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Nuclear Techniques in Food and Agriculture

Soils Newsletter

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Contents

To Our Readers	1
Staff	3
Feature Articles	6
Announcements	11
Highlights	12
Technical Cooperation Projects	13
Forthcoming Events	16
Past Events	16
Coordinated Research Projects	22
Developments at the Soil and Water Management and Crop Nutrition Laboratory	24
Publications	39
Websites and Links	40

To Our Readers

IAEA 2018 Superior Achievement Award – One House Approach

We are pleased to announce that the Soil and Water Management and Crop Nutrition (SWMCN) Subprogramme received the IAEA 2018 Superior Achievement Award under the category of One-House Approach for the work in Africa. It is a concerted effort between the Joint FAO/IAEA Division, the Division for Africa of the IAEA Technical Cooperation and the Office of Procurement Services, that helped small-scale family farmers, in impoverished rural areas, in Mauritania, Sudan and Zimbabwe, to develop climate-smart agriculture practices not only to produce enough food for their families but also to improve their livelihoods and enhance their resilience to harsh arid climatic conditions. The recipients of this award are: Ms Lee Heng, Mr Mohammad Zaman, Mr Joseph Adu-Gyamfi, Mr Christian Resch from the SWMCN Subprogramme; Mr Abdou Ndiath and Mr Thuloane Tsehlo from TC Africa and Ms Tarah Wilson from Procurement Section. I would wholeheartedly thank the whole SWMCN Subprogramme team who in many ways were behind this wonderful recognition and celebration of our efforts to transfer innovation to those who need it most: the small-scale family farmers in developing countries..

Another highlight is the publication of ‘Two decades of FAO/IAEA supported research and development for combating soil degradation through isotopes’ in Land Degradation & Development Journal. This open-access publication provides an overview on the major achievements of the SWMCN Subprogramme and its collaborators in the development of fallout radionuclides (FRN) and Compound Specific Stable Isotope (CSSI) techniques over the last two decades, along with some key findings of the current CRP D1.50.17.

Two CRPs completed this last six months: D1.20.12 on ‘Optimizing Soil, Water and Nutrient Use Efficiency in Integrated Cropping-Livestock Production Systems’ and D1.20.13 on ‘Landscape Salinity and Water Management for Improving Agricultural Water Productivity’. On the other hand, a new CRP D1.50.18 on ‘Multiple Isotope Fingerprints to Identify Sources and Transport of Agro-Contaminants’ started in July. More information on D1.50.18 is given in this Newsletter. A Consultants Meeting on ‘Use of Cosmic-Ray Neutron Sensor for Irrigation and Extreme Weather Events’ was also held in October to develop a new CRP on ‘Enhancing agricultural resilience and water security using Cosmic-Ray Neutron Technology’. The proposal for the CRP has been submitted for approval.

Good progress has been made on the greenhouse gas work through CRP D1.50.16 on ‘Minimizing Farming Impacts on Climate Change by Enhancing Carbon and Nitrogen Capture and Storage in Agro-Ecosystems’. An interesting feature article on ‘Quantifying future climate change impacts on agricultural systems: Results from a long-term FACE study on grassland’, resulting from this CRP is being prepared. Also, new research to track and trace carbon emissions from soils using natural differences in $\delta^{13}C$ is being carried out in the SWMCN laboratory. It aims to differentiate C3 versus C4 plants in their photosynthesis and determine the proportion of each plant source in different pools of carbon, such as CO_2 emissions from soil respiration.

Interesting results on cassava were also reported under the recently initiated CIALCA (Consortium for Improving Agriculture-based Livelihoods in Central Africa) project with the International Institute for Tropical Agriculture (IITA). The project is to understand how cassava varieties, planting time and nutrient supply adapt to the adverse effects of drought spells, using stable isotope techniques.

Significant progress has been made on validating phosphate purification method for oxygen isotope analysis in different phosphorus fractions of soil, as well as on soil bacterial and fungal diversity as a soil quality indicator. The latter is to determine if there are relationships among soil physicochemical properties, bacterial and fungal community and soil erosion rates as derived from fallout radionuclide information (i.e. $^{239+240}Pu$ and ^{137}Cs). The study on ^{15}N labelling in maize leaves, demonstrated variability which can occur in labelling ^{15}N in plant materials and provided important recommendations for the use of labelled material in ^{15}N studies.

As part of the practical arrangement between the National Agriculture and Food Research Organization (NARO) of Japan and the SWMCN Laboratory, Amelia Lee Zhi Yi from the SWMCN Laboratory was sent to Fukushima for a one-month scientific exchange, to work on optimizing the remediation of radioactive contamination in agriculture, particularly for rice and soybean crops.

We welcome Roel Merckx, Wivine Munyahali and Jonas Van Laere to the SWMCN Laboratory. Roel is a cost-free international visiting scientist on sabbatical leave from the KU Leuven, Belgium; Wivine is from Democratic Republic of Congo, and Jonas a fresh graduate in Bioscience Engineering from the KU Leuven (Belgium). All of them will be working on the CIALCA ‘Consortium for Improving Agriculture-based Livelihoods in Central Africa’ cassava project. We also welcome Janine Halder as a staff member to the SWMCN Section. Janine brings along her expertise in Hydrology and Geochemistry and we look forward to her contribution to the SWMCN Subprogramme.

We bid farewell to Ammar Wahbi, who is retiring after working for five years in SWMCN Laboratory. Ammar pioneered the work on cosmic ray neutron sensor (CRNS) for area-wide soil moisture monitoring and established the link with US, European and Middle-East institutions. Ammar produced many key publications on the calibration and use of CRNS. We will miss the contributions of Ammar in this important area of work.

With the year ending, I would like to take this opportunity to thank you all: our readers for your continuous interest and feedback and my staff for your continuous support. I also wish you a very happy holiday and my very best wishes for 2019..,

Lee Heng
Head
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	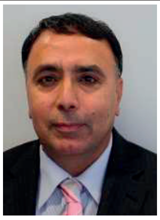		
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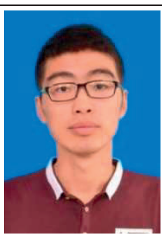
L. Mabit	A. Wahbi	J. Chen	M. Heiling
			
C. Resch	G. Weltin	A. Toloza	R. Gruber
			
N. Jagoditsch	J.M. Mletzko	L. Mayr	S. Fesenko
			
A. Lee-Zhi-Yi	J. Slaets	R. Merckx	H. Zhang
			
J. Zhang	N. Chan	J. Van Laere	

Staff News

After five years of service, **Ammar Wahbi** retired and left the SWMCN Laboratory at the end of December. He joined the SWMCN Laboratory as an FAO Soil Scientist in October 2013. Ammar worked on the development of innovative nuclear technique for improving agricultural water management. Ammar was instrumental in developing the applications of the cosmic ray neutron sensor technology for area-wide soil moisture monitoring, and producing numerous IAEA and external publications. Ammar was very active in building new partnerships with institutions in the USA, Europe and the Middle East, through technical cooperation projects. The SWMCN thanks Ammar for his dedication to enhance nuclear science in the field of soil and water management, and wish him the very best in the coming years of his retirement.

Roel Merckx joined the SWMCN Laboratory for 6 months starting 1st July 2018 as a cost-free international visiting scientist on sabbatical leave from the KU Leuven, Belgium. Roel is a full professor at the Department of Earth and Environmental Sciences, Division of Soil and Water Management. Soil fertility issues and soil organic matter dynamics in weathered soils of Sub-Sahara Africa are his main research focus. In SWMCN Laboratory Roel has explored stable isotope methods to unravel water use efficiency differences between cassava cultivars and how the isotope signals ($^{13}C/^{12}C$; $^{2}H/^{1}H$; $^{18}O/^{16}O$) vary with planting time and nutrient management in ongoing and future field trials in Nigeria, Tanzania and DRC, assisting cooperative projects with International Institute for Tropical Agriculture (IITA) and local universities and NARS in the South.

Wivine Munyahali (Democratic Republic of Congo, DRC) joined the SWMCNL in October 2018 to provide support, as a consultant on research activities within the 'Consortium for Improving Agriculture-based Livelihoods in Central Africa', a project in which SWMCNL is a partner. Wivine, based in Bukavu, the DRC, will assist in research on improving water use efficiency of cassava through the application of stable isotopes (^{13}C and ^{18}O). Wivine is a lecturer and researcher at the Faculty of Agronomy of the Catholic University of Bukavu (UCB) in DRC. She obtained her PhD in Bioscience Engineering from the KU Leuven (Belgium) in 2018. Her work has been focusing on soil and nutrient management of cassava based cropping systems and tropical soil fertility management.

Jonas Van Laere is a fresh graduate in Bioscience Engineering from the KU Leuven, Belgium, with specialization in Agro and Ecosystems Engineering. To gather more practical knowledge, Jonas joined the SWMCN Laboratory in October 2018 as an intern. He works on the application of stable isotopes (^{13}C and ^{18}O) in search for increasing the water use efficiency of cassava. As he did his MSc thesis on diagnosing nutritional needs of cassava plants in Tanzania, this opportunity of working with cassava within the FAO/IAEA Joint Division will help further improve his understanding of the challenges for this important crop.

Janine Halder joined the SWMCN Section as a staff member in November 2018. Janine is an isotope hydrologist, with expertise in Hydrology and Geochemistry. She received her PhD from University of Lausanne, Switzerland. Previously Janine was working with the Isotope Hydrology Section. We welcome Janine to the Section and look forward to her contributions to the SWMCN Subprogramme water-related activities and projects.

The SWMCN Laboratory celebrated **Maria Heiling** and **Arsenio Toloza**, who both received long-term service awards in October 2018. The awards were handed out by the Deputy Director General and Head of the Department of Nuclear Sciences and Applications, Mr. Aldo Malavasi, in recognition of their 20 years of support to the IAEA.

Feature Articles

Quantifying future climate change impacts on agricultural systems: Results from a long-term FACE study on grassland

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1. The Challenge

The world's climate is rapidly changing, which is leading to extreme weather events. A major cause of these extreme weather events is the rising temperature in the Earth's atmosphere, driven by increasing emission of greenhouse gases (GHGs) such as carbon dioxide, methane and nitrous oxide. Climate change (e.g. higher atmospheric CO_2 concentrations, higher air temperatures and varying precipitation patterns) alters the conditions under which crops are growing and will have severe impacts on crop yields, food quality and food security (Högy *et al*., 2009; Andresen *et al*., 2018; Augustine *et al*., 2018). The most realistic research approaches are facilities that operate under natural conditions to simulate expected climatic changes on agricultural systems. If only the factor CO_2 is investigated, we talk about Free *A*ir *C*O_2 *E*nrichment (*FACE*) Experiments, which simulate the effect of future atmospheric CO_2 concentrations on crops in the field to investigate the effects on ecosystem organisms and processes (Hendrey and Kimball, 1994).

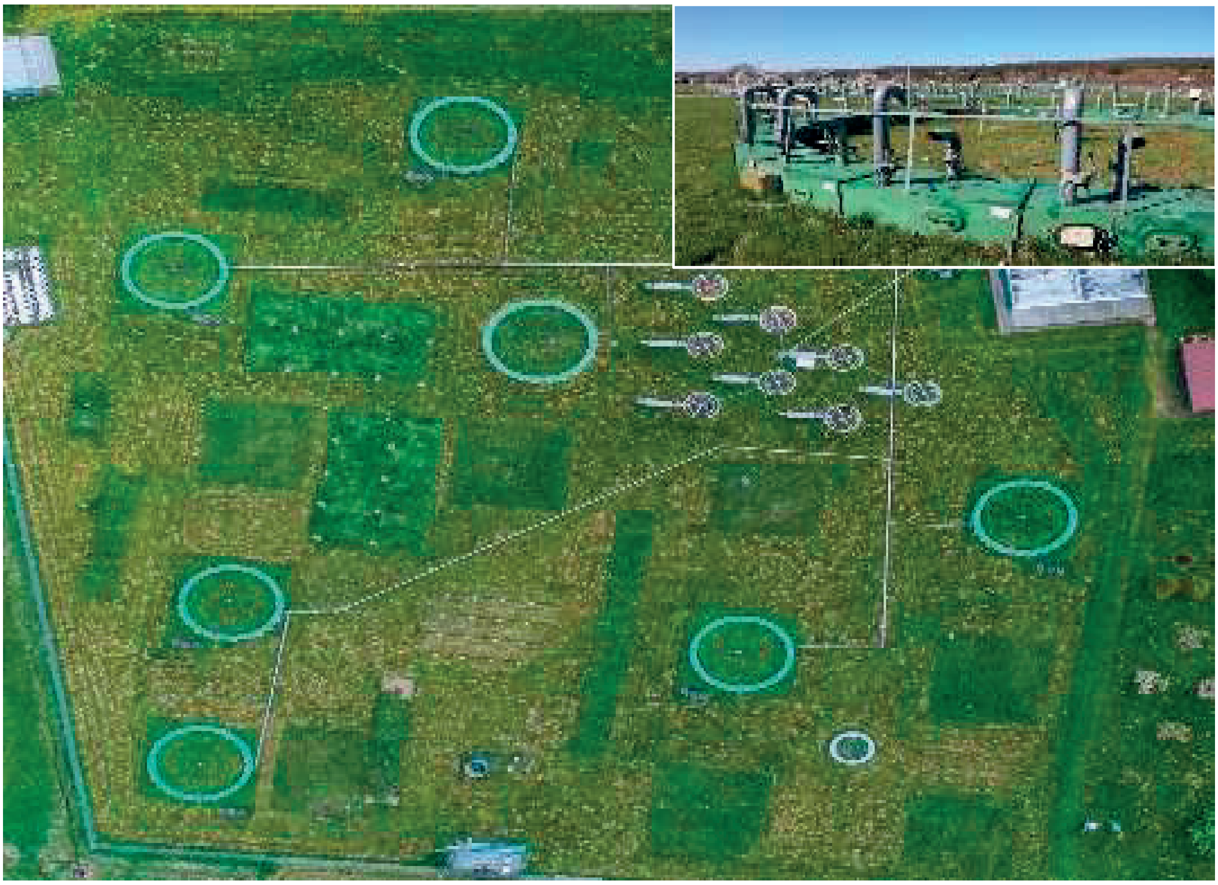

Figure 1. Giessen FACE-study on permanent grassland. This study was initiated in 1998 and is currently one of longest-running FACE studies worldwide. The rings have a diameter of 8 m. © Sebastian Egli, Marburg. The small picture shows a close up of one of the FACE-rings © Eva Diehl

2. The Study

The Institute of Plant Ecology, of the Justus-Liebig-University Giessen, Germany operates one of the worldwide longest running systems of its kind. The two FACE facilities near Giessen, Germany are installed in a species rich, semi-natural permanent temperate grassland, where experimental sites are investigated under a +20% enriched atmospheric CO_2 level compared to ambient conditions. The Giessen FACE started in 1998 in a managed grassland unploughed for more than 100 years. The grassland management since 1995: annual spring fertilization of 40 kg N ha^{-1} yr^{-1} + 600 kg ha^{-1} yr^{-1} Thomaskali (P, K, Mg, Ca), two harvests per year (end of May and beginning of September). The inner diameter of the FACE rings is 8 m, the fumigation is controlled by wind direction and wind speed. It is one of the longest running FACE systems worldwide, owning the longest time series of GHG fluxes under elevated CO_2 (eCO_2) (Andresen *et al.*, 2018).

3. The Technique

Isotopic techniques based on the enrichment of the stable isotopes ^{15}N and ^{13}C were used to identify the processes that contribute to the enhanced GHG output under higher atmospheric CO_2 concentrations (Moser *et al.*, 2018).

4. Major Outputs

Our results clearly showed that grassland ecosystems, which are typically carbon sinks of atmospheric CO_2 will gradually develop to carbon-sources and will contribute more GHG to global warming in the future. The long-term dataset of GHG fluxes showed a +12% increase in annual ecosystem respiration, a +179% increase of annual N_2O emissions and a decrease of CH_4 oxidation (-81%). The CO_2 fertilization effect on aboveground plant biomass production is highest under mesic (well-balanced) temperature and soil moisture conditions and reached a level of +16% during the period 2007-2014 (Andresen *et al.*, 2018). Under very dry and hot, but also very wet growing conditions, the increase in plant growth under eCO_2 is downregulated (Obermeier *et al.*, 2017). In most years the increased water use efficiency of plants under eCO_2 is responsible for slightly higher soil moisture and lower soil temperature compared to control rings. The grassland biomass yield under higher CO_2 was of lower quality, having lower crude protein and nitrogen concentrations, and increased crude fiber content, which would make this less digestible for ruminants.

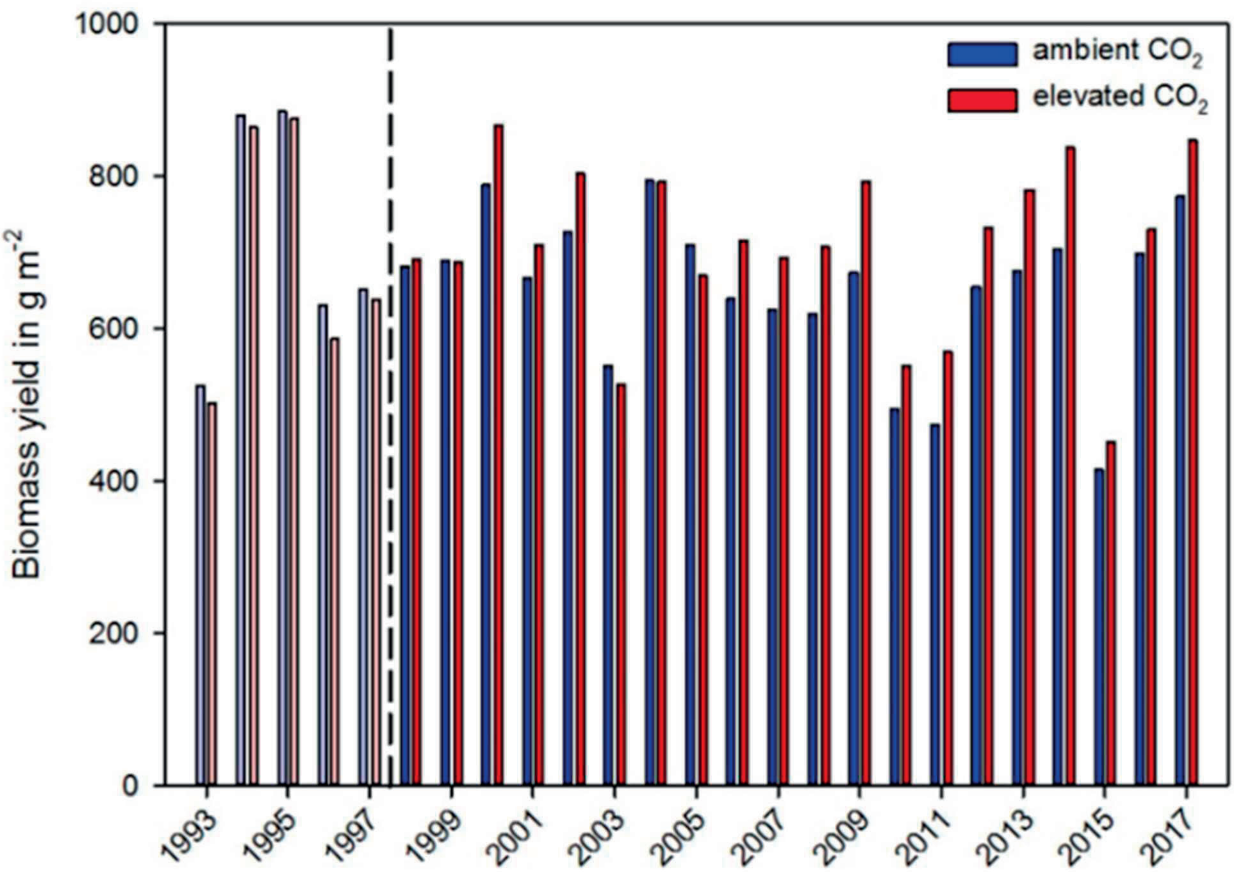

Figure 2. Total aboveground biomass yield in g m^{-2} for pre-treatment 1993 – 1997 and eCO_2-treatment period 1998 – 2017.

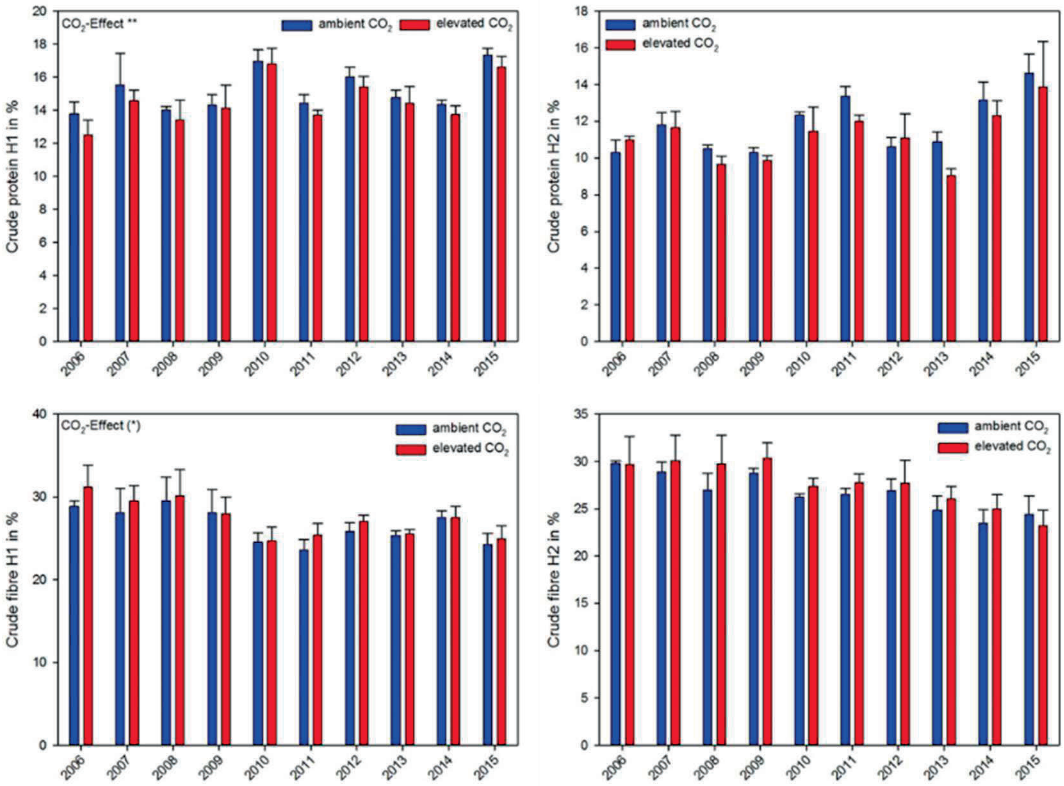

Figure 3. Crude protein and crude fibre concentration in % for total aboveground biomass, separated in harvest 1 (H1) and harvest 2 (H2). Error bars indicate standard deviation. The significance levels of CO_2-effect were reported as much significant $p \leq 0.01$ [**] and significant by tendency $p \leq 0.1$ [(*)].

5. Elevated Temperature

In a newly established system, the combined effect of elevated CO_2 and increased temperature are investigated. The technique relies on the increase of air temperature and minimizes therefore biases using other techniques, like IR-lamps or electric soil heating.

Controlled by wind direction and wind speed, heating elements are turned on and increase the air temperature in circular plots to achieve a +2°C increase compared to ambient conditions. There are separate rings for air heating, CO_2 enrichment and its combination in three replicates each. More than 300 sensors are installed and attached to automated data logger systems. Soil air probes and wick-samplers allow the sampling of gas and water samples from different soil depths, with dynamic and static chambers the greenhouse gas fluxes are measured weekly.

6. Outlook

The existing dataset of the Giessen FACE revealed large temporal variation of the effect size of eCO_2 on biomass production and ecosystem processes. The CO_2 fertilization effect is modulated by seasonal precipitation pattern and temperature sequence. Both FACE facilities are long-term experiments because of the response time of ecosystems to changing conditions – which requires also long-term funding strategies for more than a decade. Long-term-series are absolutely essential to predict the interaction of climatic variables on ecosystems, in particular if all possible environmental conditions, e.g. wet versus dry growing seasons or hard frost versus heat waves, or frost-thaw cycles should be taken into account. Thus, field experiments of this kind should be setup for operation time of at least a decade. The funding of such long-term projects remains a challenge for scientists and university management, but is crucial for valuable scientific insights and the amelioration of future projections of climate change impacts.

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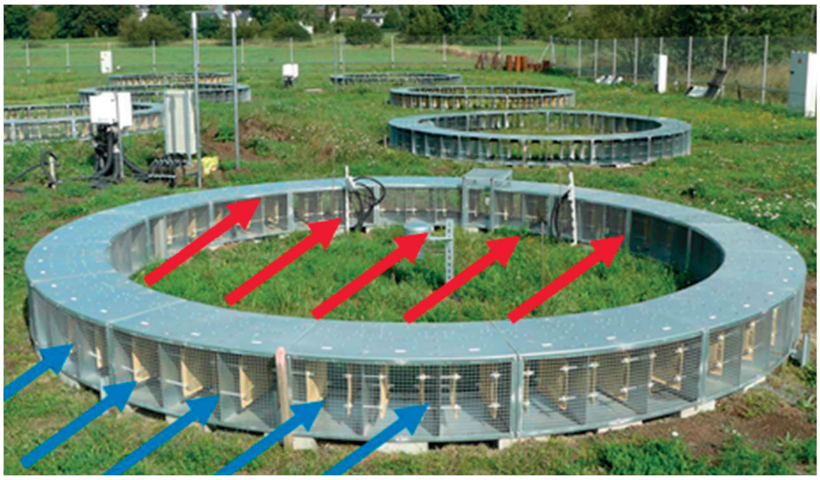

Figure 4. Giessen T-FACE (free air Temperature warming and Free Air CO_2 Enrichment) facility on the permanent grassland. This study started in 2018, its inner diameter is 4.3 m and the heating elements controlled by wind direction and speed can heat the air inside the rings to +2°C above ambient air temperature simultaneously to a +20% increase of CO_2 concentration. © Gerald Moser

Högy, P., Wieser, H., Köhler, P., Schwadorf, K., Breuer, J., Franzaring, J., Muntifering, R., Fangmeier, A. (2009). Effects of elevated CO_2 on grain yield and quality of wheat: results from a 3-year free-air CO_2 enrichment experiment. *Plant Biology 11*. 60-69.

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Two decades of FAO/IAEA supported research and development for combating soil degradation through isotopes

Mabit, L.[1], Bernard, C.[2], Lee Zhi Yi, A.[1], Fulajtar, L.[1], Dercon, G.[1], Zaman, M.[1], Toloza, A.[1], Heng, L.[1]

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This feature article is a short summary of the paper written within the IAEA CRP D1.50.17 on "*Nuclear techniques for a better understanding of the impact of climate change on soil erosion in upland agro-ecosystems*" and published with open-access in September 2018 in the Land Degradation & Development peer-reviewed journal (Mabit et al. 2018). It provides an overview and emphasizes the major achievements of IAEA and its external collaborators in the development of fallout radionuclides (FRN) and Compound Specific Stable Isotope (CSSI) techniques over the last two decades and it reports also the key findings of the recently running CRP D1.50.17. In addition, the last section of the paper (Mabit et al., 2018) presents benefits gained by IAEA Member States and FAO Member Countries through dissemination of the CRP's results by related Technical Cooperation pojects (TCPs). Successful examples of the impact obtained in Morocco, Madagascar and Vietnam in using FRN and CSSI techniques have been highlighted.

The Soil and Water Management and Crop Nutrition (SWMCN) Subprogramme has made significant contributions to the development and refinement of cost-effective isotopic techniques to localise degraded agricultural areas, to evaluate soil redistribution magnitudes from field to watershed scales, to assess the effectiveness of soil conservation strategies and, more recently, to establish the origin of the mobilised and deposited sediment.

These techniques, that have deepened our understanding of soil erosion and its related agro-environmental impacts, include FRN such as caesium-137 (^{137}Cs), excess lead-210 ($^{210}Pb_{ex}$), beryllium-7 (^{7}Be) and plutonium-239 & 240 ($^{239+240}Pu$) as well as carbon-13 (^{13}C) stable isotope and CSSI analyses (Figure 1). During the last 20 years, these methodologies were developed and refined through the work of researchers from developed and developing countries in five IAEA's Coordinated Research Projects (CRPs).

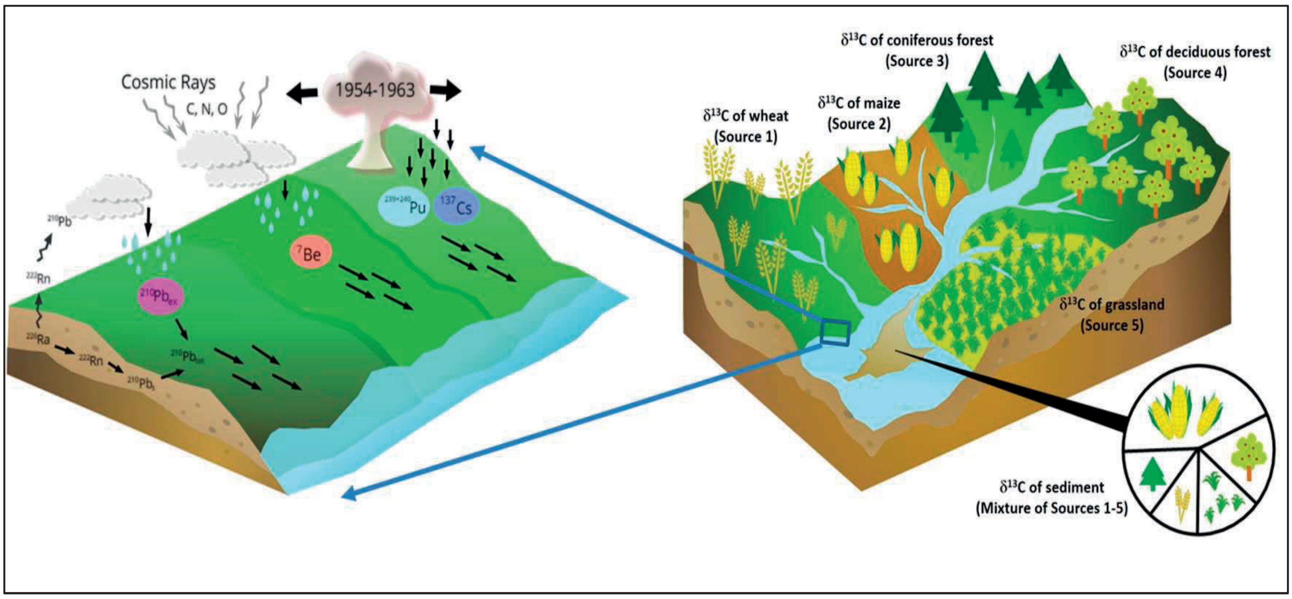

Figure 1. Main isotopic techniques being used at the SWMCN Laboratory to investigate soil and sediment transfer/redistribution (Adapted from Mabit et al., 2018)

To support these established CRP network, several research and development activities have been implemented since 2005 at the SWMCN Laboratory in Seibersdorf. One major milestone of the SWMCN Subprogramme was the publication in 2014 of a specific guideline for using FRN techniques to assess soil erosion processes and to evaluate the effectiveness of soil conservation strategies. This guideline summarises most of the knowledge gained through 20 years of partnerships and scientific collaborations with our Member States (IAEA, 2014).

The developed methodology has been subsequently disseminated by IAEA's Technical Cooperation Programme (Figure 2) to assist Member States to reduce soil degradation and to adopt climate-smart agriculture. To date, more than 70 FAO Member Countries and IAEA Member States have benefitted from the technical support and guidance of the SWMCN Subprogramme in using FRN and CSSI techniques to trace soil redistribution and evaluate soil loss at various spatial and temporal scales, and to quantify concretely soil conservation effectiveness for ensuring sustainable local and regional land management.

The SWMCN Subprogramme has played a major role in supporting the transition of nuclear and isotopic techniques from a pure research technique to a decision support tool. Scope for improvement remains in reinforcing the accuracy of these techniques and refining some operational parameters, but scientific evidence has demonstrated that the combined use of stable and radioisotopic tracers provides crucial information to guide decisions on the management of critically degraded areas and may support land managers to implement appropriate soil conservation measures.

We would like to thank all the previous and current CRP and TCP participants as well as our external collaborators across the world and previous IAEA colleagues that were or still are instrumental in supporting the SWMCN Subprogramme activities for combating soil degradation.

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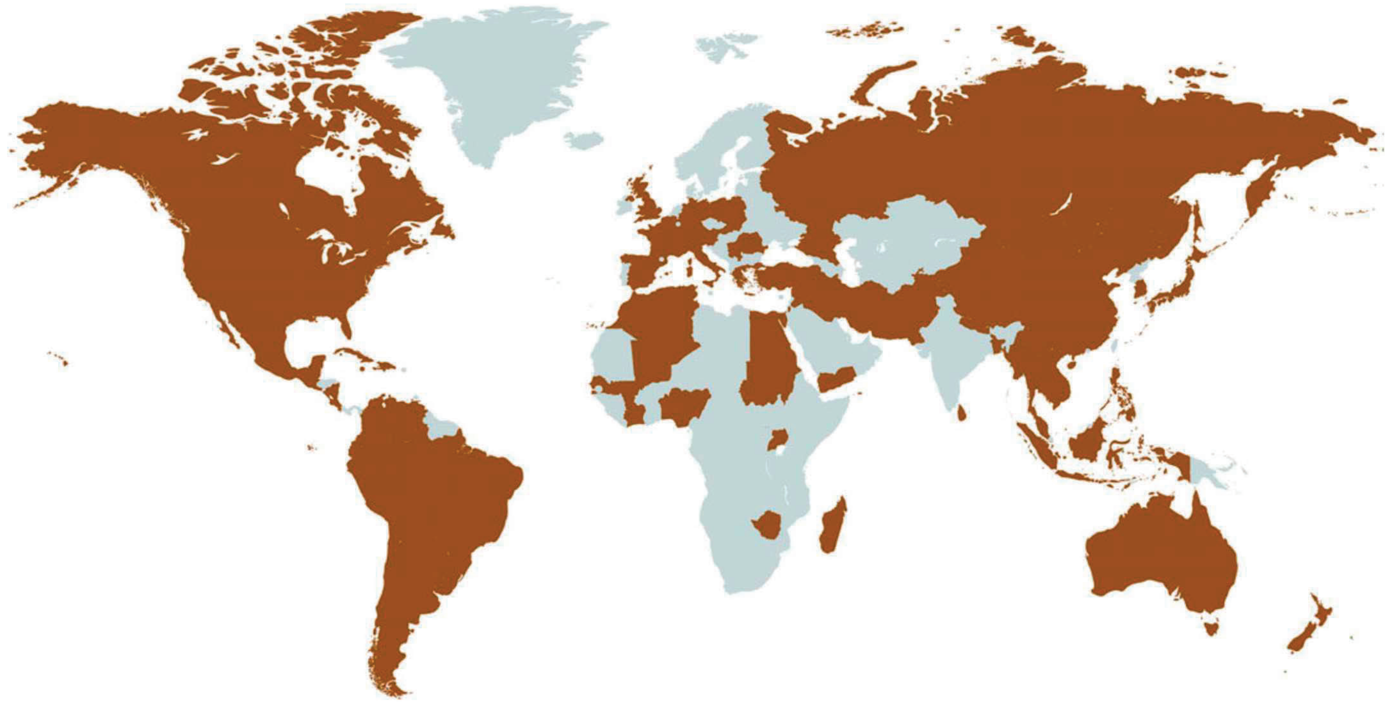
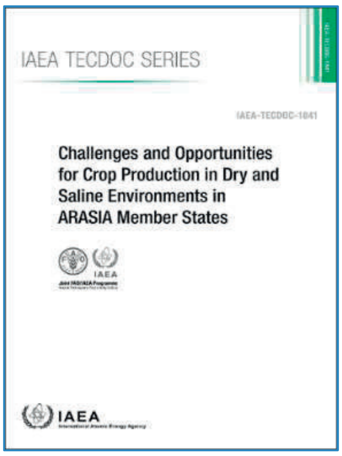


Figure 2. Countries that have benefited from FRN and CSSI techniques disseminated by the SWMCN Subprogramme *(Adapted from Mabit et al., 2018)*

Announcements

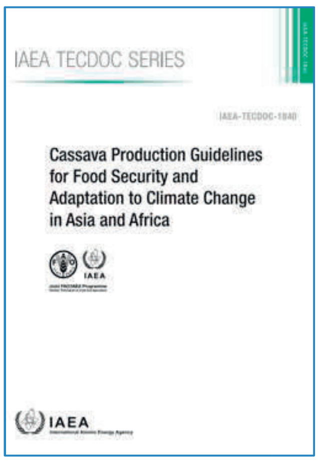
New FAO/IAEA Publications

Challenges and Opportunities for Crop Production in Dry and Saline Environments in ARASIA Member States (IAEA-TECDOC 1841)



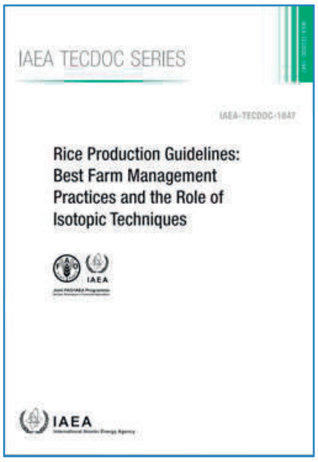
This publication serves as a guide for Member States needed to improve the agricultural production in dry and saline areas. It is particularly important for the Middle East Region and all other countries having arid and semiarid climate. All information and recommendations given in this guide are based on successful and sound practices applied in pertaining Member States for sustainable cropping of salt affected soils. It will help scientists and farmers to select management alternatives most efficient for agriculture in saline environments within their own countries. The publication also focuses on the possible use of isotopic techniques in dealing with salinity and droughts conditions affecting crop production.

Cassava Production Guidelines for Food Security and Adaptation to Climate Change in Asia and Africa (IAEA- TECDOC 1840)



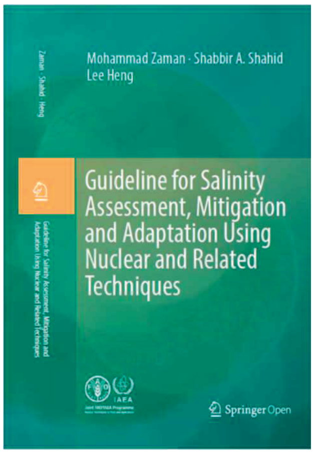
This publication is prepared on special request from Member States in Asia and Africa working together in IAEA technical cooperation projects to enhance cassava production. It provides information on the best farm management practices and the role of nuclear and isotopic techniques to better understand nitrogen use efficiency. Its use will allow farmers to adapt their cassava production methods to a wide range of soil and agro climatic conditions.

Rice Production Guidelines: Best Farm Management Practices and the Role of Isotopic Techniques (IAEA-TECDOC 1847)



This publication is prepared on special request from Member States in Asia working together in IAEA techncal cooperation projects to enhance rice production and provide information on the best management practices and the role of nuclear techniques to quantify nitrogen use efficiency and better understand the pathways of greenhouse gase (GHG) emission. This publication attempts to bring together improved rice varieties and sustainable cultivation practices from a wide range of Asian countries. These guidelines will help farmers in countries with low rice yields to improve the productivity and profitability of their rice crops through the adoption of locally adapted 'best' rice varieties together with optimal crop management practices.

Guideline for Salinity Assessment, Mitigation and Adaptation Using Nuclear and Realted Techniques



This OPEN access Springer book aims to provide updated information on protocols for salinity and sodicity assessment, and the role of isotopic and nuclear techniques to develop mitigation and adaptation measures to make the most use of saline land. We have focused on important issues related to salinity and sodicity and have described these in an easy and user-friendly way.

Highlights

IAEA Scientific Forum 2018

The IAEA Scientific Forum 2018 on Nuclear Technology for Climate: Mitigation, Monitoring and Adaptation was held on 18–19 September 2018 https://www.iaea.org/newscenter/news/what-nuclear-technology-can-offer-to-address-climate-change-conclusions-of-the-scientific-forum, during the 62nd IAEA General Conference. The work of SWMCN Subprogramme was well-represented at the Scientific Forum. In Session 2: Monitoring and measuring the change, Mr Heitor Evangelista da Silva, Professor, Department of Biophysics and Biometrics, Rio de Janeiro State University, Brazil presented "Past climate conditions", while Mr Christoph Müller, Professor, Justus-Liebig-Universität Gießen, Germany presented "Processes and sources" under Greenhouse gas emissions from agriculture. Similarly under Session 3: Adapting to a changing environment, Managing agricultural water and land degradation: Mr Emmanuel Chikwari, Chief Research Officer, Chemistry and Soil Research Institute, Department of Research and Specialist Services, Ministry of Agriculture, Mechanization and Irrigation Development, Zimbabwe presented "Managing agricultural water and land degradation" the programme of the Scientific Forum can be accessed at the following link: https://www.iaea.org/newscenter/multimedia/videos/scientific-forum-2018-session-3-adapting-to-a-changing-environment

Superior Achievement Award

The SWMCN Section and Laboratory was awarded the IAEA Superior Achievement Award under the category of One-House Approach, at a ceremony that took place on November 14, 2018. Through stable isotope nitrogen-15 and soil moisture sensors (neutron probe), the most effective use of fertilizer and water for crop production was determined. The work involved training local experts in the use of the nuclear techniques and transferring the knowledge to farmers, as well as installing small-scale family drip irrigation systems, suited to local needs. The implementation of this climate-smart agricultural practice produced measurable socio-economic impacts for small-scale farmers, especially women, children and refugees, in impoverished rural areas and villages in Mauritania, Sudan and Zimbabwe. Pictures of the ceremony and the link to the video are shown below: https://iaeacloud.sharepoint.com/sites/intranet/newsandevents/newsstories/Lists/Posts/Post.aspx?ID=124

Technical Cooperation Field Projects

Country/Region	TC Project	Description	Technical Officer(s)
Afghanistan	AFG5007	Enhancing Wheat Productivity Through Best Nutrient and Water Management Practices Under Rainfed and Supplemental Irrigation Systems	M. Zaman
Algeria	ALG5030	Contributing to the Implementation of the National Agricultural Development Programme Through Strengthening Soil, Water and Nutrient Management Practices Including Food Safety Using Nuclear and Related Techniques	M. Zaman in collaboration with FEP
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
Benin	BEN5012	Enhancing legume production in cereal-livestock cropping systems for food, wealth and soil health through the use of bio fertilizers (inoculum) in Benin	J. Adu-Gyamfi
Bolivia	BOL5021	Strengthening the Strategic Development Plan for Quinoa Production through Improved Use of Organic Manure, Soil and Crop Management	M. Zaman
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	BKF5019	Improving food and nutrition security using integrated isotopic and breeding mutation on Sorghum, Rice, Cowpea, Bambara nut and sesame in Burkina Faso	J. Adu-Gyamfi in collaboration with PBG
Burundi	BDI5001	Improving Cassava Productivity through Mutation Breeding and Better Water and Nutrient Management Practices Using Nuclear Techniques	M. Zaman in collaboration with PBG
Central African Republic	CAF5011	Building National Capacities for Improving the Efficiency of Biological Nitrogen Fixation for Food Security, Fertility Restoration and Rehabilitation of Degraded Soils	M. Zaman
Cambodia	KAM5005	Enhancing Soil, Water and Nutrient Management for Sustainable Rice Production and Optimized Yield	J. Adu-Gyamfi
Costa Rica	COS5033	Assessing and Implementing Biochar Use in Climate Smart and Environmentally Friendly Pineapple Production Using Isotopic Techniques	M. Zaman in collaboration with FEP
Costa Rica	COS5035	Building Capacity for the Development of Climate-Smart Agriculture in Rice Farming	M. Zaman
Dominica	DMI0002	Building National Capacity for the Use of Nuclear Applications in Relevant Sectors	J. Adu-Gyamfi
Gabon	GAB5003	Building National Capacities for Monitoring Sedimentation of Dams and Harbors and the Management of Remediation Operations	E. Fulajtar
Indonesia	INS5043	Intensifying Quality Soybean Production in Indonesia to achieve self-sufficiency	J. Adu-Gyamfi in collaboration with PBG
Interregional project	INT0093	Applying Nuclear Science and Technology in Small Island Developing States in Support of the Sustainable Development Goals and the SAMOA Pathway	J. Adu-Gyamfi
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

Country/Region	TC Project	Description	Technical Officer(s)
Iraq	IRQ5020	Restoring Biomass Productivity of Range Land by Using Nuclear Techniques and Advanced Technology	A. Wahbi
Jamaica	JAM5012	Optimizing Irrigation Water Management to Improve Crop Output and Water Quality Control	L. Heng
Kuwait	KUW5004	Improving Production and Water Use Efficiency of Forage Crops with Nuclear Techniques	A. Wahbi
Laos	LAO5004	Enhancing National Capability for Crop Production and Controlling Trans-Boundary Animal Diseases	M. Zaman in collaboration with APH
Lesotho	LES5008	Improving Soil Fertility for Enhanced Cereal Production in Lesotho	J. Adu-Gyamfi
Madagascar	MAG5025	Biocontrol of Striga asiatica (L.) Kuntze through the development of tolerant rice and maize lines and its impact on microbiological and ecological functioning of soil	J. Adu-Gyamfi in collaboration with PBG
Malawi	MLW5003	Developing Drought Tolerant, High Yielding and Nutritious Crops to Combat the Adverse Effects of Climate Change	E. Fulajtar in collaboration with PBG
Malaysia	MAL5031	Establishing an Environmentally Sustainable Food and Fodder Crop Production System	E. Fulajtar in collaboration with PBG and APH
Mali	MLI5028	Improving Water Use Efficiency, Soil Fertility Management Practices and the Resilience of Cultures to Climate Variability and Change	L. Heng
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 PBG
Myanmar	MYA5027	Monitoring and Assessing Watershed Management Practices on Water Quality and Sedimentation Rates of the Inle Lake - Phase II	L. Heng
Namibia	NAM5016	Developing Drought Tolerant Mutant Crop Varieties with Enhanced Nutritional Content	J. Adu-Gyamfi in collaboration with PBG
Oman	OMA5006	Using Isotopes and Nuclear Techniques in Integrated Water, Soil and Nutrients Management to Optimize Crop Productivity	J. Adu-Gyamfi
Pakistan	PAK5051	Developing Isotope-Aided Techniques in Agriculture for Resource Conservation and Climate Change Adaptation and Mitigation	M. Zaman
T.T.U.T.J of T. Palestinian A	PAL5008	Reducing Soil Degradation by Improving Soil Conservation using Fallout Radionuclides (Phase II)	E. Fulajtar
Philippines	PHI5034	Applying Nuclear Techniques in the Attenuation of Flood and Natural Disaster-Borne Contamination	E. Fulajtar
Qatar	QAT5007	Improving Productivity of Ikhlas and Berhi Date Palm Varieties	A. Wahbi
Regional project Africa	RAF0046	Promoting Technical Cooperation among Developing Countries through Triangular Partnerships and Sustaining Regional Ownership of the AFRA Programme [Bilateral TC project between Morocco and Côte d'Ivoire]	L. Mabit
Regional project 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
Regional project Africa	RAF5079	Enhancing Crop Nutrition and Soil and Water Management and Technology Transfer in Irrigated Systems for increased Food Production and Income Generation (AFRA)	L. Heng
Regional project Asia	RAS5070	Developing Bioenergy Crops to Optimize Marginal Land Productivity through Mutation Breeding and Related Techniques (RCA)	M. Zaman in collaboration with PBG

Country/Region	TC Project	Description	Technical Officer(s)
Regional project Asia	RAS5073	Climate Proofing Rice Production Systems (CRiPS) Based on Nuclear Applications, Phase II	L. Heng in collaboration with PBG
Regional project Asia	RAS5080	Developing Sustainable Agricultural Production and Upscaling of Salt-Degraded Lands through Integrated Soil, Water and Crop Management Approaches - Phase III	M. Zaman
Regional project Asia	RAS5083	Reducing greenhouse gas emissions from agriculture and land use changes through climate smart agricultural practices	M. Zaman
Regional project Asia	RAS5084	Assessing and improving soil and water quality to minimize land degradation and enhance crop productivity using nuclear techniques	J. Adu-Gyamfi
Regional project Latin America	RLA5076	Strengthening Surveillance Systems and Monitoring Programmes of Hydraulic Facilities Using Nuclear Techniques to Assess Sedimentation Impacts as Environmental and Social Risks (ARCAL CLV)	E. Fulajtar
Regional project Latin America	RLA5077	Enhancing Livelihood through Improving Water Use Efficiency Associated with Adaptation Strategies and Climate Change Mitigation in Agriculture (ARCAL CLVIII)	L. Heng
Regional project Latin America	RLA5078	Improving Fertilization Practices in Crops through the Use of Efficient Genotypes in the Use of Macronutrients and Plant Growth Promoting Bacteria (ARCAL CLVII)	J. Adu-Gyamfi
Senegal	SEN5039	Supporting Eco-Intensification of Agriculture in Small-Scale Farming Systems by Improving Water and Nutrient Management	M. Zaman
Serbia	SRB5003	Strengthening the Capacities for Soil Erosion Assessment Using Nuclear Techniques to Support the Implementation of Sustainable Land Management Practices	E. Fulajtar
Seychelles	SEY5011	Supporting Better Sustainable Soil Management as Climate Change Adaptation Measures to Enhance National Food and Nutrition Security	L. Heng
Slovenia	SLO5004	Improving Water Quality in Vulnerable and Shallow Aquifers under Two Intensive Fruit and Vegetable Production Zones	J. Adu-Gyamfi and J. Halder
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	J. Adu-Gyamfi in collaboration with PBG
Togo	TOG5002	Improving Crop Productivity and Agricultural Practices Through Radiation Induced Mutation Techniques	E. Fulajtar in collaboration with PBG
Zambia	ZAM5031	Improving the Yield of Selected Crops to Combat Climate Change	L. Heng in collaboration with PBG
Zimbabwe	ZIM5021	Assessing and Promoting Sustainable Agricultural Production in Communal and Newly Resettled Farms	L. Mabit in collaboration with PBG

Forthcoming Events

FAO/IAEA Events

Training Course of Interregional Technical Cooperation Project INT0093 on 'Applying Nuclear Science and Technology in Small Island Developing States in Support of the Sustainable Development Goals and the SAMOA Pathway', 18 – 22 February 2019, Suva, Fiji.

Technical Officers: J. Adu-Gyamfi and L.Heng

Regional Training Course and Mid-term Coordination Meeting of Technical Cooperation Project RLA5077 on 'the use of AquaCrop model to improve water use efficiency and crop productivity', 11 – 21 March 2019, Montevideo, Uruguay

Technical Officer: L. Heng

Training Course of Regional Technical Cooperation Project RAS5084 on 'Advanced Application of Stable Isotopes for Soil and Water Quality Investigations', 25 – 29 March 2019, Nanning, China

Technical Officer: J. Adu-Gyamfi

Final assessment meeting of INT5153
Assessing the Impact of Climate Change and its Effects on Soil and Water Resources in Polar and Mountainous Regions', 1 – 5 April 2019, Vienna, Austria.

Technical Officer: G. Dercon and J. Slaets

Non-FAO/IAEA Events

International Scientific Conference "XXII Dokuchaev Conference for Young Scientists" Soil as the System of Functional Connections in Nature, 25 February – 1 March 2019, Saint-Petersburg, Russia.
http://www.dokuchaevskie.ru/?lang=en

Intersoil 2019 - International Conference on Soil, Sediments and Water, 26 – 28 March 2019, Lille, France.
https://www.intersol.fr/

The European Geoscience Union (EGU) General Assembly 2019, Vienna, Austria, 7 – 12 April 2019.
https://egu2019.eu/

Sustainable Use and Management of Soil, Sediment and Water Resources, 15th International Conference, 20 – 24 May 2019, Antwerp, Belgium.
https://www.iuss.org/files/call_acs2019_a3_15112018_extdeadline.pdf

Past Events

FAO/IAEA Events

First Coordination Meeting of RLA5076 'Strengthening Surveillance Systems and Monitoring Programmes of Hydraulic Facilities Using Nuclear Techniques to Assess Sedimentation Impacts as Environmental and Social Risks', 23-27 April 2018, Havana, Cuba

Technical Officer: E. Fulajtar

The overall objective of the 1st Coordination Meeting of RLA5076 was to evaluate the state of the art of erosion and sedimentation research in Latin America, assess the capacities of research teams of project partners, develop the national work plans and agree on the overall project work plan for 2018. This new regional technical cooperation project in Latin America and Caribbean is very challenging because it intends to work on integration of three different groups of nuclear techniques related to soil erosion and siltation of water reservoirs - fallout radionuclides (FRN), compound specific stable isotope analysis (CSSI) and water isotopes. The project partners presented the objectives and study designs of national case studies. The meeting involved also technical excursion to studysite of Center of Radiation Protection and Hygiene.

Participants of the 1st CM of RLA5076 in Havana during excursion at experimental station of the host institution

The major result of the meeting was the development of the designs of national case studies (geographical characterization and sampling designs for each of the three nuclear techniques (FRN, CSSI and water isotopes)). Other important results were the planning of expert missions for 2018 and first half of 2019 and the preparation of First Regional Training Course in Peru.

First Coordination Meeting of RAS5083 'Reducing Greenhouse Gas Emissions from Agriculture and Land Use Changes Through Climate-Smart Agricultural Practices', 2 - 6 July 2018 Nanjing, China

Technical Officer: M. Zaman

The first coordination meeting of RAS5083 project on 'Reducing Greenhouse Gas Emissions from Agriculture and Land Use Changes Through Climate-Smart Agricultural Practices' was held at the Institute of Soil Science, Chinese Academy of Sciences, Nanjing, China, from 2 - 6 July 2018. Total of 26 participants attended this meeting from 19 Member States including Bangladesh, Bahrain, Cambodia, China, Iraq, Iran, Jordan, Kuwait, Lao PDR, Malaysia, Myanmar, Nepal, Oman, Pakistan, Papua New Guinea, Philippines, Saudi Arabia, Sri Lanka, Yemen. The meeting was formally opened by Prof. Renfang Shen, Director General, Institute of Soil Science, Chinese Academy of Sciences followed by presentations from IAEA PMO Mr Ho-Seung Lee and technical officer Mr Mohammad Zaman. The main objective of RAS5083 is to establish climate-smart agricultural systems in Member States, with increased farm profitability and reduced environmental footprints. After one week of coordination meeting, a one-week workshop of lectures and hands-on training was held to provide advanced knowledge and skills to participants on the role of nuclear and isotopic and related techniques to quantify GHGs and develop climate-smart agricultural practices for its mitigation. Prof Christoph Müller and John Goopy provided the training.

Participants of the 1st Coordination meeting in Nanjing, China

First Research Coordination Meeting of the on CRP D1.50.18 'Multiple isotope fingerprints to identify sources and transport of agro-contaminants', 2–6 July 2018, Vienna, Austria.

Project Officers: J. Adu-Gyamfi and L.Heng

This first research coordination meeting (RCM) of this coordinated research project (CRP) was held from 2 to 6 July 2018 in Vienna, Austria. The meeting brought together scientists who had applied multi-isotope tracer approaches to investigations of catchment water quality (e.g. tracing sources, pathways, biogeochemical processes) or were interested in learning more about these methods. Fifteen-member states participating in this CRP including eight research contract holders from Cambodia, China, Ghana, India, Morocco, Romania, Sri Lanka and Viet Nam; six agreement holders each from Austria, France, Germany, Ireland, Japan and Switzerland; and one technical contract holder from Australia. A Senior Environmentalist, World Bank Romania Country Office in Bucharest and two staff from the Ministry of Waters and Forestry Romania participated in the meeting as observers. The FAO Land and Water Division (CBL) was represented by three observers. The objectives of the CRP are to (1) develop protocols and methodologies for using multiple stable isotope tracers to monitor soil, water and nutrient pollutants from agriculture, (2) establish proof-of-concept for an integrated suite of analytical stable isotope tools, and (3) create guidelines to adapt the new toolkit to a variety of agricultural management situations. Combined stable isotope ($\delta^{18}O$, $\delta^{2}H$, $\delta^{13}C$, $\delta^{15}N$,' $\delta^{13}C$-DIC, $\delta^{15}N$-NO_3 $\delta^{18}Op$, $\delta^{34}S$) techniques and compound specific isotope (CSIA)-based monitoring approach for evaluating in-situ degradation, transport, transformation and fate of pesticides will be used. Three draft guidelines were presented and discussed: (1) for designing a water sampling program for stable isotopes studies of agricultural pollution, (2) on compound specific isotope analysis for investigation the source and transport of pesticides from soils to water bodies, and (3) on oxygen isotopes in phosphate for tracing sources of P in soil and catchment. Participants visited the Soil and Water Management and Crop Nutrition Laboratories in Seibersdorf on 5 July 2018 to see the on-going activities and the facilities.

Participants of the 1st Research Coordination Meeting of the CRP D1.50.18

Regional Training Course on the Application of FRNs and Stable Isotopes for Soil Quality and Soil Erosion Investigation, 6–10 August 2018, Da Lat, Viet Nam

Technical Officer: J. Adu-Gyamfi

The purpose of this one-week regional training course is to provide (1) basic training on site identification, characterization, sampling design & techniques, sample preparation for FRN and (2) theoretical principles on the use of stable isotopes to monitor and track sediments. Twenty-one participants from 13 countries: Bangladesh, Fiji, India, Indonesia, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Thailand and Vietnam attended the course. The training was conducted by an IAEA expert, Mr Yong Li and staff from Center for Environment Research and Monitoring of Da Lat Nuclear Research Institute. The trainees visited the field for onsite identification, sampling design, sampling techniques, sample preparation, soil sample analysis with the gamma spectrometer. The participants exchange their experiences in the study using FRNs in soil erosion assessment.

Group photo of the RAS 5084 participants

Kick-off Meeting of the project "A cloud-based system for high resolution soil moisture over Austria", 12-13 September 2018, Vienna, Austria

Technical Officers: A. Wahbi and E. Fulajtar

From 12 to 13 September, the Austrian Space Institute kicked off a new project, titled "A cloud-based system for high resolution soil moisture over Austria" in close collaboration with ten Austrian partners including the SWMCN Subprogramme. The kick-off meeting was held at Technical University of Vienna (TUW). It was attended by representatives of SWMCN Section (Mr Ammar Wahbi and Mr. Emil Fulajtar) because the meeting agenda was related to the objectives of new CRP on use of Cosmic Ray Neutrone Sensor for irrigation scheduling and extreme weather event management, which is recently under the preparation at SWMCN section.

The objective of the BMon (Bodenfeuchte-Monitor) project is to develop a cloud-based system for real-time monitoring of soil moisture conditions over Austria at high-resolution (100 m). An innovative method of integrating data from multiple satellites and different numerical models will be used to provide reliable soil moisture estimates. The system will be setup in a modular fashion on a cloud platform, which shall guarantee a seamless integration of system components to tailor the data workflow to a diverse set of applications. In view of the three main application domains considered in this project (meteorology, hydrology and agronomy) three different models will be used. Their outputs will be inter-compared with in situ data and other key variables which are known to be closely related to soil moisture (such as precipitation, runoff, vegetation status). Mr. Wahbi delivered a presentation on "Area-wide soil moisture monitoring through stationary and backpack cosmic ray neutron sensors – progress from FAO/IAEA Laboratory in Seibersdorf, Austria".

First Regional Training Course of RLA5076 'Strengthening Surveillance Systems and Monitoring Programmes of Hydraulic Facilities Using Nuclear Techniques to Assess Sedimentation Impacts as Environmental and Social Risks', 17-28 September 2018, Lima/Piura, Peru

Technical Officer: E. Fulajtar

The purpose of this regional training course was to reinforce the knowledge of the participants on the use of fallout radionuclide (FRN): ^{137}Cs, $^{210}Pb_{ex}$ and ^{7}Be as soil tracers, compound specific stable isotope (CSSI) analyses of ^{13}C and water isotopes (^{18}O, D) for investigation of the erosion – transport – sedimentation cycle at watershed level and the pollution of water resources and sedimentation in water reservoir. The major goal is to learn how to use these techniques together and to achieve through their integration greater added value for earth science research and land and water management. The programme involved three parts: theoretical lectures, laboratory exercises and field work. The In-door programme took place in Lima and the excursion was organized in watershed where the Peruan case study will be implemented in Northern Peru near Pitua city.

Participants of the 1st Regional Training Course of RLA5076 in Peru and Pirua

Consultant Meeting on Use of Cosmic-Ray Neutron Sensor for Irrigation and Extreme Weather Events, 1-4 October 2018, Vienna, Austria

Technical Officers: E. Fulajtar and A. Wahbi

A consultant meeting was held from 1 to 4 October 2018 at the IAEA's Headquarters in Vienna on the 'Use of Cosmic-Ray Neutron Sensor for Irrigation and Extreme Weather Events'. Five consultants from Austria, Germany (two consultants), UK and USA and representatives of FAO and WMO attended the meeting.

Agricultural systems are becoming more and more vulnerable under a changing climate and increasing anthropogenic pressure. This requires continuous monitoring of water, soil, and plant conditions for supporting comprehensive assessments and best agricultural practices. One major knowledge gap is the availability of information on area-wide soil moisture over the root zone. This information will be studied using Cosmic-Ray Neutron Technology (CRNT). The consultant meeting evaluated the state of the art of recent research in the field of soil moisture assessment and discussed the methodological aspects and potential of CRNT. It was concluded that CRNT can be used to provide information on area-wide soil moisture, its spatial distribution and temporal dynamics. The CRNT can be further supported by remote sensing data used for soil moisture assessment. The obtained information can be used for validation of hydrological models, calibration of remote sensing soil moisture assessment, prediction, management and mitigation of extreme weather events (especially drought management and flood forecast) and irrigation scheduling.

Participants of the Consultant Meeting on Use of Cosmic-Ray Neutron Sensor for Irrigation and Extreme Weather Events (IAEA Headquarters, Vienna)

The final result of the consultant meeting was a proposal for a new Coordinated Research Project on ''*Enhancing agricultural resilience and water security using Cosmic-Ray Neutron Technology'*. The overall objectives would be 'Establishing area-wide soil moisture sensing using novel CRNT for improving agricultural water management practices and resilience strategies'. This will cover three particular objectives:

- Advance the capabilities of CRNT for Best Management Practices (BMP) in irrigated and rainfed agricultural production systems at the field scale;
- Integrate CRNT, remote sensing and hydrological modelling for improving agricultural water management and resilience of agriculture at regional scales; and
- Contribute to long-term soil moisture monitoring in agricultural systems.

The CRP proposal is now being finalised and will be submitted for approval in Q1 2019.

Regional Training Course on Management of Biofertilizers for Enhanced Nutrient Efficiency and Crop Productivity Under Field Conditions 15–19 October 2018, Jalisco, Mexico

Technical Officer: J. Adu-Gyamfi

The purpose of the training was to provide participants with theoretical principles and practical techniques on the use of biofertilizers for promoting plant growth. Attended by 27 participants from 17 countries, the training course consisted of (1) basic concepts on the use of biofertilizers; (2) isolation and characterization of microbial strains; (3) multiplication and conservation of microbial strains; (4) conditioning of microbial strains for biofertilizers and application procedures. Dr. Ramón Arteaga Garibay, National Center of Genetic Resources (CNRG) assisted participants to conduct laboratory practical and field trials for improvement of the efficiency of biofertilizers to increase crop yields and the use biofertilizers (Rhizobium) to enhance biological nitrogen fixation by crops. Other topics such as the effect of biofertilizers on the soil microbial community and the importance of bioinformatics data processing were also addressed. Developing the production of biofertilizers constitutes an imperative need to promote sustainable agriculture under conditions where farmers have no access and /or cannot afford to buy inorganic fertilizers. The course, in addition to the knowledge and skills acquired, led to the exchange of experiences and established a network that would allow participants to exchange ideas on the management of biofertilizers for enhanced nutrient use efficiency. For more information, please visit the website: https://www.arcal-lac.org/proyecto-arcal-impulsa-produccion-de-biofertilizantes-para-contribuir-a-la-seguridad-alimentaria/

Participants of the RLA5078 training course

Regional Training Course on ^{15}N Techniques for Enhanced Nutrient Efficiency and Crop Productivity Under Field Conditions, RLA5078, 22 – 26 October 2018, Ocoyoacac, Mexico

Technical Officer: J. Adu-Gyamfi

The training course, consisting of lectures and hands-on training on the use of isotopic techniques to help improve fertilizer use efficiency and protect the environment, was attended by 32 participants from 17 countries. Participants were trained on experimental design, data collection and interpretation of the use of ^{15}N techniques for assessing fertilizer nitrogen use efficiency and quantifying biological nitrogen fixation by legumes for enhanced crop productivity. Two IAEA Experts, Mr Urquiaga Caballero (Brazil) and Mr José Antonio Vera Núñez (Mexico) conducted the training. The participants visited the Institute of Agricultural Research Aquaculture and Forestry of the State of Mexico (ICAMEX), in Metepec, and the International Center for Maize and Wheat Improvement (CIMMYT) in Texcoco, State of Mexico. The aim of the visits was to explore possibilities of future collaboration on the use of isotopic techniques for evaluating efficient use of fertilizers by cereals and high nitrogen fixation by legumes. More information on the training can be found at the following site: https://www.arcal-lac.org/las-tecnicas-isotopicas-ayudan-mejorar-el-uso-de-los-fertilizantes-y-proteger-el-medio-ambiente/

Participants of the RLA5078 training course

National Training Course on "Use of Advanced Nuclear and Related Tools for Agricultural Water Management and Use of Nuclear Techniques to Partitioning Evapotranspiration", Kuwait City, Kuwait, 4-15 November 2018

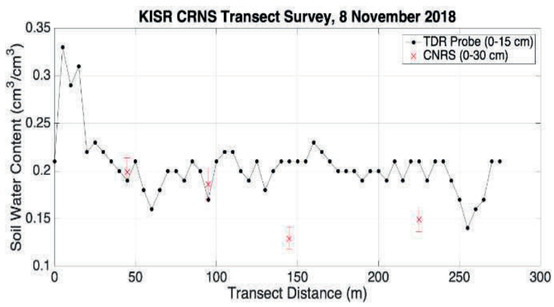
Technical officer: A. Wahbi

From 4 to 15 November, a training was held in the Kuwait Institute for scientific research (KISR), Kuwait, under TC project KUW5004 on “Improving Production and Water Use Efficiency of Forage Crops with Nuclear Techniques”. The focus of this course was on the use of advanced stable isotope and nuclear techniques such as cosmic-ray neutron sensors and oxygen-18 analysis for soil moisture monitoring and water use efficiency studies.

In total, 16 scientists from Iraq, Kuwait, Oman, Qatar and Syria participated in the course, which was given by Mr Trenton Franz from the University of Nebraska, USA, and Mr Nour Eddine Amenzou, from the Centre National de l'Energie, des Sciences et des Techniques Nucléaires, Morocco.

As part of the training course, the participates conducted a transect experiment comparing a handheld TDR sensor versus a Cosmic-Ray Neutron Sensor (CRNS) Backpack that both measure soil water content (SWC). The TDR sensor measures SWC at a point via direct insertion of the 15 cm rods. The CRNS measures area-wide (~140 m radius) SWC down to 30 cm from observations of neutrons in the air. For the TDR survey, participants measured SWC every 5 m along a 275 m long transect. For the CRNS backpack survey, the backpack was placed at 4 locations along the transect. The first point at 45 m was located in an irrigated date palm area. The second point at 95 m was located on the boundary between the date palms and the bare area. The third and fourth points were located in a bare area. From the graph below we see that the TDR and CNRS agree very well in the date palm areas. In the bare area we see the CRNS measures lower SWC compared to the TDR. This is because the rainfall water had not penetrated deeply in the soils beyond ~20 cm observed from finding the wetting front in soil pits. The CRNS sees the deeper soil zones thus recording a drier value. The ability of the CRNS to see deeper in the soil profile and the fact that it is not invasive and area-wide make it an exciting new tool to use in agriculture.

Field work with backpack CRNS



Temporal variability of soil moisture

Regional Training Course on the Advanced Application of Fallout Radionuclides for Soil and Water Quality Investigations, 12–16 November 2018, Sydney, Australia

Technical Officer: J. Adu-Gyamfi

The event was jointly hosted by Macquarie University and the Australian Nuclear Science and Technology organization (ANSTO). Twenty participants from 14 countries and the IAEA technical officer Mr Joseph Adu-Gyamfi and the IAEA Lead Country Coordinator (LCC), Mr Tim Ralph, attended the meeting. The comprehensive training course, which included laboratory and field work, consisted of (1) review of fallout radionuclides (FRN) methods for measuring soil/sediment erosion, deposition and source discrimination, (2) principles and use of Pn-210 and Cs-137 mainly to investigate sediment source tracing and fingerprinting, (3) use of fallout Pu-239, 240, U-236 and C-14 isotopes in geomorphology and soil science, (4) field site selection, sampling strategies, sample preparations, measurements, data analysis and interpretation, and (5) advanced FRN data analysis and modelling for sediment source discrimination. Numerous experts from ANSTO, Sydney Australia, Macquarie University, Sydney, IAEA Expert Mr Arman Haddadchi, National Institute of Water and Atmospheric Research (NIWA) New Zealand, Mr Yoshi Kobayashi from New South Wales Office of Environment and Heritage (OEH), shared their knowledge and skills during the five-day program that encompassed theory/applications, practical sessions and analysis/interpretation of data. Participants also learned about mathematical mixing models that contribute to the identification of soil and sediment sources, and fingerprinting. There were visits to a number of ANSTO laboratories for low-level radioactivity measurements and to accelerator mass spectrometry for carbon-14 and plutonium measurements. In conclusion, participants were requested to (1) share their training experience and knowledge with the colleagues, national project counterpart (NPC) and the national project teams (NPT), and (2) develop partnership and opportunities for outreach. For more information please see the link: https://www.ansto.gov.au/news/sharing-expertise-regional-neighbours

Group poses at Royal National Park after field sampling

Second Coordination Meeting of RAF5075 'Enhancing Regional Capacities for Assessing Soil Erosion and the Efficiency of Agricultural Soil Conservation Strategies through Fallout Radionuclides', 26-30 November 2018, Cotonou, Benin.

Technical Officer: E. Fulajtar

The objective of the meeting was to assess the results since the First Coordination Meeting and to refine the project work plan and country work plans for 2019. The major attention was paid to following topicss:

- Building gamma spectroscopy capacities (staff training and procurements of gamma detectors and basic field and laboratory equipment;
- Assessment of the fieldwork at case studies (revising background information on geographical conditions and sampling design);
- Interpretation of data and dissemination of results
- Long term achievements and strategy of IAEA technical cooperation in Africa;
- Extension of RAF5075; and
- Establishment of Regional African Network on Soil Erosion and Gamm Spectroscopy and Soil Conservation.

The meeting involved also field work aimed on improving of sampling strategies in landscapes with complex topography and land use.

The objectives of the meetings were successfully achieved. The results of case studied were summarized. Collected data sets provide representative information for assessmsent of soil erosion in participating countries. However, the assessment of the results showed that due to great complexity of land use the ^{137}Cs method characterizes only overall mean long term effect of land use while the impact of particular landuses and crops should be distinguished by ^{7}Be method. This will require more time and the project will need extension. The project extension proposal was prepared. Its major objective should be to implement additional case studies with ^{7}Be method for detailed assessments of conservation effects of crops and land uses. It will be submitted to IAEA TC Department.The next important decision was to establish the 'Regional African Network on Soil Erosion, Gamma Spectrometry and Soil Conservation. It should help to intensify the information exchange and to increase the impact of dissemination activities. The organizational structures of the network were established (steering committee with chair, vicechair and three working groups) and the work plan was agreed.

Official opening of the 2nd Coordination Meeing of RAF5075 attended by Mr. M. Daton, the General Secretar, Ministry of Superior Education

Coordinated Research Projects

Project Number	Ongoing CRPs	Project Officer
D1.20.13	Landscape Salinity and Water Management for Improving Agricultural Productivity	Lee Heng
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
D1.50.18	Multiple isotope fingerprints to identify sources and transport of agro-contaminants	Joseph Adu-Gyamfi and Lee Heng

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

Project Officer: L. Heng

This CRP had the final research coordination meeting in the IAEA HQ in July 2018 to present the final results. The CRP is now closed and the results of the CRP are currently being compiled as IAEA Technical Document (TECDOC).

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

Project Officers: G. Dercon. and L. Heng

Comprising experts from 10 Member States, CRP D1.50.15 has been developing tools and methodologies to enhance response capabilities of relevant authorities during nuclear and radiological incidents that affect food and agriculture. The project, now in its final year of implementation, has two major outputs: (1) a protocol for sampling and analysis of food and agriculture during a nuclear or radiological emergency, and (2) an IT system to improve and optimize sampling and decision-making processes during routine monitoring and emergency response. The sampling protocol output of the CRP, titled "Sampling, analysis and modelling technologies for large-scale nuclear emergencies affecting food and agriculture", will be disseminated as a Special Issue in the Journal of Environmental Radioactivity. Paper submissions from project experts and counterparts have been collected and are being reviewed internally.

Ms Amelia Lee Zhi Yi, a consultant at the SWMCNL, was sent on a 1-month scientific exchange to NARO's Fukushima campus in October 2018 to perform research on prediction of radiocesium accumulation in the edible parts of rice and soybean crop. In exchange, Mr Tetsuya Eguchi of NARO is planned to conduct research in Seibersdorf for two years starting May 2019 on radionuclide dynamics in agricultural soil. This exchange realizes the practical arrangement agreed with the National Agriculture and Food Research Organization (NARO) of Japan, signed at the 2016 Joint FAO/IAEA-NARO Technical Workshop on Remediation of Radioactive Contamination in Agriculture. With strong support of SCK-CEN, the JRC and the software developers, the advance prototype of the Decision Support System for Nuclear Emergencies Affecting Food and Agriculture (DSS4NAFA) was opened to testing with full participation by the CRP MSs in November.

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

Project Officers: M. Zaman. and L. Heng

This CRP is in its fourth year of implementation. The objective of the CRP is to mitigate the effects of nitrous oxide (N_2O) emissions and minimize nitrogen (N) losses from agricultural systems, whilst enhancing agricultural productivity and sequestering soil carbon (C). Ten Member States are participating in this CRP, including seven research contract holders (Brazil, Chile, China, Costa Rica, Ethiopia and Pakistan), two agreement holders from Estonia and Spain, and one technical contract holder from Germany.

The third RCM was held in the Technical University, Madrid from 7-11 October 2017 to assess the results obtained since the beginning of this CRP. The field data of Brazil, Chile, China, Iran and Pakistan showed that N_2O emissions from different N inputs were reduced by approximately 50% by adopting best soil nutrient management practices. In Ethiopia, soil carbon and nitrogen accumulation decreased by 23% and 40%, respectively, in conversion of natural forest to crop field. However, after 17 years of afforestation, the cropping field showed no change of C or N stocks. In addition, agroforestry was estimated to contribute to mitigating 27±14 t CO_2 equivalents ha^{-1} y^{-1} at least for the first 14 years after establishment. The ^{15}N technique identified 2 more microbial processes of N_2O production which include co-denitrification and conversion of organ N to mineral N. These results were presented in European Geosciences Union (EGU) conference in April 2018. This provided more insights on how to exert more control on N_2O production processes to reduce its emission from soil to the atmosphere.

Twelve 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 scientific journals. Five more manuscripts on the effects of farm management practices have been submitted to peer-reviewed journals. The final RCM will be held in Q3 2019 in Vienna.

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

Project Officers: L. Mabit and L. Heng

This five-year CRP (2016-2021) aims to develop nuclear techniques to assess the impacts of changes in soil erosion occurring in upland agro-ecosystems, and to distinguish and apportion the impact of climate variability and agricultural management on soil resources in upland agro-ecosystems. Nuclear techniques are used to achieve these two specific research objectives, including fallout radionuclides (FRN) such as ^{137}Cs, ^{210}Pb, ^{7}Be and $^{239+240}Pu$, Compound-Specific Stable Isotope (CSSI) techniques as well as cosmic ray neutron sensor (CRNS).

Substantial progress has been made in developing and refining FRN and CSSI techniques to deepen our understanding of erosion processes affecting upland agro-ecosystems. One major milestone was the development of the new and unique FRN conversion model MODERN. Several investigations have been performed to test and validate the use of CRNP as well as plutonium isotopes ($^{239+240}Pu$) as new soil tracer versus other more mature FRN techniques (e.g. ^{137}Cs and $^{210}Pb_{ex}$) under different agro-environments (i.e. Switzerland, South Korea, Austria).

Until present, the CRP team has already published 15 peer-reviewed publications acknowledging explicitly the CRP D1.50.17. In 2018, the publication of an IAEA TECDOC (IAEA-TECDOC-1845) on soil moisture mapping with portable cosmic ray neutron sensor has provided detailed information and recommendations how to use effectively mobile “backpack” cosmic ray neutron sensors. Additional key documents allowing the transfer of innovative or refined isotopic approaches to IAEA Member States should be available by the end of 2019: (i) an open-access handbook detailing how to assess recent soil erosion rates through the use of ^{7}Be and (ii) an IAEA publication providing guidance for using CSSI technique based on the measurement of $\delta^{13}C$ signatures of fatty acids.

Currently, the CRP team focuses on the second objective of the CRP and major efforts are on-going to test the ^{137}Cs resampling approach which appears to be one of the most suitable techniques to fulfil this challenging objective.

The first RCM was held in Vienna, Austria (25 to 29 July 2016) and the second RCM took place at the Centre National de l’Energie, des Sciences et des Techniques Nucléaires (CNESTEN) in Rabat, Morocco, from 16 to 20 April 2018. An internal IAEA mid-term review of the CRP will take place during the first quarter of 2019 and the third RCM of the CRP will be held in Vienna, Austria from 14 to 17 October 2019.

New CRP “Multiple isotope fingerprints to identify sources and transport of agro-contaminants” (D1.50.18)

Project Officers: J. Adu-Gyamfi and L. Heng

This five-year CRP (2018-2022) aims to develop protocols and methodologies for using multiple stable isotope tracers to monitor soil, water and nutrient pollutants from agriculture, establish proof-of-concept for an integrated suite of analytical stable isotope tools, and create guidelines to adapt the new toolkit to a variety of agricultural management situations. Nuclear techniques are used to achieve the objectives including a combined stable isotope ($\delta^{18}O$’ $\delta^{2}H$, $\delta^{13}C$, $\delta^{15}N$,’ $\delta^{13}C$-DIC, $\delta^{15}N$-NO_3 $\delta^{18}O$-NO_3 $\delta^{18}Op$, $\delta^{34}S$) techniques and compound specific isotope (CSIA)-based monitoring approach for evaluating in-situ degradation, transport, transformation and fate of pesticides.

The following hree draft guidelines were presented and discussed: (1) for designing a water sampling program for stable isotopes studies of agricultural pollution, (2) on compound specific isotope analysis for investigation the source and transport of pesticides from soils to water bodies, and (3) on oxygen isotopes in phosphate for tracing sources of P in soil and catchment. Individual workplans were discussed and finalized. On the last day of the meeting, participants made the following recommendations: 1) A perspective review paper, presenting the complexity of local situations with respects to agro-contaminants and the relevance of a multiple-isotope approach, may help to present the CRP concept and the diversity of the consortium; (2) Different studies should all include traditional measurements of ions and target pollution, and may integrate at least stable isotopes of NO_3, PO_4 or pesticides, and combine them whenever possible; (3) The consortium may establish databases of isotope values from fertilizers and pesticides and use inter-laboratory measurements whenever required to provide end-members values; and (4) The first year of the CRP may be dedicated to consolidating the existing observation sites and prepare them for soil and water monitoring in the next years of the CRP. The second RCM is expected be held in Nanning, China, during the first quarter of 2020. This CRP will be featured in a new European Geosciences Union (EGU) Session HS2.3.3 on '*Identification of agro-contaminants in surface and groundwater using stable isotope techniques'* *during the upcoming EGU meeting on* 7-12 April 2019, Vienna, Austria. The Conveners are Gwenaël Imfeld, Joseph Adu-Gyamfi Lee Heng, Yong Li, Grzegorz Skrzypek. For more details on the meeting please see the website: https://meetingorganizer.copernicus.org/EGU2019/session/31030

Developments at the Soil and Water Management and Crop Nutrition Laboratory

Tracing sediment sources in an agriculture and livestock catchment of Argentina through the use of geochemical fingerprints

Torres Astorga, R.[1], Velasco, H.[1], Resch, C.[2], Gruber, R.[2], Padilla, R.[3], Dercon, G.[2], Mabit, L.[2]

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[2] *Soil and Water Management and Crop Nutrition Laboratory, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, International Atomic Energy Agency, Seibersdorf, Austria*
[3] *Nuclear Science and Instrumentation Laboratory, International Atomic Energy Agency, Seibersdorf, Austria*

A mixing modelling approach (CSSIAR v2.00), using Energy Dispersive X Ray Fluorescence (EDXRF) and Total Organic Carbon (TOC) data as fingerprints for sediment sources and sinks, was applied for identifying critical hot spots of erosion in a typical Argentinian agro-ecosystem. The selected study site is the Estancia Grande catchment, covering 1235 hectares, which is located 23 km north east of San Luis (in the center of Argentina). The studied catchment, which is characterized by highly erodible Haplic Kastanozem soils, is currently being used for agriculture (*crop rotation*), and livestock (*free grazing* and *feedlots*), and some fields are used for growing *nut trees* (walnuts and almonds) (Figure 1). Further *fallow land* is found in between the agriculture land and in the upper part of the catchment.

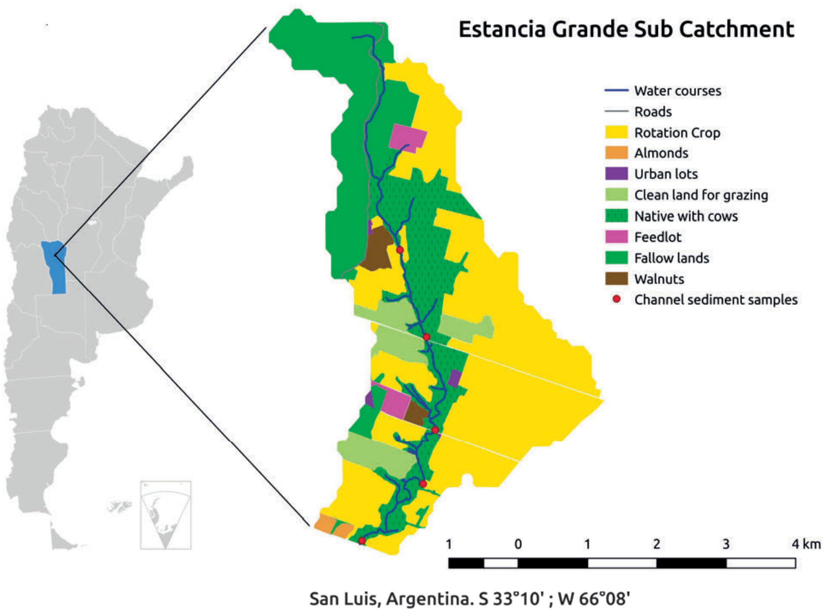

Figure 1. Landsue and location of sediment samples in the studied sub-catchment.

From the above land uses (i.e. sediment sources), composite samples of superficial soils (0 to 2 cm deep) were collected, whereas sediment mixtures (sinks) were collected from deposition zones along the stream channel (i.e. red points in Figure 1). A sample of 2 cm deep was collected at five positions along the stream channel and at three different moments in time: (1) end of rainy season, when crops had been already harvested, (2) end of dry season, and (3) middle of rainy season. Mixtures 4 and 5 were not sampled at the end of the rainy season (time 1).

Soil and sediment samples were prepared for EDXRF analysis at the Nuclear Science and Instrumentation Laboratory (IAEA) and for TOC determination at the FAO/IAEA SWMCN Laboratory.

The first step needed for applying the mixing modelling approach was the selection and validation of geochemical fingerprint elements. This task was done using artificial mixtures (Torres Astorga et al., 2018*), with known proportions of four sediment sources. The proportions of these mixtures were then estimated by the mixing model, whose result was then compared with the true values of the apportionment. The selected fingerprint elements were P, Ca, Fe, Ti and Ba, which then were used as tracers of sediments, and so to identify their sources. Total Organic Carbon was used as the sixth tracer for two of the five mixtures as this addition parameter improved the accuracy of the results without changing the resulting proportions.

Results on sediment apportionment of three out of five channel mixtures are shown in Figure 2. Uncertainties are not included in the charts for clarity. The average uncertainty in the proportions for mixture 5, 4, 3, 2 an 1 is 2%, 5%, 7%, and 7%, respectively.

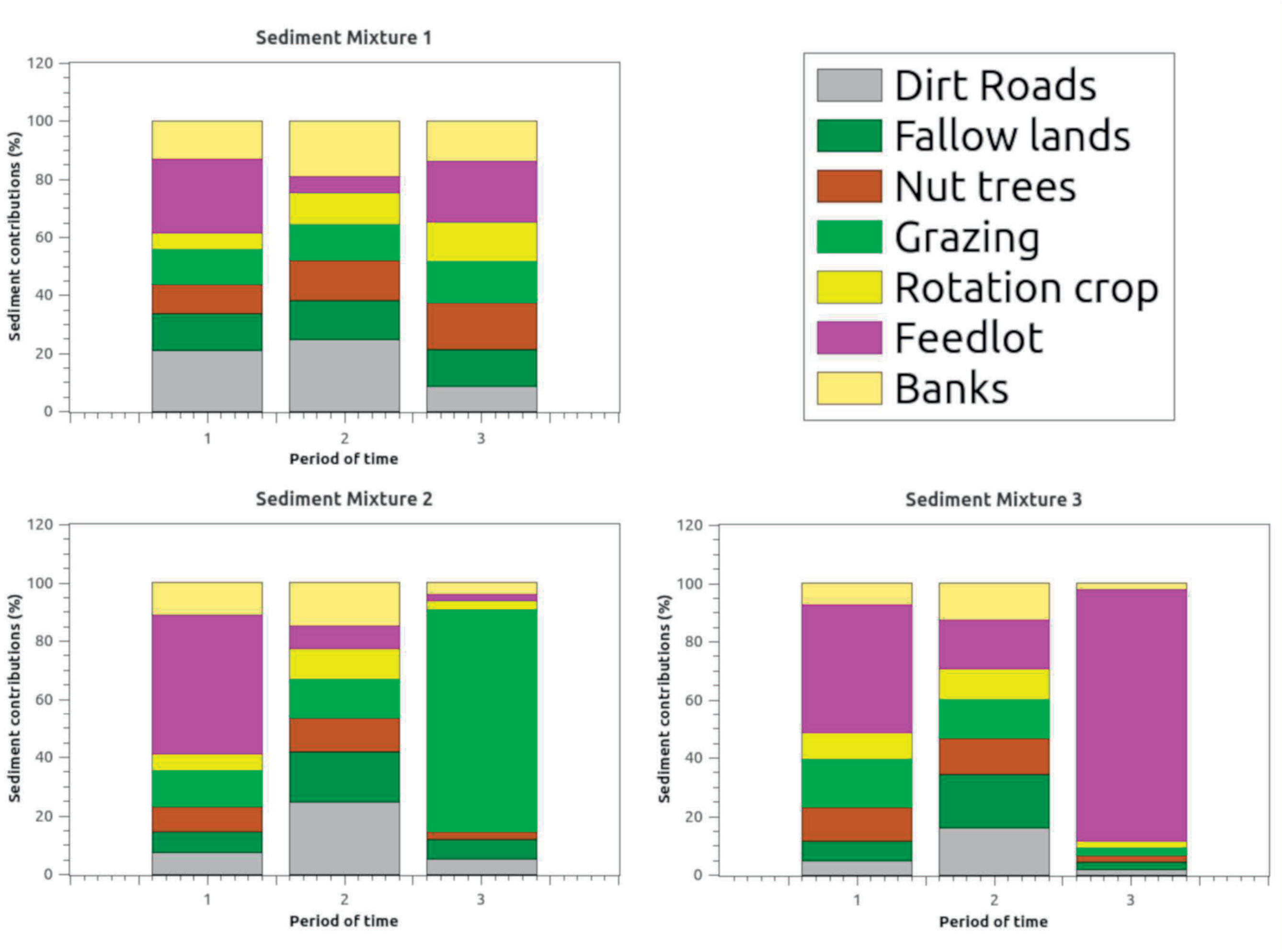

Figure 2. Sediment apportionment in three out of five channel sediment mixtures. Mixtures were collected at (1) the end of rainy season, after harvesting; (2) the end of dry season; (3) middle of rainy aseason.

Feedlots were identified to be the main source of sediments in 7 out of all 13 channel sediment mixtures analysed. This result is worrying due to the very small area this land use has compared with the size of the entire catchment. Feedlots represent only 1.7% of the catchment area. However, this result was expected since according to an important number of land owners this land use increased the sediment load in the channel over the last few years.

River banks and dirt roads together are the second most important source of sediments, and this in particular at the end of the dry season (period 2). Both sources jointly, which consist of subsoil material, are the main source of sediments in all three downstream mixtures at the end of dry season. The limited vegetation cover during every dry season, favours sediment movement. In fact, the lower part of the studied catchment is affected by gully formation. Banks and dirt roads represent an area even smaller than feedlots in the catchment, then the erosion of these sources is also a reason for concern with farmers and policy-makers.

Free grazing is the main source of sediments in only two channel sediment mixtures. This type of land use represents 25% of the catchment area. In the sediment mixtures where this source is the major contributor the proportions are high (76% and 60%). This might be explained by a larger number of animals living in that area and their proximity to the water channel.

On the other hand, the rotation crops occupy most of the area (47%) and this land use is the main source of sediments in only one sediment mixture (mixture 5, which is not shown), and this value represents the wet season. One of the reasons why the rotation crops need not to be a concern in this study might be the land management practice which the farmers apply on their fields: direct seeding known to reduce soil erosion. In mixture 5 the location of the cultivation land is exceptionally close to the channel, that might explain the high contribution of this source to the sediment mixture.

Other important outcome is the low contribution of the sources *Fallow land* and *Nut trees*, which at most contribute only 22% and 16%, respectively. In certain way this behaviour is expected as there is no soil removal in these zones. Bushes of the fallow land and short grass vegetation under the trees protect the soil.

Through the identification of major sediment sources, this study is key for improving soil conservation strategies and selecting land management practices and land uses that do not contribute much to sediment redistribution.

As a future perspective, it would be highly helpful to quantify the sediment budget for the periods of times in which the sediment load increases in the catchment.

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Soil bacterial and fungal diversity as soil quality indicator to complement soil erosion information derived from $^{239+240}$Pu

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Methods to quantify soil erosion are crucial for agro-environmental assessments as well as for optimization of soil and water conservation practices. However, erosion also affects soil quality, and the microbial community of the soil in particular. It has been widely reported in the literature that microbial community is a key indicator of soil ecosystem health, which is responsible for the regulation of biogeochemical soil nutrients cycling, promoting plants growth and maintaining ecosystem stability, and could significantly influence soil conditions (Mabuhay et al. 2004; Xiao et al, 2018).

New research has been initiated by the SWMCN Laboratory on the link between bacterial and fungal diversity and soil erosion at the Grabenegg research site in Austria. This work complements the on-going work on the use of radio-isotopes (e.g. Plutionium-239+240) as soil redistribution tracer.

Topsoil samples (i.e. 0-15 cm) to determine soil microbial diversity were collected at 5 locations along the slope of our Grabenegg experimental agricultural field (Figure 1). At each location, a soil pit was dug and four soil replicates were taken along the four exposed walls of the pit using bulk density cylinders (Figure 2). For each sample, one part of the material extracted was freeze-dried for future soil properties and stable isotope analysis, and the rest was stored at -20 °C for DNA extraction and high throughput sequencing analysis.

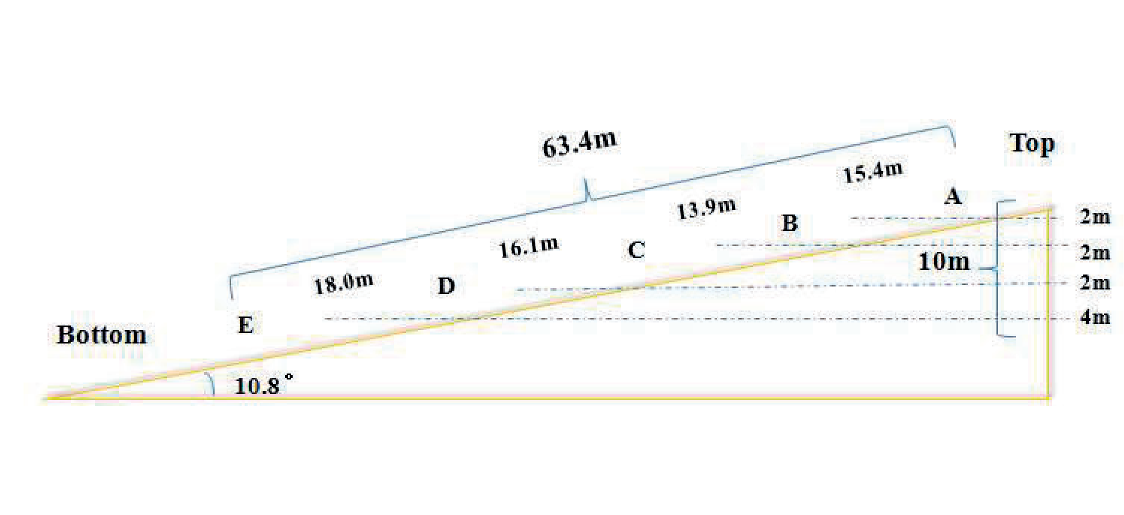

Figure 1. Grabenegg toposequence with slope position of soil samples

Figure 2. Top soil sampling by SWMCNL staff along the slope of one agricultural field at Grabenegg

Soil properties including texture, total organic carbon, pH will be analyzed at the Institute for Land & Water Management Research (Austria) and additional stable isotope analysis (i.e. $\delta^{13}C$ and $\delta^{15}N$) as well as total C_{org} (%) and total N (%) will be undertaken at the SWMCN Laboratory.

High throughput sequencing analysis of bacteria and fungi will be performed in collaboration with the Austrian Institute of Technology (AIT), for establishing the bacterial and fungal community structure and diversity (including α and β diversity and taxonomic phylogenetic analysis, etc.).

When all results will be available, redundancy analysis (RDA) will be applied to figure out the relationships among soil physicochemical properties, bacterial and fungal community and soil erosion rates as derived from fallout radionuclide information (i.e. $^{239+240}$Pu and ^{137}Cs).

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Tracking and tracing carbon emissions in a soybean and maize rotation system

Chen, J., Resch, Ch., Weltin, G., Heiling, M., Gruber, R., Dercon, G.

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With the establishment of carbon dioxide carbon isotope analyser and ^{13}C plant labelling protocols near completion (analyser protocols to be published as a TECDOC and labelling protocol to be published as a scientific article in 2019), we are now conducting new research and development to track and trace carbon emissions from soils using natural differences in $\delta^{13}C$. Plants that use C_3 photosynthesis have a more ^{13}C-depleted signature compared to plants that use C_4 photosynthesis, and this natural difference in $\delta^{13}C$ among plants can be used to determine the proportion of each plant source in different pools of carbon, such as CO_2 emissions from soil respiration. We used our ongoing greenhouse mesocosm experiment with an annual soybean and maize rotation to get baseline measurements of soil respiration $^{13}CO_2$ signatures during dominant periods of soybean versus maize root activity. This was done by measuring soil respiration with the carbon dioxide carbon isotope analyser immediately after harvest of mature soybean (C_3 photosynthesis) and maize shoot (C_4 photosynthesis) material. It was assumed that an isolated root respiration signal would be strongest immediately after removing mature shoot material. Keeling plot estimates of soil $\delta^{13}C$ CO_2 source were, as predicted, more ^{13}C-depleted (by nearly 4‰) in mesocosms containing Cambisol soils right after soybean harvest but no difference was observed in mesocosms containing Chernozem soils. Soils with crop residue application treatments also varied and only Chernozem soils with mulch had predicted $\delta^{13}C$ CO_2 source values. These preliminary measurements will be used in the future in a mixing model to determine the contribution of soybean and maize to soil respiration in these mesocosms, with soybean and maize rotation, and indicate that root respiration may play a greater role in soil $^{13}CO_2$ signatures in mesocosms with Cambisols and less of a role in mesocosms with higher soil organic matter, such as Chernozem soils and treatments with crop residue applications.

	Cambisol (–M)	Cambisol (+M)	Chernozem (-M)	Chernozem (+M)
Maize dominant	-14.18 ± 2.23	-16.07 ± 2.45	-7.88 ± 11.76	-10.31 ± 0.06
Soybean dominant	-18.63 ± 0.62	-17.35 ± 2.56	-7.11 ± 2.85	-16.98 ± 3.28

Table 1. Mean $\delta^{13}C$ of Keeling plot source CO_2 estimates (± SE) of 3 mesocosm measurements each at time of mature maize shoot harvest and mature soybean shoot harvest in mesocosms without (-M) and with (+M) crop residue application.

Variability of ^{15}N labelling in maize leaves

Slaets, J., Gruber, R., Resch, C., Weltin, G., Heiling, M., Mayr, L., Dercon, G.

Soil and Water Management and Crop Nutrition Laboratory (SWMCNL), Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture

^{15}N labelled plant material has important applications for tracing nitrogen through soil, water and air. In applications where the plant material is not fully homogenized through milling or grinding, it is important to understand the variability of the labelling for quantification of N fluxes. While the heterogeneity between plant organs (for example maize leaves, cobs and roots) is often assessed, the variation within plant leaves remains poorly understood to date. Therefore, a pot experiment was set up in the SWMCN Laboratory to assess the variation of the ^{15}N isotopic signature resulting from enriched fertilizer within maize leaves.

In the growth chamber, maize seeds were planted in 9 pots filled with sand. The pots were continuously watered with two different ^{15}N-enriched fertilizer solutions: pure nitrate, and labelled nitrate with a commercial N fertilizer containing both (unlabelled) ammonium and nitrate. Three leaves were harvested per maize plant. The ^{15}N signature in each leaf was assessed near the maize stem, in the middle of the leaf and near the tip of the leaf.

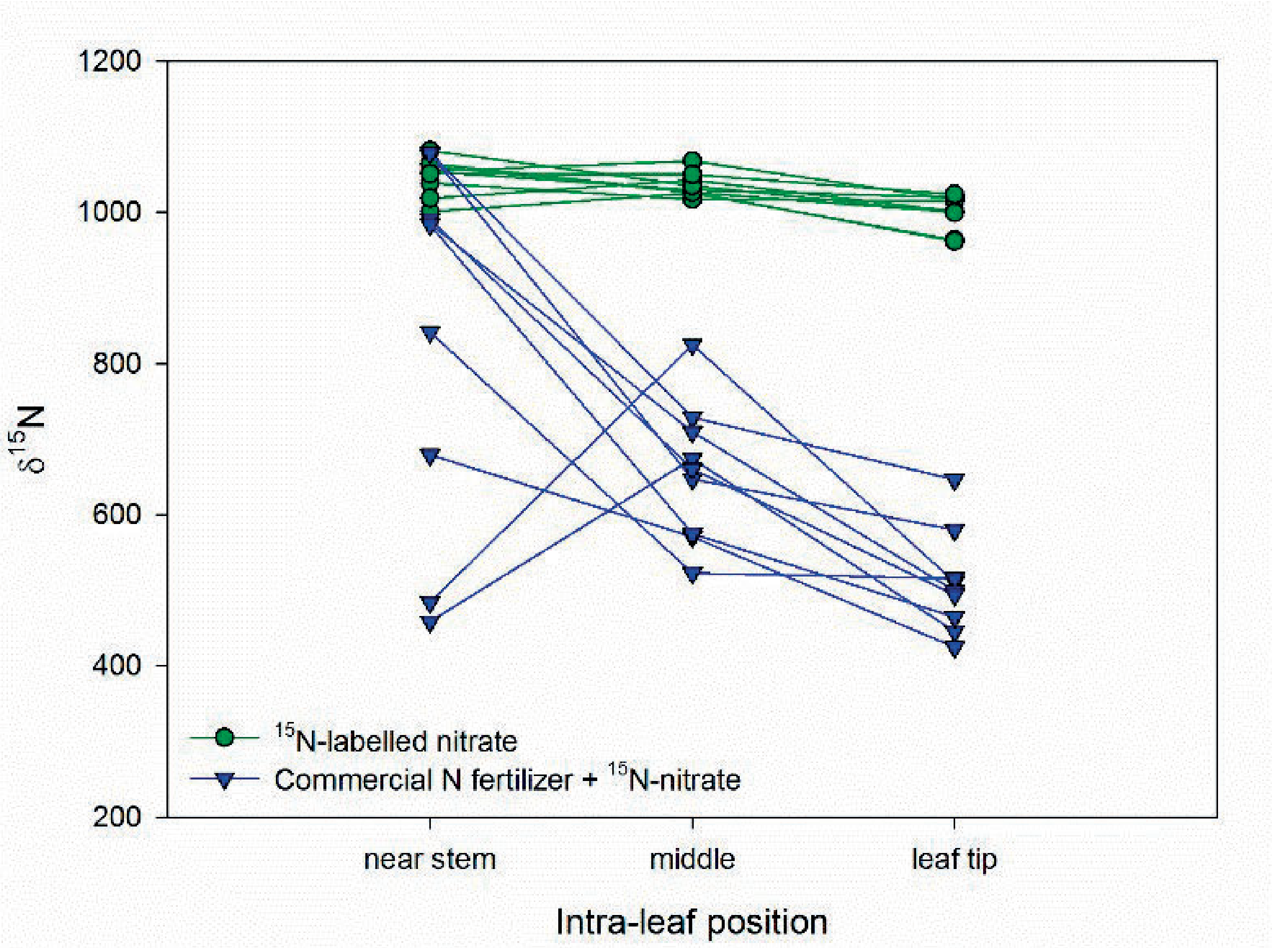

Figure 1. Isotopic signature variation within maize leaves. Commercial fertilizer contained both unlabelled ammonium and nitrate.

Maize plants exclusively treated with nitrate did not demonstrate strong intra-leaf variation (Green circles, Figure 1). When using ^{15}N-labelled nitrate in the presence of unlabelled ammonium, the leaf base is enriched compared to the leaf tip (up to 600 δ ^{15}N difference from leaf base to leaf tip, blue triangles; Figure 1). Presence of two N-pools thus results in large gradients in ^{15}N-signature in maize leaves.

Our results yield important recommendations for the use of labelled material in ^{15}N studies: First, it is crucial to harvest the whole plant and homogenize with extreme care when material has been labelled in the field, for example, in fertilizer use efficiency studies. Second, in experiments where non-homogenized ^{15}N labelled plant material is used for assessing N movement (e.g. labelled mulch or compost), it is essential to develop the material using only one N-source to reliably quantify fluxes.

Cassava productivity and stable isotope methods: CIALCA takes off in Seibersdorf

Merckx, R.[1], Heiling, M.[2], Resch, C.[2], Gruber, R.[2], Weltin, G.[2], Mayr, L.[2], Jagoditsch, N.[2], Birindwa, D.[1,2,3,4], Van Laere, J.[2], Toloza, A.[2], Slaets, J.[2], Pypers, P.[5], Kintche, K.[3], Munyahali, W.[2,4], Dercon, G.[2]

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Following the agreement between the International Institute for Tropical Agriculture (IITA) and the Joint FAO/IAEA Division of Nuclear techniques in Food and Agriculture (see Soils Newsletter Vol. 41, No 1, July 2018), to collaborate on a project intended to enhance our understanding of how cassava deals with periods of water shortage with the aid of novel stable isotope techniques, activities have been initiated in the Seibersdorf greenhouses and in the ^{13}C-CO_2-growth chamber. Initial steps were taken to obtain information on how $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratios vary in cassava plants under the influence of water and nutrient availability, for different cassava varieties. As a first step, ten different cassava varieties, were obtained from Burkina Faso and two from the Democratic Republic of Congo, were planted in pots in the greenhouse, serving as test material to explore variability in growth patterns and isotope signals. These varieties were either landraces with poor resistance to diseases and water stress or improved varieties, resistant to CMD (cassava mosaic virus disease) and moderately to very drought tolerant.

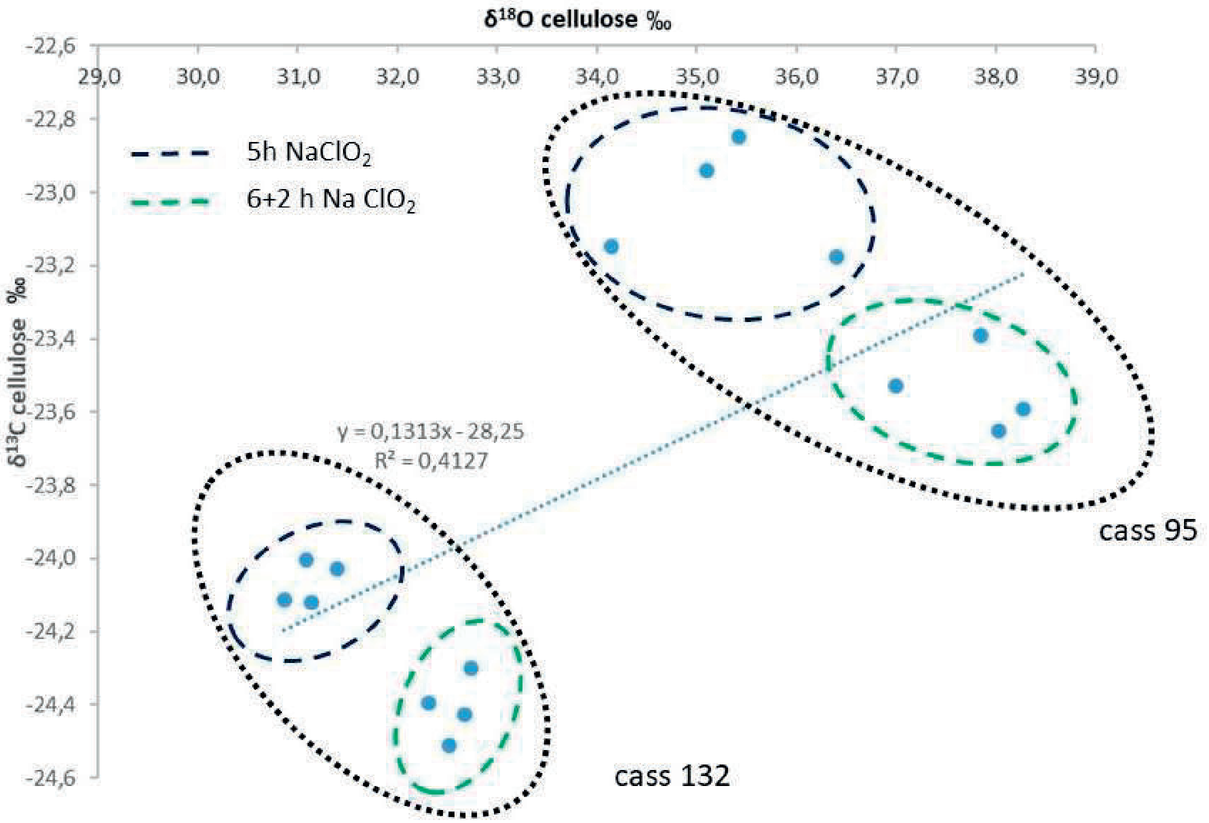

Figure 1. Relations between δ13C versus δ18O-values of cellulose extracted from leaves of two different cassava varieties, (cass 95 and cass 132) grown at different sites in Tanzania, and with two different extraction methods..

Simultaneously, exploratory tests were made, to find the optimal method for later use to extract cellulose from large numbers of cassava leaves or other plant organs. Reasons to go for cellulose extraction build on literature, stating that the stable isotope composition of cellulose is more appropriate than that of the bulk material, as (i) the latter is of a more variable composition including species and growth phase dependent components, (ii) the $^{18}O/^{16}O$ ratio in cellulose reflects the one of plant water at the time of cellulose synthesis and is from then onwards no longer exchangeable with its environment and hence a more reliable indicator of stomatal conductance (g_s) (e.g. Yakir, 1992; Moreno-Guttierez et al. 2012) and (iii) the $^{13}C/^{12}C$ ratio in cellulose also seems less influenced by the same and accordingly a better indicator for WUE. These initial try-outs were performed on cassava samples obtained through IITA, from their large number of field trials within the framework of ACAI (African Cassava Agronomy Initiative; http://www.iita.org/iita-project/acai-african-cassava-agronomy-initiative/) a Bill and Melinda Gates Foundation sponsored project. The chosen method was based on $NaClO_2$ bleaching and followed by NaOH removal of beta- and gamma-celluloses according to Leavitt and Danzer (1993). Cellulose samples were subject to $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratio analysis at the labs of Seibersdorf and KU Leuven, respectively. The two varieties taken for this preliminary test differed in $\delta^{13}C$ and $\delta^{18}O$ values of the bulk sample (*cass95* had delta values of -24.8‰ and 32.6‰ while *cass132* had -25.8‰ and 27.7‰ for $^{13}C/^{12}C$ and $^{18}O/^{16}O$, respectively). This is reflected in the isotope values of the cellulose samples, demonstrating values in line with literature (Fig 1.) (e.g. Moreno-Guttierez et al., 2012). The results obtained confirmed that (i) cellulose can be extracted from cassava leaves and lead to isotope ratios that are very reproducible with little variation, and that (ii) the longer the bleaching time, the more negative the $\delta^{13}C$-values and the larger the $\delta^{18}O$-values. This points to a more effective lignin removal, as lignin is reported to have higher $\delta^{13}C$-values and lower $\delta^{18}O$-values (Harada et al., 2014).

Figure 2. A view of cassava plants in the growth chamber to prepare for ^{13}C-CO_2 labelling

After three months, some plants were transferred to the growth chamber (Fig. 2), to assess their performance in this facility. With time, the intention is to pulse-label cassava plants in this chamber with ^{13}C-CO_2, to trace the flow of assimilates from tops to roots and how this varies with variety, time, drought and/or nutrient stress.

Simultaneously, in cooperation with the FAO/IAEA Plant Breeding and Genetics Laboratory, tissue culture of cassava plants of three more varieties coming from IITA-Nigeria were also transferred to the greenhouse. This will allow the team to have access to plant material on a more continuous basis, and independent from the sending of planting material (cassava sticks) from Africa.

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Validating phosphate purification method for oxygen isotope analysis in different phosphorus fractions of soil

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The soil phosphate oxygen isotope ($\delta^{18}O$-PO_4) is being used more and more to understand soil phosphorus (P) cycling, as well as to trace the source of P pollution, such as manure and fertilizers. In June 2018, the SWMCN Subprogramme hosted the First RCM of the CRP D1.50.18 on “Multiple Isotope Fingerprints to Identify Sources and Transport of Agro-Contaminants”. The RCM participants selected the phosphate oxygen isotope as one of the isotopes to trace the source of pollutions, along with nitrogen and sulfur stable isotopes.

In support of the CRP, the SWMCN Laboratory team validated the phosphate purification method for oxygen isotope analysis in different phosphorus fractions of a forest soil (Humic Cambisol) and an agricultural soil (Haplic Chernozem) from areas int the vicinity of Vienna.

The soil available P, $NaHCO_3$-extractable P and the HCl-extractable P pools were selected for phosphate extractions, followed by the purification process.

To purify these three pools, ammonium phosphor-molybdate (APM) and magnesium ammonium phosphate

(MAP) were precipitated. Depending on the pH, the purification process starts with forming APM for acidic extracts, while for alkaline extracts the purification starts with forming MAP. As a final product, silver phosphate is formed and its $\delta^{18}O\text{-}PO_4$ signature is determined using isotope-ratio mass spectrometry.

Footprint and effective depth of mobile cosmic-ray neutron sensor technology

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To further improve the application of cosmic-ray neutron sensor technology, the SWMCN Laboratory during the summer validated the footprint, effective depth and accuracy of the mobile or "backpack" version of the sensor. Through sixteen different calibrations for five research sites in Austria, located between 300 and 1700 m a.s.l., a comparison was made between the volumetric water content measured by the backpack and gravimetric measurements for different radii of influence. Results indicated similar outcomes based on a 0-75-meter footprint as compared to a 0-200 meter study (Figure 1) suggesting that measurements by the mobile cosmic-ray neutron sensor have a footprint with a 200-meter radius (i.e. 20 hectares). The same data were also used to determine the effective depth (Figure 2), results showed that the effective depth is about 10 cm for volumetric water contents ranging between 30 and 60%.

In the coming year, the SWMCN Laboratory will focus on improving the calibration methods for the cosmic-ray neutron sensors, by having more data points near the sensor, which could play a major role in error reduction. Further, the technology will be tested for satellite imagery calibration.

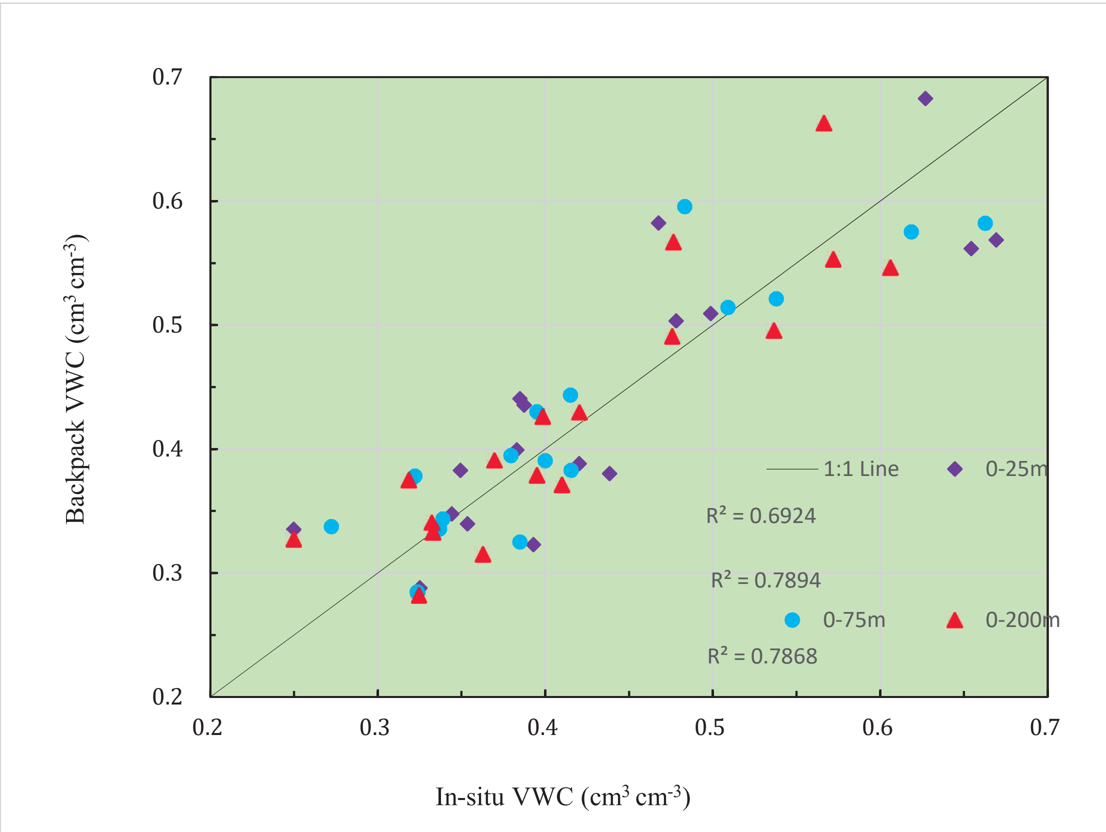

Figure 1. Relation between in-situ and mobile cosmic ray neutron sensor (CRNS) backpack volumetric water content (VWC) for three different footprints at different elevations (from 300 to 1700 m a.s.l.) across study sites in Austria

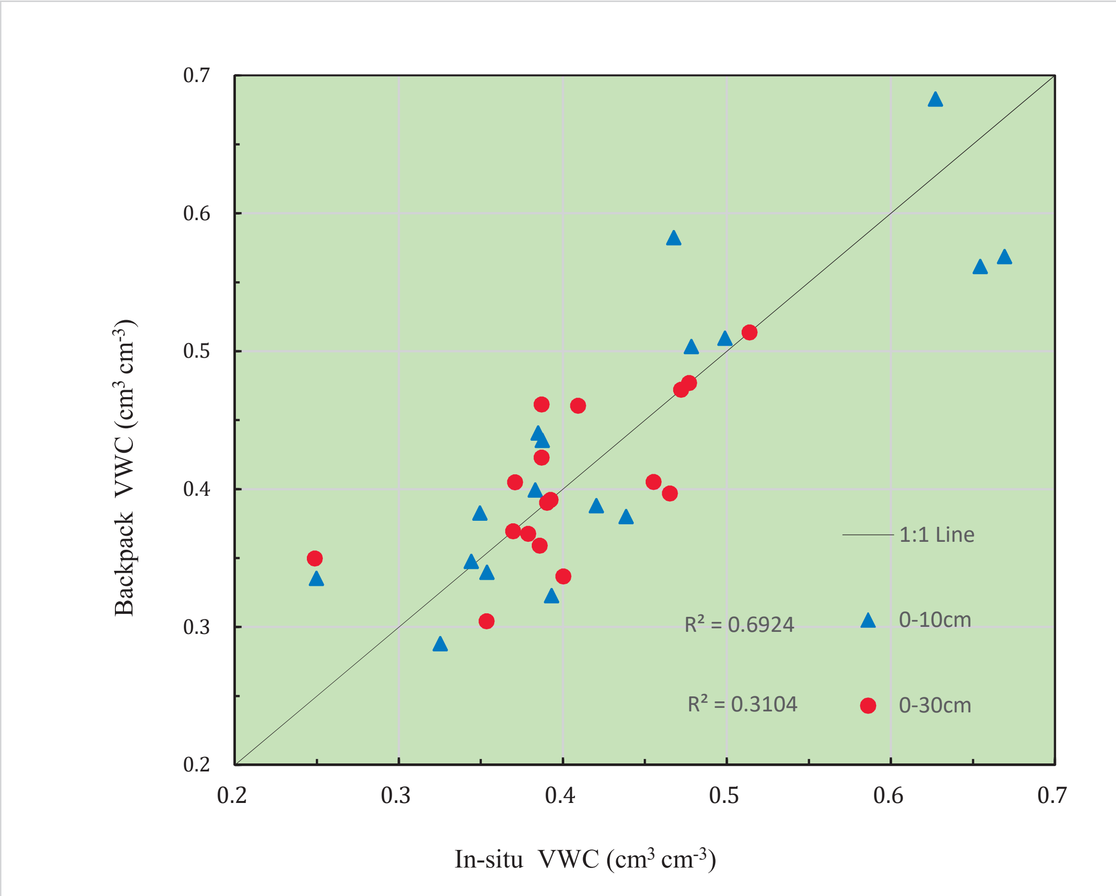

Figure 2. Relation between in-situ and mobile cosmic ray neutron sensor (CRNS) backpack volumetric water content (VWC) for two different soil depths at different elevations (from 300 to 1700 m a.s.l.) across study sites in Austria.

Prediction of Radiocesium Accumulation in Edible Parts of Crops

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In October, the SWMCN Laboratory sent Ms Amelia Lee Zhi Yi as consultant to Fukushima for one-month as part of a scientific exchange with the National Agriculture and Food Research Organization (NARO) of Japan. This visit was part of the practical arrangement between NARO and the SWMCNL signed in 2016 at the Joint FAO/IAEA-NARO Technical Workshop and marked the first step in synergistic research supported by both institutions. Amelia has been involved in CRP D1.50.15 on Nuclear Emergency Preparedness in Food and Agriculture for the past 2.5 years and thus selected for this assignment.

The main research theme of the exchange, initiated in preparation of a new CRP (as a follow up to CRP D1.50.15), focuses on optimization of remediation of radioactive contamination in agriculture, particularly for rice and soybean crops. Collaborative research was performed between NARO and SWMCNL to investigate the possibility of using information on radiocaesium (RC) accumulation in crops at different stages of development to predict RC accumulation in edible parts at maturity. Key tasks conducted during the visit were: (1) sampling and analysis of target crops, (2) data interpretation and prediction model development and (3) drafting of guidelines on the methodologies utilized in sampling.

Prior to the scientific visit, three sampling campaigns were performed by NARO for soybean and rice samples harvested at different growth stages. The SWMCNL supported in the final sampling campaign for fully matured soybean and rice plants in two field sites located in Ryozen town of Date city. Processing of plant and soil samples included drying, separating, cleaning, cutting, grinding, and placement in specialized containers for gamma spectrometry measurements. Approximately 70 soil and plant samples were collected and prepared under the guidance of NARO staff.

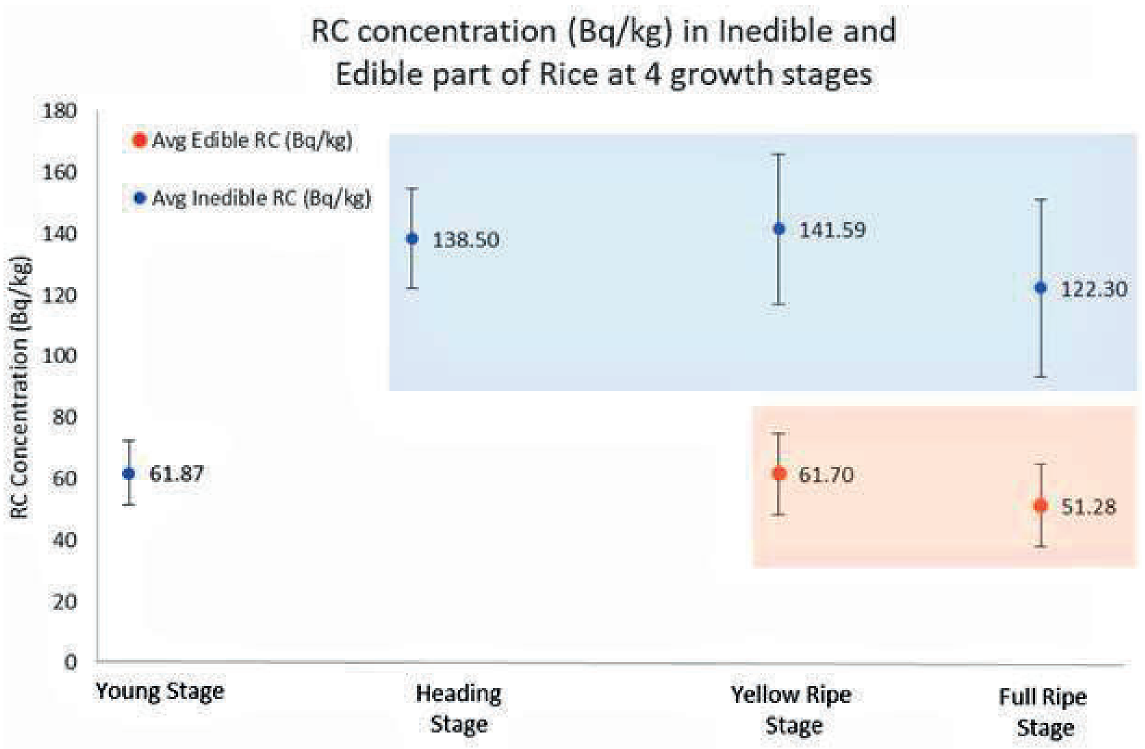

Figure 1. Inedible (leaf blade, sheath, and culm) and edible biomass (brown rice) in 4 stages – young (30 DAP), heading (60 DAP), yellow ripe (90 DAP) and full ripe were collected. Variability in measurements was shown to be higher in the inedible samples than edible samples, and the trend of Radiocaesium (RC) concentration in inedible parts show a general stabilization from the heading stage onwards. RC concentration nearly doubles in the inedible parts from young to heading stage.

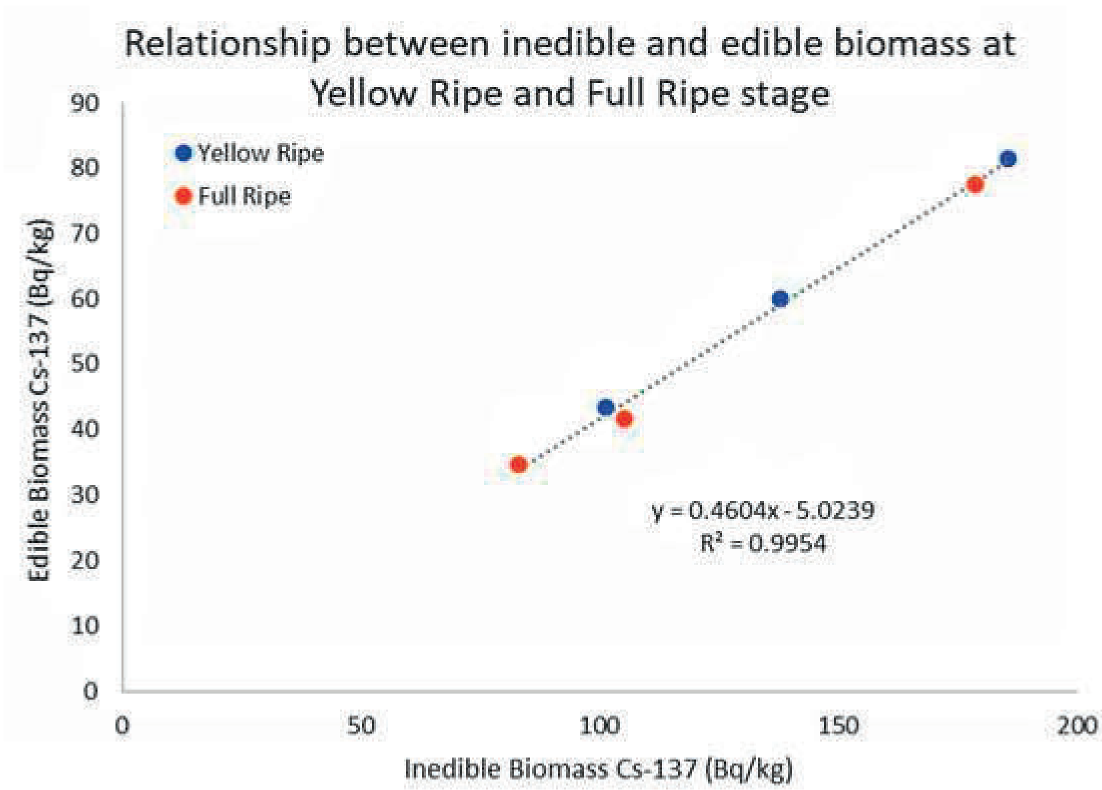

Figure 2. RC concentration in edible and inedible parts of the rice plant during yellow ripe stage and full ripe stage showed a good correlation and may be used as in indicator of RC concentration in edible part at harvest

Rice was sampled as inedible biomass (leaf blade, sheath, and culm) and edible biomass (brown rice) at four stages – young, heading, yellow ripe and full ripe. Initial analysis of data from the rice study (n=18) showed a larger variability in measured RC concentration values for inedible parts (young (62±10 Bq/kg), heading (139±16 Bq/kg), yellow ripe (142±24 Bq/kg) and full ripe (122±29 Bq/kg)), compared to mature edible grains that had a lower variability (yellow ripe (62±11 Bq/kg) and full ripe (51±13 Bq/kg)). Average RC concentration of inedible biomass at the heading stage was found to be nearly twice that of the young stage, but the trend stabilized during the heading, yellow ripe, and full ripe stage (Figure 1). In examining the relationship between inedible and edible parts of the rice plant at yellow ripe and full ripe stage, a clear relationship between biomass and grain during the yellow ripe and full ripe stage was found, with the K_d at harvest (K_d = edible biomass RC/inedible biomass RC) to be 0.46 (Figure 2). The cursory conclusion from the findings above is that the RC concentration in leaves stabilizes during the heading stage and can be used to predict the RC concentration in grains at maturity using the K_d at harvest. Further research is needed to link RC concentrations in young plants (inedible part) and the edible part of rice.

Findings of similar experiments with soybean will be reported in the next newsletter. The sampling methodologies for rice and soybean, with particular emphasis on process optimization during emergency periods, were drafted as an IAEA Standard Operating Procedure. An extra chapter was also drafted for lessons learnt from the Fukushima Daiichi Nuclear Power Plant incident on sample management and prevention of cross contamination during gamma measurements.

Ms Lee Zhi Yi was further invited to visit NARO's study sites around Fukushima Prefecture, the Fukushima Agricultural Technology Center (FATC) Headquarters in Koriyama and the Fukushima Prefecture Rice Sampling Facility. The NARO field trip provided an overview of current status and farming practices implemented on decontaminated land post-Fukushima. Visits to FATC aimed to initiate collaboration in knowledge sharing of sample preparation of other food products such as fruits (persimmons) and meat (fish). A tour of Fukushima prefecture's high- throughput rice sampling facility showcased a setup capable of measuring RC concentration in a 30kg bag of rice in 13 seconds. Finally, Ms. Lee Zhi Yi attended the DEMETERRES* project meeting on development of innovative methodologies and technologies to deal with RC contaminated agricultural soil.

With 70 samples collected and processed, 3 SOP chapters drafted and 1 elementary model developed, the one-month scientific exchange supported by NARO accomplished all key tasks and furthers the SWMCN Laboratory's research objective of understanding prediction of RC accumulation in edible parts of crops.

** The DEMETERRES project was launched in 2013 to develop bio- and eco-technological methods for the decontamination of soil and effluents in support of a strategy for post-accident rehabilitation. The five-year project involves various French and Japanese institutions such as Veolia, the Institute for Radiological Protection and Nuclear Safety (IRSN), Center for Research in Isotopes and Environmental Dynamics (CRiED), the National Agriculture and Food Research Organization (NARO) and the French Agricultural Research Centre for International Development (CIRAD).*

Bridging the gap between science and decision makers – Sharing advancements in Nuclear Emergency Preparedness tools to the EGU community

Lee Zhi Yi, A., Dercon, G.

Since 2015, the SWMCN Laboratory has been developing DSS4NAFA, an IT-based decision making support system for optimizing response to nuclear emergencies affecting food and agriculture. This work, now in its final stages for beta release to the Member States, was presented to the general public for the first time at the European Geophysical Union (EGU) General Assembly. Presentation of the DSS4NAFA system generated strong interest and positive responses, and the SWMCNL was invited to interview on both the EGU Geopolicy and EGU Natural Hazards onlineblog, open to all 15,000 members of EGU. The interviews can be found at the links below:

https://blogs.egu.eu/geolog/2018/09/13/geopolicy-bridging-the-gap-between-science-and-decision-makers-a-new-tool-for-nuclear-emergencies-affecting-food-and-agriculture/

https://blogs.egu.eu/divisions/nh/2018/08/27/iaea-interview/#more-490

Training Climate Change Researchers in Isotopic Techniques to Assess Impacts on Soil and Water in Glaciated Watersheds

Slaets, J., Dercon, G.

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The impacts of climate change are highly visible in polar regions and high mountains. Accelerated glacier retreat results in changed water availability and altered sedimentation patterns. Warming soils emit greenhouse gases, thus further feeding back to global warming. However, understanding and monitoring these impacts in such difficult to access areas, is challenging. Through fingerprinting and dating, nuclear and isotopic techniques offer a way to obtain time series data at the landscape level with single-site visits.

From 25 June to 6 July 2018, the SWMCN Laboratory hosted a two-week training course for twelve scientists from seven Member States, in collaboration with the University of Vienna's Department of Microbiology and Ecosystem Science and the Department of Geography and Regional Science at Graz University. The course was organized under the project INT5153 "Assessing the impact of climate change and its effects on soil and water resources in polar and mountainous regions".

In this project, soil and water resources in eleven benchmark sites on five continents were characterized. These very same protocols were taught to the researchers in the training course, enabling them to contribute to the established global monitoring network. "Often, methods to collect data are not comparable to other parts of the world. By using techniques and methodologies taught in this course, our assessments can be compared to results from around the world", said participant Ksenia Poleshchuk from the Arctic and Antarctic Research Institute (AARI) in the Russian Federation.

To provide hands-on training in field data collection and landscape analysis, the course included a four-day field excursion to the Austrian Alps, to the municipality of Rauris (Figure 1) and Austria's largest glacier, the Pasterze (Figure 2). Training course participants hiked to the glacier tongue to train on sampling techniques for water, suspended and deposited sediment, ice and snow. Local farmers, the mayor of the municipality of Rauris and the Director of the Sonnblick meteorological observatory gave participants an insight into the local socioeconomic context of climate change impacts.

Figure 1. Learning to identify landforms in high mountains: the remnants of an ancient landslide have left the forest in two different growth stages in Rauris, Austria.

Figure 2. Training course participants hike to the Pasterze glacier in the Austrian Alps, here passing the 2015 glacier tongue position

In Seibersdorf Laboratories (Figure 3), INT5153 experts held lectures on formulating research questions, data interpretation and modelling for assessing impacts of climate change on land and water. The course thus provided participants with the tools to support evidence based decision making for soil and water management in glaciated watersheds.

Figure 3. Course participants touring the SWMCN IRMS Laboratory

Analytical Services

Resch, C., Gruber, R., Toloza, A.

Soil and Water Management and Crop Nutrition Laboratory (SWMCNL), Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture

In 2018, 3670 samples were analysed for stable isotopes and 300 FRN 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 for climate-smart agriculture. Analytical support has been given also to the Food and Environmental Protection Laboratory with about 50 samples and to the Insect Pest Control Laboratory with about 470 samples analysed.

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

Resch, C.

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

The 2018 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 was 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, eleven stable isotope laboratories participated in the PT-round 2018: Africa (1): Morocco; Asia and the Pacific (3): New Zealand, Pakistan and Philippines; Europe (4): Austria, Belgium, Germany and France; Latin America (3): Argentina, Brazil and Chile. All nine laboratories participating in the nitrogen analysis test reported ^{15}N-data within the control limits for the enriched plant sample (Figure 1) and seven out of nine participating laboratories in carbon analysis test reported ^{13}C isotopic abundance results within the control limits (Figure 2).

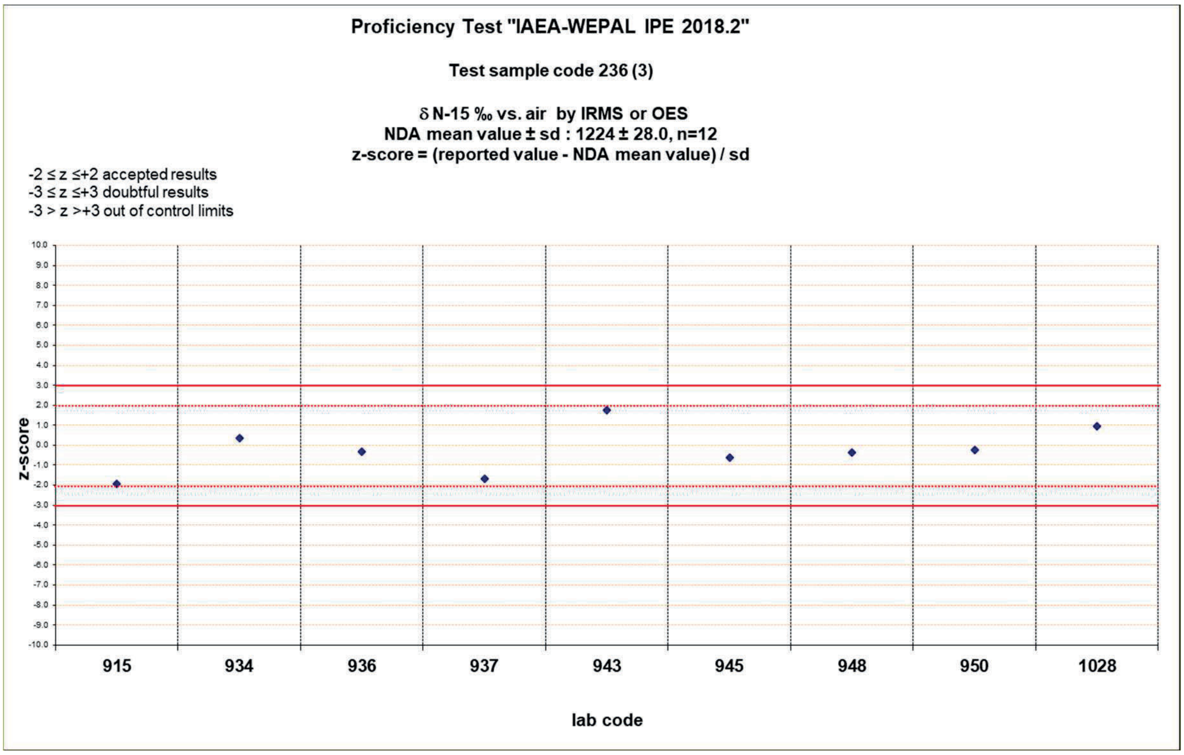

Figure 1. Z-score evaluation of the ^{15}N analysis

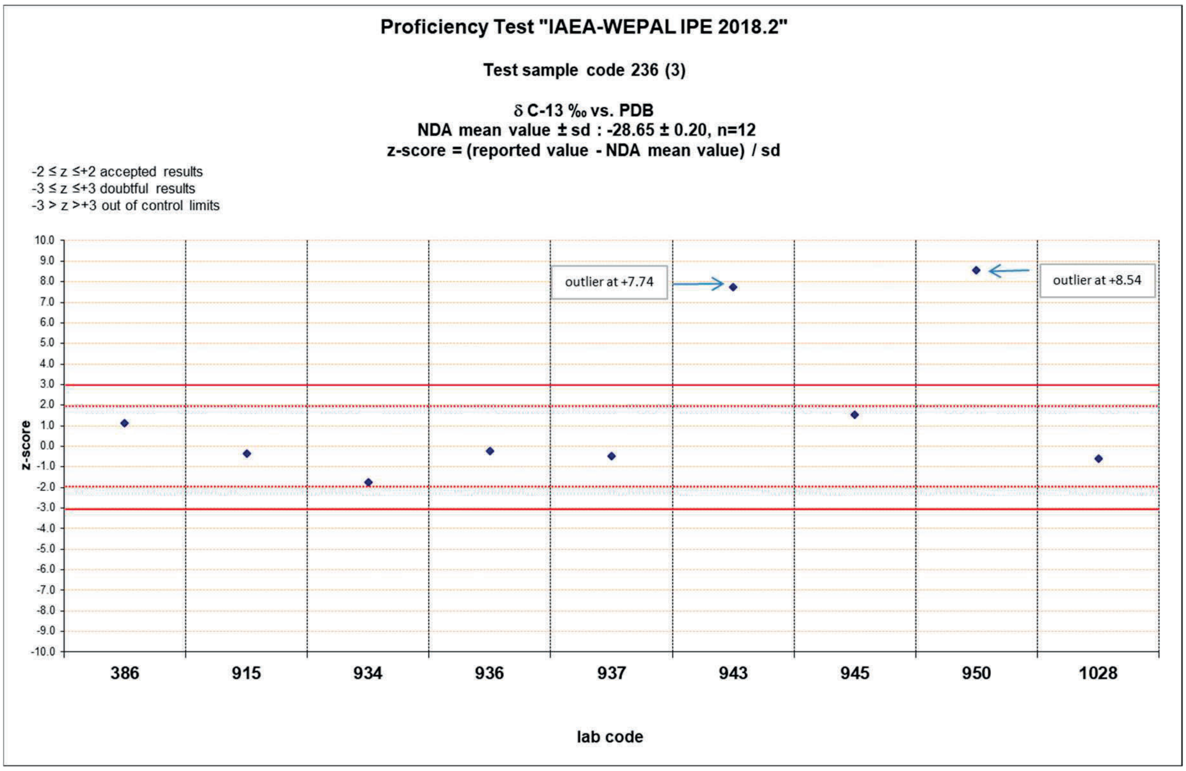

Figure 2. Z-score evaluation of the 13C analysis

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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):
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- FAO Agriculture and Consumer Protection Department
  http://www.fao.org/ag/portal/ag-home/en/
- FAO Land & Water:
  http://www.fao.org/land-water/en/ 1
- New communication materials outlining successes in the area of nuclear techniques in food and agriculture:
  http://www-naweb.iaea.org/nafa/resources-nafa/IAEA-success-Stories-3.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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