



Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Soils Newsletter



<http://www-naweb.iaea.org/nafa/index.html>
http://www.fao.org/ag/portal/index_en.html

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To Our Readers

As 2016 is coming to a close, let us reflect what the Soil and Water Management and Crop Nutrition (SWMCN) Subprogramme has accomplished and also to inform you about some of the planned activities in 2017. The SWMCN and the Plant Breeding and Genetics Subprogrammes of the Joint FAO/IAEA Division joined the international communities and celebrated the International Year of Pulses with an exhibition at the IAEA Headquarters in September. The theme was 'Enhancing pulses for food security using nuclear applications'. The event highlighted the work done on the use of stable isotope of nitrogen (^{15}N) to identify pulses and legumes with high nitrogen fixing abilities and to quantify the amount of nitrogen fixed, towards supporting Member States for food security and mitigating the effects of climate change. A variety of pulses and pulse plants were displayed, showing their nitrogen-fixing roots and nodules. Also presented were mutant pulse varieties that have been released in Member States.

The year 2016 also marked the 60th anniversary of the establishment of the IAEA, we thank our partners and counterparts worldwide for their dedication and continuous support during all these years.

The year 2016 was also very productive in the area of publication, four IAEA technical documents were published, including IAEA-TECDOC-1783 'Supporting sampling and sample preparation tools for isotope and nuclear analysis', IAEA-TECDOC-1784 'Management and Area-wide Evaluation of Water Conservation Zones in Agricultural Catchments for Biomass Production, Water Quality and Food Security', IAEA-TECDOC-1802 'Integrated Soil, Water and Nutrient Management for Sustainable Rice - Wheat Cropping Systems in Asia' and

IAEA-TECDOC-1805 'Use of Phosphorus Isotopes for Improving Phosphorus Management in Agricultural Systems'. An animated infographic on 'Managing Nitrogen', a brochure on 'Soils and Pulses' as well as more than 30 publications in scientific journals and peer-reviewed journals were also produced. Further information on the publications is given on the SWMCN Subprogramme website at <http://www-naweb.iaea.org/nafa/swmn/index.html>.



The International Year of Pulses celebration at the IAEA Headquarters

In 2016 two CRPs in the Subprogramme were completed, that is 'Soil Quality and Nutrient Management for Sustainable Food Production in Mulch-Based Cropping Systems in Sub-Saharan Africa' and 'Approaches to Improvement of Crop Genotypes with High Water and Nutrient Use Efficiency for Water Scarce Environments'. At the same time, a new CRP on 'Nuclear Techniques for

a Better Understanding of the Impact of Climate Change on Soil Erosion in Upland Agro-ecosystems' started. In 2017, one Research Co-ordination Meeting for CRP 'Response to Nuclear Emergencies Affecting Food and Agriculture' and two Consultants' Meetings to develop two new CRPs ('Water, nutrient management for agriculture-driven non-point source pollution' and 'Response to drought and flooding emergencies affecting agriculture') will be held.

The year 2016 is also the start of the 2016-17 programme and budget (PWB) for the Regular Programme and the Technical Co-operation (TC) Programme 2016-17 biennium. For this biennium, the SWMCN has a total of 45 TC projects and currently new TC project designs for 2018-19 cycles are being evaluated.

In terms of staffing, finally all the vacant posts in the SWMCN Subprogramme are filled. The last vacant post on Soil Fertility Specialist went to Mr Joseph Adu-Gyamfi who has been assisting the Section as a consultant. We welcome Joseph to the team. We also want to take this opportunity to congratulate Arsenio Toloza from the SWMCN Laboratory for receiving the IAEA merit award; Arsenio has been providing excellent support to the work on soil erosion control and soil conservation practices.

The SWMCN Laboratory also had a very productive year in terms of research and development in 2016 as you can read from the feature articles and the work under 'Developments at the Soil and Water Management and

Crop Nutrition Laboratory' in the newsletter. Major advances have been achieved in developing plutonium for investigating the magnitude of erosion and sedimentation processes and the use of CSSI for determining sources of soil erosion. Good progress has also been made on the development of agricultural sampling strategies during nuclear and radiological emergencies. Work on developing a method to determine sources of nitrate agricultural pollution is also coming along well. Work on monitoring landscape soil water content using cosmic-ray neutron sensors and on developing simple tools for determining soil evaporation and the fate of crop residues when applied to an agricultural field has made very good progress. The Laboratory also successfully developed guidelines on carbon-13 (^{13}C) labelled plant material to trace the fate of plant-derived C into the atmosphere, soil, water and organisms. The Laboratory continues to support analytical services for stable isotopes and for fallout radionuclides relating to research and development activities. In 2016, four interns joined the Laboratory and their work contributed towards the achievements this year.

I would like to end by thanking all my colleagues from the Section and the Laboratory for their hard work and support to the SWMCN Subprogramme, and also our counterparts, partners and you, the readers for helping us in achieving a successful year.

On behalf of the SWMCN Subprogramme, I wish you a prosperous 2017.



Lee Heng
Head
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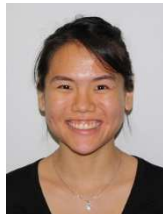



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Staff News



Marlies Zaczek joined the SWMCN Section on 1 July 2016 as a team assistant. She is responsible for the administrative implementation of planned events and Research Coordination Meetings as well as for travels, procurement, review of TecDocs and other administrative tasks.

She has been working within the UN system since 2008 and holds a Master's degree in International Law and Politics, Chinese and French from the University of Vienna. She studied Chinese language for one year at the Nanjing University in China. Prior to joining the United Nations, Marlies worked as Foreign Language Assistant for several institutions in France for two years and then in Vienna at the University of Economics and Business Administration at the Asia Department as Coordinator for Asia.



William Avery joined the SWMCN Laboratory as an intern in July 2016 to work on the calibration, validation, and application of the Cosmic Ray Neutron Sensor, a technology capable of estimating area wide soil moisture content and as an informing tool for water management decisions. William graduated from the University of

Nebraska-Lincoln, USA with a MSc. in Natural Resource Science, majoring in water science. His Master's work involved developing new tools for the use of satellite-based remote sensing in the Cosmic Ray Neutron Sensor calibration and validation process as well as its measurement around agricultural fields of central North America. Prior to this, he studied Environmental Science on topics such as Ornithology, Hydrology, Soil Science and Ecology at the University of Nebraska-Lincoln as part of his undergraduate. His past work has taken him most notably to the Andes Mountains of Colombia and the Rocky Mountains of Montana, USA to study land use impacts on water quality and quantity.



Aamir Khan joined the SWMCN Laboratory as an intern in October 2016 to work on the use of laser isotope analysis for better understanding the role of nitrification inhibitor and manure in nitrous oxide and carbon di oxide emissions. Aamir is currently an MSc. student at the University of

Agriculture Peshawar in Pakistan focusing on soil fertility management, nitrogen uptake using N-15 technique and nitrous oxide emission from arable cropping. For his

Master's research, he worked on exploring the effect of coated urea with nitrification inhibitor on wheat yield and greenhouse gas emission, using the ^{15}N technique. He



attained his BSc. (H) in Agricultural Sciences from Gomal University, in Dera Ismail Khan city in Pakistan.

Joseph Adu-Gyamfi completed his one year tenure as a consultant with the SWMCN Section on 22 November 2016 and returned to Ghana. Joseph provided

technical expertise and inputs in project management for 14 Technical Cooperation (TC) projects and one Coordinated Research Project (CRP) relating to integrated soil fertility and crop management practices in Africa, Asia & Pacific and Latin America & Caribbean regions. Joseph also updated and published the phosphorus and carbon guidelines, as well as a TECDOC on Nutrient Management in Rice-Wheat Cropping Systems in Asia. He also provided support on the celebration of 2016 International Year of Pulses by producing a brochure on 'Soils and Pulses: Managing Soils for Sustainable Pulse Production' and coordinating an exhibition event at the IAEA Headquarter in Vienna. We thank Joseph for his support and contribution to the Subprogramme. Meanwhile Joseph was offered the Soil Fertility Specialist position and will rejoin the Section in mid-January 2017. Joseph will play a key role in the Section as a technical officer for both CRP and TC projects on soil fertility management.



Arsenio Toloza received a Merit Award in November 2016 from Deputy Director General and Head of the Department of Nuclear Applications (Mr. Aldo Malavasi) in recognition of his excellent work supporting the Soil and Water Management and Crop Nutrition Subprogramme. This award is

to honour specifically his outstanding contribution to the work of the Soil and Water Management and Crop Nutrition Laboratories of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture in the field of soil erosion control and soil conservation practices.

Feature Articles

Unique Conversion Model for Assessing Soil Redistribution Magnitudes from Fallout Radionuclides Inventories: MODERN

Laura Arata⁽¹⁾, Katrin Meusburger⁽¹⁾, Elena Frenkel⁽²⁾, Annette A'Campo-Neuen⁽³⁾, Andra-Rada Iurian^(4, 5), Michael E. Ketterer⁽⁶⁾, Lionel Mabit⁽⁷⁾, Christine Alewell⁽¹⁾

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Soil erosion is one of the major threats to soil stability and agricultural productivity but monitoring erosion magnitude remains a challenge. In the last 50 years, fallout radionuclides (FRNs) – such as artificial ^{137}Cs and $^{239+240}\text{Pu}$, natural ^{210}Pb fallout and cosmogenic ^7Be – have been widely used as soil tracers to provide estimates of water induced soil erosion rates under different environmental conditions. Once deposited on the ground, FRNs strongly bind to fine particles at the soil surface and move across the landscape primarily through physical processes. As such, FRNs are effective tracers of soil and sediment redistribution. The method is based on the comparison between the inventory (total radionuclide activity per unit area) at a given sampling site and that of a reference site, located in a flat and undisturbed area. If the FRN inventory at a sampling site is lower than the reference site, the result indicates that the site experienced erosion processes. However, if a site presents a greater FRN inventory than the reference site, this site experienced deposition processes. Different available conversion models allow derivation of quantitative estimates of soil erosion and deposition rates from FRN measurements.

Arata *et al.* (2016a) recently developed a new conversion model, called MODERN (Modelling Deposition and Erosion rates with Radionuclides), to derive soil redistribution rates from FRN inventories. MODERN is based on the comparison between the depth profile of the FRN distribution at the reference site and the total FRN inventory at the sampling site. To estimate soil losses or gains, MODERN aligns the total inventory of the sampling site to the depth profile of the reference site. The point of intersection along the soil profile represents the model solution (Figure 1).

The uniqueness of MODERN, compared to the other classical conversion models, can be summarised as

following: (a) it does not make any assumptions on the depth profile of the FRN, but accurately describes the soil profile shape of any selected FRN at reference sites, (b) it accurately estimates the soil redistribution rates, c) it allows adaptation of the depth profile by simulating the behaviour of the selected FRN under different agro-environmental conditions (e.g. ploughing activities, erosion and sedimentation processes).

An arbitrary number of layers can be simulated above and below the measured depth profile, and a range of possible solutions is produced by this model.

MODERN is based on a unique algorithm to convert FRN inventories into both erosion and deposition rates, whereas common conversion models (e.g. the Profile Distribution Model, the Diffusion and Migration Model) are specifically developed to quantify rates of only one redistribution process (i.e. erosion or deposition). MODERN was developed in the MatlabTM environment, and a forthcoming release of the code in open source programming codes (i.e. R) is planned. The code is easily adaptable and freely available at: <https://umweltgeo.unibas.ch>.

MODERN's adaptability and ability to convert different FRN inventories were compared to the results of two already published case studies i.e. a ^{137}Cs study in an Alpine and unploughed area in the Aosta valley (Italy) and a $^{210}\text{Pb}_{\text{ex}}$ study on a ploughed area located in the Transylvanian Plain (Romania). The tests showed highly significant correspondence between the results of MODERN and the published results of other models currently used by the FRN scientific community (Figure 2). Furthermore, MODERN has been already applied to a $^{239+240}\text{Pu}$ dataset collected in a study area in the Swiss Alps (the Urseren Valley, canton Uri) (Arata *et al.*, 2016b). The specific characteristics of $^{239+240}\text{Pu}$, such as the more homogeneous fallout distribution, the long half-

life and the cost and time effective measurements, make this tracer application for investigating soil degradation in Alpine grasslands more suitable than any other FRN (e.g. ^{137}Cs). However, the conversion of $^{239+240}\text{Pu}$ inventories into soil erosion rates remains a challenge (Arata *et al.*, 2016b).

Sedimentation processes typical for alpine slopes were also taken into account, and the depth profile adapted through the simulation of deposition layers. The results presented at Figure 2 showed the potential of MODERN to convert $^{239+240}\text{Pu}$ into soil redistribution rates (Arata *et al.*, 2016b).

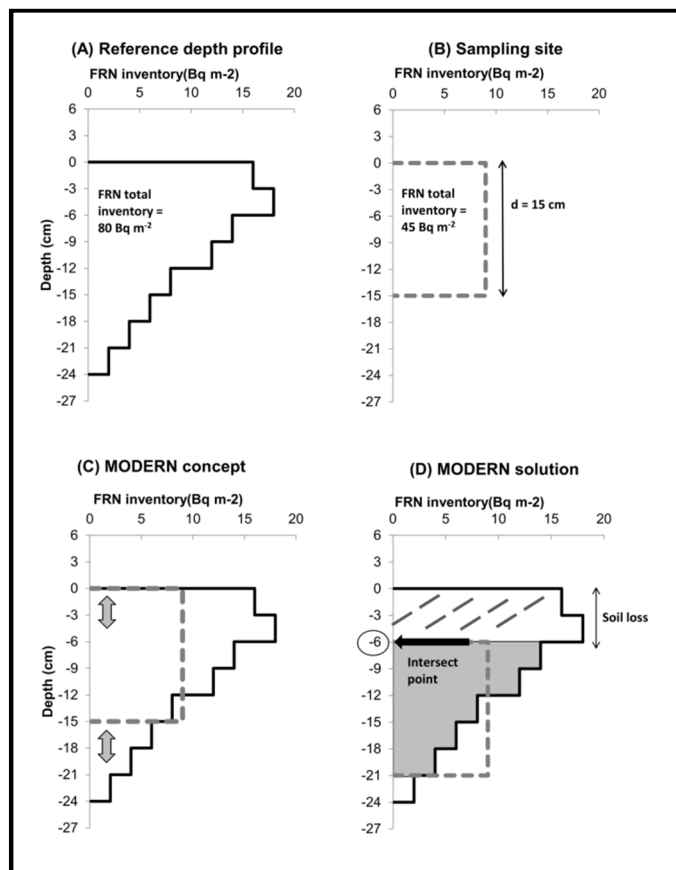


Figure 1. Concept of MODERN (Arata *et al.*, 2016a). MODERN compares the area covered by the depth profile of the reference site (A) with the area of the total inventory of a sampling site (B). MODERN overlaps the two areas (C) until it finds the intersection point where they match (D).

Currently available conversion models have been developed for ^{137}Cs with later adaptation to other FRNs (e.g. $^{210}\text{Pb}_{\text{ex}}$, ^7Be), each model being used for specific land use (ploughed and/or unploughed). As such, they may fail to describe the behaviour of Pu isotopes in alpine soils. Also in this case, MODERN outputs were compared to the application of other established models to assess soil erosion rates from FRN inventories at unploughed sites. Due to its characteristics, MODERN allows representation of the precise depth profile of $^{239+240}\text{Pu}$ in the soil, and considers its specific polynomial depth

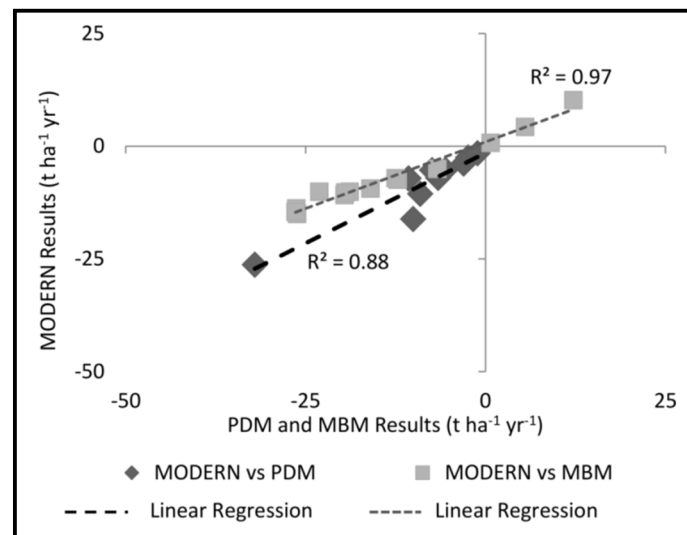


Figure 2. Relationship between soil redistribution rates obtained by MODERN and by two commonly used conversion models: the Profile Distribution Model (i.e. PDM) and the Mass Balance Model (i.e. MBM) (Arata *et al.*, 2016a).

References

- Arata, L., Alewell, C., Frenkel, E., A'Campo-Neuen, A., Iurian, A. R., Ketterer, M. E., Mabit, L., Meusbürger, K. (2016b). Modelling Deposition and Erosion rates with RadioNuclides (MODERN) - Part 2: A comparison of different models to convert $^{239+240}\text{Pu}$ inventories into soil redistribution rates at unploughed sites. *Journal of Environmental Radioactivity*, 162, 97–106.
- Arata, L., Meusbürger, K., Frenkel, E., A'Campo-Neuen, A., Iuran, A.R., Ketterer, M.E., Mabit, L., Alewell, C., (2016a). Modelling Deposition and Erosion rates with RadioNuclides (MODERN) - Part 1: a new conversion model to derive soil redistribution rates from inventories of fallout radionuclides. *Journal of Environmental Radioactivity*, 162, 45–55.

Technical Workshop on Remediation of Radioactive Contamination in Agriculture, IAEA Headquarters, Vienna, Austria, 17 - 18 October 2016

Technical Officers: Carl Blackburn, Gerd Dercon, Ivancho Naletoski, Stephan Nielen, Zhihua Ye

The year 2016 marks the fifth anniversary of the accident at the Fukushima Daiichi nuclear power plant (NPP) and the 30th anniversary of the accident at the Chernobyl NPP. A Technical Workshop on Remediation of Radioactive Contamination in Agriculture was co-organised by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and the National Agriculture and Food Research Organization of Japan (NARO) and held at the IAEA headquarters, Vienna, Austria from 17 to 18 October 2016. Over 100 experts from around the world participated in the event. All presentations and discussions focused on research results and practical experience from Japan and from countries affected by Chernobyl NPP accident. This event was a great success in promoting and sharing knowledge and experience related to remediation of radioactive contamination in food and agriculture. Copies of the presentations are available online at <http://www-naweb.iaea.org/nafea/news/2016-FAO-IAEA-NARO.html>.

From an agricultural perspective, the impacts of these two major accidents are related to caesium radionuclides, specifically ^{137}Cs , which is a relatively long lived isotope with a half-life of some thirty years. Research and technical efforts to remediate and ameliorate the impact of radioactivity on agricultural production aim to minimize and prevent contamination of foods and other commodities, and further to assist the social and economic recovery of affected rural communities by enabling sustainable production. However, these efforts are not widely appreciated outside the affected areas.

The two-day event commenced with opening statements from representatives of the three host organizations: Mr Aldo Malavasi, Deputy Director General of the IAEA Department of Nuclear Sciences and Applications; Mr Qu Liang, Director of the Joint FAO/IAEA Division in representation of FAO and Mr Imbe Tokio, President of NARO of Japan.

The plenary session provided technical overviews of key agricultural events since the Fukushima Daiichi NPP accident in 2011 and the main activities in this area over the 30 years since the accident at the Chernobyl NPP. A very touching presentation was also made by a farmer from the Fukushima Prefecture in Japan which highlighted the importance of remediation not only in terms of radiation safety but also to help alleviate the social and psychological impact on communities. The plenary closed with an overview of current Joint FAO/IAEA activities related to the control of radionuclides in food and agriculture. The plenary set the scene for the five technical sessions that followed, where presentations and discussions were held under the headings of: (i) Agricultural Land and Water, (ii) Plants and Crop Products, (iii) Animals and Animal Feeds, (iv) Food and Commodities, (v) Socio-Economic Aspects. Presentations and discussions focused on research results and practical experience from Japan and from countries affected by the Chernobyl NPP accident.

Announcements

Anniversary of IAEA



Set up in 1957 as the world's centre for cooperation in the nuclear field, the International Atomic Energy

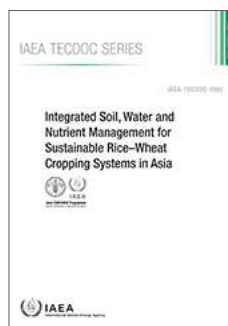
Agency (IAEA) works with its Member States and multiple partners worldwide, especially in the developing world, to promote the safe, secure and peaceful use of nuclear technologies. In September 2016, the IAEA held its sixtieth regular session of the General Conference, and in recognition thereof, the Secretariat will commemorate its sixtieth anniversary throughout the coming year.

Nuclear technologies continue to provide competitive and often unique solutions to help fight hunger and malnutrition, combat plant and animal diseases and pests, improve agricultural productivity and environmental sustainability and ensure that food is safe. Since 1964, the IAEA and the Food and Agriculture Organization of the United Nations (FAO) have worked in partnership through the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture to help Member States use these technologies safely and appropriately. Throughout this time the programme of the Joint FAO/IAEA Division, with its unique laboratories at Seibersdorf, has continuously evolved to meet the world's changing needs. In doing so, it has focused on expanding its ongoing contribution to agricultural development and global food security, and proactively embraced and added its expertise to efforts to adapt to and mitigate the effects of climate change, respond to globalization, conserve ecosystem services and broaden biodiversity. Today, it strives to mobilize commitment and concerted action towards meeting the Sustainable Development Goals of the United Nations through appropriate integration of nuclear and related technologies for sustainable agriculture development and food security.

We take this opportunity to thank our numerous partners worldwide, whether institutions or individuals, for their dedication and continuous support to our mission since 1964.

New FAO/IAEA Publications:

Integrated Soil, Water and Nutrient Management for Sustainable Rice – Wheat Cropping Systems in Asia

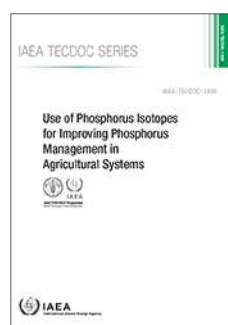


This FAO/IAEA publication (IAEA-TECDOC-1802) compiled the work carried out under the coordinated research project (CRP) “Integrated Soil, Water and Nutrient Management for Sustainable Rice–Wheat Cropping Systems in Asia” involving ten participants from six countries (Australia, Bangladesh, China,

India, Pakistan and Nepal). The overall objective was to improve the productivity and sustainability of rice–wheat cropping systems through increased efficiency of water and nutrient use. The publication provides relevant information on how to modify existing water and nutrient management systems and improve soil management in both traditional and emerging crop establishment methods for sustainable intensification of cereal production in Asia.

<http://www-pub.iaea.org/books/IAEABooks/11074/Integrated-Soil-Water-and-Nutrient-Management-for-Sustainable-Rice-Wheat-Cropping-Systems-in-Asia>

Use of Phosphorus Isotopes for Improving Phosphorus Management in Agricultural Systems



This FAO/IAEA publication (IAEA-TECDOC-1805) provides comprehensive and up to date information on several topics related to phosphorus (P) in soil–plant systems, in agricultural systems and in the environment. It presents the theoretical background as well as practical information on how to use nuclear and radioisotope tracer

techniques in both laboratory and greenhouse experiments to assess soil P forms and plant-available soil P pools, and to understand P cycling processes in soil–plant systems. The TECDOC focuses on practical applications of radiotracer techniques and can serve as a resource material for research projects on improving sustainable P management in agricultural systems and as practical guidance on the use of phosphate isotopes in soil–plant research.

<http://www-pub.iaea.org/books/IAEABooks/11073/Use-of-Phosphorus-Isotopes-for-Improving-Phosphorus-Management-in-Agricultural-Systems>

Obituary: Robert Joseph Soper

F.A.I.C, F.C.S.S.S.



*August 25, 1927 - † July 21, 2016

Bob Soper, the outstanding specialist in soil chemistry, soil fertility and crop production from Ontario, Canada, joined the Joint Division of the Food and Agriculture Organization and the International

Atomic Energy Agency in 1972 after a long scientific experience at University of Manitoba, Winnipeg where he started in 1958. During his career at the Joint FAO/IAEA Division, he was instrumental in the implementation of the training programs at the IAEA Seibersdorf Laboratory. His active participation in the soils training course was very much appreciated. Dr Soper also developed the radioactive phosphorus (^{32}P) and nitrogen stable isotope (^{15}N) methods for crop nutrition studies and became a leading personality in the use of ^{15}N -labelled nitrogen fertilizer to measure nitrogen dynamics in soil and biological nitrogen fixation by legumes. He developed a soil test for available nitrogen that has been used also in potassium, sulphur and zinc nutrition micronutrients. Adopted from:

http://passages.winnipegfreepress.com/passage-details/id-237330/SOPER_ROBERT

Highlights

Celebration of International Year of Pulses

As reported in our previous Soils Newsletter (Vol 39, No. 1), the international community gathered at the IAEA headquarters in Vienna on 20 September to celebrate the International Year of Pulses (IYP) as part of the declaration by the 68th UN General Assembly to help raise public awareness of the nutritional benefits and the role of pulses in sustainable food production. The event on 'Enhancing Pulses for Food Security using Nuclear Applications', jointly organized by the SWMCN and the Plant Breeding and Genetics Subprogrammes of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, highlighted the work supporting Member States on the contribution of pulses to increased food security and towards mitigating the effects of climate change. A variety of pulses and pulse plants were

displayed with their nitrogen-fixing roots and nodules visible. Also presented were mutant pulse varieties that have been officially released in Member States.

The event also highlighted the role of nuclear applications related to pulses on the use of stable isotope of nitrogen (^{15}N) to identify pulses and legumes with high nitrogen fixing abilities and to quantify the amount of nitrogen fixed. The Joint FAO/IAEA Division has been assisting Member States in developing ^{15}N isotopic methodology to identify pulses and legumes with high nitrogen fixing abilities for the past 30 years. A banner 'Soils and pulses: the symbiosis of life' and a brochure 'Soil and pulses: Managing soils for sustainable pulse production' were produced. A slide show and infographic materials summarized the important role of pulses during the exhibition, and different pulse foods were prepared for tasting.

More information can be found at:

<https://www.iaea.org/newscenter/multimedia/videos/pulse-s-celebrating-a-powerful-superfood>



Technical Cooperation Field Projects

Operational Projects and Technical Officers Responsible for Implementation

Country/Region	TC Project	Description	Technical Officer(s)
Afghanistan	AFG5006	Developing and Implementing Soil and Water National Management System Using Nuclear Techniques	E. Fulajtar/M. Zaman
Algeria	ALG5029	Improving Wheat and Legume Yield through Better Water and Fertilizer Management and Introduction of New Vegetal Material	M. Zaman
Bangladesh	BGD5029	Evaluating Promising Abiotic Stress Tolerant Crop Mutants/Varieties and Measuring the Suitable Management Practices for the Promotion of Sustainable Production at Saline, Submergence and Drought Prone Areas	A. Wahbi
Bolivia	BOL5021	Strengthening the Strategic Development Plan for Quinoa Production through Improved Use of Organic Manure, Soil and Crop Management	M. Zaman
Botswana	BOT5012	Improving Soil and Water Management Options to Optimize Yields of Selected Crops	J. Adu-Gyamfi
Brazil	BRA5059	Strengthening Strategies of Soil and Water Conservation at the Landscape Level in Natural and Agricultural Ecosystems	E. Fulajtar and G. Dercon
Burkina Faso	BKF5016	Using Nuclear Techniques for Improving Rice Yield and Quality	J. Adu-Gyamfi in collaboration with Plant Breeding and Genetics Section
Burundi	BDI5001	Improving Cassava Productivity through Mutation Breeding and Better Water and Nutrient Management Practices Using Nuclear Techniques	M. Zaman in collaboration with Plant Breeding and Genetics Section
Central African Republic	CAF5008	Cassava androgeneses culture and contribution to soil fertilization	M. Zaman
Cameroon	CMR5021	Developing Best Nutrient and Water Management Practices to Improve Soil Fertility and Productivity and Minimize Land Degradation Using Isotopic Techniques	J. Adu-Gyamfi
Chad	CHD5012	Using Nuclear Technology to Improve Knowledge and Sustainable Agricultural Production to Safeguard Lake Chad	J. Adu-Gyamfi

Country/Region	TC Project	Description	Technical Officer(s)
Costa Rica	COS5033	Assessing and Implementing Biochar Use in Climate Smart and Environmentally Friendly Pineapple Production Using Isotopic Techniques	M. Zaman in collaboration with Food and Environmental Protection Section
Cuba	CUB5019	Strengthening National Capacity for Monitoring Heavy Metals to Improve Soil and Food Quality Using Nuclear and Related Techniques	E. Fulajtar in collaboration with Food and Environmental Protection Section
Ecuador	ECU5028	Consolidating Food Security and Environmental Sustainability in Palm Oil Production Using Nuclear Applications	J. Adu-Gyamfi in collaboration with Food and Environmental Protection Section
Haiti	HAI5006	Increasing Productivity and Exportability in the Agricultural Sector through Soil and Water Management and Food Safety Monitoring	J. Adu-Gyamfi in collaboration with Food and Environmental Protection Section
Interregional project	INT5153	Assessing the Impact of Climate Change and its Effects on Soil and Water Resources in Polar and Mountainous Regions	G. Dercon
Iran	IRA5013	Investigating the Effects of Deforestation and Afforestation on Soil Redistribution	M. Zaman
Iraq	IRQ5020	Restoring Biomass Productivity of Range Land by Using Nuclear Techniques and Advanced Technology	A. Wahbi
Cambodia	KAM5001	Improving Soil Fertility and Crop Management Strategies in Diversified Rice Based Farming Systems	L. Heng
Jamaica	JAM5012	Optimizing Irrigation Water Management to Improve Crop Output and Water Quality Control	L. Heng
Kenya	KEN5036	Developing Soil Fertility and Water Management for Soil, Crop and Livestock Integration in Three Agro-Ecological Zones	J. Adu-Gyamfi
Kuwait	KUW5001	Improving Production and Water Use Efficiency of Forage Crops with Nuclear Techniques	A. Wahbi
Laos	LAO5002	Improving Soil Fertility and Water Use Efficiency in the Cassava-Rice-Soybean Production System under Smallholder Farming Systems	M. Zaman

Country/Region	TC Project	Description	Technical Officer(s)
Mauritania	MAU5006	Contributing to the Improvement of Rice Crop Yields through the Application of Nuclear Techniques To Water Management and Soil Fertility	M. Zaman in collaboration with Plant Breeding and Genetics Section
Myanmar	MYA5025	Monitoring and Assessment of Watershed Management Practices on Water Quality and Sedimentation Rate of Inle Lake	L. Heng
Namibia	NAM5014	Evaluating Efficient Water and Nutrient Use, Molecular Characterization and Nutritional Composition of Mutant Germplasm Populations	J. Adu-Gyamfi in collaboration with Plant Breeding and Genetics Section
Nicaragua	NIC5009	Introducing Integrated Environmental Management in the Watershed of the Nicaraguan Great Lakes and the San Juan River: Responding to Future Challenges with Nuclear Techniques	E. Fulajtar
Niger	NER5019	Improving Sesame Plant Productivity by Obtaining High-Yielding Induced Mutants Adapted to Semi-Arid Conditions	J. Adu-Gyamfi in collaboration with Plant Breeding and Genetics Section
Niger	NER5021	Using Microbial Biotechnology to Improve Productivity and Adapt Cowpea to Climate Change	J. Adu-Gyamfi in collaboration with Plant Breeding and Genetics Section
Panama	PAN5023	Enhancing Rice Crop Yields by Improving Water and Nutrient Management Using Nuclear and Isotopic Techniques	J. Adu-Gyamfi
Sri Lanka	SRL5045	Establishing a National Centre for Nuclear Agriculture	M. Zaman
T.T.U.T.J of T. Palestinian A.	PAL5008	Reducing Soil Degradation by Improving Soil Conservation using Fallout Radionuclides (Phase I)	E. Fulajtar
Africa	RAF0038	Promoting Technical Cooperation Among Developing Countries (TCDC) in Africa through Triangular Partnerships (AFRA). [Bilateral TC project between Morocco and Côte d'Ivoire]	L. Mabit
Africa	RAF5071	Enhancing Crop Nutrition and Soil and Water Management and Technology Transfer in Irrigated Systems for Increased Food Production and Income Generation (AFRA)	L. Heng

Country/Region	TC Project	Description	Technical Officer(s)
Africa	RAF5075	Enhancing Regional Capacities for Assessing Soil Erosion and the Efficiency of Agricultural Soil Conservation Strategies through Fallout Radionuclides	E. Fulajtar and L. Mabit
Asia	RAS5069	Complementing Conventional Approaches with Nuclear Techniques towards Flood Risk Mitigation and Post-Flood Rehabilitation Efforts in Asia	E. Fulajtar in collaboration with Plant Breeding and Genetics, Animal Production and Health and Isotope Hydrology Sections
Asia	RAS5070	Developing Bioenergy Crops to Optimize Marginal Land Productivity through Mutation Breeding and Related Techniques (RCA)	M. Zaman in collaboration with Plant Breeding and Genetics,
Asia	RAS5072	Enhancing the Use of Salt Affected Soils and Saline Water for Crop and Biomass Production and Reducing Land and Water Quality Degradation in ARASIA states parties	A. Wahbi
Asia	RAS5073	Climate Proofing Rice Production Systems (CRiPS) Based on Nuclear Applications, Phase II	L. Heng in collaboration with Plant Breeding and Genetics Section
Latin America	RLA5064	Strengthening Soil and Water Conservation Strategies at the Landscape Level by Using Innovative Radio and Stable Isotope and Related Techniques (ARCAL CXL)	G. Dercon
Latin America	RLA5065	Improving Agricultural Production Systems Through Resource Use Efficiency (ARCAL CXXXVI)	J. Adu-Gyamfi
Seychelles	SEY5007	Increasing Crop Production through Effective Management of Soil Salinity in the Coastal Area using Nuclear and Related Techniques	L. Heng
Sudan	SUD5037	Application of nuclear and related biotechnology techniques to improve of crop productivity and lively hood of small scale farmers drought prone areas of Sudan	M. Zaman in collaboration with Plant Breeding and Genetics Section
Uganda	UGA5037	Introducing Integrated Soil Fertility Management for Improved Crop Production and Food Security	E. Fulajtar and L. Mabit
Zimbabwe	ZIM5021	Assessing and Promoting Sustainable Agricultural Production in Communal and Newly Resettled Farms	L. Mabit in collaboration with Plant Breeding and Genetics Section

Forthcoming Events

FAO/IAEA Events

The 1st Coordination Meeting of Regional Technical Cooperation Project RAS5075 “Enhancing Regional Capacities for Assessing Soil Erosion and the Efficiency of Agricultural Soil Conservation Strategies through Fallout Radionuclides”, 12-16 December 2016, Abidjan, Ivory Coast.

Technical Officer: Emil Fulajtar

Mid-Term Review Meeting of Regional Technical Cooperation Project RAS5073 on “Climate Proofing Rice Production Systems (CRiPS) Based on Nuclear Applications, Phase II”, 6-10 February 2017, Kota Kinabalu, Malaysia.

Technical Officer: Lee Heng

Third Research Coordination Meeting of the Coordinated Research Programme D1.50.15 on “Nuclear Emergencies Affecting Food and Agriculture” 20-24 February 2017, Vienna, Austria.

Technical Officer: Gerd Dercon

Mid-Term Review Meeting of Regional Technical Cooperation Project RAF5071 on “Enhancing Crop Nutrition and Soil and Water Management and Technology Transfer in Irrigated Systems for Increased Food Production and Income Generation (AFRA)”, 13-17 March 2017, Dakar, Senegal

Technical Officer: Lee Heng

Regional Training Course on the Interdisciplinary Application of Isotope Hydrology and Soil-Related Isotopic Techniques for Flood Risk Mitigation and Post-Flood Rehabilitation in Asia Organised Under the Regional Technical Cooperation Project RAS5069 “Complementing Conventional Approaches with Nuclear Techniques Towards Flood Risk Mitigation and Post-Flood Rehabilitation Efforts in Asia” 20-24 March, Chicago, USA.

Technical Officer: Emil Fulajtar

Coordination Meeting of Regional Technical Cooperation Project RAS5072 “Enhancing the Use of Salt Affected Soils and Saline Water for Crop and Biomass Production and Reducing Land and Water Quality Degradation in ARASIA”, 26-30 March 2017, Dubai, United Arab Emirates.

Technical Officers: Mohammad Zaman

Regional Training Course on ¹⁵N Isotope Data Processing and Interpretation Organised Under the Regional Technical Cooperation Project RLA5065 “Improving Agricultural Production Systems Through Resource Use Efficiency”, 15-26 May 2017, Havana, Cuba.

Technical Officer: Joseph Adu-Gyamfi

Non-FAO/IAEA Events

European Geosciences Union General Assembly 2017, 23-28 April 2017, Vienna, Austria
<http://www.egu2017.eu/>

ISSPA2017 - 15th International Symposium Soil and Plant Analysis: The roles of soil, plant, water and waste analyses in food security and environmental quality, 14-18 May 2017, Nanjing, China
<http://isspa2017.csp.escience.cn/dct/page/1>

International Interdisciplinary Conference on Land Use and Water Quality Effect of Agriculture on the Environment, 29 May - 1 June 2017, The Hague, The Netherlands
<http://www.luwq2017.nl/>

1st World Conference on Soil and Water Conservation under Global Change (CONSOWA), Sustainable Life on Earth through Soil and Water Conservation, 12-16 June 2017, Lleida, Spain
<http://www.consowalleida2017.com/>

Soil science in a changing world, 27-31 August 2017, Wageningen, The Netherlands
<http://www.wur.eu/wageningensoilconference>

Past Events

Meetings and Training at the IAEA

Group Fellowship Training on “Nitrogen and Soil Water Management in Agro-Ecosystems”, 25 July-19 August 2016, Seibersdorf, Austria

Gerd Dercon, Ammar Wahbi, Georg Weltin, Maria Heiling, Christian Resch, Roman Gruber, Johanna Slaets and Joseph Adu-Gyamfi

The SWMCNL with financial support from IAEA Technical Cooperation (TC) projects hosted a group fellowship training from 25 July to 19 August 2016 in Seibersdorf. The training focused on the use of stable isotope ^{15}N technique for improving nitrogen management in agro-ecosystems in the first two weeks as part of the 2016 International Year of Pulse. The trainees were trained on how to assess with isotopes the capacity of grain legume crops (pulses) to capture nitrogen from the atmosphere. The contribution by Ms. Rebecca Hood of the Austrian Institute of Technology was well-appreciated. A WebEx video lecture was also delivered by Mr. Walter Palme on unmanned aerial vehicle (UAV) based multispectral analytical tools for assessing nitrogen and water status in crops. In the last two weeks of the course, agricultural water management was addressed, in particular the use of soil moisture sensors and data interpretation. Ten fellows participated during the full duration of the course; an additional nine fellows attended the first part of the course on nitrogen management.



Fellows Attending the Training on “Nitrogen and Soil Water Management in Agro-Ecosystems”

Regional Training Course on “The Use of Short-Lived Fallout Radionuclides (e.g. ^7Be) for Evaluating Soil Erosion/Sedimentation Magnitudes and Effectiveness of Soil Conservation”, 17-28 October 2016, SWMCN Laboratory, Seibersdorf, Austria

Technical Officer and Course Director: Lionel Mabit

A two-week regional training course on the use of short-lived fallout radionuclides – with focus on the use of ^7Be for evaluating soil erosion and sedimentation magnitudes

and the effectiveness of soil conservation – was held at the Soil and Water Management and Crop Nutrition Laboratory (SWMCNL) at Seibersdorf, Austria from 17 to 28 October 2016. The main focus of this training organized under RAF5075 “*Enhancing Regional Capacities for Assessing Soil Erosion and the Efficiency of Agricultural Soil Conservation Strategies through Fallout Radionuclides*” was to provide the fellows with knowledge and information through lectures, guided exercises and discussion on how to use short-lived FRN such as ^7Be (and to some extent ^{137}Cs) to investigate short time scale soil redistribution processes and to assess the effectiveness of soil conservation strategies implemented in the agro-ecosystems of their respective countries.

This training course was intended for participants with an academic background in soil science or related sciences and previous practical experience in soil erosion investigations using FRNs such as ^{137}Cs . The training was provided by the Technical Officer of RAF5075 and by two international experts from Plymouth University, UK (i.e. Prof. William Blake and Dr. Andra Iurian). A total of twenty eight participants attended this two-week training course: twenty-four (24) fellows from eleven (11) African Member States (i.e. Algeria, Benin, Côte d’Ivoire, Egypt, Madagascar, Morocco, Senegal, Soudan, Tunisia, Uganda and Zimbabwe), one intern from Malaysia, one fellow from Argentina under the ICTP/IAEA Sandwich Training Educational Programme, as well as two Iranian participants funded through the national TCP IRA5013 “*Investigating the Effects of Deforestation and Afforestation on Soil Redistribution*”. This training course could not have been successful without the administrative and logistical support provided by Ms. Catherine Evstafiev (IAEA TCAF-PMA) and Ms. Ruby Cueto (IAEA TSA-Seibersdorf).



Participants of the Regional Training Course of RAF5075 at Seibersdorf Laboratories, Austria

INT5153: Progress Review and Coordination Meeting of TC project INT5153 Investigations in Benchmark Sites for Assessing the Impact of Climate Change in polar and mountainous regions, 7-11 November, 2016, IAEA, Vienna, Austria

Technical Officer: Gerd Dercon

The mid-term review meeting was held in Vienna at the IAEA Headquarters for the project INT5153 “*Assessing the Impact of Climate Change and its Effects on Soil and Water Resources in Polar and Mountainous Regions*”. The aim of the project is to improve the understanding of the impact of climate change on fragile polar and mountainous ecosystems at the local and global scale for their better management and conservation. The aim of the meeting was to assess the results of the project during the first half of its lifetime.

Twenty one scientists from 13 countries, representing 11 out of 13 benchmark sites, participated in the mid-term review meeting, (i) to discuss the progress of the project to date, specifically the scientific results from the expeditions and analysis of samples in benchmark sites, and (ii) to discuss the way forward for data integration and interpretation to improve the understanding of the impact of climate change on fragile polar and mountainous ecosystems for their better management and conservation.

Twenty seven months after the first coordination meeting that we held in June 2014, a wide range of activities have been implemented to target the achievement of following expected project outputs.

- Update and ways forward for capacity building: Until present over 50 scientists were trained in sampling, isotope data interpretation, modelling and remote sensing techniques for better understanding the impact of climate change in polar and mountain environments.
- Previous expeditions were evaluated and two new campaigns were identified and organized, i.e. Bolivia and Russian Federation.
- The team has interpreted the partial datasets and formulated preliminary conclusions and recommendations, and fine-tuned hypotheses where needed.
- Integration of science activities, including data management, processing and interpretation, has been agreed upon.

Training course on design and analysis of field, greenhouse and laboratory based experiments, held from October to December 2016, Seibersdorf, Austria

Technical Officer: Gerd Dercon

To ensure high quality of our work and services at the FAO/IAEA Laboratories, the Joint FAO/IAEA Division organized a nine day training course at Seibersdorf for the laboratory staff to refresh the concepts of design and analysis of experiments carried out under field, greenhouse and laboratory conditions. The course included theory focusing on how to design and install experiments and to analyse the data, with examples in JMP and R software for basic and more advanced experiments, respectively. The training course included three sessions:

- (i) Session 1: Design and installation of experiments (e.g. randomized, block, split-plot designs), with exercises in JMP basic;
- (ii) Session 2: Design and installation of experiments including focus on advanced experiments (e.g. randomized, block, split-plot designs, long-term trials, repeated measurement, trend analysis), with exercises in R;
- (iii) Session 3: Follow-up session on optimal design.

The total duration of the course (all three sessions) was 9 days spread over 5 weeks in October - December.

The training course was given by Mr. Juan Carlos Laso Bayas from The International Institute for Applied Systems Analysis, Austria, and Mr. Peter Goos from the University of Leuven, Belgium.

Duty Travel

United States of America: To Attend The Conference on “2016 Water For Food” at the University of Nebraska-Lincoln, 24-27 April, 2016, and Scientific Visit to the University of Nebraska, 28-30 April 2016, USA

Technical Officer: Ammar Wahbi

The 2016 "Water for Food Global conference" was attended by over 350 scientists from the USA and around the world, including those from CGIAR and UN organizations, farmer associations and private sector. The main theme of the conference was "Catalytic Collaboration: Building Public-Private Partnerships for Water and Food Security".

The conference started on the topic "the Opportunity and Challenges of Expanding Smallholder Irrigation in Sub-Saharan Africa". Presentations were given targeting yield gaps in irrigated and rainfed agriculture in Sub-Saharan Africa, and lessons learned from agricultural water

management. Other presentations on the importance of partnerships in water management and irrigation for smallholder farmers in Sub-Saharan Africa, mitigating the effects of climate change on water and food security and public health were also presented.

A field trip to visit the Antelope Valley project (www.ipsnrd.org) near Lincoln, and the Nebraska Agricultural production area was arranged to show examples of public-private partnerships. Lastly, a visit to the International Irrigation, Valmont Industries where presentations on pivot irrigation system and technology development were given.

During the final two days, Mr. Wahbi, together with Dr. Everson from South Africa, visited Dr. Trenton Franz and his team at the University of Nebraska. The visit allowed to discuss the future joint work plan on the use of Cosmic Ray Neutron Sensor that will be carried out at the SWMCNL of the joint FAO/IAEA Division.

Italy: Visit of the International Fund for Agricultural Development (IFAD) to discuss extra budgetary funding opportunities, 14-15 June 2016, Rome, Italy

Technical Officer: Joseph Adu-Gyamfi

Mr. Joseph Adu-Gyamfi and Mr. Qu Liang (Director of Joint FAO/IAEA Division) travelled to Rome to visit the International Fund for Agricultural Development (IFAD) to explore extra budgetary funding opportunities and future collaboration. Mr. Adu-Gyamfi also met the President of IFAD Mr Kanayo Nwanze. The outcome of the meeting in Rome with the Technical Specialist of the Policy and Technical Advisory Division of IFAD is the preparation of three Concept Notes for Kenya, Sudan and Benin to IFAD for Country Grant Financing of US\$ 500,000 each that was submitted to the IFAD Country Officers in Rome before the deadline of 15 November 2016.



Mr. Joseph Adu-Gyamfi with the President of IFAD, Mr. Kanayo Nwanze

Nepal: To facilitate and provide Regional RCA Training on 'Advanced Knowledge and Skills on the Use of Best Management Practices to Improve Soil Fertility and Nutrient and Water Management of Marginal Land Using Nuclear Techniques', 11-16 July 2016, Kathmandu, Nepal

Technical Officer: Mohammad Zaman

The Technical Officer (TO) travelled to Kathmandu, Nepal to facilitate and provide a regional training on advanced knowledge and skills on best management practices to improve soil fertility and nutrient and water management of marginal land using nuclear techniques. The TO, together with the help of two experts, arranged the 10-day regional training session that was held on 11-22 July 2016, in Kathmandu, Nepal. The TO stayed during the first 5 days of the training session, which was attended by 22 participants from Bangladesh, Cambodia, Indonesia, Laos, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, South Korea, Thailand, Sri Lanka, and Viet Nam. The training session was opened by the Secretary of the Ministry of Science and Technology of Nepal, Mr Anup Kumar Upadhyay, who highlighted the issue of marginal lands in Nepal. The TO described the objectives of the regional training session, key challenges of low soil fertility and crop productivity of marginal lands. The TO also discussed food security problems that the agriculture sector is confronted with due to subsistence farming and climate change. The resource persons and the TO provided lectures and hands-on training which covered a range of topics, including assessing soil fertility, selecting soil tests for making nutrient recommendations, reducing nutrient losses, sustainable management of soil fertility and fertilizer application. Methods of assessing soil water content and its conservation were covered, as was the use of stable isotopes in understanding N dynamics and biological N₂ fixation. Soil water management and the testing of new tools such as Environmental Balance Device (EBD) for soil fertility improvement and land remediation was discussed. All participants went on a field visit to assess the fertility of marginal land near Kathmandu. Participants also visited laboratories at NARI where they were shown soil and plant sample preparation for nutrient assessment, using a moisture neutron probe for measuring soil water content, setting up field trials, and applying different management practices designed to improve the fertility of marginal land.



Participants of the RAS5070 regional RCA training in Katmandu, Nepal

Chad: To conduct a CHAD5006 project start-up meeting: to assess the counterpart's laboratory facilities for conducting experiments using stable isotopes, and to provide advice for establishing field studies, 25-29 July 2016, N'Djamena, Chad

Technical Officer: Joseph Adu-Gyamfi

Mr. Joseph Adu-Gyamfi travelled with the PMO Mr. Michel Warnu to N'djamena to discuss an efficient way to accelerate the implementation of the activities of the TC project CHD5006 'Using Nuclear Technology to Improve Knowledge and Sustainable Agricultural Production to Safeguard Lake Chad' with project counterpart from the Institut Tchadien de Recherche Agronomique pour le Developpement, ITRAD. During the visit, Mr. Adu-Gyamfi (1) assessed the counterpart's facilities (laboratory and field) and made recommendations for basic equipment and consumables to support current and future projects, (2) assisted the counterparts to design field experiments on the use of ^{15}N to evaluate crop varieties for their high N use and high BNF, and (3) made technical adjustments to the work plan to achieve realistic outputs. Although the project plans to use nuclear technology to help build knowledge on developing sustainable land management that would minimize water use and silting-up of Lake Chad, it lacks the capacity and logistics to undertake this activity. It was therefore recommended that the main counterpart explores the possibility of participating in an African Regional Project on small-scale irrigation to address the challenges of improving the water quality of the Lake Chad.



The Technical Officer with a Chadian farmer

Kenya: To train counterparts on ^{15}N methodology, assist in the field design of multi locational soil fertility trials and visit the proposed experimental sites under TC project KEN5036, 15-19 August 2016, Nairobi, Kenya

Technical Officer: Joseph Adu-Gyamfi

The visit was related to the IAEA TC project KEN5036 on 'Developing Soil Fertility and Water Management for Soil, Crop and Livestock Integration in Three Agro-Ecological Zones' to work with the project counterparts at the Kenya Agricultural and Livestock Research Organization (KALRO). The Technical Officer trained the counterparts on the ^{15}N methodology and helped to design the on-farm experiments for two selected agro-ecological zones. As part of the visit, Mr. Adu-Gyamfi travelled to one of the agro-ecological zones at the Kajiado County to assist and select sites and farmers who will implement the on-farm experiments. Site characterization of three agro-ecological sites is currently on-going.



Using water efficiently: A drip irrigation method to produce vegetables by a Maasai farmer

Jamaica: To discuss work plan of JAM5012 TC project and advise on the implementation of the activities for optimizing irrigation water management, 22-25 August 2016, Kingston, Jamaica

Technical Officer: Lee Heng

Ms. Lee Heng travelled to Kingston, Jamaica on a new TC project JAM5012 on 'Optimizing Irrigation Water Management to Improve Crop Output and Water Quality Control', to discuss work plans and advise on the implementation of the activities for optimizing irrigation water management. An official opening and introductory ceremony was held at the Ministry of Industry, Commerce, Agriculture and Fisheries (MICAFA) during the visit. Both the Director of Engineering and Technical Services of National Irrigation Commission (NIC) Limited (Mr. Milton Henry, the project counterpart), the Managing Director (Dr. Mark Richards) of NIC Limited, Senator Aubyn Hill and the Minister Without Portfolio, Ministry Of Industry, Commerce, Agriculture and

Fisheries (Hon. J.C Hutchinson) gave the welcome, introduction and opening remarks. The technical officer also gave a presentation on 'Isotopic Techniques for Soil, Water and Crop Management', while an expert Mr. Peter Buss, Manager of Agronomic Research and Development, Sentek Technologies, Australia, gave a presentation on 'Importance of soil water sensors for Irrigation Scheduling and Environmental Monitoring'. In the subsequent days training was conducted on the installation of soil moisture sensors at both the Bodles Research Station at Old Harbour, 40 km outside Kingston and in Hounslow in St. Elizabeth some 150 km west of Kingston, where the two experimental sites are situated. The technical officer gave more lectures including 'AquaCrop for improving Crop WUE' and provided training on ^{15}N fertilizer to measure nitrogen uptake isotopic techniques. Discussion was held on the way forward and on human resource capacity development requirements including fellowships and scientific visits; laboratory infrastructure and logistic support for field studies.

Iran: To facilitate and provide Group National Training on FRNs and to assist the CP and his team in site selection, soil/sediment collection and planning and designing future project activities, 27- 29 August 2016, Tehran, Iran

Technical Officer: Mohammad Zaman

The TO, together with Mr. Naivo Rabesiranana as expert, conducted a three day group national training session on land degradation on 27-29 August 2016, in Tehran, Iran. It was attended by 30 participants from different research and academic institutes in Iran. The training session was opened by Mr. Javad Mozafari, Head of Scientific Relationships and International Corporation, Agricultural Research, Education, Extension Organization, Tehran. Mr. Mozafari highlighted the issue of land degradation in Iran. The TO presented the objectives of the group national training session, the challenges of assessing land degradation and the competitive advantages of using nuclear techniques such as fallout radionuclides (FRNs) for assessing land degradation. Later, the expert and the TO delivered presentations covering a range of topics including land degradation and its long, medium and short-term assessment using FRNs (^{137}Cs , $^{210}\text{Pb}_{\text{ex}}$ and ^7Be). The use of conversion models and the determination of the parameters for quantifying soil erosion, e.g. the use of compound specific stable isotopes (CSSI) to identify the source of land degradation and practical exercises with FRNs in order to assess soil erosion, and soil conservation practices for mitigating land degradation. To provide hands on training, all participants visited a forest catchment near Tehran, where they were shown how to assess land degradation, identify the reference site and collect soil samples along different transects followed by soil processing and analysis. Digital copies of the scientific papers and materials on land degradation and

copies of the lectures were distributed among all participants. On day four, the TO, together with the invited expert, left for Suma Sahara catchment near Rasht to select a forest site for assessing land degradation using FRNs. After showing the CP taking soil sampling for assessing land degradation in Suma Sahara catchment, the TO came back to Tehran to meet the NLO.

Costa Rica: RLA5065 Second Regional Technical and Mid-life Review Meeting of TC project 'Improving agricultural production systems through resource use efficiency (RCAL CXXXVI)', 29 August-2 September 2016, San Jose, Costa Rica

Technical Officer: Joseph Adu-Gyamfi

Mr. Joseph Adu-Gyamfi travelled to Costa Rica to support the host counterpart to (i) organize the second regional technical and mid-life review meeting, (ii) evaluate and discuss results obtained from field studies in relation to approved work plan, (iii) review project progress, identify gaps and make technical adjustments to the work plan, (iv) discuss additional implementation strategies to enhance capacity to use isotopic techniques for estimating BNF in the region, (v) discuss major problems/hindrances to achieve some of the outputs, and (vi) formulate conclusions and the way forward. Twelve countries (Argentina, Bolivia, Brazil, Chile, Costa Rica, Cuba, Dominican Republic, Guatemala, Mexico, Nicaragua, Paraguay and Uruguay) participated in the meeting. The following conclusions were made at the end of the meeting: (1) Provide additional expert technical advice on field design using ^{15}N methodology to Bolivia, Costa Rica, Ecuador, Guatemala and Nicaragua in February 2017 as these counterparts could not attend the previous training course. (2) A regional training course on isotope data processing and interpretation that was not implemented during 2016 is scheduled to take place in Havana, Cuba in May 2017.. (3) A communication material (including a video) is to be developed from at least four of the participating countries. The final coordination meeting is planned for December 2017 or the first quarter of 2018.



Field visits by the participants at a farm in La Fortuna de San Carlos, Costa Rica.

United Arab Emirates: To facilitate the Training Course on ‘Water Management and Use of Crop Simulation Model (AquaCrop)’ under RAS5072, 2-7 October 2016, International Centre for Biosaline Agriculture (ICBA), Dubai, UAE

Technical Officer: Ammar Wahbi

Under regional TC Project RAS5072 on ‘Enhancing the Use of Salt Affected Soils and Saline Water for Crop and Biomass Production and Reducing Land and Water Quality Degradation in ARASIA States Parties’, a regional training activity was conducted on ‘Water Management and Use of Crop Simulation Model (AquaCrop)’ at the International Centre for Biosaline Agriculture (ICBA), Dubai, United Arab Emirates, from 2-13 October 2016. The training included an introduction to soil moisture neutron probe, its proper use and safety protocol. Following that, neutron probe access tube installation procedures were shown to the course participants. Calibration was also carried out by taking soil samples at different depths under a range of soil wetness conditions. The full calibration process was demonstrated to and conducted by the fellows through practical exercises. Data downloading and management procedures were also shown. During the mission, the technical officer visited the UAE experimental farms and attended different lectures delivered by the ICBA scientists on irrigation scheduling and water use.



Participants of the training course at ICBA

Malaysia: To facilitate an IAEA Group Fellowship Training on ‘Application of Nuclear Techniques in Agriculture’, 8-14 October 2016, Kuala Lumpur, Malaysia

Technical Officer: Ammar Wahbi

The Malaysian Nuclear Agency (MOSTI) is a premier research and development organization in the field of nuclear science and technology located in Kuala Lumpur, Malaysia. A group fellowship training activity was conducted on ‘Applications of Nuclear Techniques in Agriculture’ at MOSTI, from 22 August - 14 October 2016.

During his visit, the technical officer delivered a seminar on ‘Improving Crop Water Productivity through Nuclear Techniques’. The technical officer held meetings with all seven fellows from Afghanistan, Bangladesh, Iraq, Kuwait, and Yemen. Additionally, the technical officer visited the MOSTI laboratories and participated in meetings to explore the possibility of joint collaborative activities with the MOSTI scientists.



Group photo of participating fellows in the Malaysian training course

Bolivia: To review the BOL5021 project work plan for 2016, and to provide technical assistance to the CP in designing future field trials to enhance productivity of Quinoa crop using nuclear and conventional techniques, 10-14 October 2016, La Paz, Bolivia

Technical Officer: Mohammad Zaman

The TO travelled to La Paz, Bolivia to discuss the activities of the national Technical Cooperation project (BOL 5021) with the two counterparts from (i) Instituto Boliviano de Ciencia y Tecnología Nuclear (IBTEN) and (ii) Instituto de Investigaciones Agropecuarias; Facultad de Agronomía; Universidad Mayor de San Andrés (UMSA). During the first 2 days, discussions with the two counterparts focused on revising work plan for 2016-17, organizing national training on enhancing quinoa productivity through best nutrient and water management practices, and visiting laboratories in both institutes to assess the need for procuring new equipment, chemicals and glassware. The TO then visited two field sites (IBTEN farm in Viacha Municipality and UMSA farm in Patacamaya) to show the two CPs and their team how to lay out field experiments for quantifying N use efficiency using the ¹⁵N technique. The TO had separate meetings with the country National Liaison Officer and the Agricultural Minister to update them about the activities of the TC project. Finally, the TO arranged a workshop in UMSA on the role of nuclear and isotopic techniques in improving nutrient and water use efficiencies, minimizing land degradation and reducing GHG emissions which was attended by 200 students and researchers from IBTEN and UMSA.

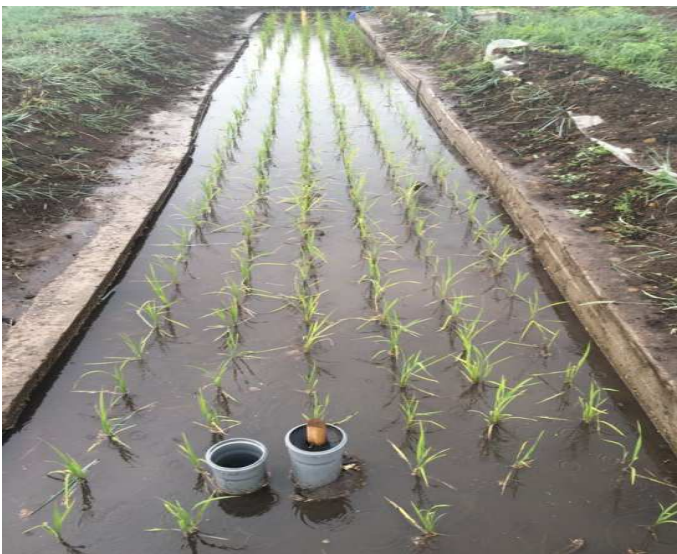


Field visit to IBTEN farm in Viacha Municipality, Bolivia

Mongolia: to attend a German-Mongolia Cooperation Workshop on ‘Soil Erosion and Degradation in Crop Production Areas of Mongolia: Options for Sustainable Soil Management’ and to discuss progress on rice cultivation under RAS5073 project, 17-21 October 2016, Ulaanbaatar and Darkhan, Mongolia

Technical Officer: Lee Heng

Ms. Lee Heng travelled to Mongolia at the invitation of Mr. Alfred Kather, the team leader of German-Mongolian Cooperation Project on Sustainable Agriculture (DMKNL), to attend the workshop organized by DMKNL on ‘Soil Erosion and Degradation in Crop Production Areas of Mongolia: Options for Sustainable Soil Management’. She gave a presentation on ‘Isotopic Techniques for Soil, Water and Nutrient Management’, participated in the discussion on soil problems encountered in Mongolia on arable land and provided strategies to avoid further soil degradation. Approximately 50 international and local experts attended this two-day workshop in Ulaanbaatar.



Rice growing pilot field study in Darkhan, Mongolia

At the end of the workshop, recommendations for political decision makers and scientists on how to facilitate initiatives/strategies for sustainable soil management in Mongolia were formulated. A visit was

also made to the Institute for Plant and Agriculture Science (IPAS) in Darkhan, north-west of Ulaanbaatar to meet and discuss with Director of IPAS Dr. Bayarsukh and RAS5073 project on ‘Climate Proofing Rice Production Systems (CRiPS) based on Nuclear Applications, Phase II’, counterparts Ms. Myagmarsuren Yadamsuren and Ariungerel Mandakh on the rice work. At IPAS, Ms. Lee presented a lecture on ‘Advance nuclear and isotopic techniques for improvement of soil and plant’ to the staff and visitors.

Italy: To attend the AquaCrop core group meeting in the FAO Headquarters in Rome, 2-4 November, 2016, Rome, Italy

Technical Officer: Lee Heng

Ms. Lee Heng travelled to FAO Headquarters in Rome to join the AquaCrop model core group meeting which was attended by FAO staff and experts from Belgium, Spain and USA. The aim of the meeting was to discuss and review new features and updates, new training materials and other technical matters since the last meeting held 1.5 years ago. The meeting concluded with follow-up decisions, future work-plan and distribution of work.

Burundi: To review the BDI5001 project work plan for 2016-17, and to provide technical assistance to the CP in designing future field trials to enhance productivity of quinoa crop using nuclear and conventional techniques, 14-18 November 2016, Bujumbura, Burundi

Technical Officer: Mohammad Zaman

The Technical Officer (TO), together with an expert Mr. Imad-Eldin Ali Babiker, organized a two week regional/national training course “Nutrient and Water Management for Cassava Crop under Subsistence Farming in Africa” on 14-25 November 2016, at the Institut des Sciences Agronomique de Burundi (ISABU) Bujumbura, Burundi. The TO stayed during the first 5 days of the training session, which was attended by 27 participants (25 from Burundi) and 2 from Central Africa Republic under national TC (CAF5008). The training session was opened by Mr. Nahimana Dievdonne, Director General of ISABU, followed by a speech from the TO and NLO. Mr. Nahimana Dievdonne highlighted the challenges and issues of subsistence farming, climate change and variability and low crop productivity in Burundi. During the five day training session, the TO provided lectures and hand on training on (a) essential plant nutrients and their role in crop production, (b) calculations of nutrient from different N inputs (chemical fertilizer and animal manure), (c) nutrient requirement of Cassava and other crops, (d) best management practices of nutrients to build soil fertility and enhance cassava productivity using isotopic and nuclear techniques, (e) designing field trials on nutrient management using ¹⁵N technique, (f) practical demonstration of soil sampling for

assessing soil fertility, ^{15}N fertilizer application and layout of field experiments. During the 5 days, the TO discussed key project activities including preparing detailed work plans for setting up future field trials on cassava, soil and plant sample collection and their analysis, fellowships, scientific visits and procurement within the framework of the Technical Cooperation project BDI5001.



Participants at the national training in Bujumbura, Burundi

Viet Nam: To attend the 3rd RCM of CRP on ‘Landscape Salinity and Water Management for Improving Agricultural Water Productivity’, 12-16 December 2016, Ho Chi Minh City, Viet Nam

Technical Officer: Lee Heng

Ms. Lee Heng travelled to Ho Chi Minh City, Viet Nam to conduct the 3rd Research Coordination Meeting (RCM). Mr. Dang Kieu Nhan, project counterpart (Deputy Director of Mekong Delta Development Research Institute), Can Tho University, was the host of the meeting. All participants presented results from their field studies. Vietnamese counterparts used the ^{18}O isotopic technique to determine the contribution of seawater intrusion for the salinity of the irrigation water

used for rice production in the Red River and Mekong Delta to improve water management. Bangladesh, China, Iran and Pakistan reported work on integrated soil, water and crop management approach whereby improved irrigation scheduling monitored using soil moisture neutron probe and the use of salt-tolerant crops such as barley, rice and wheat in reducing soil and water salinity or making agriculture resilient to salinity in salt-affected soils and saline water. Simulation modelling using both HYDRUS and AquaCrop models were used to simulate the field salinity results. A one-day field trip to the Mekong Delta to salt-affected rice field was organized. During the meeting, project work plan and activities for the coming years were revised.



CRP participants during the field trip at the national training in Bujumbura, Burundi

Scientific Visitors

Ms. Kelebonye Bareeleng, from the Department of Agricultural Research, Ministry of Agriculture, Botswana received training on data processing and interpretation of ^{15}N isotope analysis at SWMCN during 13 - 17 June 2016.



Scientific visitor from Botswana

Ms. Su Su Win and Ms. Sandar Toe, Ministry of Agriculture and Irrigation, Myanmar, visited the SWMCN from 24-28 October 2016, received training on stable isotope N-15 data analysis and interpretation.

Scientific visitors from Myanmar



Mr. Imad-eldin A. Ali Babiker, scientist from Drylands Research Center, Agricultural Research Corporation, Sudan was an invited speaker at the IAEA General Conference Scientific Forum. He gave a presentation on 'Enhancing Food Security and Alleviating Poverty through Water and Soil Management Using Nuclear Techniques' on the achievement of his work in Sudan under RAF5071. Mr. Babiker visited the SWMCN from 19–23 September 2016.



Mr. Imad-eldin A. Ali Babiker with IAEA Director-General Mr. Yukiya Amano

Coordinated Research Projects

Project Number	Ongoing CRPs	Scientific Secretary
D1.20.12	Optimizing Soil, Water and Nutrient Use Efficiency in Integrated Cropping-Livestock Production Systems	Mohammad Zaman
D1.20.13	Landscape Salinity and Water Management for Improving Agricultural Productivity	Lee Heng and Joseph Adu-Gyamfi
D1.50.12	Soil Quality and Nutrient Management for Sustainable Food Production in Mulch-Based Cropping Systems in Sub-Saharan Africa	Mohammad Zaman and Gerd Dercon
D1.50.13	Approaches to Improvement of Crop Genotypes with High Water and Nutrient Use Efficiency for Water Scarce Environments	Joseph Adu-Gyamfi and Ljupcho Jankuloski
D1.50.15	Response to Nuclear Emergencies Affecting Food and Agriculture	Gerd Dercon and Lee Heng
D1.50.16	Minimizing Farming Impacts on Climate Change by Enhancing Carbon and Nitrogen Capture and Storage in Agro-Ecosystems	Mohammad Zaman and Lee Heng
D1.50.17	Nuclear Techniques for a Better Understanding of the Impact of Climate Change on Soil Erosion in Upland Agro-ecosystems	Lionel Mabit and Lee Heng

Optimizing Soil, Water and Nutrient Use Efficiency in Integrated Cropping-Livestock Production Systems (D1.20.12)

Technical Officer: Mohammad Zaman

This CRP is in its third year and the main objective of the project is to enhance food security and rural livelihoods by improving resource use efficiency and sustainability of integrated crop-livestock systems under a changing climate. The specific objectives are to: (1) optimize water and nutrient use efficiency in integrated crop-livestock production systems, (2) identify the potential for improving soil quality and fertility in integrated crop-livestock systems, (3) assess the influence of crop - livestock systems on greenhouse gases (GHG) emissions, soil carbon (C) sequestration and water quality, (4) assess socio-economic and environmental benefits of crop-livestock systems, (5) strengthen the capacity of the Member States to use isotopic and nuclear techniques as tools for improving the management of crop-livestock systems, and (6) develop soil, water and nutrient management options for use in integrated crop-livestock systems so that they can be adopted by farmers. The CRP was started in July 2013 with nine research contract holders from eight countries (Argentina, Brazil (2), China, India, Indonesia, Kenya, Uganda and Uruguay) and three agreement holders from France, Nigeria and the

United States of America. The third RCM was held in Buenos Aires, Argentina from 14-18 March 2016. The mid-term review for the project was completed and was approved by the CCRA.

Key results of the project over the first three years are:

1. The soil organic carbon (SOC) accumulation of no-tillage summer crops and integrated crop-livestock system (ICLS) has a history of seven years and involved in the same production system as the wet pampas of Argentina. Preliminary results were assessed and showed that in the top 20 cm of the soil, the continuous cropping system (CCS) accumulated less organic C (1.25%) when compared to the ICLS, which had 1.55%.
2. Small (6 ha) scale ICLS involving a soybean/maize rotation and a large (22 ha) scale ICLS with a soybean/pasture rotation were compared with the conventional cropping systems (continuous maize and continuous soybean) for maize and soybean crop yields. Preliminary results showed that soybean and maize yield under rotational grazing were greater than yields under continuous maize or continuous soybean cropping. The potential of the ICLS for minimizing emissions of methane and N₂O were assessed for Rio Grande do Sul and Parana States in Brazil and the results showed that ICLS reduced N₂O emissions by 50% relative to the continuous cropping systems.

3. The impact of ICLS that involved rice and two forage crops (a legume and grass) were assessed for crop and livestock production and soil quality in four different agro-eco regions in southern state of Tamil Nadu, India. Results to date showed that SOC for the paddy which received animal manure increased, from 0.68% to 0.79%.
4. Soil physical and chemical characteristics of the three agricultural rotation practices that involved soybean/maize, soybean/maize given manure and maize/giricidia legume also given manure were assessed in Bogor, Indonesia. Preliminary data showed that there was an increasing trend in soil cation exchange capacity, soil total N and soil total C contents. The isotopic signature data of ^{15}N and ^{13}C in both of the soil and plants are currently being analyzed.
5. The effect of ICLS on maize yield and soil properties (pH, SOC, N, P and K) were assessed in the Mukona district, northeast of Kampala, Uganda. Preliminary results showed that SOC was negatively affected by continuous maize cultivation and a maize-grazing rotation.

Landscape Salinity and Water Management for Improving Agricultural Productivity (D1.20.13)

Technical Officers: Lee Heng and Joseph Adu-Gyamfi

This project started in July 2013 and has the following objectives: a) to identify ways to improve crop productivity and sustainability through water and salinity management, b) to define approaches and technologies to assess and monitor soil water content and salinity at field and area-wide scales, c) to reduce the impacts of climate change and variability on the widespread increase in landscape. The project has three research coordination meetings (RCM) so far, with the first RCM held in July 2013 in Vienna, Austria; second RCM held in Beijing, China in September 2014 and a third one held recently, December 2016, in Ho Chi Minh City, Viet Nam.

The project has eight research contract holders, from Bangladesh, China (2), Iran, Korea, Pakistan and Vietnam (2), and three agreement holders from Australia, Spain and USA. The project also just had a mid-term review assessing the progress made towards achieving objective and was approved for its continuation. So far, oxygen-18 isotopic technique was successfully used to quantify the extent of seawater intrusion into saline rice field in both Red River and Mekong Delta in Viet Nam. Integrated soil, water and crop management approaches using improved irrigation scheduling and salt-tolerant crops such as barley, rice and wheat were successfully tested in reducing soil and water salinity in salt affected soils in Bangladesh, China, Iran, Pakistan and Uzbekistan. Data generated from field studies in this CRP were also used to

calibrate the salinity module of AquaCrop model, and together with HYDRUS model, were used to simulate the yield response of crop to salinity stress. Good progress was also made in terms of testing the cosmic ray neutron probe (CRNS) for area-wide soil water monitoring. New developments of mobile CRNS (both in the form of a backpack or attached to a vehicle) showed that they behave in the same way as the stationary sensor, with the same area-wide footprint. Mobility gives the CRNS technique the capacity to explore the spatial heterogeneity of soil moisture in the environment, indicating where the land is dry and where it is not, for precision irrigation.

Soil Quality and Nutrient Management for Sustainable Food Production by Mulch-Based Cropping Systems in Sub-Saharan Africa (D1.50.12)

Technical Officers: Mohammad Zaman and Gerd Dercon

This CRP just had its final research coordination meeting in November, which was attended by six research contract holders from Benin, Kenya, Mauritius, Mozambique, Pakistan and Zimbabwe. Here are the results obtained after 5 years of work:

- The CRP counterparts successfully implemented 7 long-term field trials focusing on nitrogen (N), water and carbon (C) management under maize mulch-based cropping systems in Sub-Saharan Africa. These trials have been going on for 4 years, which allowed them to better understand the different aspects of mulch based cropping systems, such as the presence of mulch, intensity of tillage, and use of N fertilizer, across different agro-ecosystems in Sub-Saharan Africa.
- Lime application corrected soil acidity in Kenya and Madagascar, and animal manure application improved low soil fertility in Benin and Mozambique which then led to increased biomass production for mulching.
- Mulch application with N fertilizer increased maize yield and improved soil fertility in Benin. In Zimbabwe, co-application of N fertilizer and mulch did not show such significant increase in maize yield probably due to drought conditions during maize growing seasons.
- In Pakistan under irrigated conditions, mulch application without tillage increased crop yield. However, in Mauritius mulch with tillage improved crop yield under irrigation. In Kenya, there was a trend of increased crop yield under mulch application but such increase in crop yield was not statistically significant. In Mozambique, mulch reduced nitrogen use efficiency probably due to immobilization of N.

- These results showed that the performance of mulch-based systems is location specific and depends on soil water availability. These ongoing long-term field studies will show how mulch based cropping systems perform under changing climatic conditions. Therefore it is essential to keep the established trials for long-term studies to gain further insights.
- Seven manuscripts on the effects of mulch on soil quality and health, nutrient and water use efficiency and crop productivity are under preparation from the 4 years results of this CRP. These manuscripts will be submitted to journals with a rigorous system of peer review by the end of March 2017.
- A network of at least ten research institutions across 7 countries was established through the CRP to target the optimization of mulch-based cropping systems in Sub-Saharan Africa.

The SWMCN Laboratory team has helped the CRP research activities with follow-up support. Three counterparts will send soil samples for ^{13}C analysis to Seibersdorf Laboratory to gain further insights on the storage and stability of C under mulch based cropping system. Based on samples collected from several long-term experiments in Austria, Belgium, Kenya, Senegal and China, a protocol was produced to assess soil organic carbon stability using ^{13}C and ^{15}N stable isotope techniques. These results from four years of intensive research by SWMCN Laboratory team also resulted in a research paper, published in the Soil Biology and Biochemistry Journal.

Approaches to Improvement of Crop Genotypes with High water and Nutrient Use Efficiency for Water and Nutrient Scarce Environments (D1.50.13)

Technical Officers: Joseph Adu-Gyamfi and Ljupcho Jankuloski

The final RCM scheduled on 7-11 November 2016 was postponed.

Response to Nuclear Emergencies Affecting Food and Agriculture (D1.50.15)

Technical Officers: Gerd Dercon and Lee Heng

This CRP aims at developing and assessing systems of innovative data collection, management and geo-visualization platforms that can be used for both routine monitoring and also in emergency response to nuclear and radiological incidents that could affect food and agriculture. Through this CRP network, institutions and governments involved in nuclear emergency response for food and agriculture will be strengthened. The CRP will also assist in compiling Standard Operating Protocols

(SOPs) for actions required in case of a nuclear emergency affecting food and agriculture, as well as sampling analytical SOPs for activity measurements.

The objectives of the CRP are:

1. To identify sampling and analytical strategies in nuclear emergencies affecting food and agriculture.
2. To determine how online geo-visualization tools can influence emergency response strategies, approaches to learning from nuclear accidents, and end-users ability to generate future short-term and long-term scenarios about the impact of nuclear accidents on food and agriculture.
3. To ensure that systems use common or standardized protocols that can be shared across different software platforms.
4. To produce low-cost computer-based platforms that are robust and can be used both routinely to monitor everyday sampling as well as in nuclear emergency situations.
5. To produce decision support tools that will help rapid analysis of the situation in radionuclide contamination of food stuffs.

Four research contract holders from China, Morocco, the Russian Federation and Ukraine, four technical contract holders from France, Japan (2) and Macedonia and four agreement holders from Belgium, European Commission, India and Japan participate in this CRP. Close collaboration has been established as well with IEC-IAEA.

To date, Standard Operating Procedures (SOPs) are being compiled for sampling and analysis of soil and foodstuffs in case of a nuclear or radiological emergency affecting food and agriculture, protocols for supporting large-scale sampling and radionuclide concentration analysis of foodstuffs are being prepared, and an advanced prototype of the online information system to support decision-making in food safety in case of a nuclear emergency is available. This information system is currently being further developed, The Information Technology Advisory Group (ITAG) of the IAEA has approved the development of the system, and an independent review of the system has just been started by KPMG in close collaboration with the IAEA - MTIT department to ensure sustainable implementation and information security.

Major efforts are being made to integrate the data management and visualization part of the information system, and to establish the algorithm for decision-support with regards to the implementation of food restrictions. Significant progress has been made as well to link this system with existing data exchange platforms of the IAEA, such as the Unified System for Information Exchange on Incidents and Emergencies (USIE) and

International Radiation Monitoring Information System (IRMIS) managed by IEC.

The second RCM was held from 28 September to 2 October 2015 in Fukushima, Japan to review progress made and plan for the second phase of the CRP. The third RCM is planned for 20-24 February 2017.

Minimizing Farming Impacts on Climate Change by Enhancing Carbon and Nitrogen Capture and Storage in Agro-Ecosystems (D1.50.16)

Technical Officers: Mohammad Zaman and Lee Heng

The objective of this CRP is to mitigate the effects of nitrous oxide (N₂O) emissions and minimize N losses from agricultural systems, whilst enhancing agricultural productivity and sequestering soil C. The first RCM was held in Vienna, Austria from 3 to 7 November 2014 to review individual experimental plans of the research contractors with regard to the objectives of the CRP, and to provide the research contract holders with suggestions for the next 18 months. There were 10 participants at the RCM, seven of whom were research contract holders from Brazil, Chile, China, Costa Rica, Ethiopia and Pakistan, two agreement holders from Estonia and Spain, and one technical contract holder from Germany. After the first RCM, all CRP participants have established field trials to assess the effects of applying N process inhibitors (urease and nitrification) on N₂O emission, and also on C sequestration under differing agro-climatic conditions. Measurements of N₂O emissions and collection of soil and plant samples for chemical analyses are currently underway. Data on N₂O emissions from different cropping systems were presented earlier, during the second RCM, which was held on 23 to 27 May 2016, at Justus-Liebig University Giessen, Germany. The key results obtained since the beginning of this CRP include:

- Observations that N₂O emissions across both arable crop and pastoral systems were appreciably influenced by both soil and environmental factors.
- Co-application of urea fertilizer with N process inhibitors (such as urease and nitrification inhibitors) has the greatest potential to improve fertilizer use efficiency, minimize N₂O emissions and promote crop productivity.
- Land use changes also had a significant impact on carbon sequestration and soil quality. Four research papers on the effects of land use changes and farm management practices on emissions of greenhouse gases and soil quality have been published in refereed scientific journals.

- Each research contract holder will now write a manuscript for publication in a scientific journal by March 2017. The CRP is expected to continue for five years (2014-2019).

Nuclear Techniques for a Better Understanding of the Impact of Climate Change on Soil Erosion in Upland Agro-ecosystems (D1.50.17)

Technical Officers: Lionel Mabit and Lee Heng

The Coordinated Research Project (CRP) D1.50.17 planned for the next 5 years (2016-2021) is aimed at: (i) identifying and testing combinations of nuclear and conventional techniques to assess the impacts of changes occurring in upland agro-ecosystems, (ii) distinguishing and apportioning the impact of climate variability and agricultural management on soil and water resources in uplands, and (iii) supporting adaptive agricultural management for soil and water conservation in uplands to reduce impacts of climate variability. Nuclear techniques will be used to fulfil these specific objectives, including fallout radionuclides (FRNs) such as ¹³⁷Cs, ²¹⁰Pb, ⁷Be, and ²³⁹⁺²⁴⁰Pu, Compound-Specific Stable Isotope (CSSI) techniques and Cosmic Ray Neutron Probe (CRNP). The first Research Co-ordination Meeting (RCM) of the CRP D1.50.17 was held in Vienna, Austria, on 25-29 July 2016. All CRP participants were present consisting of thirteen contractors which include four research contracts from China, Islamic Republic of Iran, Madagascar and Morocco, two technical contracts from Austria and New Zealand and seven research agreements from Canada, Italy, Spain, Switzerland, UK, and USA (2). In total, twelve participating countries were represented. During the first three days of the meeting, the participants presented their background activities, their current work as well as some preliminary results followed by question and answer sessions. The fourth day of the RCM was dedicated to reviewing and refining each individual work plan and expected output for 2016-2017. Research, analytical protocols and collaboration were further discussed. The last day of the RCM, the participants improved their work plans to ensure the achievement of the CRP objectives. The CRP team agreed that the second RCM of the CRP D1.50.17 will be hosted in Rabat (Morocco) end of March 2018.



Participants of the First RCM of CRP D1.50.17.at Vienna International Centre, Austria.

Developments at the Soil and Water Management and Crop Nutrition Laboratory

Alternative Statistical Approach for Selecting Best Discriminant Fatty Acids to Establish Soil Source Contribution to Sediment Mixture: Example for the Austrian Sub-Watershed of Mistelbach

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Through the example of our compound-specific stable isotope (CSSI) investigation in Mistelbach (see our two previous Soils Newsletters from January and July 2016), an example of a step-by-step statistical approach to study

agro-environmental source-sink interaction is proposed when using fatty acids (FAs) as soil/sediment fingerprints. Our Austrian Mistelbach study site consists of one sediment mixture (M) and four different contributing sources that include three agricultural fields (S1, S2, S3) and one grassed waterway (S4). The $\delta^{13}\text{C}$ values of the bulk soil carbon and of four different FAs (i.e. C_{16} , C_{18} , C_{22} and C_{24}) have been determined in the soil sources and in the sediment mixture.

Prior to applying statistical tests, exploratory data set analysis was performed for allowing visual inspection and to obtain an overall qualitative description of the variables. Figure 1 presents a series of bi-scatterplots of all possible combinations of $\delta^{13}\text{C}$ FAs including the bulk soil carbon $\delta^{13}\text{C}$. This preliminary simple data comparison already illustrates that bulk soil carbon $\delta^{13}\text{C}$ is a strong discriminant among the other FAs (see Figure 1).

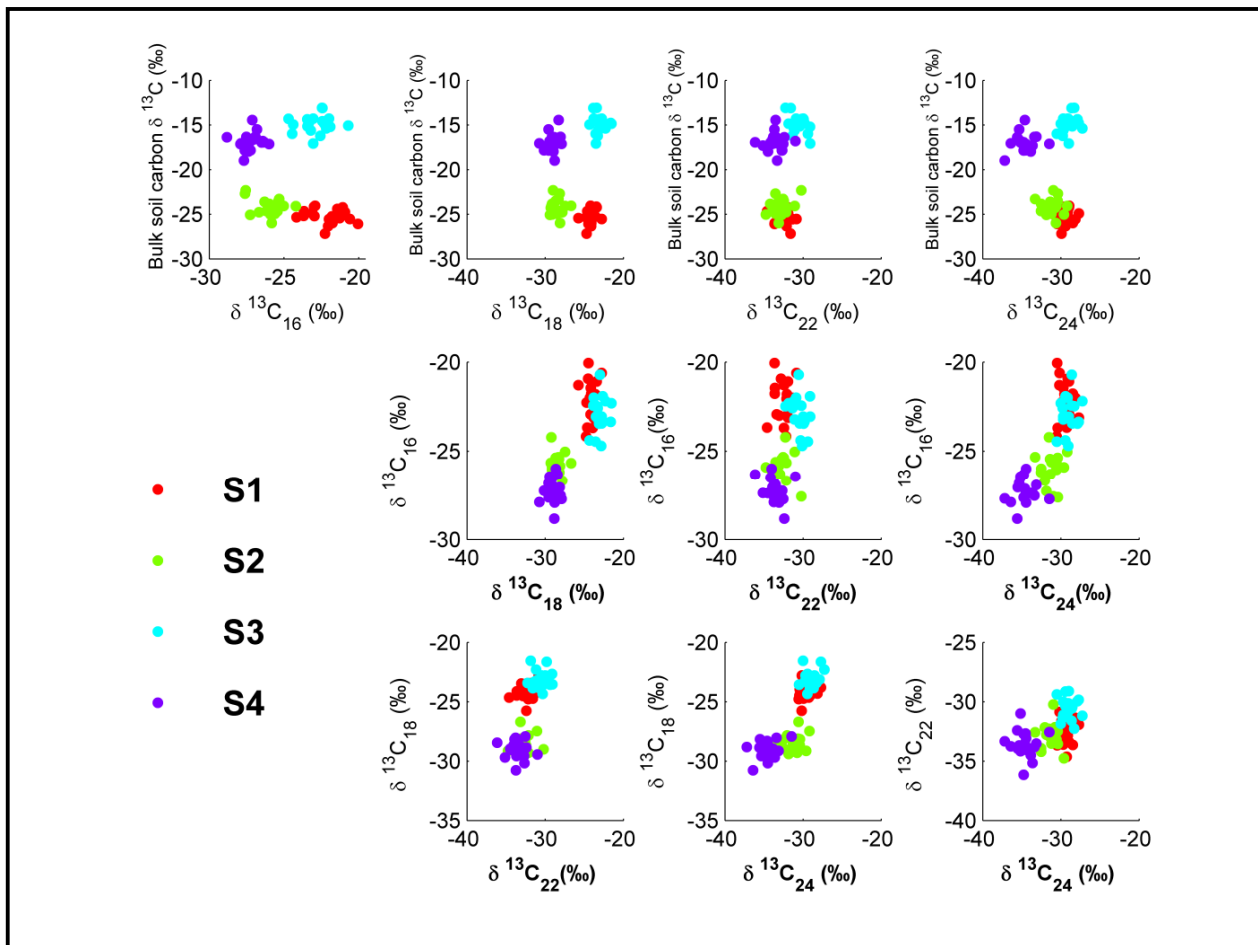


Figure 1. Distribution and variability of the $\delta^{13}\text{C}$ signature of FAs and bulk carbon of the soil sources

The results of one-way analysis of variance through Tukey multiple comparisons of means with 95% confidence level provide information about the differences in $\delta^{13}\text{C}$ among sources and FAs. For example, the bulk soil carbon $\delta^{13}\text{C}$ values showed the highest significant difference between the four sources: S4 vs. S1 ($P < 0.0001$), S3 vs. S1 ($P < 0.001$), S3 vs. S2 ($P < 0.001$), S2 vs. S4 ($P < 0.001$), S3 vs. S4 ($P < 0.001$), and S2 vs. S1 ($P < 0.001$). S3 vs. S1 and S4 vs. S2 did not differ with $\delta^{13}\text{C}$ of FAs C_{16} ($p = 0.10$) and C_{18} ($p = 0.10$) respectively. The $\delta^{13}\text{C}$ values of Lignoceric Acid (C_{24}) showed significant differences for all sources ($p < 0.001$) while $\delta^{13}\text{C}$ of Behenic Acid (i.e. C_{22}) did not exhibit a significant difference between S1 and S2 ($P = 0.80$). Figure 1 corroborates all these statements.

After the one-way analysis of variance, a correlation analysis was performed to establish the relationship between the different biomarkers. This analysis revealed that the highest significant linear dependencies are between $\delta^{13}\text{C}_{16}$ & $\delta^{13}\text{C}_{18}$ ($r = 0.86$; $p < 0.01$), $\delta^{13}\text{C}_{18}$ & $\delta^{13}\text{C}_{24}$ ($r = 0.79$; $p < 0.01$), and $\delta^{13}\text{C}_{16}$ & $\delta^{13}\text{C}_{24}$ ($r = 0.77$; $p < 0.01$). Among the variables, the bulk soil carbon $\delta^{13}\text{C}$ was found to be the least correlated parameter, highlighting that it is the most reliable discriminator for determining the sediment origins in the mixture.

Based on the results obtained from the above steps, only Behenic (C_{22}) and Lignoceric (C_{24}) acids as well as the bulk soil carbon $\delta^{13}\text{C}$ pass our multivariate statistical approach. Principal Component Analysis (Figure 2b) confirmed our findings, and our previous FAs fingerprint selection based on the mixing polygon tests (Figure 2 a).

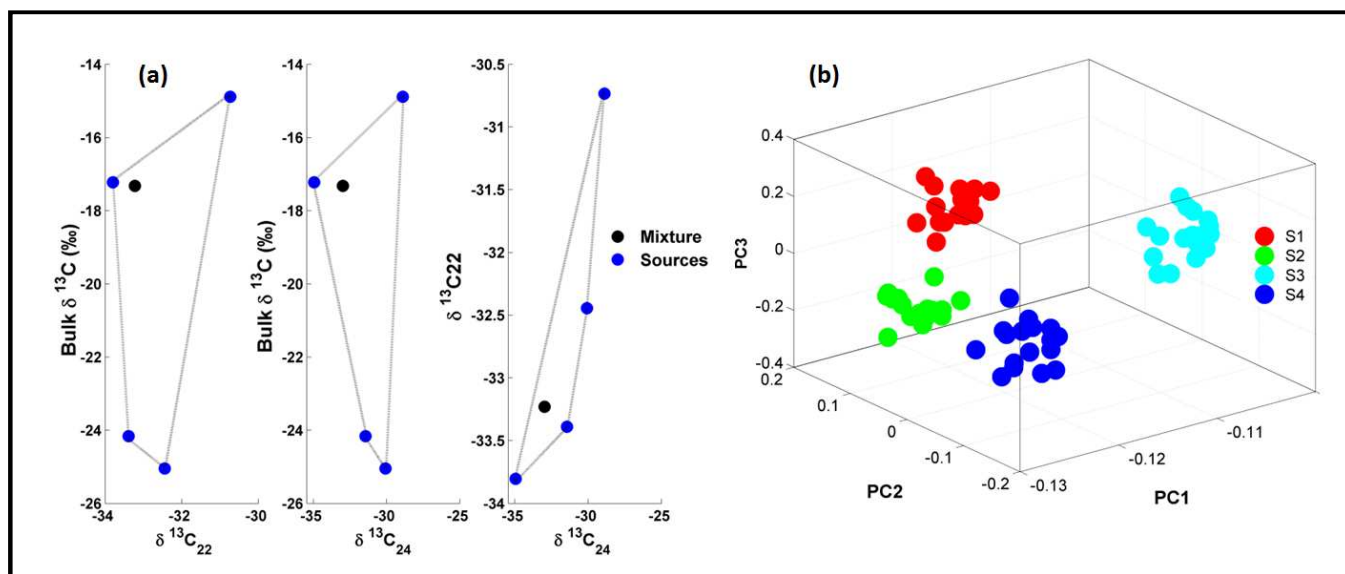


Figure 2. (a) Mixing polygon of selected FAs contributing to the mixture; (b) Principal Component Analysis of the data set

New On-Going Investigation Using Plutonium (Pu) Isotopes in Grabenegg, Austria

Lionel Mabit⁽¹⁾, Amelia Lee Zhi Yi⁽¹⁾, Modou Mbaye⁽²⁾, Romina Torres-Astorga⁽³⁾, Arsenio Toloza⁽¹⁾, Moncef Benmansour⁽⁴⁾

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As less than 30% of the deposited ^{137}Cs global fallout is still present today due to its radioactive decay, the use of alternative anthropogenic isotopic soil tracers should be promoted for investigating the magnitude of erosion and sedimentation processes. Recently, a new artificial radioisotopic tracer, mostly originating from the past aerial nuclear weapon tests, has raised the attention of the scientific community: Plutonium (Pu). One of the main advantages of anthropogenic Pu isotopes over ^{137}Cs (half-life of 30 yrs) is their long half-life (i.e. ^{239}Pu = 24110 yrs and ^{240}Pu = 6561 yrs) that ensures long-term availability to be used as tracers for agro-environmental purposes.

To date, soil redistribution research in agroecosystems using Pu is still in their infancy. Until now only a couple of studies have been conducted in Australia, China, Germany, South Korea and Switzerland. However, existing studies have demonstrated the potential of using

these isotopes especially in Chernobyl affected area where Pu homogeneity is higher as compared to ^{137}Cs .

As reported in a previous Soils Newsletter (i.e. Soils Newsletter Vol. 38, No 1, July 2015), the experimental research station of the Austrian Agency for Health and Food Safety (AGES) located in Grabenegg (Austria) has been already investigated for establishing a preliminary ^{137}Cs fallout baseline in an undisturbed reference site ($7890 \pm 1510 \text{ Bq m}^{-2}$; CV (%) = 19.2; AE (%) = 11.8 at 90% confidence level; n=9).

The SWMCNL team has initiated new activities for reinforcing the ^{137}Cs information gained on the Grabenegg reference site and for testing $^{239+240}\text{Pu}$ versus ^{137}Cs . Depth distribution of these radioisotopes and their spatial variability will be tested in the coming months. Pu isotopic determinations of Grabenegg soil samples are currently being performed using alpha spectrometry analytical facilities at CNESTEN in Morocco. This collaboration will allow us to obtain key information using Pu ratios for determining and quantifying the ^{137}Cs that originates from Chernobyl and from the previous nuclear bomb tests. This additional information will also increase precision of derived soil erosion rate estimates when using ^{137}Cs conversion model.

In comparing the reference site's spatial heterogeneity and depth distribution of $^{239+240}\text{Pu}$ to ^{137}Cs , the main objective of the first investigation to test Pu isotopes as potential tracers of soil and sediment redistribution under Austrian agro-climatic condition will be achieved. Further work involving a new sampling campaign to quantify soil redistribution through a multi-fallout radionuclides approach including ^{137}Cs , $^{210}\text{Pb}_{\text{ex}}$ and $^{239+240}\text{Pu}$ determination will be scheduled along a typical transect of an adjacent agricultural field.

Decision Tree and Survey Development for Support in Agricultural Sampling Strategies during Nuclear and Radiological Emergencies

Amelia Lee Zhi Yi, Gerd Dercon

Soil and Water Management & Crop Nutrition Laboratory, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Department of Nuclear Sciences and Applications, International Atomic Energy Agency, Vienna, Austria

In the event of a severe nuclear or radiological accident, the release of radionuclides results in contamination of land surfaces affecting agricultural and food resources. Speedy accumulation of information and guidance on decision making is essential in enhancing the ability of stakeholders to strategize for immediate countermeasure strategies. Support tools such as decision trees and sampling protocols allow for swift response by governmental bodies and assist in proper management of the situation. While such tools exist, they focus mainly on protecting public well-being and not food safety management strategies. Consideration of the latter is necessary as it has long-term implications especially to agriculturally dependent Member States. However, it is a research gap that remains to be filled.

To date, many countries have developed agricultural sampling protocols respectively post-Chernobyl and Fukushima. Yet, there is limited harmonization of protocols to ensure consistency in sampling strategies. Furthermore, lack of studies on large scale soil sampling strategies hamper efforts to pre-prepare for such emergencies. To this end, research efforts are being made by the SWMCN Laboratory team, as part of the CRP D1.50.15 *Response to Nuclear Emergency affecting Food and Agriculture* project.

Firstly, the SWMCN Laboratory team is collating information on crop product sampling practises during large scale nuclear and radiological emergencies, through an online survey, presented as a 15-minute questionnaire, to understand commonalities and differences in sampling practices across the world. Target survey responders include sample collectors, sampling project coordinators, laboratory analysts and decision-makers. Questions pertaining to site selection, crop sample selection, manpower management and sampling density were included to define and understand the bottlenecks in field based sampling. Once survey answers have been compiled, answers will be analysed and lessons learnt incorporated in the drafting of a large-scale sampling protocol for use by Member States.

Secondly, a decision tree was developed to better understand the flow of decision-making with regard to food and planting restrictions. This decision tree will be part of a proposal for an agriculture-focused, large-scale radiological emergency sampling protocol to include soil and food criterion. Target users are authorities involved in directing the sampling campaign. Decision actions are suggested for processed foods, animal products, animal feed and crop products (including plants at the growing stage, mature stage, fallow farmland, and forestry products). Operational Intervention Levels (OILs) - action levels used for protective measures based on environmental assessments - will be used. A modified version of the OILs 5 & 6 pertaining to food will be developed for the soil component. Discussions are currently underway for development of default values of OILs for the soil component.

Establishing Ideal Conditions for Complete Denitrification by *Pseudomonas aureofaciens* - An Update on Determining Isotopic Composition of Dissolved Nitrate Using Bacterial Denitrification and Laser Spectroscopy

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This serves as update on research entitled “Determining isotopic composition of dissolved nitrate using bacterial denitrification and laser spectroscopy” first published in the Vol. 39, No. 1, July 2016 SWMCN Soils Newsletter. In this research, isotopic $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$ composition of dissolved nitrates is measured by laser spectroscopy after reduction of nitrate to N_2O by *Pseudomonas aureofaciens*. Quantifying the isotopic composition of nitrates in aqueous samples allows for better identification of potential nitrate sources, which in turn assists in remediation of nitrate-contaminated water and design of future agricultural management practises. The overall objective of the project is to establish a technical guide in the form of a standard operating procedure outlining best practises for denitrification method.

Growing batches of healthy *Pseudomonas aureofaciens* to fully denitrify nitrate is the first step to ensuring reproducible measurements of N_2O . In our experiments, we determined ideal conditions for growth and complete denitrification of the *Pseudomonas aureofaciens* bacteria by varying (1) availability of oxygen during the rapid

growth phase and (2) duration of autoclave time for starter and growth mediums.

Firstly, we tested *Pseudomonas aureofaciens*' growth potential in aerobic and anaerobic conditions. Breathable plastic covers were used to create an aerobic growing environment while capped bottles were used for partial anaerobic growing conditions and (Figure 1). Bottles were placed on an orbital shaker for 5-7 days. Denitrification progress was tested using the sulphanilamide and NED indicator test. Optical density was measured as an indicator for bacteria growth.

Yield of aerobically grown *Pseudomonas aureofaciens* was on average double compared to that of the anaerobically grown bacteria (Figure 2). However, the aerobic growth medium exhibited excess skin and film on top of the growth medium, which also indicated potential of contamination in the medium bottles. This may be caused by introduction of foreign bacteria and fungi into medium through the semi-permeable plastic covers. Sulphanilamide and NED indicators showed that the aerobically grown bacteria were unable to completely denitrify all dissolved nitrate in water samples, even after 10 days.



Figure 1. Triplicate experiment studying the differences in effects of aerobic (in bottles with plastic covers) and anaerobic (in bottles with blue caps) growth of *Pseudomonas aureofaciens*. Aerobic growth tended to be faster, leading to higher yields as evidenced through higher optical density values and pallet size. However, bacteria in aerobic growth bottles were not able to fully denitrify even after 10 days.

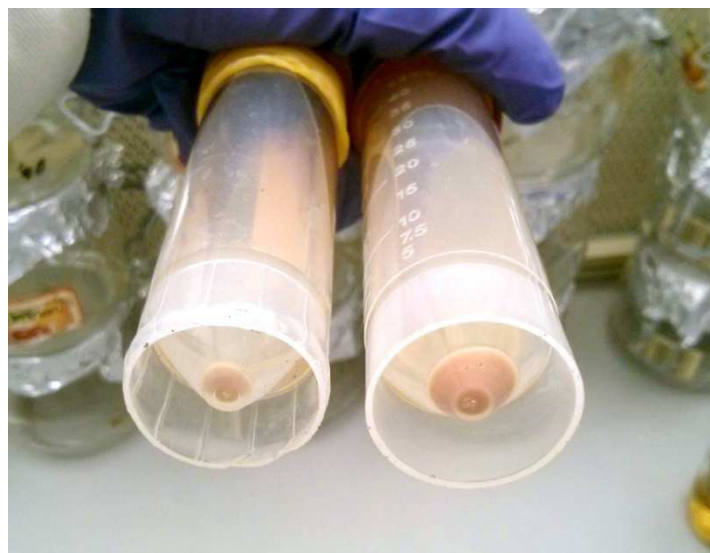


Figure 2. Pallet bacteria yield of aerobic growth bottle (right) and anaerobic growth bottle (left). While aerobically grown *Pseudomonas aureofaciens* produced higher yields, the risk of contamination was also increased due to the semi-permeable membrane covers

The second parameter tested was autoclave times of medium in which *Pseudomonas aureofaciens* were grown in. Growth medium was autoclaved for 30, 60, and 90 minutes. *Pseudomonas aureofaciens*, pre-grown in starters with the same autoclave times, were inoculated into the growth medium and left to grow in anaerobic conditions. The sulphanilamide and NED indicator test was performed from day 3 onwards to prove for denitrification. It was found that bacteria of all 3 autoclave times completely denitrified on the same day (Day 5). Growth medium with 30- and 60-minute autoclave times produced slightly higher bacteria yields than that with the 90-minute autoclave time. Autoclave times of the starter and growth medium had slight, but not significant effects on bacteria growth and yield.

Increased oxygen availability in the growing phase resulted in significantly increased bacteria growth and yield but incomplete denitrification. It is hypothesized that in an aerobic growing environment O_2 competes with NO_3^- and is preferentially consumed by *Pseudomonas aureofaciens*, thus restricting complete denitrification of dissolved nitrate in growth medium. With an anaerobic environment, the bacteria are able to consume the headspace O_2 , enter anaerobic growth, and subsequently fully denitrify.

Increasing Precision and Accuracy of Laser Isotope Analyser Data

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Isotope analysis with laser spectroscopy is an emerging technology that is growing in scientific demand. Because this technology allows for real-time, *in situ* measurements of carbon-13 (^{13}C) and nitrogen-15 (^{15}N) of CO_2 , CH_4 and N_2O , it is increasingly being used to monitor fluxes of these greenhouse gases. However, despite its potential to provide robust data to researchers, methods of calibration and data correction are still being developed and refined. Furthermore, standard reference gases are currently not available and researchers must make their own gases to ensure proper calibration and data correction. To improve quality of data and allow for comparison of data between studies, it is essential that standard CO_2 , CH_4 and N_2O gases are accessible to researchers.

Within the SWMCN laboratory we are developing methods to make CO_2 , CH_4 and N_2O gas standards on a universal gas mixing line that can both evacuate gas bottles and fill them with desired gas mixtures. These gases are being isotopically labelled at natural isotope abundance levels as well as depleted and enriched isotope abundance levels so that they can be used in both natural abundance and tracer isotope studies. Furthermore, these gas mixtures will be produced at ambient and elevated concentration levels similar to those measured in natural environments and experiments. In addition to filling gas bottles to create larger volumes of standard gases, our universal gas mixing line can be used to produce mixed gases in small volume multi-layer foil gas sampling bags.

Using standard CO_2 , CH_4 and N_2O gases in laser isotope analysis studies, we can improve confidence and accuracy in reported data and larger comparisons across studies. Once our methods for making gas standards for laser isotope analysers are finalized, we plan to develop standard operating procedures for IAEA Member States to use to replicate our gas standards.

Future Applications in Quantitative Isotopic Tracing using Homogeneously Carbon-13 Labelled Plant Material

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Carbon-13 (^{13}C) and nitrogen-15 (^{15}N) labelled plant material is increasingly being used to trace the fate of plant-derived C and N into the atmosphere, soil, water and organisms in many studies, including those investigating the potential of soils to store greenhouse gases belowground. Storage of C in soils can offset and even reduce atmospheric levels of the greenhouse gas, CO_2 , and interest in such studies is growing due to problems associated with anthropogenic greenhouse gas emissions impacting climate change. Reduction of N loss in soils is also of great interest, as it reduces release of the greenhouse gas, N_2O , into the atmosphere. However, accurate quantitative tracing of plant-derived C and N in such research is only possible if plant material is labelled both homogeneously and in sufficient quantities.

The SWMCN laboratory has developed a method that achieves both requirements for ^{13}C labelling by monitoring $^{13}\text{CO}_2$ labelling of plants in a walk-in growth chamber with laser spectroscopy. This approach allows us to create homogeneously labelled material at the intra-plant, inter-plant and metabolic level, which can be used for quantitative tracing. Our initial labelling trials focused on maize (Figure 1, 2) due to its global importance as a crop and due to its potential to produce relatively large amounts of biomass, yielding one kilogram of dry plant material per run. With successful ^{13}C labelling of corn plants achieved, we are now further attempting to label other agricultural plants, such as soybeans, that can open more research avenues to better understand carbon dynamics. Additionally, we are attempting to create homogeneously labelled ^{13}C and ^{15}N plant material by supplying both labelled $^{13}\text{CO}_2$ and ^{15}N -labelled hydroponic nutrient solution during plant production. Dual labelling of plants is advantageous when studying agricultural greenhouse gas emissions, as it allows researchers to simultaneously account for plant-derived CO_2 as well as another greenhouse gas, N_2O .



Figure 1. Maize plants grown in a walk-in growth chamber with $^{13}\text{CO}_2$ labelling at time of harvest. Ethylene scrubbers hang from the centre of the chamber to reduce levels of ethylene in the chamber and a desiccant rests on the floor to reduce humidity. CO_2 sensors at the top of the chamber are used to control CO_2 concentration and a

further sampler is linked to a ^{13}C -CO₂ laser isotope analyser (outside of the growth chamber) that is used to monitor the level of ^{13}C enrichment.

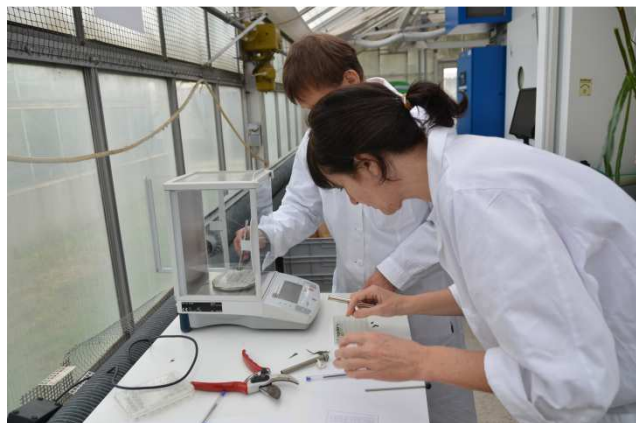


Figure 2. SWMCNL researchers prepare samples of maize leaf tissue to check for homogeneity of ^{13}C labelling throughout the labelled plants.

In addition to homogenous ^{13}C and ^{15}N labelling of plant material, we plan to also produce heterogeneously labelled plant material, in which only labile, easily decomposable material is labelled. By performing incubation and field decomposition experiments using both types of labelled plant material, researchers will investigate the forms of plant material that more significantly contribute to greenhouse gas emissions and, conversely, store them belowground. Furthermore, a comparison between the two types of plant material should allow us to elucidate the error propagation that can occur from using heterogeneously labelled material and its effects on accuracy of estimating sequestration rates, emission rates as well as residence times.

In summary, the method developed at the SWMCN laboratory for producing large amounts of homogeneous ^{13}C labelled plant material opens up new research pathways and assessment methods in the field of soil carbon dynamics and agricultural greenhouse gas emissions. Further development of homogenous ^{15}N -labelled plant material will also help with research in the field of soil nitrogen dynamics and agricultural greenhouse gas emissions, as will the production of additional ^{13}C and ^{15}N labelled agricultural plants. This plant material will allow FAO/IAEA Member States to accurately quantify carbon storage and reduction of atmospheric greenhouse gas levels of various agricultural systems as well as assess the efficacy of different agricultural practices under local conditions, both via *in situ* and incubation experiments.

Analytical Services

Christian Resch, Roman Gruber, Arsenio Toloza

In 2016, 4400 samples were analysed for stable isotopes and 220 samples were measured for fallout radionuclides respectively in the SWMCN Laboratory. Most analyses were carried out for supporting Research and Development activities at the SWMCNL focused on the design of affordable isotope and nuclear techniques to improve soil and water management in climate-smart agriculture. Analytical support has been given as well to the Plant Breeding and Genetics Laboratory with about 300 samples and to the Insect Pest Control Laboratory with about 340 samples analysed.

External Quality Assurance: Annual Proficiency Test on ^{15}N and ^{13}C isotopic abundance in plant materials

Christian Resch

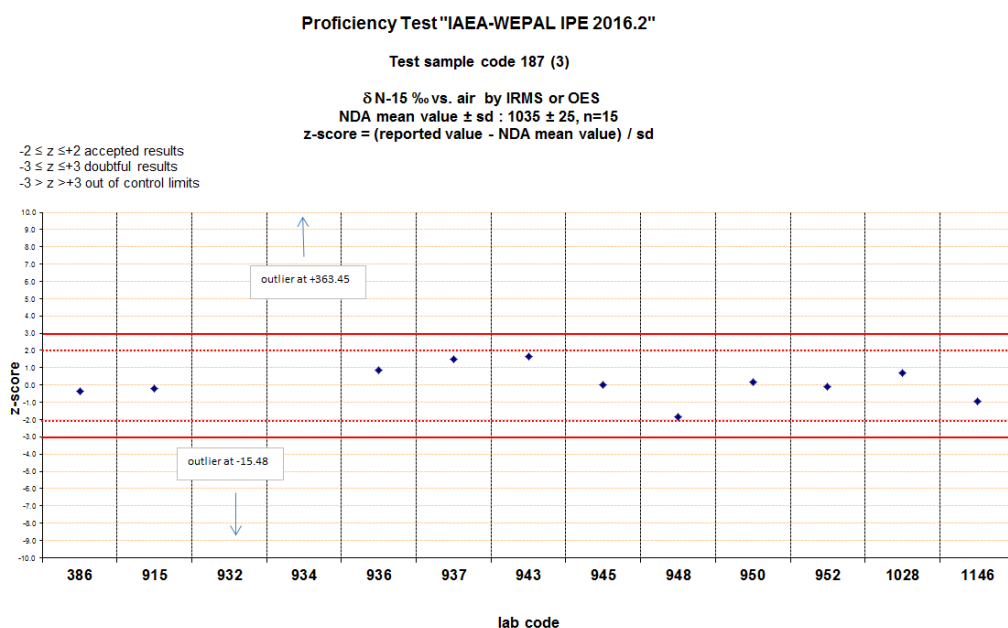
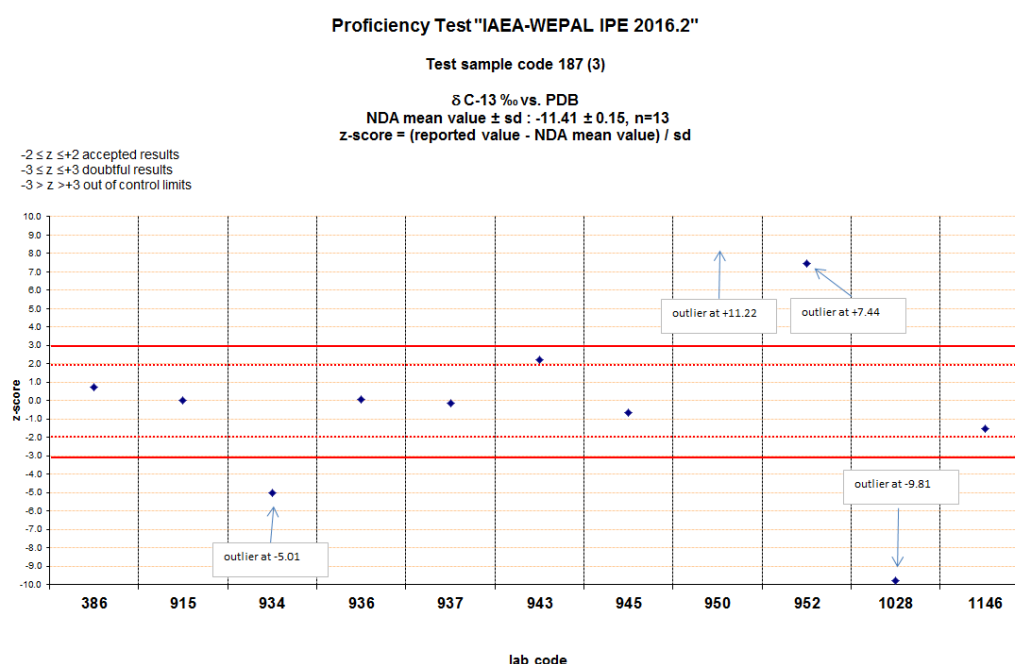
The worldwide comparison of stable ^{15}N and ^{13}C isotope measurements provides confidence in the analytical performance of stable isotope laboratories and hence an important tool for external quality control.

The 2016 Proficiency Test (PT) on ^{15}N and ^{13}C isotopic abundance in plant materials, organized by the University of Wageningen, the Netherlands, and funded by the SWMCN Laboratory has been successfully completed. The Wageningen Evaluating Programs for Analytical Laboratories (WEPAL, <http://www.wepal.nl>) is accredited for the organization of Inter-laboratory Studies by the Dutch Accreditation Council.

Every year, one ^{15}N -enriched plant test sample is included in one round of the WEPAL IPE (International Plant-Analytical Exchange) programme. A special evaluation report for IAEA participants on the analytical performance in stable isotope analysis is issued by the SWMCN Laboratory and sent to the participants together with a certificate of participation additionally to the regular WEPAL evaluation report. The participation fee for one round per year is covered by the IAEA.

In total fourteen stable isotope laboratories participated in the PT-round 2016: **Africa (2)**: Kenya and Morocco, **Asia (3)**: Pakistan and Philippines (2 labs), **Europe (4)**: Austria, Belgium, France and Germany, **Latin America (4)**: Argentina, Brazil, Chile and Uruguay) and **Pacific (1)**: New Zealand.

Eleven out of thirteen laboratories participating in the nitrogen analysis reported ^{15}N -data within the control limits for the enriched plant sample (Figure 1) and seven out of eleven participating laboratories in carbon analysis reported ^{13}C isotopic abundance results within the control limits (Figure 2).

Figure 1. Z-score evaluation of the ^{15}N analysisFigure 2. Z-score evaluation of the ^{13}C analysis

Monitoring Landscape Scale Soil Water Content with Cosmic-Ray Neutron Sensors: Validation and Calibration

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Increasing populations growth combined with climate change are putting pressure on water resources and agricultural systems around the world. The need for effective water management strategies designed to

maximize water use efficiency has made access to soil water content (SWC) information crucial to the global community.

This work builds upon ongoing research that began in December 2013 in which a stationary Cosmic-Ray Neutron Sensor (CRNS) was used to monitor SWC within an agricultural system located in north central Austria (Figure 1a). Past work at this study site at Petzenkirchen, Austria (100 km west of Vienna) has focused on the calibration and validation of the CRNS technology, and has shown the CRNS to reliably estimate SWC on a large scale (circle with radius of cca. 250 m) when compared to other methods of estimating SWC (Figure 2). This was determined via comparisons of in-situ soil sampling, time domain reflectometry (TDR), and time domain transmissivity (TDT) of SWC with estimates of SWC determined from the CRNS. However, questions remain regarding the effective use of the CRNS technology.

The effect of hydrogen contained within plant biomass on the CRNS signal requires further investigation. This is particularly true in agricultural areas where biomass changes quickly in time from planting to harvest. This can be seen in a CRNS signal and must be quantified. Methods to do this are diverse and vary in their accuracy. The effect of plant biomass and the water contained within is also being partially examined. Methods to quantify plant biomass for the purpose of calibration of both a mobile and stationary CRNS include: destructive in-situ sampling, satellite based remote sensing, and the use of the CRNS itself. Due to the relationship between neutrons (cosmic rays) and environmental hydrogen, the CRNS may be capable to serve as a tool to quantify plant biomass in an agricultural setting. This activity has begun, however more data are needed. Additional investigation into this question is planned for the coming year.

Additionally, the capacity for the CRNS to provide data representative of a large area is well known; however, a stationary sensor is incapable of capturing the natural heterogeneity of soil moisture within its footprint. Therefore, field campaigns have begun in September of 2016, to calibrate and validate a mobile “backpack” version of the normally stationary CRNS (Figure 1b). This backpack sensor is capable of estimating SWC at the same spatial resolution as a stationary CRNS. This builds upon the advantage inherent to a CRNS in that it can characterize SWC over landscape scales non-invasively thus eliminating the intrusion of traditional in-situ sensors within agricultural systems. Utilizing the mobility of the CRNS backpack has the potential to capture the natural heterogeneity of soil moisture within the landscape, a capacity that a traditional stationary CRNS lacks. Water

management decisions can benefit from detailed spatial SWC information. Results will be reported in the coming Soils Newsletter.

Another key area of interest is the application of CRNS technology in high altitude environments. Such diverse environments are often disproportionately affected by climate change and land degradation. However, the remote locale and difficult terrain makes traditional SWC monitoring as well as stationary CRNS installation impractical. This mobile backpack has been deployed recently in the Austrian Alps in three locations where comparisons of in-situ soil sampling and TDR SWC estimations were compared to the mobile CRNS signal. This was carried out at different elevations to explore the relationship of these data in high-altitude alpine environments typically prone to erosion from hydrological and anthropogenic sources.

Preliminary results from past and current work at the Petzenkirchen site show:

- 1) SWC data produced from a stationary CRNS are similar to SWC information produced via in-situ soil sampling, the mobile “backpack” CRNS, and in-situ TDR SWC values (Figure 2). It is important to note that the “backpack” CRNS consistently shows higher SWC values than its stationary counterpart. More experiments over the course of 2017 will be needed to fully explore this phenomenon.
- 2) Conducting in-situ sampling campaigns is intended to validate and improve the accuracy of the CRNS data (both stationary and backpack versions) by comparing the sensor SWC readings with those determined via in-situ soil sampling for SWC. Determining the appropriate number of sampling campaigns to perform is necessary for effective time management. Comparisons of the stationary CRNS signal of SWC calculated from a single calibration campaign (R^2 : 0.6398) compared to the same signal calculated from six calibration campaigns (R^2 : 0.6423) seems to show very little difference (Figure 3a). Further investigation into the possibility of requiring fewer calibration campaigns will be conducted in the coming year.
- 3) The CRNS calibration variable “ N_0 ” (defined as the counts of cosmic rays per unit time in a dry environment devoid of biomass), is calculated via in-situ calibration campaigns. Changing estimates of SWC derived via in-situ soil sampling show a poor relationship with N_0 . However, N_0 seems to be in wet conditions (Figure 3b), this will be further explored in 2017.

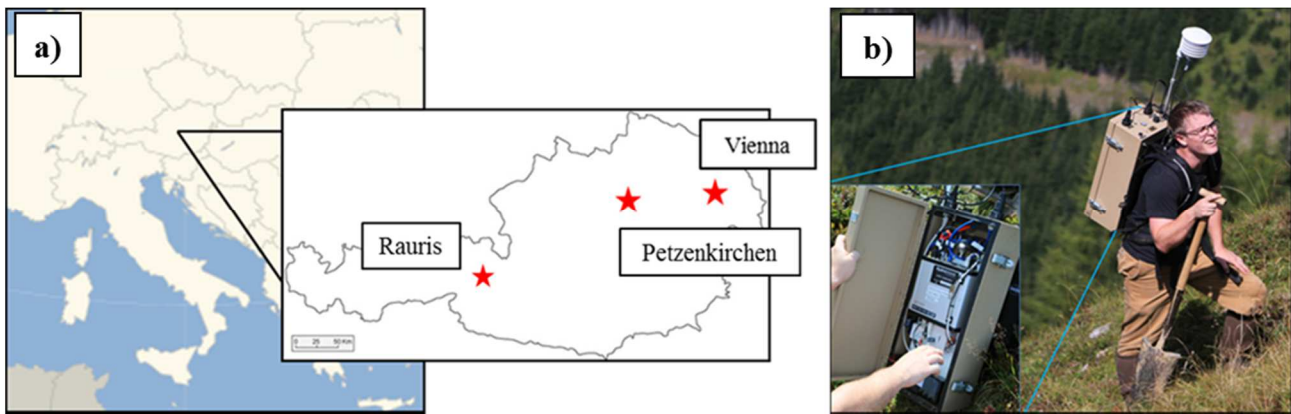
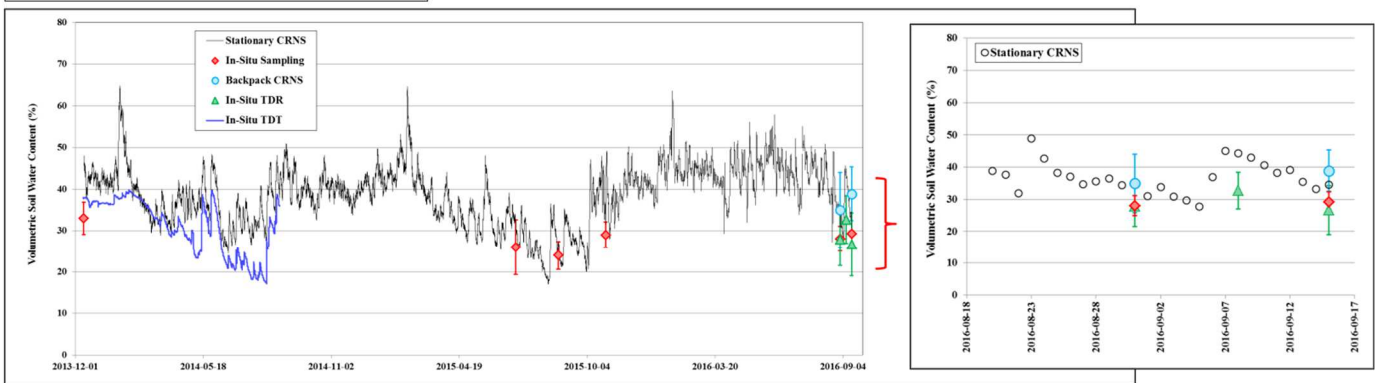


Figure 11 a) Location of the stationary Cosmic Ray Neutron Sensor (CRNS) at Petzenkirchen Austria (48.154°N, 15.1483°E). b) Mobile backpack CRNS, photo taken near Rauris, Austria in a grazed alpine setting, photo credit to Dale Pulker

Petzenkirchen Site – N_0 from 6 Calibrations



Petzenkirchen Site – N_0 from 1 Calibration

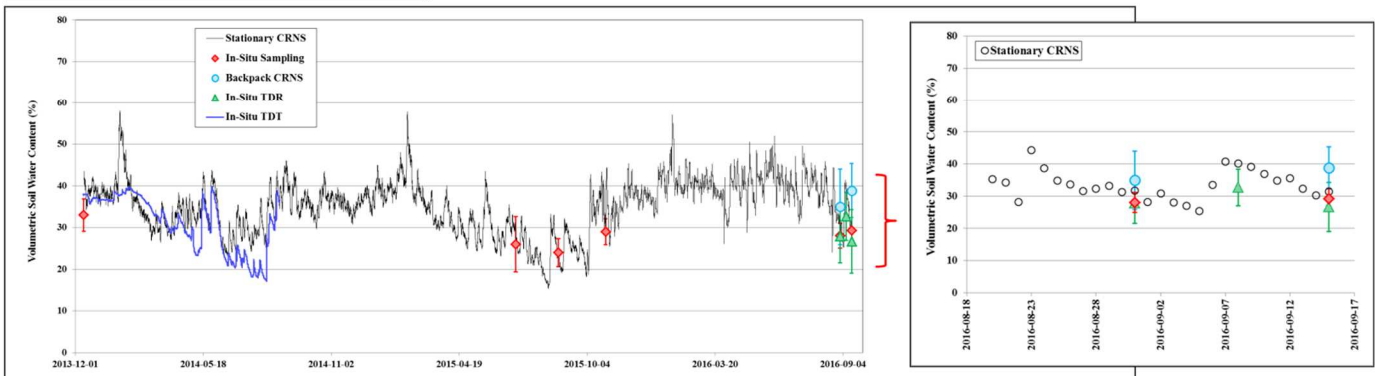


Figure 2. Time series of mean Soil Water Content (SWC) values (24 hr) derived from a stationary Cosmic Ray Neutron Sensor (CRNS) (at Petzenkirchen, Austria), Time Domain Transmissivity (TDT) values in the top 10 cm, in-situ Time Domain Reflectometry (TDR), CRNS backpack values, and in-situ soil sampling SWC values for the purpose of data validation (error bars represent standard deviation).

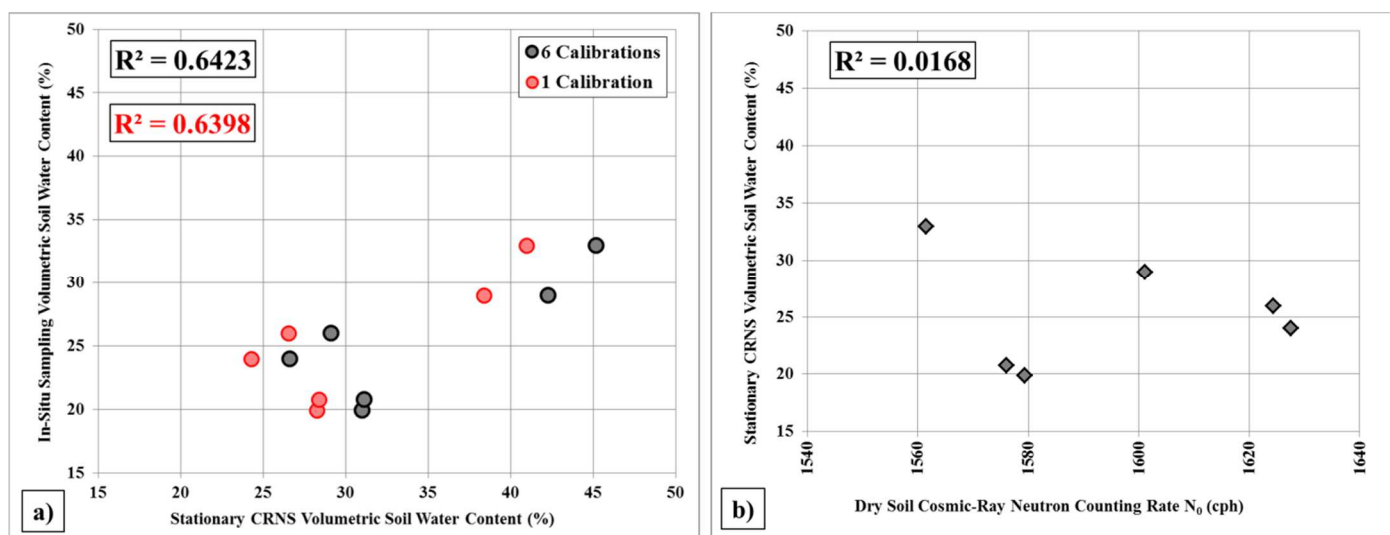


Figure 3. a) Stationary Cosmic Ray Neutron Sensor (CRNS) soil water content (SWC) vs. SWC determined via in-situ soil sampling. Red indicates CRNS SWC values determined from a single in-situ calibration campaign, black indicates CRNS SWC values determined from 6 in-situ calibration campaigns. b) Stationary CRNS N_0 (cosmic ray neutron counting rate assuming dry conditions devoid of biomass) compared to SWC determined via in-situ soil sampling from 6 calibration campaigns

Mitigating Soil Moisture Evaporation via Organic Mulch Application in Cultivated Agricultural Environments

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Soil evaporation constitutes one of the most significant sources of water loss from agricultural soils around the world, particularly in arid regions. Changing climate and precipitation patterns combined with population growth will drive a need to reduce soil water evaporation for better water resource management.

This work represents a preliminary effort to develop simple tools for determining the fate of crop residues, or mulch, when applied to an agricultural field, over the course of a growing season. Organic mulch protects the soils and therefore water present in the subsurface is less likely to evaporate thus preserving its presence for use by crops. The slow decomposition of mulch varies depending on the type used. For example, a legume contains a greater amount of nitrogen. This allows microorganisms to break down its tissues faster. This is in contrast to other mulch cover types such as grain cereal, where lower nutrient levels and a more stable organic composition increase its residence time in any particular field. Therefore,

legumes are not likely to reduce soil evaporation as effectively as non-legume mulch types.

Small plots ($\sim 7 \text{ m}^2$) planted with maize located at the experimental fields of the SWMCNL were compared. Vetch (a type of legume) mulches were applied to half of the maize plots with the other half receiving no mulch. Photographs were taken above the crop canopy at a fixed height and pre-determined location approximately once a week during the growing season from planting until full canopy cover. This was done via a handheld digital camera attached to an expandable tripod and remotely controlled via a smart phone (Figure 1a). Images of the canopy were then processed by image analysis software for cover percentages (specifically, green leaves, bare soil, mulch, rocks, and biological soil film; (Figure 1b)).

The gradual breakdown of applied mulch and build-up of living biomass has been shown (Figure 2). Vetch mulch was applied initially (28/7/2016) at a concentration of 2 tons per hectare (air dried). Figure 2 showed that the mulch cover began at approximately 30% and decreased to about 10% over the course of 20 days, a decrease of approximately 1% per day. This rapid decrease is likely due to the acceleration of natural decomposition due to high nitrogen content of vetch mulch as well as high summer temperatures and moist soil conditions. As such, the use of a legume such as vetch may not be the best mulch type to choose to minimize soil evaporation.

Because of the imperfect nature of image processing software, we recommend many replications of plot experiments and frequent image acquisition to mitigate

the occurrence of outliers (such as the last mulch cover point in Figure 2). Evidence of possible soil water content (SWC) changes throughout the growing season have yet to be explored. The possible effect of mulch on evaporation rates and subsequent SWC will be investigated during the spring of 2017 in a similar experiment building upon and enlarging the scale of

the current work. This will be done via a combination of continuous SWC measurement devices placed in-situ prior to crop cultivation as well as using the ^{18}O isotopic mass balance approach of soil and plant materials to separate evapotranspiration into soil evaporation and transpiration.

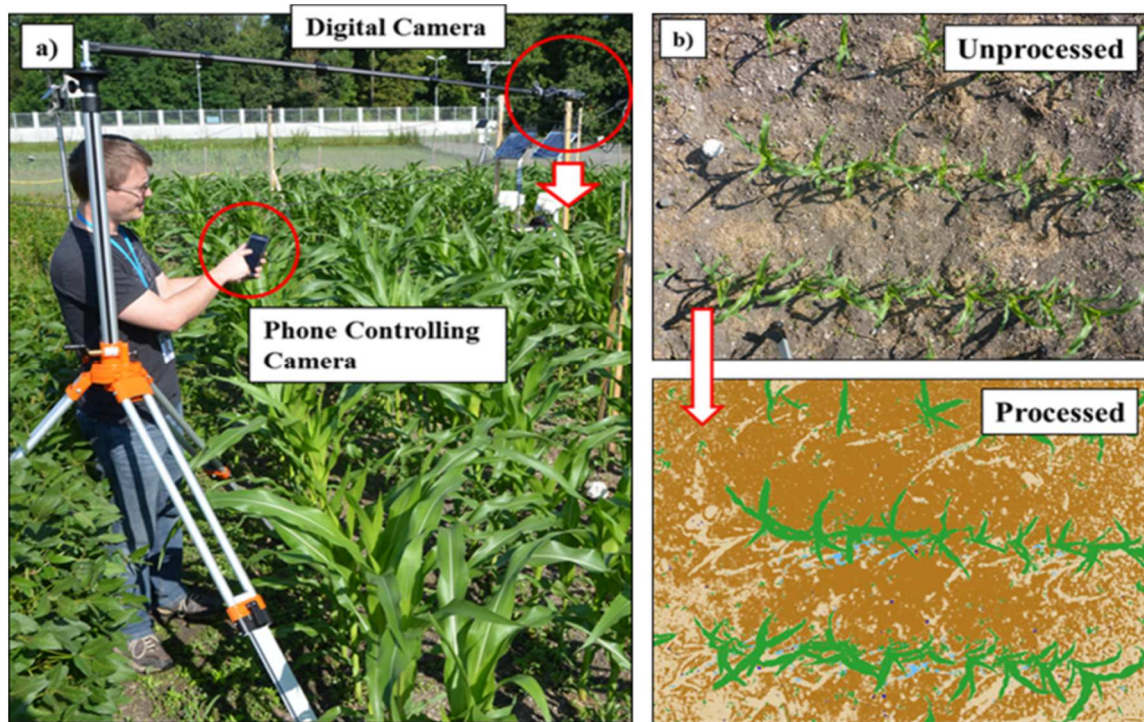


Figure 1. a) Capturing canopy cover at the SWMCNL at Seibersdorf, Austria. b) Example of unprocessed and processed canopy cover images.

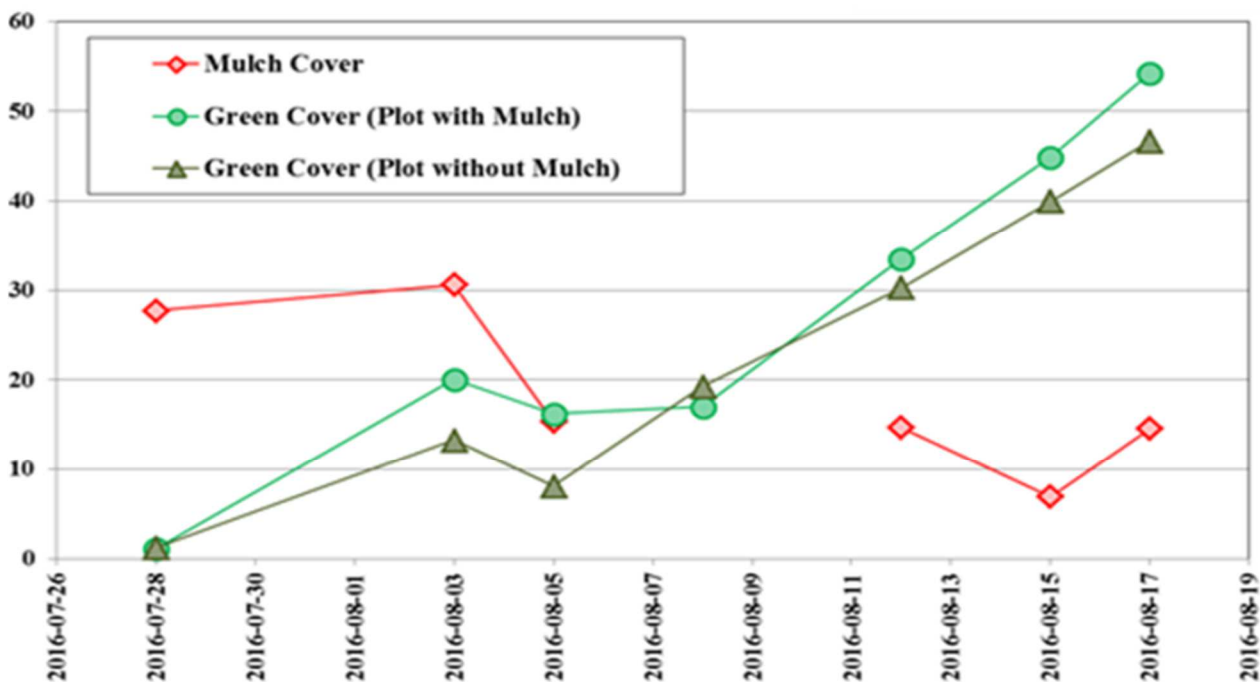


Figure 2. Preliminary mulch experimental maize plots at the SWMCNL near Seibersdorf, Austria. Percentages of green leaf and dead organic matter are shown in a field with added legume mulch and one without

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Websites and Links

- 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>
<http://www-naweb.iaea.org/nafa/news/index-ss.html>
- Food and Agriculture Organization of the United Nations (FAO):
<http://www.fao.org/about/en/>
- FAO Agriculture and Consumer Protection Department
<http://www.fao.org/ag/portal/ag-home/en/>
- FAO/AGL (Land and Water Development Division):
http://www.fao.org/nr/water/landandwater_what.html
- New communication materials outlining successes in the area of nuclear techniques:
<http://www-naweb.iaea.org/nafa/resources-nafa/IAEAsuccessStories-2014.pdf>
<http://www-naweb.iaea.org/nafa/resources-nafa/ProgBrochure-2014.pdf>
<http://www-naweb.iaea.org/nafa/resources-nafa/LabBrochure-2014.pdf>

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