.6 tonnes C ha^{-1} and 0.2 tonnes N ha^{-1}) and agricultural crops (6.5 tonnes biomass ha^{-1}, 3.3 tonnes C ha^{-1} and 0.13 tonnes N ha^{-1}),
- With appropriate design and placement, a farm pond with a surface area of less than 3% of the catchment

(265 ha) in Tunisia was able to capture and store up to 100% of runoff water generated from the catchment and reduce N by 50% in the pond. This water was sufficient to irrigate between 6 and 9 ha of cropland, providing 25 kg N ha^{-1} and producing up to 5 tonnes ha^{-1} of biomass including wheat, maize, tomato and pepper,

- Water harvested using riparian wetlands along river streams that received runoff from a 34000 ha agricultural catchment in Uganda was sufficient to produce rice crops in 340 hectares of land, three times per year producing up to 3.5 tonnes ha^{-1} milled rice.

Eight research contract holders from China, Estonia, Islamic Republic of Iran, Lesotho, Nigeria, Romania, Tunisia and Uganda, two technical contractors from the UK (University of Birmingham) and the USA (University of Florida) and agreement holders from the USA (University of Rhode Island) and France (Institut de recherché pour le Development) are involved in the project. Since the second RCM, which was held during 10-14 May 2010, all research contract holders have continuously collected field data on $\delta^{15}N$, $\delta^{18}O$ and $\delta^{2}H$ from water and plants from wetlands, farm ponds and riparian buffer zones to identify sources of water and the biomass N use efficiency and are being analysed for inclusion in the CRP's mid-term review.

Integrated Isotopic Approaches for an Area-wide Precision Conservation to Control the Impacts of Agricultural Practices on Land Degradation and Soil Erosion (D1.20.11)

Technical Officers: Long Nguyen and Gerd Dercon

The overall objective is to develop integrated isotopic approaches to identify hot spots or critical areas of land degradation in agricultural catchments for effective soil conservation measures (precision conservation).

Specific research objectives are (i) to develop the combined use of fallout radionuclide (FRN) techniques with conventional techniques and spatial analysis to establish soil redistribution patterns and rates over several temporal scales on an area-wide basis (catchment), (ii) to develop and validate protocols for the application of compound specific stable isotope (CSSI) techniques to identify and apportion the amount of source soils (land-degraded areas) from main land uses/management (cropland, grassland and forestland) in the catchment, (iii) to integrate nuclear based approaches with other non-nuclear techniques through modelling and other tools to establish comprehensive soil redistribution studies on an area-wide basis and (iv) to create the basis to develop decision support tools for implementing precision conservation and contributing to sustainable land management.

This CRP, which was formulated on the basis of the recommendation of a Consultants Meeting held at IAEA Headquarters, Vienna, 5-7 November 2007, is in its third year. The first RCM was held at IAEA headquarters in Vienna from 8 to 12 June 2009. The second RCM was held at the National Centre for Atomic Energy, and Nuclear Sciences and Applications (Centre national de l'énergie, des sciences et des techniques nucléaires (CNESTEN) in Rabat, Morocco, from 27 September to 1 October 2010. Eight research contract holders from Chile, China, Morocco, Poland, Russian Federation, Syrian Arab Republic and Vietnam, four technical contract holders from Germany (University of Hohenheim), New Zealand (National Institute of Water & Atmospheric Research), United Kingdom (University of Exeter) and Belgium (University of Ghent), and three agreement holders from Australia (CSIRO), Canada (University of Manitoba) and the United Kingdom (University of Plymouth) attended the meeting. The third RCM will be held at IAEA Headquarters in Vienna from July 23-26 2012 at the same time as the FAO/IAEA International Symposium on 'Managing Soils for Food Security and Climate Change Adaptation and Mitigation'.

Key outputs:

The following approaches to up-scale soil redistribution patterns were explored and tested in this CRP:

- The use of representative geographic units as a basis for extrapolation (e.g. Morocco, Canada),
- Spatial sampling programmes aimed at maximising the information return from a limited number of samples (transects, grids, random spatial sampling), as undertaken in Italy, Syrian Arab Republic, China, Morocco, Chile and Canada,
- Paired catchment approaches to compare soil redistribution in neighbouring catchments with similar size and landscape properties (e.g. topography and soil type), but different land use or management (e.g. Chile), and
- The use of nested sub-catchments to determine the effect of scale (from river sub-catchment to catchment and from catchment to basin) on soil redistribution (Poland).

The following tests represent encouraging first steps in the development of effective extrapolation and up-scaling procedures.

- CSSIs were shown to be a useful technique to identify and apportion hot spots of land degradation/erosion (by linking biomarkers of land use to the sediment in deposition zones).
- The first draft of a harmonized protocol for the application of CSSI techniques to identify critical areas of land degradation at the catchment scale in a range of environments and land use systems was developed. This protocol was sent to the CRP participants in October 2010 for further validation under different agroecological conditions.
- The link of FRNs (Cs-137, Be-7 and Pb-210) with CSSIs (e.g. fatty acids) also improved the power for distinguishing the sediment sources (Australia).

- Integrating the use of FRNs such as Pb-210 and CSSIs (New Zealand) showed how land use history over the last hundred years can be reconstructed. The CSSIs of different depth layers in a sediment core can identify land use changes associated with changes in sediment accumulation rates (defined by Pb-210).

Integrated soil, water and nutrient management in conservation agriculture (D1.50.09)

Technical Officer: Gerd Dercon

Manuscripts for the IAEA-TECDOC of this CRP, which was concluded in 2009, are now under review. In addition, the CRP team has compiled all data into one comprehensive dataset, which will be the basis for an overview paper of this CRP.

This CRP created an effective network of research scientists and national agricultural research systems (NARS) involved in conservation agriculture research and promotion. The CRP increased awareness and stimulated interest in the unique role of nuclear techniques in acquiring new knowledge of key physical (e.g. water retention), chemical (e.g. C sequestration) and biological (e.g. BNF) processes in conservation agriculture. Finally, it paved the way for the implementation of projects in CA under the IAEA's Technical Cooperation Programme.

This CRP had a total of ten participants comprising seven research contractors from Argentina, Brazil, India, Morocco, Pakistan, Turkey and Uzbekistan, two technical contractors (Australia and Chile), and one agreement holder (CIMMYT-Mexico). In addition, one individual contractor (Mr. Bernard Vanlauwe) conducted research on the evaluation of C and N dynamics in long-term trials in Sub-Saharan Africa, focusing on tillage, residue management and rotational effects.

Selection and Evaluation of Food (Cereal and Legume) Crop Genotypes Tolerant to Low Nitrogen and Phosphorus Soils Through the Use of Isotopic and Nuclear related Techniques (D1.50.10)

Technical Officers: Joseph Adu-Gyamfi and Gerd Dercon

This CRP is in its fifth year and the final RCM will be held during the fourth Quarter of 2011 at IAEA Headquarters in Vienna. The first RCM was held at IAEA headquarters in Vienna from 16-20 October 2006. The second RCM was held in Morelia, Mexico from 21-25 April 2008. The third RCM was held in Maputo, Mozambique from 23-27 August 2010.The project has a total of 16 participants with nine research contract holders (Burkina Faso, Brazil, Cameroon, China, Cuba, Ghana, Malaysia, Mexico, and Mozambique), six agreement holders (Australia, Benin, Germany, Kenya, Nigeria, and France) and one technical contractor (USA).

The overall objective of this CRP is to develop integrated crop, soil and nutrient management practices to increase crop production in marginal lands by identifying and promoting the development of food crop genotypes (cereal and legume) with enhanced nitrogen (N) and phosphorus (P) use efficiency and greater productivity. Significant outputs include:

- Out of 150-200 genotypes from four different food security crops (rice, maize, common bean, soybean/cowpea) that were tested in 17 countries, 10-15 were selected with an increased N and P use efficiency of at least 15%.
- Root traits that contributed to enhanced N and P efficiency under low N and P were identified, resulting in a 5-20% increase in biomass (depending on the crop type).
- Branching angle interval was identified as a suitable root selection parameter for soil N use efficiency, while adventitious rooting and root hair formation were identified as suitable plant parameters for selecting P use efficiency.

Stable (^{15}N) and radioactive (^{32}P) isotopes were effectively used to assess N and P acquisition by the tested crop genotypes under diverse agroecological conditions. The team further improved protocols to assess root characteristics. The CRP has created a database on how cereal and legume crops can acquire N and P in low nutrient soils. This database will be further expanded and interpreted using multivariate analysis (coordinated by Mexico, the USA and IAEA) during the last 14 months of the CRP.

Activities of the Soil and Water Management and Crop Nutrition Laboratory, Seibersdorf

Research and Development

Assessment of carbon distribution and soil organic carbon storage in mulch-based cropping systems by using isotopic techniques

G. Dercon, M. Heiling, M. Aigner, L. Mayr, J. Arrillaga, N. Jagoditsch, J. Adu-Gyamfi, M.L. Nguyen

An integrated soil-water-plant-nutrient approach is required to improve productivity, restore and maintain soil fertility and its resilience against degradation and climate change.

A recently completed Coordinated Research Project on Integrated Soil, Water and Nutrient Management in Conservation Agriculture (D1.50.09) collected evidence on the extent to which an integrated soil-water-plant-nutrient approach such as conservation agriculture can have beneficial effects on agricultural resource use efficiency and crop production in a range of agroecosystems worldwide. Conservation agriculture, which is currently employed on 105 million hectares worldwide, involves three main principles: (i) minimum or zero soil cultivation, (ii) the use of crop rotation and (iii) the retention of a permanent soil cover or mulch.

However, little is known about how mulch-based agricultural systems (such as conservation agriculture) can improve soil quality and assist in mitigating the impacts of climate change, or how these systems, in combination with reduced tillage and crop rotations, can enhance soil organic carbon accumulation and sequestration. The mechanisms of how this carbon sequestration is improved by external nutrient inputs derived from fertilizer or nitrogen fixing legume crops grown in conservation agriculture also need further attention.

The quest for rapid and cost-effective techniques to assess the above mentioned processes led to isotopic techniques based on the use of the natural ^{15}N and ^{13}C abundance signal of bulk soil, soil organic matter pools and specific organic components derived from the crops deposited in the soil.

Therefore the SWMCN laboratory team has established a long-term mesocosm experiment to develop and adapt innovative isotopic techniques that can assist Member States in the near future in the assessment of carbon distribution between above and below-ground plant parts, the effectiveness of land management strategies in enhancing soil organic carbon (SOC) accumulation and storage, and the quantification of the stability of the stored SOC. It will look at how SOC accumulation and storage are influenced through (i) retained crop residues on the soil, (ii) root development and (iv) dissolved organic carbon in the soil.

The team is currently running pre-trial tests to optimize the conditions of the mesocosm experiment by analysing the optimal configurations of the columns used and the best ways to carry out soil and plant sampling and isotopic analyses. The experiment is expected to start in autumn 2011, with a soil stabilization period of six months. The first crops will be planted in March 2012.

Vacuum extraction of soil and plant water for stable isotope analyses

M. Aigner, L. Mayr, L. Heng and G. Dercon

Analysis of the isotopic signature of water in soil or plant material is useful for the investigation of the dynamics of water within the soil-plant system. Oxygen-18 ($\delta^{18}O$) and Deuterium ($\delta^{2}H$) data from the extracted water could be used to determine the movement of rainfall or irrigation water in soil, and to partition evapotranspiration (ET) into its individual components of soil evaporation (E) and plant transpiration (T).

Measuring stable isotope ratios of water in biological samples (plant, soil) by mass spectrometry or laser spectroscopy requires the quantitative extraction of water from the sample without isotopic fractionation. The most common method is vacuum distillation. However, this extraction is often the bottle-neck as a laborious laboratory setup is required. A simple, fast and portable vacuum distillation setup and methodology were developed in the SWMCN Laboratory for extracting soil and plant water. The methodology was tested across a range of soils, plant samples, extraction times and temperatures. The preliminary results showed that full recovery (extracting more than 99% of the total water) and reproducible isotopic ratios (±0.15‰ for $\delta^{18}O$ and ±0.5‰ for $\delta^{2}H$) were reached after 60 minutes distillation time with a sandy soil and 90 minutes with a clay soil at 100°C distillation temperature. This portable setup (Fig. 1) could be used to support CRPs and TC projects in Member States.

Fig. 1. Portable vacuum extraction distillation equipment in field operation

Training Activities

One of pillars of the Soil and Water Management & Crop Nutrition Laboratory (SWMCNL) is training activities to support technology transfer under various technical cooperation projects (TCPs). A fellow from Zimbabwe was trained on the use of N-15 isotopic techniques to quantify biological nitrogen fixation and nutrient budgets in a cereal/legume cropping system.

The potential benefit in reducing the need of manufactured nitrogen fertilizers can be enormous if biological nitrogen fixation (BNF) can be optimized in cereal-based cropping systems. One of the main tenets of cereal–legume cropping systems is that legumes contribute to soil fertility and the long-term sustainability of the system because they derive a proportion of their nitrogen (N) requirements from the atmosphere through symbiotic N_2 fixation.

A greenhouse study was conducted to quantify N_2 fixation by cowpea (*Vigna unguiculata*) as a sole crop or intercropped with sorghum (*Sorghum bicolor*), using a low-P soil from Hungary classified as a *Dystric Eutrocrept*, and a medium-P soil from the Waldviertel, Austria classified as a *Dystric Cambisol*. Sorghum was also grown as a sole crop. The 15N isotope dilution method was used to quantify BNF while a simple input/output model was used for estimating N and P budgets to determine the long term sustainability of the soil in the sole crop and the intercropping system.

The results show that despite the apparent variations in total N fixed under the sole cowpea and cowpea-sorghum cropping systems, cowpea derived 14-73% of its N from N_2 fixation. Although intercropping cowpea with sorghum in both soils reduced individual biomass production compared to the sole crops, the overall productivity measured by the land equivalent ratio (LER>1) was higher in intercropping than in sole cropping. The input/output model showed that the inclusion of cowpea in a sorghum-based cropping system would result in a positive N balance provided the legume and cereal residues are incorporated into the soil and are not removed.

Fig. 1 Zimbabwean fellow , Mr Tonny Tauro, working on the intercropping cowpea and sorghum study in a glasshouse experiment in the SWMCN Laboratory

Updated status of the training manual on the use of fallout radionuclides (FRNs) to assess erosion and sedimentation processes

Technical Officer: Lionel Mabit (SWMCN Laboratory)

Worldwide soil degradation is currently affecting 1.9 billion hectares and is increasing at a rate of 5 to 7 million hectares each year. More than three quarters of this degradation is caused by poor land management practices in cropping and livestock production systems.

With increasing attention being paid to land degradation worldwide, there is a need to produce a training manual that can be used as a practical guide for (i) tracing and assessing soil degradation processes associated with soil erosion at different temporal scales, and (ii) evaluating the effectiveness of soil conservation strategies to ensure sustainable land management and productivity in agricultural systems using FRN techniques. The manual also includes method and instrumentation that are important for quantifying FRNs.

This manual entitled Use of Fallout radionuclides to Assess Erosion and Effectiveness of Soil Conservation Strategies. *A Practical Guide to* ^{137}*Cs*, ^{7}*Be and* ^{210}*Pb Based Methods* will be published in the Training Course Series of the International Atomic Energy Agency (IAEA) and will summarize experiences and know-how in this field gained since the end of the 1990s by the IAEA and scientists from developed and developing countries involved in IAEA networks. It will provide guidance in the application of FRN to an audience of scientists and technicians from different disciplines (e.g., soil science, ecology and agronomy) as well as extension workers, undergraduate and graduate students, and staff of non-governmental organizations and other stakeholders involved in sustainable agricultural development at the local, national, regional and international levels.

The manual will include the following 9 chapters and contributions from IAEA staff and 20 authors from 8 different Member States (Austria, Canada, Chile, Hungary, Morocco, Slovakia, Switzerland and the United Kingdom).

Chapter 1. Assessment of soil erosion and sedimentation: the role of fallout radionuclides

Chapter 2. ^{137}Cs: a widely used and validated medium-term soil tracer

Chapter 3. The use of excess ^{210}Pb ($^{210}Pb_{ex}$) as a soil and sediment tracer

Chapter 4. The use of ^{7}Be as short term soil redistribution tracer

Chapter 5. Conversion models and related software

Chapter 6. Combined use of ^{137}Cs and $^{210}Pb_{ex}$ to assess long term soil redistribution in a small agricultural field in Morocco

Chapter 7. The use of ^{7}Be and ^{137}Cs in soil redistribution evaluation in South America - Chile

Chapter 8. The combined use of ^{137}Cs and stable isotopes to evaluate soil redistribution in mountainous grasslands, Switzerland

Chapter 9. Trends in the use of ^{137}Cs, $^{210}Pb_{ex}$ and ^{7}Be for documenting soil redistribution: the future

Analytical services conducted by the SWMCN Laboratory in 2010 (January to October)

Samples measured:

	^{15}N enriched	^{15}N nat. ab.#	^{13}C nat. ab.	^{18}O nat. ab.	Total
CRP	526	67	257	518	1368
TC	207	61	109	0	377
Seibersdorf	1806	983	2580	180	5549
Total	**2539**	**1111**	**2946**	**698**	**7294**

refers to natural abundance

Measurements carried out:

(Including standards, blanks, test samples, replicates)

	^{15}N enriched	^{15}N nat. ab.	^{13}C nat. ab.	^{18}O nat. ab.	Total
CRP	672	106	339	661	1778
TC	274	107	175	0	556
Seibersdorf	2630	1576	3835	315	8356
Total	**3576**	**1789**	**4349**	**976**	**10690**

Fellows and Scientific Visitors at the SWMCN Laboratory in 2010

a. Fellows

- Ms Nourice (Bonne), Therese Monette, SEY10010 (Seychelles) on Use of nuclear techniques in soil water management, 11 April to 20 July.
- Mr Julius Sesay, SIL10001 (Sierra Leone) on Use of trace technology to quantify biological nitrogen fixation, 11 April to 8 July 2011.

b. Scientific visitors

- Mr David Abass Kamara SIL/10010V (Sierra Leone) on Use of trace technology to quantify biological nitrogen fixation and nitrogen budgets in cropping systems, 9 to 20 May 2011.

Publications

List of Publications in 2011

Hsiao, G., Heng, L., Williams, D. and Dang Duc, N. (2011). New Experimental Approaches to Measuring Plant-Extracted Waters. In: Geophysical Research Abstracts, European Goesciences Union – General Assembly 2011, Vienna, Austria. Abstract EGU2011-13123.

Mabit, L. (2011). Sediment dynamics assessed at catchment scale using nuclear techniques with the support of Geographical Information Systems. In: Geophysical Research Abstracts, Volume 13, European Geosciences Union – General Assembly 2011. Vienna, Austria. Abstract EGU2011-1016.pdf. http://meetingorganizer.copernicus.org/EGU2011/EGU2011-1016.pdf

Marchetti, A., Piccini, C., Santucci, S., Chiuchiarelli, I., Francaviglia, R., Mabit, L. (2011). Spatial distribution of soil organic matter using geostatistic: a key indicator to assess soil degradation status in Central Italy. *Pedosphere* (In press).

Muraoka, T., Franzini, V., Trevizam, A. R. and Adu-Gyamfi, J. (2011). Biological nitrogen fixation efficiency in common bean cultivars. 5th International Nitrogen Conference, 5-7 December 2010, New Delhi.

Schlink, A. C., M.-L. Nguyen and G. J. Viljoen (2010) Water requirements for livestock procution: a global perspective. Plurithematic issue of the Scientific and Technical Review, 29 (3), 603-619.

Schmitter, P., Dercon, G., Hilger, T., Hertel, M., Treffner, J., Lam, N., Vien, T.D., Cadisch, G. (2011). Linking spatio-temporal variation of crop response with sediment deposition along paddy rice terraces. Agriculture Ecosystems & Environment, 140, 34-45.

Websites

- Soil and Water Management and Crop Nutrition Section: http://www-naweb.iaea.org/nafa/swmn/index.html
- Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture: http://www-naweb.iaea.org/nafa/index.html
- FAO website: http://www.fao.org/about/en/
- FAO/AGL (Land and Water Development Division): http://www.fao.org/nr/water/landandwater_what.html

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