Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Soils Newsletter

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To Our Readers

2019 World Soil Day was held under the theme, 'Stop Soil Erosion, Save our Future'!

The Soil and Water Management and Crop Nutrition (SWMCN) Subprogramme had a very busy and exciting year. Two new coordinated research projects (CRPs) were initiated in 2019 with their respective 1st research coordination meetings (RCMs), these are D1.20.14 on 'Enhancing agricultural resilience and water security using Cosmic-Ray Neutron Sensor' and D1.50.19 'Monitoring and predicting radionuclide uptake and dynamics for optimizing remediation of radioactive contamination in agriculture'. Two other RCMs were also held: 3rd RCM of D1.50.17 'Nuclear Techniques for a Better Understanding of the Impact of Climate Change on Soil Erosion in Upland Agro-Ecosystems' and final RCM of D1.20.16 'Minimizing Farming Impacts on Climate Change by Enhancing Carbon and Nitrogen Capture and Storage in Agro-Ecosystems'. A consultants' meeting also took place in July to develop a new CRP to replace D1.50.16 on greenhouse gas emission; It is anticipated to start in mid-2020. By then, there will be a total of six CRPs running.

In the 2020-2021 cycle, the SWMCN Subprogramme will be providing support to a total of fifty-one Technical Cooperation projects, with current and new national, regional and inter-regional projects. Please see page 10 of this newsletter for the whole list including the technical officers in charge. We hope to continue making an impact under both CRPs and TC projects.

Three guidelines and a number of articles were published in the last six months, this includes two FAO publications on 'Antimicrobial Movement from Agricultural Areas to the Environment: The Missing Link. A Role for Nuclear Techniques' and 'Data Management and Visualisation in Response to Large-Scale Nuclear Emergencies Affecting Food and Agriculture' and an IAEA TECDOC titled 'Guideline on Sediment Tracing Using the Compound Specific Carbon Stable Isotope Technique'. The publication on antimicrobials (AM) is the first ever on the potential use of isotopic techniques (Compound Specific Stable Isotope Analysis) to determine the origin, production process and the movement of AM in soil and water and the environment in general. The FAO technical guideline on Data Management and Visualisation in Response to Large-Scale Nuclear Emergencies Affecting Food and Agriculture, which was an output under CRP D1.50.15, elaborates how IT-Decision Support System tools and algorithms can be used to improve real-time management of large volumes of data and integrated decision-making support. The Guidelines for Sediment Tracing Using the Compound Specific Carbon Stable Isotope Technique provides step-by-step instructions on how to use this innovative approach for applications in climate smart agriculture and improve area-wide soil conservation strategies.

The 2019 World Soil Day was held under the theme, 'Stop Soil Erosion, Save our Future'! In Africa, about 65 percent of the continent's farmland is affected by erosion-induced losses of topsoil and soil nutrients, according to the Food and Agriculture Organization of the United Nations (FAO). The SWMCN Subprogramme has been using nuclear and isotopic techniques (fallout radionuclides and compound specific stable isotopes) to assess the extend and sources of soil erosion and recommend improved soil conservation practices to stop erosion and preserve this vital resource for future generations. Emil Fulajtar from the SWMCN Section represented the Joint Division at an event dedicated to soils and climate-smart agriculture organized by FAO Liaison Office in Sochi, Russia, in collaboration with World Bank Moscow Office, Eurasian Food Security Center (Moscow State University) and other local organizations.

Meanwhile, research and development work at the Soil and Water Management and Crop Nutrition Laboratory in Seibersdorf continues on several topics. The work on greenhouse gas (GHG) emission is gaining momentum with the addition of an intern and a PhD consultant.

Collaborative work with the Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA), the International Institute of Tropical Agriculture (IITA) and Bioversity International on cassava and banana is making good progress. Advances have been made in using stable isotopes of oxygen and carbon to better understand drought stress and nutrient deficiency and their impacts on water and nutrient use efficiencies of these two important crops.

The SWMCN Subprogramme together with the IAEA Isotope Hydrology laboratory is participating in the 4^{th} Joint Danube Surveys, organized by the International Commission for the Protection of the Danube River (ICPDR), to provide information about the origin of water and nitrate sources in the Danube watershed.

The Subprogramme also conducts annual External Quality Assurance proficiency test on ^{15}N and ^{13}C isotopic abundance in plant materials, a free service offered to Member States to ensure the analytical performance of the stable isotope laboratories.

The Subprogramme staff received hands-on, practical training annually, this year the topic was on the use of Unmanned Aerial Vehicles (UAV) based multispectral camera in agriculture and soil research.

We would like to welcome new staff, consultants, interns and visitors to the SWMCN Section and Laboratory. Ms Belinda Westmacott joined the Section as the team assistant, Ms Abhishri Gupta, Ms Mona Kühn, and Ms Stefani Ritter, also joined the Section as M. Sc. scientific visitors, while Mr Xavier Dengra i Grau from Spain, Ms Hoda Jabbarimalayeri from Iran and Ms Annemie Willemen from Belgium joined the Laboratory as interns working on various R&D projects. In addition, Mr Jonas Van Laere from Belgium and Ms Rayehe Mirkhani from Iran joined the SWMCN laboratory as PhD consultants. Jonas will be working on the improvement of cassava agronomy to counteract drought effects under the collaborative work with CIALCA, while Rayahe will be measuring greenhouse gas emissions and identifying their microbial sources in soil using isotopic and related techniques.

Finally, I would like to take this opportunity to once again thank all our readers for their continuous support. My very best wishes for 2020.

Lee Heng
Head
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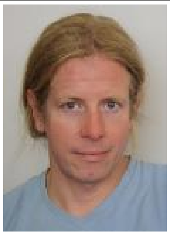			
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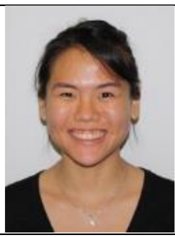
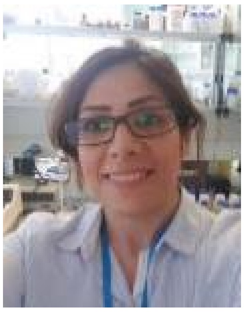
			
J.M. Mletzko	A. Lee-Zhi-Yi	T. Eguchi	M. Vanthygem
			
J. Van Laere	R. Mirkhani		

Francesc Xavier Dengra i Grau (Spain) joined the SWMCN Laboratory as an intern in September 2019. He is a graduate in Biotechnology from the Autonomous University of Barcelona, Spain, with the specialisation in environmental, food and industrial bioprocessing. He is currently conducting his MSc thesis on the effect of zeolite application on the radiocaesium interception potential of Japanese and European soils. The opportunity of working in the Joint FAO/IAEA Division will allow him to gain practical experiences in the use of techniques to improve remediation of agricultural land affected by a nuclear emergency, while the SWMCN Laboratory develops new partnerships with the University of Natural Resources and Life Sciences (BOKU), Vienna, Austria, and the University of Copenhagen, Denmark where Xavier is jointly developing his MSc studies.



Hoda Jabbarimalayeri (Iran) joined the SWMCN Laboratory in October 2019 as an intern. Hoda holds a BSc in Plant Protection from the Razi University of Kermanshah, Iran. Hoda is now completing her MSc study at the University of Natural Resources and Life Sciences (BOKU), Vienna, Austria. For her master's research, she worked on Myxomycetes for possible applications as antagonists in biocontrol of plant pathogens. During her internship at the SWMCN Laboratory she will be working on the analysis of stable isotopes (^{13}C and ^{15}N) and ion chromatography for improving land, water and crop management.

Jonas Van Laere (Belgium) joined the SWMCN Laboratory as a PhD-consultant in October. He will conduct his research under the Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA), a collaboration between FAO/IAEA, IITA and Bioversity International. Jonas graduated last year from the University of Leuven, Belgium, as a Bioscience Engineer and is now enrolled in a joint PhD program between the University of Leuven, Belgium, and University of Natural Resources and Life Sciences (BOKU), Vienna, Austria. For his MSc thesis research, Jonas focused on nutrient management of cassava, a staple crop for almost 800 million people worldwide. After his graduation, he started working as an intern in the SWMCN Laboratory on stable isotope (^{13}C and ^{18}O) applications for water use management in cassava cropping systems. He will now further explore the possible applications of stable isotopes to assess water use efficiency of cassava cropping systems, mainly focussing on Central Africa during his PhD. The majority of the work will consist of greenhouse experiments in Seibersdorf, although field experiments in the Democratic Republic of Congo will also be part of his work package.

Annemie Willemen is a master's student in Bioscience Engineering at KU Leuven, Belgium, with specialization in Environmental Technology – Industrial Microbiology. For the research of her MSc thesis proof, she will work from August on the application of stable isotopes in the search for increasing the water use efficiency of cassava. She is looking forward to delve into this challenging research within the FAO/IAEA Joint Division and hopes to deeply abroad her scientific skills and knowledge with this internship.

Rayehe Mirkhani (Iran) joined the SWMCN laboratory in November 2019 as a PhD consultant for one year. She will conduct experiments under glasshouse and field conditions measuring greenhouse gas (GHG) emissions, and identifying their microbial sources in soil using isotopic and related techniques. Rayehe is currently a PhD student at the Tehran University, focusing on developing climate smart agricultural practices to enhance crop productivity and mitigate GHG emissions from agriculture using ^{15}N and related techniques.

Belinda Westmacott (UK) joined the SWMCN team in November 2019 as a Team Assistant. She has been at the IAEA for over a year and was previously with the Isotope Hydrology Section. Prior to joining the IAEA she worked for the UK Ministry of Defence for 7 years as an Open Source Analyst and Geospatial Analyst.

Feature Articles

Antimicrobial movement from agricultural areas to the environment: A role for nuclear techniques

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Introduction

Antimicrobials (AM) play a critical role in the treatment of human and animal (aquatic and terrestrial) diseases, which has led to their widespread application and use. Antimicrobial resistance (AMR) is the ability of microorganisms (e.g. bacteria, viruses and some parasites) to stop an antibiotic, such as an antimicrobial, antiviral or antimalarial, from working against them. Globally, about 700 000 deaths per year arise from resistant infections as a result of the fact that antimicrobial drugs have become less effective at killing resistant pathogens. Antimicrobial chemicals that are present in environmental compartments can trigger the development of AMR. These chemicals can also cause antibiotic-resistant bacteria (ARB) to further spread antibiotic resistance genes (ARG) because they may have an evolutionary advantage over non-resistant bacteria. A report on the Joint FAO/WHO Expert Meeting in collaboration with the World Organization for Animal Health (OIE) on Foodborne Antimicrobial Resistance 'Role of the Environment, Crops and Biocides' (November 2018) indicated that conventional and organically grown vegetables can be vehicles for the dissemination of AMR bacteria and their resistance genes to humans if consumed raw, and that soil, organic fertilizers and irrigation water are sources of microbial residues and contamination. Thus, AMR bacteria are present in agricultural soil and may spread into the food. A better understanding of how antimicrobial resistance moves from agricultural areas to the environment through soil and water is important if we are to develop guidance to managing it cost effectively. The paper focuses on the potential of the use of nuclear techniques (Compound Specific Stable Isotope Analysis) to determine the origin, production process and transport of AM through soil and water to the environment.

Antimicrobial movement from agricultural areas to the environment

Antibiotic resistance can originate from several mechanisms: (1) the transformation ('breakdown') of antibiotics; (2) changes in the bacterial target site; (3) active efflux or decreased permeability; and (4) general cell adaption (Figure 1). Often, bacteria develop several strategies in parallel in order to circumvent antibiotic action. The transformation of antibiotics includes different degradation mechanisms. Antibiotics can enter the environment during the production process when they are discharged into waste water or, in some cases, directly into surface water, or as a result of their use in human and veterinary medicine or in plant production. While water is the main vector for moving compounds from human medicine and antimicrobial production (via waste water and release into surface water), soil is the most important vector when antibiotics are used as pesticides, or when manure and slurry used as fertilizers contain antibiotics from veterinary medicine and agricultural use. As can be seen in Figure 2, there are important knowledge gaps regarding the interdependency of antibiotics concentrations, ARGs concentrations and the abundance of pathogenic antibiotic-resistant bacteria. For antibiotics, we need to better understand how these chemicals spread from different sources in the environment and the environmental compartments in which they are degraded, so that elimination can be better predicted, and management efforts better targeted.

Existing conventional methods for monitoring antimicrobials

Liquid chromatography, mass spectrometry, and bioanalytical quantification of antibiotics are currently some of the conventional methods used for monitoring antimicrobials. Antimicrobial resistance in the environment is either identified by the cultivation of bacteria or by molecular biological methods. ARBs are isolated after cultivation on selective media, which contain the antibiotic of interest. The ARBs are picked depending on the morphology of the colonies on agar plates or their color contain the antibiotic of interest. The quantification, detection, typing and characterization of ARGs in environmental samples are possible using molecular biological methods. These methods are based on nucleic acid amplification tests (NAATs), DNA sequencing, or DNA hybridization (Zhang *et al.*, 2009) and are applied either after cultivation or directly after filtration of water samples.

Nuclear techniques (multi-element stable isotopes fingerprinting) and tools for determining the source and transport of AM

Nuclear techniques trace the antibiotic medicine – the chemical, not the antimicrobial resistance which is the pathogen in question. Once a selection pressure is imposed, antimicrobial resistance genes may potentially originate, amplify and distribute in a dynamic of their own. Compound-specific stable isotope analysis (CSIA) is a powerful tool that can provide answers when existing monitoring methods fall short. On the one hand, isotopic source fingerprinting may reveal different sources of an identical chemical; on the other hand, degradation-induced changes in isotope ratios (isotope fractionation) may detect when a given chemical has been transformed or degraded. Successful applications have focused on the sources and fates of many common groundwater contaminants such as chlorinated solvents and BTEX (benzene, toluene, ethylbenzene, and xylene) compounds (Fischer *et al*., 2016). While a decrease in concentration of a contaminant can result from transformation (Barber *et al*., 2009), dilution or sorption, pronounced changes in the stable isotope composition of a contaminant are the hallmark of kinetic isotope effects and are thus a reliable indicator that (bio)transformation has occurred (Elsner *et al*., 2005). The observed isotope fractionation in situ can be compared with laboratory observations, determining a pathway-specific enrichment factor. Thus, CSIA can be used to qualify and quantify in situ transformations. The latest methodological advances even allow the analysis of several elements (H, C, Cl, N) within a molecule. This multi-element isotope information can be used to elucidate in situ transformation pathways and underlying reaction mechanisms. In addition, an analysis of stable isotope patterns can be used to determine the source of a contamination, because the ground stocks and synthesis pathway used during production can leave a typical 'stable isotope fingerprint'(Nijenhuis *et al.*, 2016). CSIA may also help to determine the source and fate of antibiotics in the environment, with some restrictions.

Conclusions and the way forward

Antibiotics kill bacteria, healing infections that cause diseases and death. Unfortunately, bacteria have learned how to quickly evolve and resist the effect of antibiotics. The antibiotic resistance genes coding for these adaptations may be transferred to pathogens which can lead to multi-resistances causing millions of deaths each year. Hence, an urgent need exists to understand the sources and environmental fate of antibiotics, antibiotic resistance genes and the pathogens carrying the resistance genes. Tracing antibiotics and antibiotic resistance is extremely complex because it requires us to consider three different contaminants at the same time: antibiotics, resistance genes and pathogenic bacteria. To make matters worse, the conditions under which antibiotics are eliminated are not necessarily those under which resistance genes and pathogenic bacteria are eliminated. This paper identifies three major knowledge gaps namely: (1) what are the sources of antibiotics and where are the antibiotics eliminated? (2) how is ARG gene abundance influenced by antibiotic concentrations and environmental driver? (3) in which host organisms are antibiotic resistances located?

To answer the first question further advances in compound-specific isotope analysis could contribute to isotopic fingerprinting of sources and may detect the degradation of antibiotics by transformation-induced isotope effects. To answer the second question we argue that quantitative and time-resolved data are needed. To this end, we propose microarray-based bioanalytics for targeted analysis of ARGs and ARBs as a rapid, cultivation-independent approach. Finally, to answer the third question we argue that further advances – based on sorting and/or single-cell analysis – will be necessary to link resistance to infectivity, and to characterize the spread of antibiotic resistance based on antibiotic concentrations and environmental factors. For the future, there is a need to develop a step-wise methodology to monitor antimicrobial and antimicrobial resistance in the environment.

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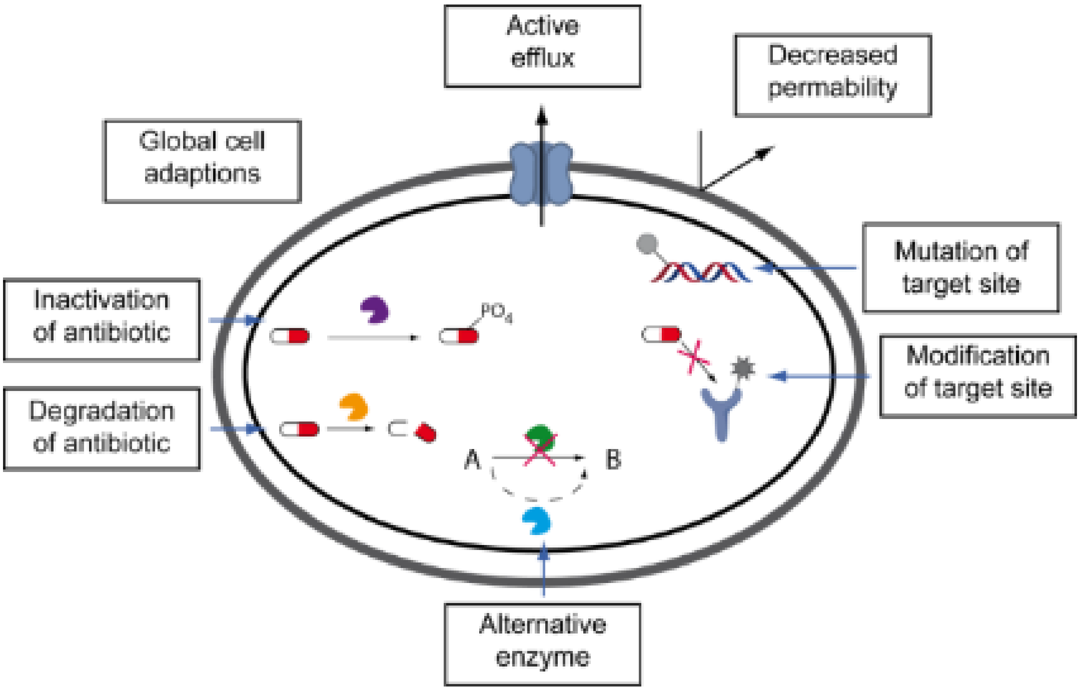


Figure 1. Overview of different resistance strategies of microorganisms

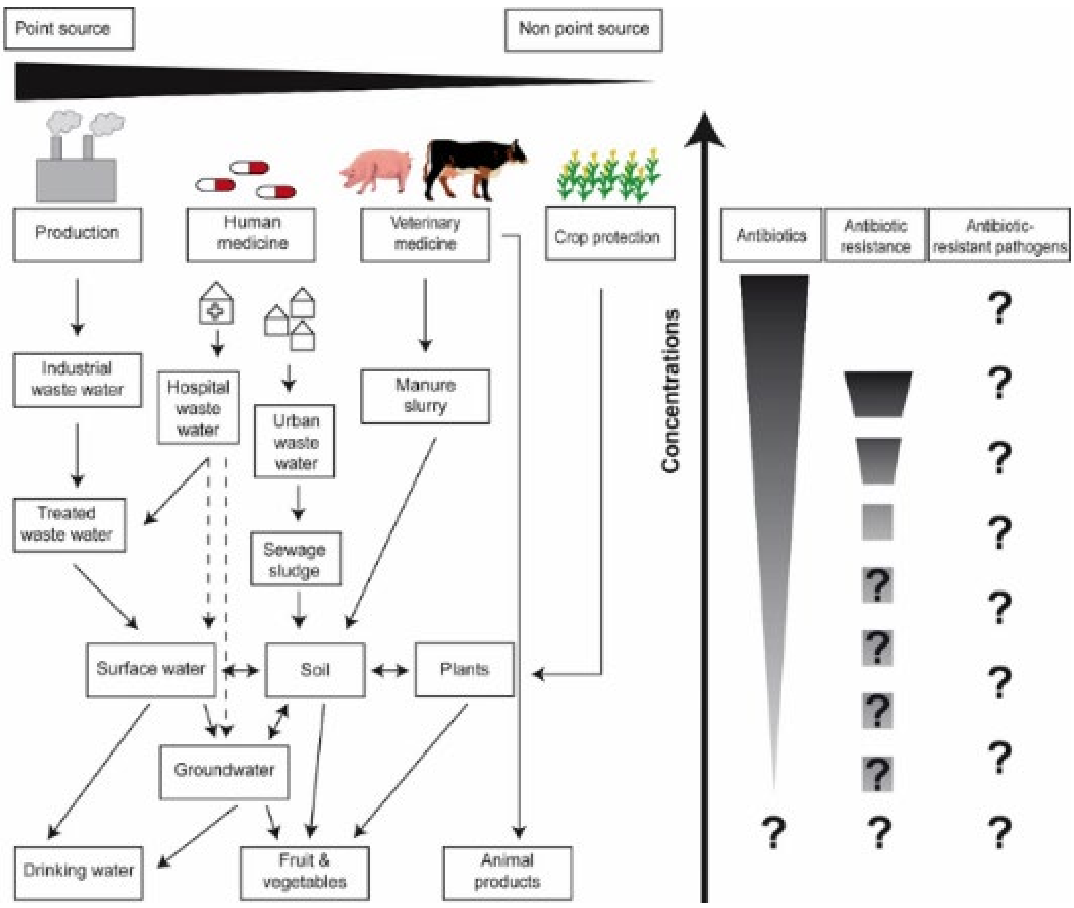


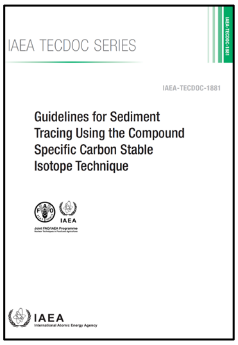
Figure 2. Input pathways for antibiotics, antibiotic resistance and antibiotic-resistant pathogens into the environment and the food chain (left) and current knowledge gaps about their concentration behaviour throughout the process (right).

Announcements

New FAO/IAEA Publications

Guidelines for Sediment Tracing Using the Compound Specific Carbon Stable Isotope Technique (IAEA-TECDOC-1881)

With increasing attention being paid by both developing and developed countries to soil erosion and its associated sedimentation processes, this TECDOC addresses both theoretical and practical aspects of the compound-specific stable isotopes (CSSI) technique, based on the determination of $\delta^{13}C$ signatures of fatty acids (FAs) used as soil and sediment fingerprints.



This publication provides guidance in the use of the CSSI technique for identifying areas at risk and the sources of sediment within agro-ecosystems, and disseminates the technical knowledge gained within the on-going Coordinated Research Project D1.50.17 '*Nuclear Techniques for a Better Understanding of the Impact of Climate Change on Soil Erosion in Upland Agro-ecosystems*', which started in mid-2016.

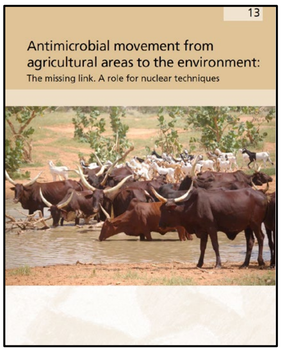
While covering the fundamental concepts of the CSSI technique, this comprehensive illustrated guideline distinguishes itself from others by providing step-by-step instructions for scientists, technicians and students on how to effectively use this innovative approach for effective application of climate smart agriculture and for improving area-wide soil conservation strategies in fragile agricultural landscapes.

This publication is divided into five sections. After giving background information, the first section introduces the concepts and assumptions behind the technique; the second section details the sampling strategy to optimise its field application; the third section gives information how to prepare and analyse the soil and sediment samples collected; and the fourth and fifth sections provide guidance on data treatment and interpretation of the results.

It is important to mention that the CSSI technique using $\delta^{13}C$-FAs is still in its infancy. We therefore encourage scientists and experts in Member States to test it under various agro-ecosystems and as well to update their knowledge about the latest development as new studies and methodological papers are regularly published in peer-reviewed soil and environmental science journals.

https://www.iaea.org/publications/13564/guidelines-for-sediment-tracing-using-the-compound-specific-carbon-stable-isotope-technique

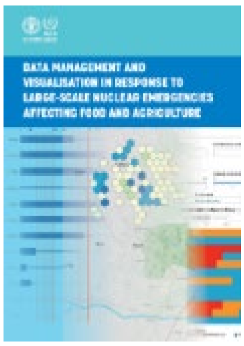
Antimicrobial Movement from Agricultural Areas to the Environment: The Missing Link. A Role for Nuclear Techniques



Antimicrobials play a critical role in the treatment of human and animal (aquatic and terrestrial) diseases, which has led to their widespread application and use. For some time now, antimicrobial resistance (AMR) has been approached mainly from the human and animal health angles, however little is known about the impacts that AMR in the environment may have on health. This technical paper developed by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture (AGE), the Animal Health Service (AGAH) and the Land and Water Division (CBL), Climate, Biodiversity, Land and Water Department of the Food and Agriculture Organization of the United Nations (FAO), examines the potential of nuclear techniques to determine the sources of antibiotics and may detect the degradation of antibiotics by transformation-induced isotopic effects.

http://www.fao.org/3/ca5386en/ca5386en.pdf

Data Management and Visualisation in Response to Large-Scale Nuclear Emergencies Affecting Food and Agriculture



This FAO technical guideline presents the challenges of data management, geo-visualisation and decision making in nuclear emergency preparedness and response in food and agriculture. It further elaborates how IT-Decision Support System (IT-DSS) tools and algorithms allow for improved, real-time management of large volumes of data and integrated decision-making support in a spatial and temporal context. Two case studies of such IT-DSS are presented; one by the Soil and Water Management and Crop Nutrition Laboratory of the Joint FAO/IAEA Division, and the other case study by Japanese Competent Authorities in the aftermath of the Fukushima Daiichi Nuclear Power Plant accident.http://www.fao.org/3/ca6666en/ca6666en.pdf

Technical Cooperation Field Projects

Country/Region	TC Project	Description	Technical Officer(s)
Afghanistan	AFG5008	Strengthening Climate Smart Agricultural Practices for Wheat, Fruits and Vegetable Crops	M. Zaman
Algeria	ALG5031	Using Nuclear Techniques to Characterize the Potentials of Soils and Vegetation for the Rehabilitation of Regions Affected by Desertification	M. Zaman
Azerbaijan	AZB5003	Determining of Radioactive Substances in the Environment with a Focus on Water and Soil	E. Fulajtar
Bangladesh	BGD5033	Using Nuclear Techniques in Assessing River Bank Erosion	E. Fulajtar
Burundi	BDI5001	Improving Cassava Productivity through Mutation Breeding and Better Water and Nutrient Management Practices Using Nuclear Techniques	M. Zaman with PBG
Cambodia	KAM5005	Enhancing Soil, Water and Nutrient Management for Sustainable Rice Production and Optimized Yield	J. Adu-Gyamfi
Central African Republic	CAF5012	Building Capacities in Developing Best Agricultural Practices for Enhanced Production of Maize and Its Quality – Phase I	M. Zaman
Chad	CHD5009	Developing Sustainable Water Resources Management through the Use of Nuclear Isotopic Techniques in Drip Irrigation Systems	J. Halder
Colombia	COS5033	Enhancing Crop Productivity of Creole Potato Using Nuclear and Related Techniques	M. Zaman and PBG
Costa Rica	COS5035	Building Capacity for the Development of Climate-Smart Agriculture in Rice Farming	M. Zaman
Cuba	CUB5023	Strengthening National Capacities for the Development of New Varieties of Crops through Induced Mutation to Improve Food Security While Minimizing the Environmental Footprint	E. Fulajtar
Gabon	GAB5003	Building National Capacities for Monitoring Sedimentation of Dams and Harbors and the Management of Remediation Operations	E. Fulajtar
Gabon	GAB5004	Improving Soil Fertility Management for Enhanced Maize, Soybean and Groundnut Production	J.Adu-Gyamfi
Haiti	HAI5008	Strengthening National Capacities for Enhanced Agricultural Crop Productivity	J.Adu-Gyamfi
Indonesia	INS5043	Intensifying Quality Soybean Production in Indonesia to achieve self-sufficiency	J. Adu-Gyamfi 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	INT5156	Building Capacity and Generating Evidence for Climate Change Impacts on Soil, Sediments and Water Resources in Mountainous Regions	G. Dercon
Iran	IRA5015	Enhancing Capacity of National Producers to Achieve Higher Levels of Self-Sufficiency in Key Staple Crops	M. Zaman with FEP and PBG
Iraq	IRQ5022	Developing Climate-Smart Irrigation and Nutrient Management Practices to Maximize Water Productivity and Nutrient Use Efficiency at Farm Scale Level Using Nuclear Techniques and Advanced Technology	M. Zaman
Kuwait	KUW5004	Improving Production and Water Use Efficiency of Forage Crops with Nuclear Techniques	J. Halder

Laos	LAO5004	Enhancing National Capability for Crop Production and Controlling Trans-Boundary Animal Diseases	M. Zaman with APH
Lesotho	LES5009	Determining Soil Nutrient and Water Use Efficiency Using Isotope Techniques	J. Adu-Gyamfi
Madagascar	MAG5026	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 with PBG
Malawi	MLW5003	Developing Drought Tolerant, High Yielding and Nutritious Crops to Combat the Adverse Effects of Climate Change	E. Fulajtar with PBG
Malaysia	MAL5032	Strengthening National Capacity in Improving the Production of Rice and Fodder Crops and Authenticity of Local Honey Using Nuclear and Related Technologies	E. Fulajtar with PBG and APH
Mali	MLI5030	Developing and Strengthening Climate Smart Agricultural Practices for Enhanced Rice Production — Phase I	M. Zaman
Mauritania	MAU5006	Contributing to the Improvement of Rice Crop Yields through the Application of Nuclear Techniques to Water Management and Soil Fertility	M. Zaman 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	NAM5017	Improving Crops for Drought Resilience and Nutritional Quality	J. Adu-Gyamfi with PBG
Pakistan	PAK5051	Developing Isotope-Aided Techniques in Agriculture for Resource Conservation and Climate Change Adaptation and Mitigation	M. Zaman
Panama	PAN5028	Improving the Quality of Organic Cocoa Production by Monitoring Heavy Metal Concentrations in Soils and Evaluating Crop Water Use Efficiency	J. Adu-Gyamfi
Peru	PER5033	Application of Nuclear Techniques for Assessing Soil Erosion and Sedimentation in Mountain Agricultural Catchments	E. Fulajtar
Qatar	QAT5008	Developing Best Soil, Nutrient, Water and Plant Practices for Increased Production of Forages under Saline Conditions and Vegetables under Glasshouse Using Nuclear and Related Techniques	M. Zaman
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 Africa	RAF5081	Enhancing Productivity and Climate Resilience in Cassava-Based Systems through Improved Nutrient, Water and Soil Management (AFRA)	M. Zaman and G. Dercon
Regional project Asia	RAS5073	Climate Proofing Rice Production Systems (CRiPS) Based on Nuclear Applications, Phase II	L. Heng 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 Asia	RAS5089	Enhancing the Sustainability of Date Palm Production in States Parties through Climate-Smart Irrigation, Nutrient and Best Management Practices (ARASIA)	H. Said

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
Regional project Latin America	RLA5084	Developing Human Resources and Building Capacity of Member States in the Application of Nuclear Technology to Agriculture	J. Adu-Gyamfi with PBG and FEP
Rwanda	RWA5001	Improving Cassava Resilience to Drought and Waterlogging Stress through Mutation Breeding and Nutrient, Soil and Water Management Techniques	M. Zaman with PBG
Senegal	SEN5041	Strengthening Climate Smart Agricultural Practices Using Nuclear and Isotopic Techniques on Salt Affected Soils	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
Sierra Leone	SIL5021	Improving Productivity of Rice and Cassava to Contribute to Food Security	M. Zaman with PBG
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 with PBG
Togo	TOG5002	Improving Crop Productivity and Agricultural Practices Through Radiation Induced Mutation Techniques	E. Fulajtar with PBG
Zambia	ZAM5031	Improving the Yield of Selected Crops to Combat Climate Change	L. Heng in collaboration with PBG

Forthcoming Events

FAO/IAEA Events

Second Coordination Meeting of RLA5078 'Improving Fertilization Practices in Crops through the Use of Efficient Genotypes, Macronutrients and Plant Growth Promoting Bacteria (ARCAL CLVII)', 20-24 January 2020, Santiago, Chile.

Technical Officer: J. Adu-Gyamfi

Second Research Coordination Meeting of CRP D1.50.18. 'Multiple Isotope Fingerprints to Identify Sources and Transport of Agro-Contaminants', 2–6 March 2020, Accra, Ghana.

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

Final Coordination Meeting of RAS5073 'Climate Proofing Rice Production Systems (CRiPS) Based on Nuclear Applications, Phase II', 16-20 March 2020, Jakarta, Indonesia.

Technical Officer: L. Heng

Workshop of RAS5084 'Assessing and Improving Soil and Water Quality to Minimize Land Degradation and Enhance Crop Productivity Using Nuclear Techniques', on 'Land Use and Management Practices to Reduce Sediments and Agro-contaminants on Trans-boundary Rivers', 8-12 June 2020, Manila, Philippines.

Technical Officer: J. Adu-Gyamfi

Non-FAO/IAEA Events

European Geoscience Union (EGU) General Assembly, 3-8 May 2020, Vienna, Austria.

Past Events

FAO/IAEA Events

IAEA's expert visit to Azerbaijan, 3-4 July 2019, Baku, Azerbaijan

Technical Officer: L. Heng

At the request of Azerbaijan Permanent Mission in Vienna, Lee Heng and Mr Qu Liang, Director of the Joint FAO/IAEA Division travelled to Baku to discuss with counterparts in the Ministry of Agriculture of Azerbaijan the strategic and technical aspects relevant to increasing cotton production in Azerbaijan and to raise awareness of the government's vital role prior to the initiation of cooperation.

A meeting was held with Mr. Ghulm Isaczai, the United Nations Resident Coordinator (UNRC) to brief him of the mission. The office of UNRC coordinates inter-agency, country-level implementation of all UN programmes and their reporting. Joining the meeting was Mr Shahin Isayev, FAO Project Team Leader from FAO Partnership and Liaison Office in Azerbaijan.

A group discussion was held with 15 scientists on the strategic advice for sustainable cotton production in Azerbaijan through mutation breeding and effective soil, water and, nutrient management by using nuclear and related techniques at the Ministry of Agriculture.

A meeting took place with Mr. Inam Karimov, Minister of Agriculture of the Republic of Azerbaijan. Mr Karimov mentioned his ministry is taking various measures to develop the cotton industry. He also emphasized the needs for eco-, social-and environmentally friendliness, using modern technology in all aspects of agricultural production in Azerbaijan including cotton production.

A trip was made to Ujar, a cotton growing region. In the field, cotton mutant field experimental trials under current Technical Cooperation project AZB5002 'Developing Mutant Cotton Breeding Lines Tolerant to Diseases, Drought and Salinity through Mutation Breeding' implemented. Finally, a meeting was also held with Azerbaijan NLO Ms Aygun Asadova to brief her of the mission.

Regional Training Course of RAF5079 on 'Water Use Efficiency and its Impact on Socio-Economic Factors', 8-19 July 2019, Gaborone, Botswana

Technical Officer: L. Heng

The purpose of this regional training course was to enhance African Member States in the knowledge on water use efficiency and its impact on socio-economic factors. The training course was attended by thirty-three participants from sixteen countries: Algeria, Benin, Botswana, Cote D'Voire, Egypt, Ethiopia, Ghana, Kenya, Mali, Mauritius, Morocco, Nigeria, Senegal, Sudan, Uganda and Zimbabwe. Mr Douglas Machacha, from Botswana Department of Agricultural Research, Ministry of Agriculture was the course director. The technical officer gave lectures on the chain of water use efficiency steps from reservoir water to harvest yield to its improvement by various water management practices and demonstrated the potential impacts on the overall WUE. A systematic way to evaluate different parts of WUE or productivity was provided, whereby precise way to calculate the overall efficiency and the impact of improvement in these steps. The means to do economic analysis and optimization of resource allocation and case studies in the improvement of WUE were explained and given, to show where resource should be allocated to steps with the least cost for each relative unit of improvement in its existing efficiency. The illustration showed that it is more effective to improve several or more steps than on one single step.

Horticultural farmers around Gaborone

Individual calculations of WUE from each country and results were subsequently presented. A field trip was carried out to visit horticultural farmers around Gaborone and to the Department of Agricultural Research experimental station. During the training, national and regional work plans were revised and updated.

Consultant Meeting to Develop the Second Phase of the Greenhouse Gas CRP 'Developing Climate Smart Agricultural Practices for Carbon Sequestration and Mitigation of Greenhouse Gases' 22–25 July 2019, IAEA, Vienna, Austria

Project Officers: M. Zaman & L. Heng

On a global scale, carbon dioxide (CO_2) is responsible for approximately 66% of the greenhouse gases (GHGs) effect. Direct and indirect GHG emissions from agriculture, forestry, and other land use sectors contribute to approximately 25% of the global anthropogenic GHG emissions globally, and the largest contributors to these GHGs are methane (CH_4) and nitrous oxide (N_2O), which predominantly originate from natural sources including agriculture. Many farm practices such as soil cultivation, application of nitrogen (N) fertilizers, animal manure, farm effluent, crop residues and excreta from grazing livestock lead to GHG emissions to the atmosphere. Increasing demands for food in developing countries as a result of human population growth and of increasing demands for dairy and meat products in both the developed countries and fast-growing economies will markedly exacerbate these GHG emissions. Five experts - Mr Zucong Cai, Nanjing Normal University, China; Mr Scott Chang, University of Alberta, Edmonton, Canada; Mr Miloslav Simek, University of South Bohemia, České Budějovice, Czech Republic; Mr Tim Clough, Lincoln University, New Zealand; and Mr Christoph Müller, Justus-Liebig University Giessen, Germany were invited to attend a consultant meeting to design the second phase of the CRP (Developing Climate Smart Agricultural Practices for Carbon Sequestration and Mitigation of Greenhouse Gases). During the 4 days consultant meeting, the experts reviewed the outputs of the completed CRP D1.50.16, identified gaps in the current knowledge on cost effective climate smart agricultural practices for mitigation of GHGs (N_2O, CO_2 and CH_4) and key risks in adaption of such technology.

First Research Coordination Meeting of CRP D1.20.14 'Enhancing Agricultural Resilience and Water Security using Cosmic-Ray Neutron Sensor', 26-30 August 2019, Vienna, Austria.

Technical Officers: E. Fulajtar and J. Halder

The major objectives of the first RCM was to review the state of the art Cosmic-Ray Neutron Sensor use in partner countries and to develop the detailed work plan for all project partners. In total 9 partners attended the meeting (Brazil, 2 partners from China, Mexico, United Kingdom, Denmark, Netherlands, Italy, Spain and USA). Mr M. Schroen, an expert from Germany, participated the RCM remotely.

The major results of this meeting were: (1) reviewing the state of the art research on use of CRNS and GRS for soil moisture assessment on agricultural land; (2) development of detailed work plans for national case studies and updating overall workplan of CRP; (3) establishing specific cooperation activities of technical contract holders and research agreement holders to support research contract holders through provision of methodological guidance, help with processing of their data and using the collected data for soil moisture dynamics modelling and remote sensing validation and 4) publication plan.

Advanced Regional Training Course of RLA5078 'Bio-stimulants and Biofertilizers for Crop Growth Enhancement', 2–6 September 2019, University of Sao Paulo, Piracicaba, Brazil.

Technical Officer: J. Adu-Gyamfi

The purpose of this one-week RAS5084 regional training course was to provide participants with theoretical principles and practical techniques on the use of biofertilizers for enhanced crop production. The training was attended by 12 participants from 10 countries. Participants were trained on (1) basic concepts related to biofertilizers, (2) isolation and characterization of strains, (3) multiplication, conservation, conditioning and application procedures, (4) field trials on efficiency of biofertilizers to enhance crop yields and (5) use of biofertilizers (Rhizobia) to enhance biological nitrogen fixation.

RLA5078 participants visiting greenhouse experiments

In a welcome address, Prof. Takashi Muraoka, of Centro de Energia Nuclear na Agricultura (CENA), Universidade de Sao Paulo (USP) Piracicaba, Brazil thanked all the participants and stressed the importance of the training course in terms of using isotopic techniques to assess the effect of bio-stimulants and biofertilizers to enhance crop productivity in the region, on plant growth, and the current and future potential of bio-stimulants and bio-fertilizers on agriculture. A state-of-the-art research on microelements for plant growth such as inductors, bio-stimulants and bio-regulators with practical examples and case studies was presented. This regional course enabled attendants to develop skills concerning bio-fertilizers and bio-stimulants, through ´hands-on-training´, acquiring practical techniques to be applied in their individual countries to promote a sustainable agriculture to face challenges from the accelerated climate change.

Training Course of BDI5001 on 'Using Climate Smart Agricultural Practices to Improve Cassava Production and ^{15}N Technique to Measure Fertiliser Use Efficiency', 23–27 September 2019, Bujumbura, Burundi.

Technical Officer: M. Zaman

There is a big yield gap in cassava productivity in Burundi and Central Africa Republic due to poor farming practices. Therefore, it is necessary to equip scientists with knowledge on climate smart agricultural practices to increase cassava production in the region. The Technical Officer travelled to Bujumbura, Burundi to train researchers, extension workers and university staff from Burundi and Central Africa Republic on how to enhance cassava production using climate smart agricultural practices and measure fertiliser use efficiency through ^{15}N technique. The training was attended by 22 participants from Agricultural Research Institute (IABBU), IFDC, Ministry of Agriculture and livestock and University of Burundi and 4 participants from Bangui University in Central Africa Republic.

Training course participants and local farmers at the cassava demonstration site

During the opening ceremony of the training, the IABBU director highlighted the challenges of food security, subsistence farming and the lack of technical resources in Burundi. The technical officer described the objectives of the national training, and the role of isotopic and related techniques to develop climate smart agricultural practices for cassava production. The technical officer then provided lectures and hands on training by covering a range of topics including improving soil fertility, nutrients and water use efficiencies, and best soil, nutrients and water management practices for cassava production, and ^{15}N technique to measure fertiliser use efficiency. All participants visited a demonstration site near Gisozi Research Station where female farmer association comprised of over 50 farmers previously learnt and adopted climate smart agricultural practices for cassava cultivation. These best practices enabled those farmers to triple their cassava yield. The leader of the farmer association shared his experience of getting higher cassava yield and income by adopting climate smart agricultural practices. The technical officer and the project counterpart are now working together to develop a mechanism to disseminate these climate smart agricultural practices to farmers in other regions of Burundi to enhance cassava production.

Training course on 'Use of UAV Based Multispectral Camera in Agriculture', 23-27 September 2019, IAEA Laboratories, Seibersdorf, Austria.

SWMCN Section Staff: J. Halder

In order to explore the opportunities to use UAV (Unmanned Aerial Vehicles) based multispectral cameras for soil research a training course was organized for the staff of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. For information on this event see the SNL Section on Soil Lab Developments (page 27).

Advanced Regional Training Course of RLA5078 on 'Use of ^{15}N for Evaluating Efficiency of Nitrogen Fertilizer and Plant Growth Agents', 26–30 September 2019, University of Sao Paulo, Piracicaba, Brazil.

Technical Officer: J. Adu-Gyamfi

The purpose of this one-week RAS5084 regional training course was to provide participants with theoretical principles and practical techniques using ^{15}N for assessing fertilizer nitrogen use efficiency, and quantify biological nitrogen fixation by legumes for enhanced crop productivity under field conditions. The training was attended by 14 participants from 12 countries.

Participants of the RLA5078 training course in Brazil

Participants were trained on (1) principles of using stable and radioactive isotopes in soil-water-nutrient management, (2) field experimentation to use 15N isotopic techniques to quantify biological nitrogen fixation (BNF) by legumes and nitrogen use efficiency (NUE) by cereals including field experimental design, microplots, ^{15}N calculations for field application and the use of reference crops for quantifying BNF. The participants visited the

Laboratories of Centro de Energia Nuclear na Agricultura (CENA), where they received training on plant and soil sample processing and the procedure to elaborate enriched 15N fertilizers; also, research lines of each laboratory were presented. Participants exchanged information and experiences concerning the current status of the project and were encouraged to develop partnership and opportunities for outreach.

Installation and Training on Cryogenic Water Extraction Systems, 6-14 October 2019, Bukavu, Democratic Reoublic of Congo.

SWMCN Laboratory Staff: G. Weltin

Since last year, SWMCNL is part of the CIALCA initiative (Consortium for Improving Agriculture-based Livelihoods in Central Africa, https://www.cialca.org/) supporting research and development in Burundi, eastern DR Congo and Rwanda. In October 2019 CIALCA supported the expert mission of G. Weltin from SWMCNL to Bukavu, DRC, to provide technical support for the installation of a Cryogenic Water Extraction System (CWES), which was developed by SWMCN Laboratory staff in 2012, at the IITA Kalambo Research Station. The system setup, its operation and related sampling techniques were covered within IAEA-TECDOC-1783 https://www.iaea.org/publications/10991/supporting-sampling-and-sample-preparation-tools-for-isotope-and-nuclear-analysis.

The main goals of the mission were achieved successfully. Hands-on training regarding sampling for cryogenic water extraction systems, as well as handling and evacuating the system-specific glassware and explaning the theoreties of the system (Figs. 1 and 2). The experience gained from this training was salutary not only for scientists from the Democratic Republic of Congo, but for SWMCL laboratory as well. It was a chance to field-test the SWCNL's manual and CWES, under tropical conditions of Central Africa. This experience and gained knowledge will help to further improve both CWES and the manual. It will help to make CWES system capable of operation under a wide range of external conditions, producing extracts in a comparable way, which is the prerequisite for comparable results of water isotopic analysis.

Another useful experience and technical challenges while setting up the equipment was power interruptions encountered, as a result, the cooling unit could not manage to facilitate isopropanol temperatures anticipated.

These problems were solved with an UPS (Uninterruptible Power Supply), additional insulation of the cooler's hose, a more pronounced spatial separation of the cooler's heat exchanger and the Dewar vessel. In the end, all issues, except the temperature offset in the Dewar vessel, have been solved.

Figure 1. IITA Kalambo: evacuation of CWEU glassware

Figure 2. Sampling for CWE, CWES temperature assessment

Regional Training Course on 'Greenhouse Gas Emissions Using Nuclear and Related Techniques, 7–11 October 2019, Dhaka, Bangladesh.

Technical Officer: M. Zaman

The technical officer, together with an expert, Mr. Christoph Müller, travelled to Dhaka, Bangladesh, to facilitate the Mid-term Coordination Meeting of the regional TC project RAS5083 and Workshop for 5 days at Bangladesh Atomic Energy Commission. The meeting was attended by 16 representatives, five from Bangladesh, two from Iran, one each from China, Indonesia, Iraq, LAO, Malaysia, Philippine, Saudi Arabia, Sri Lanka and Yamen. Mr. Lutful Hassan, Vice-Chancellor of Bangladesh Agricultural University welcomed the meeting participants and presented a brief overview of the research activities in Bangladesh. The technical officer described the objectives and expected outcome of the meeting, priorities and platforms for collaboration. Each country representative presented a summary of his/her ongoing and future field research work on GHG emission from agriculture in their respective country followed by feedback from the technical officer and the expert. The expert and the technical officer also provided lecture and hands on training on ^{15}N tracing and chamber techniques to quantify GHGs and identify the exact source of GHG production in soil. The technical officer left Dhaka after 5 days and the participants went to Bangladesh Agricultural University, Mymensingh, where the expert provided hands on training on GHGs from rice paddies.

Third RCM of CRP 'Nuclear Techniques for a Better Understanding of the Impact of Climate Change on Soil Erosion in Upland Agro-ecosystems' (D1.50.17), 14-17 October 2019, Vienna, Austria

Technical Officers: L. Mabit and L. Heng

The major objectives of the third RCM was to present the results achieved since the 2nd RCM and to review the country work plans for the last period of the project lifetime. The RCM summarized, discussed and evaluated the new results and it was concluded that the project has already had a lot of good achievements and the project activities are advancing in accordance with work plans. It was highlighted that ^{137}Cs resampling can be a suitable approach to distinguish and apportion the impact of climate variability and agricultural management. Moreover, as demonstrated by case studies in Morocco and Iran, this approach allows to assess the effectiveness of soil conservation measures.

First Research Coordination Meeting of CRP 'Remediation of Radioactive Contaminated Agricultural Land' (D1.50.19), 21-24 October 2019, Vienna, Austria.

Technical Officers: G. Dercon and A. Lee Zhi Yi

Eleven countries participated in this new CRP: seven research contract holders from Belarus, Chile, China, Morocco, Russia and Ukraine; two technical contract holders from France and Macedonia; and six agreement holders from Belgium, India and Japan.

The objectives and experimental plans of the national research projects were discussed and adjusted to be in line with the objectives and work plan of the CRP. Common guidelines for implementing projects and collaboration networks were established for the upcoming years.

Mid-Term Review Meeting of CIALCA Phase 4, 28 October-1 November 2019, Kigali, Rwanda.

SWMCN Lab Head: G. Dercon

Over thirty participants from the International Institute of Tropical Agriculture (IITA), Bioversity International, the SWMCN Subprogramme, regional and national governmental institutions, academia and industry gathered in Kigali, Rwanda to evaluate the mid-term results of the fourth phase of CIALCA (2017-2020).

During the mid-term review meeting, the CIALCA team strived for a good mix of science and development discussion, field visits, and interaction among the teams to keep CIALCA ahead of its game.

Halfway into the current CIALCA phase, the teams involved can already report good progress. CIALCA entered into several co-investment agreements with scaling partners such as One Acre Fund in Rwanda (serving approx. 300,000 farmers) and the International Fertilizer Development Center (IFDC) in Burundi. Also, in total CIALCA identified four new PhD students from Rwanda, Burundi, and eastern DR Congo that are starting their doctoral studies with Belgian universities and have five additional students that conduct their PhD under the CIALCA umbrella. CIALCA also attracted considerable additional investment of US$7.25 million that complement or build upon previous and ongoing CIALCA work. The innovative research for development work with the SWMCN Laboratory (SWMCNL) is providing insights in increased water use efficiency to counteract drought effects on cassava and banana production in Central Africa. CIALCA further builds on big data platforms such as RHoMIS and AKILIMO to better understand household heterogeneity and cassava agronomy at scale.

Mr Gerd Dercon presented the advances made in sampling and sample preparation methods for stable isotope analysis to address water use efficiency and drought stress in cassava and banana production systems. The importance of drivers such as potassium fertilizer in water use by cassava was emphasised, based on the results of the SWMCNL R&D. Further, the work at 121 CIALCA trials across the three targeted countries was discussed, which are implemented in close collaboration with the IITA. In these trials focus is put on how fertilizer management, the choice of varieties and planting time can improve yield and enhance resilience to changing climate conditions. Isotope analysis plays a major role in these trials as an indicator for water use efficiency and water stress. Mr Gerd Dercon informed the participants about the 2020 new IAEA regional TC project (RAF5083) which has 13 countries of the region participating, on the use of isotopes for improving cassava production. He also indicated that three PhD studies, linked to CIALCA, are implemented with the support of the SWMCN Subprogramme and one with the support of the Plant Breeding and Genetics Subprogramme.

Participants at cassava fields during excursion

During the field visit to the CIALCA trials, Mr. Gerd Dercon interacted with the different teams for achieving additional synergisms. This interaction led to new R&D ideas, such as the exploration of the link between drought, fertilizer management and nutritive quality of cassava. Further collaboration on this topic with the CIALCA partners is now being explored.

During final interactive exercises, the meeting participants explored how it can move towards a full consortium structure. Key pillars which should focus more were identified. Ways to improve partnership and capacity building were analysed. The results of these exercises will be used for future phases of CIALCA after 2020.

In total 121 field trials are installed in Burundi, the Democratic Republic of Congo and Rwanda by the CIALCA teams and are the basis for improving fertilizer management to increase cassava productivity. Stable isotope techniques are an integral part of these trials to make cassava production more climate-resilient.

Testing New Methods to Measure Isotopic Ratios of Inorganic Nitrogen in Soil Extracts, 4-8 November 2019, Giesen, Germany.

SWMCN Laboratory Staff: M. Heiling

The Institute for Plant Ecology at the Justus-Liebig University Giessen, Germany, invited Maria Heiling to participate in the evaluation of novel methods to determine the stable nitrogen isotope signatures of nitrate and ammonium in soil extracts. Different ways of sample preparation were tested to convert inorganic nitrogen to nitrous oxide (N_2O). The ^{15}N isotopic signature of that originated N_2O was determined, comparing two analytical instruments: cavity ring down spectrometer at the SWMCN laboratory, Seibersdorf and isotope ratio mass spectrometry at Justus-Liebig University, Giessen.

This visit supports R&D activities based at the SWMCN Laboratory, of a new upcoming CRP on greenhouse gas emission.

Second Regional Training Course of RLA5076 on 'Use of Fallout Radionuclides, Compound Specific Stable Isotope and Water Isotope Techniques for Erosion and Sedimentation Assessment in Watersheds and Water Reservoirs', 4-15 November 2019, Valdivia, Chile

Technical Officer: E. Fulajtar

The purpose of this regional training course was to reinforce the knowledge of the participants on the use of nuclear techniques for control of soil erosion in watersheds and sedimentation in water reservoirs. Three groups of techniques were trained: fallout radionuclides (^{137}Cs, $^{210}Pb_{ex}$ and ^{7}Be) used as soil erosion tracers; compound specific stable isotope (CSSI) analyses of ^{13}C in fatty acids used for identification of major sediment sources attributed to different land uses; and water isotopes (^{18}O, D, T) used to quantify the water fluxes within watershed. The major focus of the training course was on learning and practicing the fatty acid extraction for CSSI method. This was the weakest point of the methodological knowledge identified in last project meeting. In total 24 researchers from 12 countries (Argentina, Brazil, Chile, Colombia, Dominican Republic, Honduras, Nicaragua, Panama, Peru, Uruguay and Venezuela) participated in this training course.

Participants of RLA5076 Training Course in Valdivia

Project evaluation: ZAM5029 & ZAM5031, 11-15 November 2019, Lusaka, Zambia.

Technical Officer: L. Heng

Lee Heng visited Lusaka, Zambia to evaluate the work done and output of past and current IAEA TC national projects ZAM5029 and ZAM5031. The current project is shared with Plant Breeding and Genetics Section. The work is carried out at both the Zambia Agriculture Research Institute (ZARI), Ministry of Agriculture in Mount Makulu, and at the University of Zambia in Lusaka.

A meeting was held with the NLO Ms Jane Chinkusu, at the Ministry of Higher Education, Department of Science and Technology and with Dr Benson Chishala, Dean of School of Agricultural Sciences, both thanked the IAEA for the technical and financial support received. Visited both field trials and laboratories work in ZARI and University of Zambia. Through ^{15}N techniques, ZAM5029 and ZAM5031 project counterpart Dr Kalaluka Munyinda developed a coated urea with Agrotain which demonstrated under several field experiments to reduce the fertilizer N requirement by 50%. This could potentially reduce the cost of N fertilizer by half. This work attracted local fertilizer company to collaborate.

University of Zambia ZAM5031 team

A trip was made to visit FAO Office and met FAO Representative Mr George Okech, to brief him about the IAEA projects in Zambia. Mr Okech is particularly interested to use modern technology e.g. CRNS to monitor soil water in the newly started (2019-2024) FAO program on Sustainable Intensification of Smallholder Farming Systems in Zambia (SIFAZ), funded by EU. The project focuses on building demonstrable synergies between research and promotion of appropriate sustainable agriculture intensification practices.

Extended Core Group Meeting on AquaCrop, 2-3 December 2019, Gammarth, Tunisia

Technical Officer: L. Heng

During the last decade since its development in 2006, the Core Group of FAO's AquaCrop model has been formulating model improvements and the blueprint for its dissemination. However, there is a need to discuss the inclusion of new crops into the model database, new model applications and programming languages, as well as the future strategies for the technical support, training and dissemination, as the core group members are retiring. Lee Heng as part of AquaCrop core group, attended the Extended Core Group Meeting, which has the objective to set a clear roadmap for the technical improvement and support of AquaCrop, as well as for training and dissemination activities of the model. Special attention was dedicated to the potential contributions of new partners.

This meeting was organized by FAO as part of the 1st Conference on Improving Water Productivity in the NENA region, hosted by the Collaborative Platform on Water Productivity of the Regional Water Scarcity Initiative (FAO-WSI) for the Near East and North Africa:

World Soil Day 2019 - event in Russia, 5-6 December 2019, Sochi, Russia.

SWMCN staff: E. Fulajtar

The FAO Liaison Office in Russia together with World Bank Moscow Office, Eurasian Food Security Center (Moscow State University), and other local organizations organized the World Soil Day Event in Sochi dedicated to soils and climate-smart agriculture. The Joint FAO/IAEA Division was represented by Mr E. Fulajtar, staff member of SWMCN Section. He presented the Joint Division's work on soil erosion assessment using fallout radionuclides including overview of activities carried out since 1990s through Coordinated Research Projects, National and Regional IAEA Technical Cooperation Projects and Research and Development activities curried by Seibersdorf Soil Science Laboratory. Mr Fulajtar also used this opportunity to discuss with represntatives of countries participating in the event the possibilities of cooperation and partnership.

Participants of World Soil Celebration in Sochi, Russia

Scientific Visitors

Ms Katja Van Nieuland from the Isotope Bioscience Laboratory (ISOFYS), Department of Green Chemistry and Technology, Ghent University, Belgium, visited the SWMCN Laboratory from 26-27 September to learn more on the use of laser isotope analysers for measuring the ^{15}N signature of nitrate in water samples and the ^{15}N and ^{13}C signatures in greenhouse gases and to discuss isotope ratio mass spectrometry related issues and workarounds.

Paving the road for the New CRP: "Developing Climate Smart Agricultural practices for mitigation of greenhouse gases"

Three Master's students, Abhishri Gupta, Mona Kühn, and Stefani Ritter, are working as scientific visitors (19 August – 9 December) to write their theses in collaboration with the SWMCN section, under the supervision of Mr. Mohammed Zaman. The three students are part of the joint degree program MSc Global Change: ecosystem science and policy from Justus Liebig Universität in Gießen, Germany and University College Dublin in Dublin, Ireland. A core aspect of their theses is to initiate research for the new CRP2252 which will begin in 2020. Each student is focusing on Climate Smart Agricultural (CSA) practices on different continents with the goals of identifying best practices and areas for additional research. Abhishri is focusing on CSA concerning rice production in Asia, Mona on agroforestry as CSA in Africa, and Stefani on integrated cropping-livestock systems in Latin America.

Abhishri Gupta, Mona Kühn, and Stefani Ritter with SWMCN Section Head, Lee Heng and supervisor, Mohammad Zaman.

Coordinated Research Projects

Project Number	Ongoing CRPs	Project Officer
D1.20.14	Enhancing agricultural resilience and water security using Cosmic-Ray Neutron Sensor	E. Fulajtar and J. Halder
D1.50.16	Minimizing Farming Impacts on Climate Change by Enhancing Carbon and Nitrogen Capture and Storage in Agro-Ecosystems	M. Zaman and L. Heng
D1.50.17	Nuclear Techniques for a Better Understanding of the Impact of Climate Change on Soil Erosion in Upland Agro-ecosystems	L. Mabit and L. Heng
D1.50.18	Multiple isotope fingerprints to identify sources and transport of agro-contaminants	J. Adu-Gyamfi and L. Heng
D1.50.19	Monitoring and predicting radionuclide uptake and dynamics for optimizing remediation of radioactive contamination in agriculture	G. Dercon and A. Lee Zhi Yi

Enhancing Agricultural Resilience and Water Security using Cosmic-Ray Neutron Sensor (D1.20.14)

Technical Officer: E. Fulajtar and J. Halder

This CRP which has just started (2019-2023) aimed to test the potential of cosmic ray neutron sensor (CRNS) for its applications in agriculture and environment protection, especially on irrigation scheduling and management of extreme weather events. Understanding soil water dynamics is of paramount importance for soil water and irrigation management, water conservation, improvement of soil fertility and the development of crop management strategies. CRNS provides soil moisture data at a large-scale and in real-time, which has a great value for land and water management. In addition to CRNS, the Gamma Ray Spectrometer (GRS) will be used in soil moisture assessment. The GRS has a much smaller footprint than CRNS and thus it is especially useful in heterogeneous areas with small fields and greater soil and relief variability.

The objectives of the CRP are: (1) advance the capabilities of CRNS for Best Management Practices (BMP) in irrigated and rainfed agricultural production systems; (2) integrate CRNS, GRS, remote sensing and hydrological modelling for improving agricultural water management and its resilience at regional scales; and (3) develop approaches using CRNS and GRS for long-term soil moisture monitoring in agricultural systems and early warning systems for flood and drought management. The final output of the CRP will be sets of practical methodological tools applicable in irrigantion scheduling and flood prediction and drought management.

This CRP was approved in March 2019. The call for proposals was closed in May 2019 and the CRP involves 10 partners: four research contract holders (2 partners from Brazil, 2 partners from China and Mexico), three research agreement holders (United Kingdom, Denmark and Netherlands) and three technical contract holders (Italy, Spain and USA).

The first Research Coordination Meeting was held on 26-30 August 2019, in IAEA HQ in Vienna, Austria. The major results of this meeting were: (1) reviewing the state of the art of research on the use of CRNS and GRS for soil moisture assessment; (2) developing detailed individual work plan and updating overall workplan of the CRP; (3) establishing specific cooperation activities of technical contract holders and research agreement holders to support research contract holders through provision of methodological guidance, help with processing of data and using the collected data form soil moisture dynamics modelling and remote sensing validation.

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

The final RCM of this CRP was held on 8–12 July 2019, Vienna, Austria to present and discuss the results obtained since the beginning of the CRP and evaluate progress report in the light of project objectives and expected outputs.

The main outputs and results of this CRP as follow: In Brazil, green manure legume residues contributed more than 300 kg N ha^{-1}, offering environmental advantages over synthetic N-fertilizers due to reduced GHG emissions (360 – 944 CO_2-eq. ha^{-1} yr^{-1}). The fraction of N from green manure lost as N_2O was <1% (i.e. below IPCC default value). In China, biochar addition rates of 3–12 ton ha^{-1} reduced N_2O emissions in maize-wheat rotation systems by up to 35%. Field studies in Spain, showed that manure incorporation abated ammonia (NH_3) emissions by 90% compared to surface applied pig slurry, thus, reducing the potential for indirect N_2O emissions. Drip irrigation (based on crop water demand), compared to sprinkler irrigation reduced N_2O emissions by 55% during the cropping period. This strategy increased crop yields and reduced yield-scaled N_2O emissions. The Ethiopian studies showed that agroforestry has a large mitigation potential of about 27 ± 14 t CO_2 equivalents ha^{-1} y^{-1} at least for the first 14 years after establishment. Field studies in Brazil, Chile, China, Pakistan and Spain using nitrification inhibitors (NI, e.g. Nitrapyrin) showed that N_2O emissions ranged from: no effect (tropical Andosols, Costa Rica) to a 79% decrease (under alkaline conditions, Iran) compared to urea without NI.

Scientists from SWMCN and the Agrobiology Centre of the Brazilian Corporation for Agricultural Research (EMBRAPA) and the Agronomic Institute of Parana, Parana State (IAPAR) worked together and developed a simple NH_3 chamber, made of a plastic bottle. The use of this simple open-chamber method is a suitable and reliable technique to quantify NH_3 volatilisation losses from agricultural soils, with a construction cost of under $1 USD. This new method of NH_3 measurement is being rolled out for use by both developed and developing countries to help monitor and respond to the environmental impact of NH_3 from the livestock and agriculture industries. This cheap and simple method is rapidly gaining recognition for its practicality, accuracy and reliability, and have been successfully used by scientists from Brazil, Chile, China, Costa Rica, Iran, Pakistan, Spain and US. The ^{15}N tracing method developed under this CRP by scientists from Justus Liebig University, Giessen Germany can precisely identify the microbial processes that produce N_2O in soil and the only way to quantify the effectiveness and suitability of mitigation options (e.g. NIs, biochar) on individual N transformation processes. Ten papers has been accepted for publications in a special issue (Pedosphere).

The phase-2 of this CRP will be initiated from 2020 to further improve our understanding of the complex processes of GHGs emissions and develop more mitigation options for reduction of GHGs and C-sequestration.

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

The two research objectives of this five-year CRP (2016-2021) are: (i) to further develop nuclear techniques to assess the impacts of changes in soil erosion occurring in upland agro-ecosystems, and (ii) to distinguish and apportion the impact of climate variability and agricultural management on soil resources in upland agro-ecosystems.

Several isotopic and nuclear techniques are being used to achieve these 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).

The first Research Coordination Meeting (RCM) was held in Vienna, Austria (25-29 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 16-20 April 2018. The IAEA mid-term review of the CRP that took place on 13 March 2019 praised the results reached so far.

The third RCM held in Vienna, Austria (14-17 October 2019) highlighted that ^{137}Cs resampling can be a suitable approach to distinguish and apportion the impact of climate variability and agricultural management. Moreover, as demonstrated by case studies in Morocco and Iran, this approach allows to assess the effectiveness of soil conservation measures.

Since its start in March 2016, significant progress has been achieved in developing and refining FRN and CSSI techniques to deepen our understanding of erosion processes affecting upland agro-ecosystems (e.g. development of the new and unique FRN conversion model MODERN; $^{239+240}Pu$ tested and validated as soil redistribution tracer under various agro-environments, i.e. Austria, Iran, Switzerland and South Korea).

So far, the CRP team has published 19 peer-reviewed publications acknowledging the CRP D1.50.17 and an IAEA publication on soil moisture mapping with portable cosmic ray neutron sensor (IAEA-TECDOC-1845). The year 2019 was also very productive with the publication of two major documents: (i) a Springer open-access book "Assessing Recent Soil Erosion Rates Through the use of Beryllium-7 (Be-7) https://www.springer.com/gp/book/9783030109813" available since March 2019 and (ii) IAEA guidelines for using CSSI technique based on the measurement of $\delta^{13}C$ signatures of fatty acids published in September 2019 (IAEA-TECDOC-1881).

The fourth and final RCM of the CRP is expected to be held in Vienna, Austria during the second quarter of 2021.

Participants of the Third RCM of CRP D1.50.17, Vienna, Austria

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 draft guidelines were presented and discussed: (1) designing a water sampling program for stable isotopes studies of agricultural pollution, (2) compound specific isotope analysis for investigation the source and transport of pesticides from soils to water bodies, and (3) 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 the 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.

The first year of the CRP was dedicated to consolidating the existing observation sites and prepare them for soil and water monitoring during the next years of the CRP. The second RCM will be held in Accra, Ghana on 2–6 March 2020. This CRP will be featured for the second time in a European Geosciences Union (EGU) Session HS2.3.3 on '*Sources and transport of agro-contaminants in soil, surface and groundwater using stable isotope techniques'* during the upcoming EGU meeting on 3-8 May 2020, Vienna, Austria. The conveners were Grzegorz Skrzypek, Gwenaël Imfeld, Joseph Adu-Gyamfi and Lee Heng.

Remediation of Radioactive Contaminated Agricultural Land (D1.50.19)

Project Officers: G. Dercon and A. Lee Zhi Yi

After a nuclear emergency affecting food and agriculture, optimisation of remediation based on monitoring and prediction of the fate of radiocaesium and radiostrontium in the agricultural environment is essential in the return of the affected territories to normal life conditions. Innovative monitoring and prediction techniques such as field, laboratory and machine-learning modelling tools present a unique solution to predicting and monitoring the fate of radionuclide uptake by crops and related dynamics at the landscape level.

CRP D1.50.19 aims to develop, test and validate remediation optimisation methodologies with the emphasis on under-explored environments and related main crop categories. The specific objectives are: (1) to combine experimental studies with field monitoring and modelling to understand and predict the role of environmental conditions on radiocaesium and radiostrontium transfer in the food chains and their dynamics at landscape level particularly for under-explored agro-ecological environments such as arid, tropical and monsoonal climates; and (2) to customise the remedial options in agriculture to these under-explored agro-ecological environments and to adapt and develop innovative decision support systems for optimizing remediation of agricultural lands affected by nuclear accidents, based on machine learning and operations research techniques.

The first Research Coordination Meeting (RCM) was held on 21-24 October 2019 in Vienna. Eleven countries participated in this CRP: seven research contract holders from Belarus, Chile, China, Morocco, Russia and Ukraine; two technical contract holders from France and Macedonia; and six agreement holders from Belgium, India and Japan.

The objectives and experimental plans of the national research projects were discussed and adjusted to be in line with the objectives and work plan of the CRP. Common guidelines for implementing projects and collaboration networks were established for the upcoming years.

Participants of the First RCM of CRP D1.50.19, Vienna, Austria

Developments at the Soil and Water Management and Crop Nutrition Laboratory

Tracing sediment origin in the agricultural watershed of Petzenkirchen using the CSSI-δ^{13}C FAs based technique: preliminary results

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As part of the R&D activities performed by the SWMCNL to support the CRP D1.50.17, this study is to identify the on-site areas contributing to the sedimentation processes observed at the outlet of the Petzenkirchen watershed. Background information regarding this Austrian study site has been reported by Blöschl *et al.* (2016). In the last decade, the land use of the Petzenkirchen watershed has been dominated by rotation of winter wheat and maize.

The CSSI technique based on the measurement of delta ^{13}C of fatty acids (δ^{13}C-FAs) was proposed to be used as sediment fingerprint to supplement the information provided by bulk delta ^{13}C signal in pinpointing the areas at risk within that agricultural site.

To identify and account for potential material contributing to the mixture collected at the outlet of the site, all the fields and other possible sources within the watershed were investigated by Falcao *et al.* (2018) following the sampling strategy presented by Mabit *et al.* (2018). Sixteen agricultural sources (i.e. 1 to 17 excluding 6), one mixture combining sources 7 to 17 excluding source 8 were investigated. After sampling and pre-treatment of samples by the SWMCNL team, the determination of δ^{13}C-FAs was performed at National Institute of Water and Atmospheric Research (NIWA), Hamilton, New Zealand. A representative mixture of sediment produced by the watershed was collected at its outlet located at the southeast of the site.

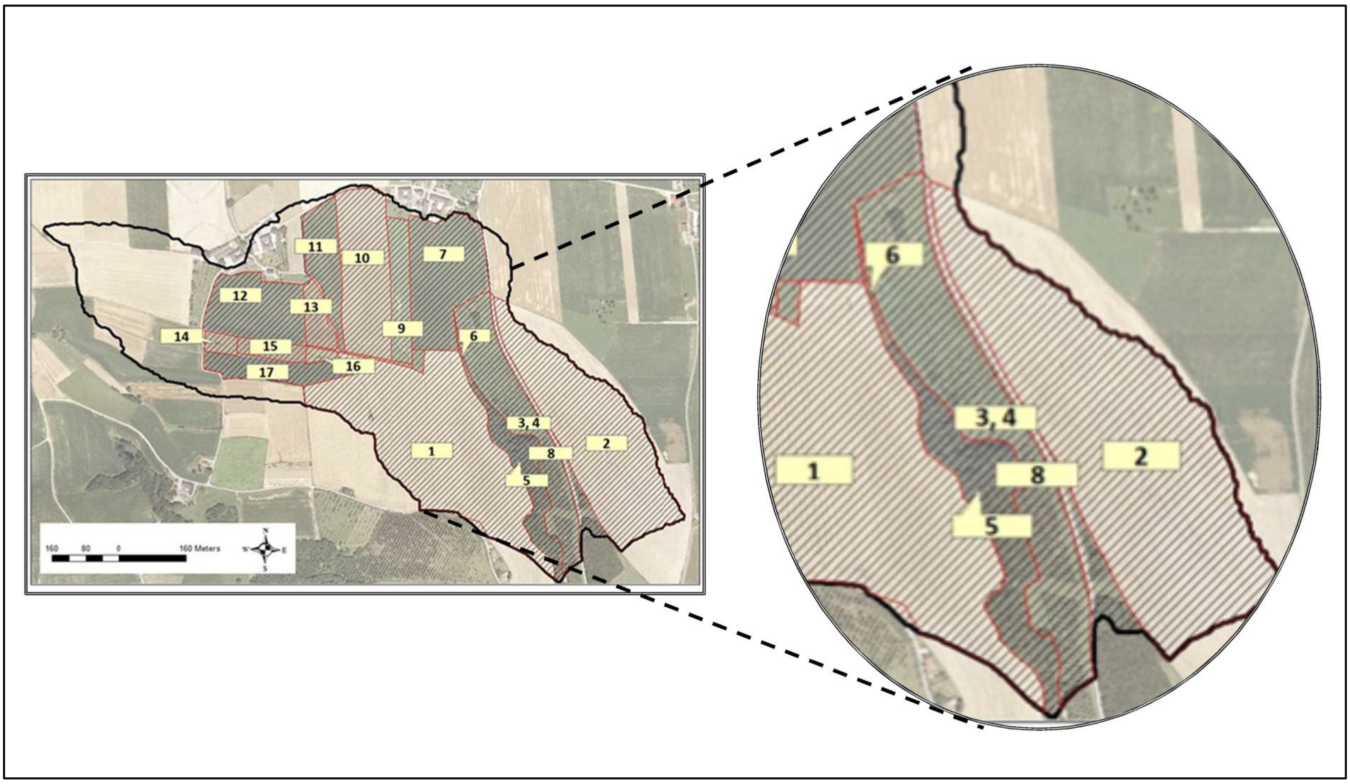

Figure 1. Identified sources of sediment within the Petzenkirchen watershed, Austria (Adapted from Falcao et al., 2018)

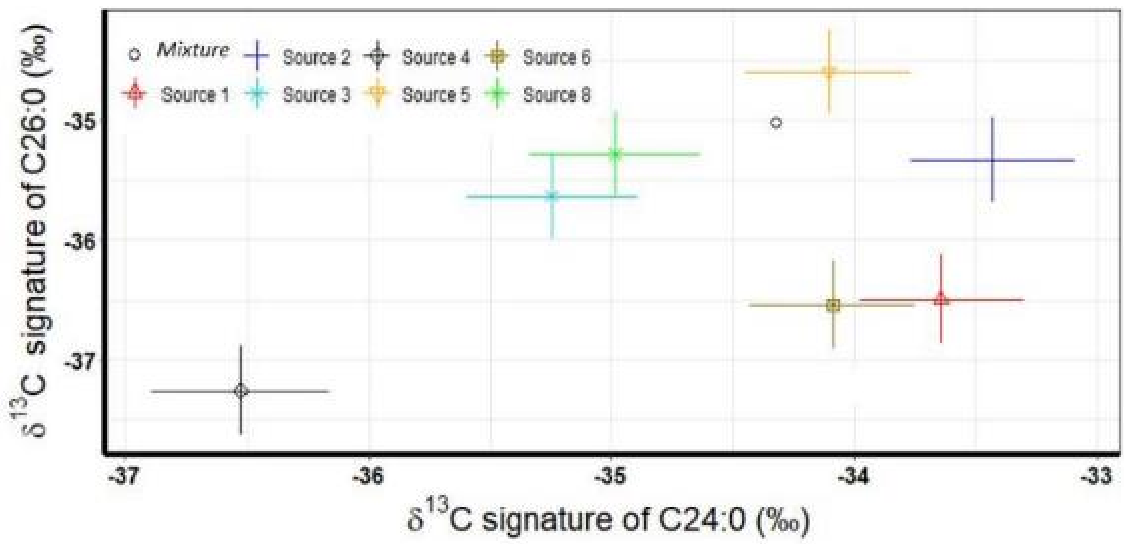

Figure 2. δ^{13}C-FAs of the sources and the mixture, specific example of C24:0 versus C26:0

A closer situation analysis was performed on the south east part of the catchment as magnified in Figure 1. This selected area of the site includes the source 6; the sources from 2 agricultural fields (1 and 2), the sources from 2 small forested areas in the riparian zone (3 and 8) and the sources 4 and 5 representing respectively a pasture and the streambank. Under our experimental conditions, the most suitable FAs to be used as input in the Stable Isotope Mixing Models in R (SIMMR) were determined based on the validation technique of the mixing polygons. As expected, the δ^{13}C signature of saturated long chain FAs above 20 carbon atoms (i.e. C24:0 and C26:0) allowed the best discrimination for establishing the contribution of sources to the mixture (see Figure 2). In addition, Figure 3 indicates clusters of similar isotopic source contribution to the mixture (i.e. S1 & S6 and S3 & S8).

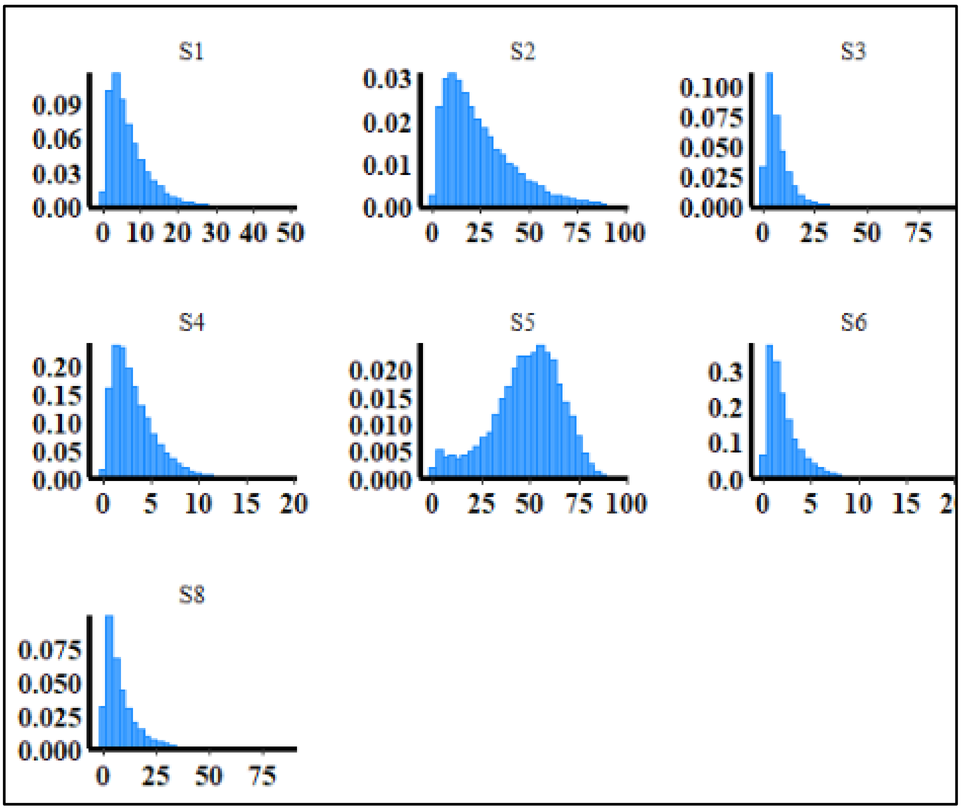

Figure 3. Density distribution of source contribution to the mixture collected at the outlet of the watershed. (NB: Values corrected using the organic carbon content of each source)

	%C_{org} content	Mixing Model output (isotopic proportion)	% of the soil sources within the mixture (corrected values)
Source 1	1.89	5.1	6
Source 2	0.90	8.4	21
Source 3	2.51	6.6	6
Source 4	3.10	4.1	3
Source 5	2.15	51.7	55
Source 6	6.01	5.0	2
Source 8	2.80	8.4	7

Table 1. Contribution of the soil sources to the sediment mixture collected at the watershed outlet

Output from the SIMMR model was expressed as isotopic proportions. Using the equation proposed by Gibbs (2008), the SIMMR results reported in Table 1 were converted into soil proportions based on the specific organic carbon (%C_{org}) content of the sources.

The simulated results obtained with the mixing model SIMMR highlight that the main sediments reaching the outlet of the Petzenkirchen watershed (i.e. 55%) originate from erosion processes impacting its bank (see Table 1). It is also interesting to note from Table 1 that agricultural field S2 contributes significantly to the mixture with an influence of above 20%.

Future investigations of detailed historical land use of the watershed will help improve our understanding of the sediment budget obtained.

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Comparison of $^{239+240}$Pu and ^{137}Cs derived soil erosion rates: a case study in an Austrian agricultural field (Grabenegg, Lower Austria)

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In a previous investigation at Grabenegg, 100 km west from Vienna, twelve soil cores were collected in a flat undisturbed meadow from which the initial fallout of $^{239+240}$Pu and ^{137}Cs were respectively determined at 56.1 ± 15.8 Bq m^{-2} and 8179 ± 1794 Bq m^{-2}. The vertical distribution for the studied fallout radionuclides (FRNs) showed a clearly exponential decrease of their content with depth and a limited lateral spatial variability with coefficients of variation below 30% (see IAEA-Soil Newsletter, Vol.40/2), proving the sampled meadow being a good reference site.

This information has now been used to compare ^{137}Cs and $^{239+240}$Pu based methods for erosion studies in Grabenegg as well as understanding the time frame of the erosion rates, measured through the different radionuclides. The time frame can be determined by knowing the origin of the radionuclides.

To achieve this objective soil erosion rates were calculated along a newly investigated transect located within an agricultural field (slope inclination approximately 5%) located close to the above mentioned reference site. Eleven soil profiles collected along the transect were analysed for ^{137}Cs and $^{239+240}$Pu content.

The obtained datasets showed that the plutonium at the investigated agricultural site is of global fallout origin (peak of fallout at 1963) as evidenced by an activity ratio ^{238}Pu/$^{239+240}$Pu below 0.025 (data from reference site). This result was confirmed by an additional determination of the atom ratio ^{240}Pu/^{239}Pu of 0.134 ± 0.035 (n=20) at the reference site. Established ^{240}Pu/^{239}Pu values reported in the literature for mid-latitude of the northern hemisphere not affected by the Chernobyl nuclear power plant accident (1986) vary from 0.14 to 0.24, while Pu originating from Chernobyl fallout would have a ^{238}Pu/$^{239+240}$Pu ratio close to 0.50 and an atom ratio ^{240}Pu/^{239}Pu characterized by values of 0.37 to 0.41 (Alewell *et al.,* 2017).

Based on the geographical location of the studied site and its average yearly precipitation, we could expect an areal activity level of ^{137}Cs around 2000 Bq m^{-2} from global fallout only. Recorded values at the undisturbed reference site fluctuate around 8000 Bq m^{-2} thus indicating a clear Chernobyl contribution of around 70-80% of the total ^{137}Cs soil content.

To identify the ^{137}Cs origin, the^{137}Cs/ $^{239+240}$Pu activity ratio can also be used (Meusburger *et al.,* 2018). When most of the fallout originates from Chernobyl, the ratios are significantly higher than the expected average ratio of 36, which is indicative of global fallout contribution from previous nuclear tests. In our case study, this specific ratio is reaching 140 ± 24. Our findings are in agreement with Alewell *et al.* (2014) who investigated the Northern and Southern Alpine sites mostly affected by Chernobyl fallout and reported ratio values ranging from 90 up to 898.

If we include analytical errors of both FRN measurements, we could consider that most sampling points highlight limited soil erosion or no significant soil redistribution rates. As a matter of fact, most areal activities of ^{137}Cs and $^{239+240}$Pu determined for the eleven soil cores are below the established reference site values (see Figure 1). The model MODERN (MOdelling DEposition and Erosion rates with RadioNuclides) developed by Arata *et al.* (2016) was used to derive soil erosion magnitudes from established ^{137}Cs and $^{239+240}$Pu data sets which resulted in similar mean erosion rates around 5 t ha^{-1} yr^{-1}.

As it has been clearly proven that the origin for ^{137}Cs and $^{239+240}$Pu at the Grabenegg site is different, these findings showed that the ^{137}Cs and $^{239+240}$Pu based methods can provide complementary information on soil erosion over time. As the estimated soil erosion rates are similar, soil erosion seems not to have significantly changed over the last 33 years (1986-2019) in comparison with the period of 1963 until 1986.

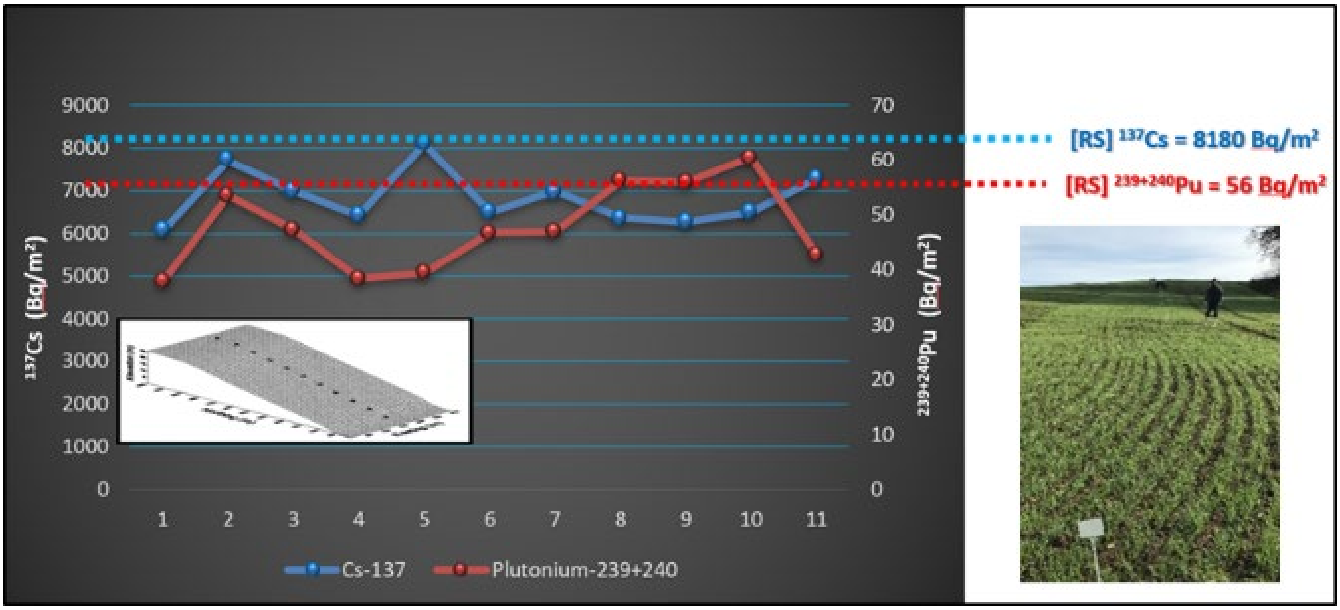

Figure 1: ^{137}Cs and $^{239+240}$Pu areal activities (Bq m^{-2}) along the agricultural transect compared to the reference site (RS) values

Additional calculation of soil erosion magnitudes derived from ^{137}Cs data set will be performed using the conversion model mass balance model 2 (MBM 2) including the dominant contribution of Chernobyl fallout. Result will then be compared with MODERN.

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Impact of future precipitation patterns on GHG emissions – a stable isotope and lysimeter study

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Marchfeld is one of the main food producing areas of Austria. According to regional climate model scenarios from EURO-CORDEX, this region is very vulnerable to climate change because of lower predicted rainfall. The influence of precipitation on soil organic matter mineralization, nutrient release and therefore plant production was studied in collaboration with the University of Natural Resources and Life Sciences Vienna (BOKU) and the Austrian Agency for Health and Food Safety (AGES). Dual labelled (^{13}C and ^{15}N) green manure was applied to long-term lysimeters containing two different soil types – a sandy calcaric Phaeozem and a calcic Chernozem, representative for the Pannonian area of the Marchfeld region. The lysimeters were irrigated according to the predicted future scenario, compared with current precipitation since 2011. N_2O and CO_2 concentrations and their corresponding isotopes were measured before and after the application of labelled green manure, simulated heavy rainfall and fertilizer application of 50 kg N ha^{-1} using off-axis Integrated Cavity Output Spectroscopy (OA-ICOS) and gas chromatography isotope ratio mass spectrometry (GC-IRMS) respectively. Nitrogen (N) and $\delta^{15}N$ of inorganic and organic N soil pools and plants were determined using IRMS.

Results from the lysimeter experiments showed significantly reduced plant growth under predicted future rainfall regimes by around 10%. Further, under the same future rainfall conditions a lower mineralization rate of the green manure could be observed, in particular for the calcaric Phaeozem. Based on the measurement of the N_2O fluxes and the ^{15}N signal of N_2O, the study suggests the relevance of green manure as a fertilization strategy to reduce N_2O emissions.

N_2O measurement on a lysimeter, using off-axis Integrated Cavity Output Spectroscopy (OA-ICOS).

This study suggests that changing rainfall regimes in the future due to a changing climate may likely reduce soil CO_2 emissions from soils in the Marchfeld region. It is driven mainly by reduced plant biomass input. Further analysis is now being carried out on the datasets.

Using laser spectroscopy to evaluate the influence of soil storage on N_2O emission

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To improve fertiliser use efficiency, it is essential to quantify nitrogen (N) mineralization processes including measuring gaseous emission of nitrous oxide (N_2O). Laboratory incubation experiments are conducted using disturbed soils to study these processes. After collecting and processing (sieving), soil samples are generally stored either in the fridge or in the laboratory at room temperature before being used in incubation studies. To evaluate the influence of soil storage on N mineralization and N_2O emission, an incubation experiment was set up in the SWMCN laboratory, Seibersdorf. Fresh soil (Chernozem, 0-10 cm depth) collected from Seibersdorf was compared with the soil from the same spot either dried at room temperature or stored at 4 ºC. After collection, all soils were passed through a 2 mm sieve and compacted to achieve a bulk density of 1.2 g cm^{-3}. The dried soil was rewetted 14 days before the gas measurement and the cooled soil was reconditioned at room temperature 7 days before the start of the experiment. Supplementary, fresh undisturbed soil cores were taken. All soil samples were brought to 60 % water-filled pore space (WFPS) by adding water, treated with ^{15}N labelled urea (1 atm %) at the rate of 50 mg N kg^{-1} soil, and incubated at room temperature (23 ºC). The four treatments include fresh undisturbed (FU), fresh sieved (FS), fridge stored (ST), and room temperature dried (PI). The N_2O fluxes were measured for 5 weeks using off-axis integrated cavity output spectroscopy (ICOS, Los Gatos Research, California, USA). Cumulative N_2O fluxes and Keeling plot intercepts ($\delta^{15}N$ source) were calculated. Soil storage had an impact on N_2O emission (Figure 1).

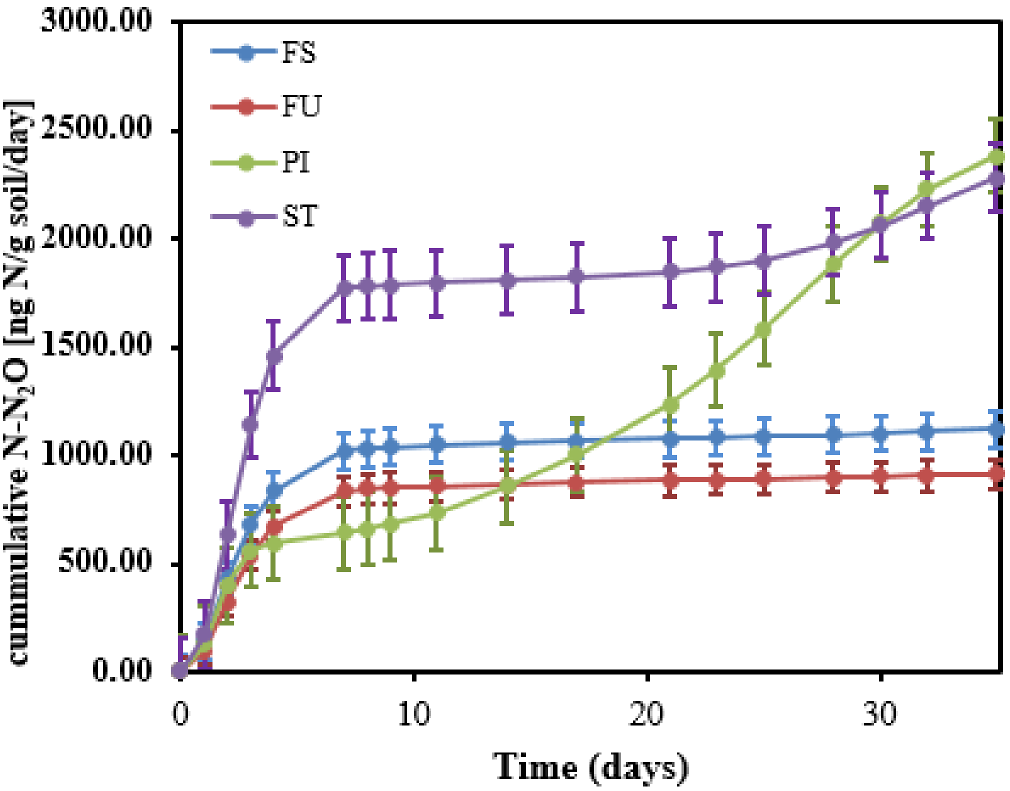

Figure 1. Effect of soil storage on N_2O emission (fresh sieved (FS), fresh undisturbed (FU), room temperature dried (PI), and fridge stored (ST))

Soil stored at 4 ºC (ST) produced the highest cumulative N_2O emissions (1.80 µg Ng^{-1} soil) as well as the largest amount of N derived from fertilizer (Ndff) (1.2 µg N/g soil) over the 5-week period instead of N derived from soil (Ndfs). This trend was followed by soils FS and FU, except PI and ST soil which exhibited higher N_2O than those of FS and FU after day 15 and 23, respectively. Fresh undisturbed soils (FU) exhibited the highest amount of cumulative N_2O emissions from fertiliser N (81% Ndff) compared to the remaining three soils (Figure 2), FS 74% Ndff, PI 52% Ndff, ST 66% Ndff. These results indicate that soil storage after collection affects microbial processes that release N from applied fertiliser and produce N_2O emission. Our results suggest using fresh soil to avoid these negative effects rather using stored soils.

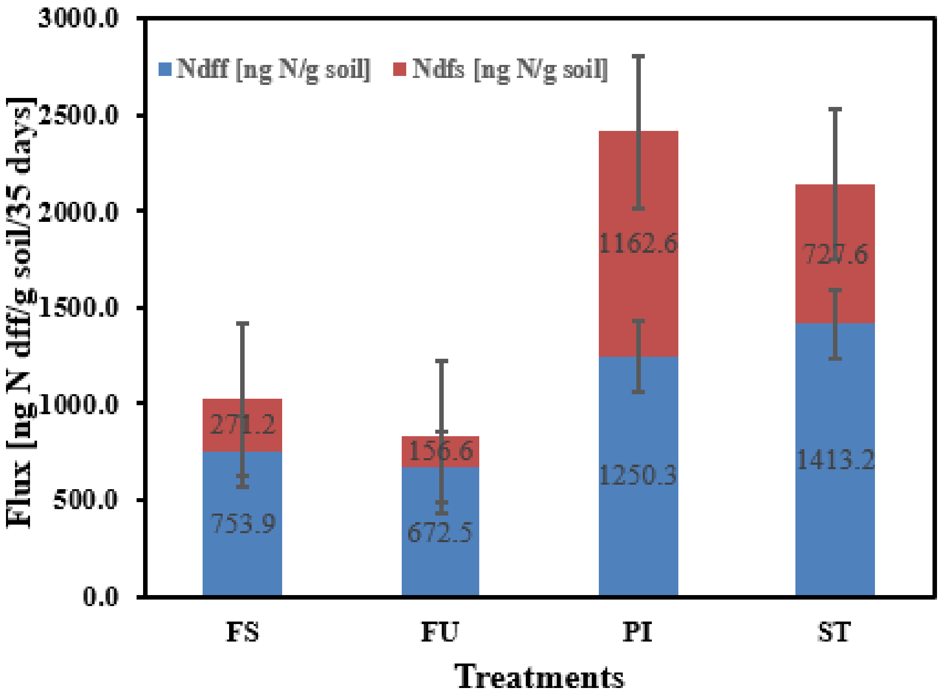

Figure 2. N source of N_2O emission for different soil storage (fresh sieved (FS), fresh undisturbed (FU), room temperature dried (PI), and fridge stored (ST))

Training course on the use of UAV based multispectral camera in agriculture

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In the last decades the use of satellite images and remote sensing for agricultural activities has increased to emcompass factors such as plant growth or biomass. However, satellite images may not be available for all regions or during all seasons (cloud cover) and precision agriculture requires smaller resolutions for mapping small elements as for example trees or smaller crops. The application of multispectral cameras mounted on UAVs (Unmanned Aerial Vehicles) is therefore a new and fast developing market and methodology. In order to explore its opportunities a training course on the use of UAVs and multispectral camera systems in agriculture was organized for the staff of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture in Vienna, Seibersdorf from 23-27 September 2019. The course was led by Mr Erik de Badts (Micasense) but included several guest lecturers from different companies and research facilities. In total six staff members from the SWMCN laboratory and section participated. The course provided insights into the different UAVs available, camera systems, software and data processing programmes. IAEA staff learnt how to plan a UAV survey and process acquired data. In total three different methods were introduced. First, the photo method, which is simply producing an aerial photo image, mapping the field and crops during different seasons. Its main application in agriculture is to observe the density of crops and density for thinning during flowering time but also to control the germination rate (counting) and disease detection. Secondly, the multispectral method, which allows calculation of vegetation indices such as NDVI (Normalized Difference Vegetation Index) and NDRE (Normalized Difference Red Edge). Such remote sensing methods can detect chlorophyll and are therefore used to monitor crop vigor, crop stress, crop damage, biomass, and its growth. This monitoring can for example help to reduce fertilizer application and improve the irrigation management. The third method is thermal remote sensing, which can be used to determine soil evaporation and canopy transpiration for a more effective soil moisture monitoring and irrigation scheduling.

In the future the SWMCN laboratory is planning to combine the use of UAV remote sensing with nuclear methods. As a first step an IAEA test site will be monitored with a UAV mounted multispectral camera and its results will be compared to ground CNRS (Cosmic Neutron Ray Sensor) and soil moisture measurements.

Comparing stationary Cosmic-Ray Neutron Sensor with Drill & Drop capacitance probe for monitoring soil water content of two cropped fields in Rutzendorf (Austria)

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For some years, it has become clear that climate change is having a major impact on water availability for agriculture and crop productivity. To improve the use of this resource in agriculture, it is essential to measure the water content of the soil.

The Cosmic Ray Neutron Sensor (CRNS) has recently been used for measuring soil moisture content (SWC) in large areas and appears to become a credible and robust alternative to the other device.

Figure 1. Cosmic Ray Neutron Senor (left); Drill & Drop capacitance probe (right) installed in Rutzendorf Austria

The calibration and validation of the CRNS technology at Petzenkirchen, Austria (100 km west of Vienna), carried out by the SWMCN laboratory, has shown the reliability of the CRNS to estimate the SWC on a large scale of approximately 30 hectares (IAEA-TECDOC-1809 https://www-pub.iaea.org/MTCD/Publications/PDF/TE-1809_web.pdf).

The SWMCN laboratory has also conducted a study on the use of a mobile 'backpack' CRNS device in high elevation heterogeneous terrain in the alpine mountains of western Austria. This study demonstrates the efficacy of this technique in remote mountain landscapes and shows potential for watershed hydrology and high elevation agricultural water management (IAEA-TECDOC-1845 https://www-pub.iaea.org/MTCD/Publications/PDF/TE-1845-WEB.pdf).

In view of those advantages, the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture has launched a new Coordinated Research Project (CRP) titled 'Enhancing agricultural resilience and water security using Cosmic-Ray Neutron Sensor' in August 2019.

As part of this CRP, the laboratory is conducting a study to compare the stationary CRNS with Drill & Drop capacitance probe for monitoring soil water content of two cropped fields in Rutzendorf, Marchfeld region (Austria) (Figure 1).

A common limit with the CRNS is that it only provides data in the surface depending on SWC. The monitoring of the SWC with CRNS in the rooting zone is and remains a challenge.

One of the objectives of this study is to measure the SWC up to 60 cm in two cropped fields by combining CRNS and Drill & Drop capacitance probe, as well as gravimetric water content.

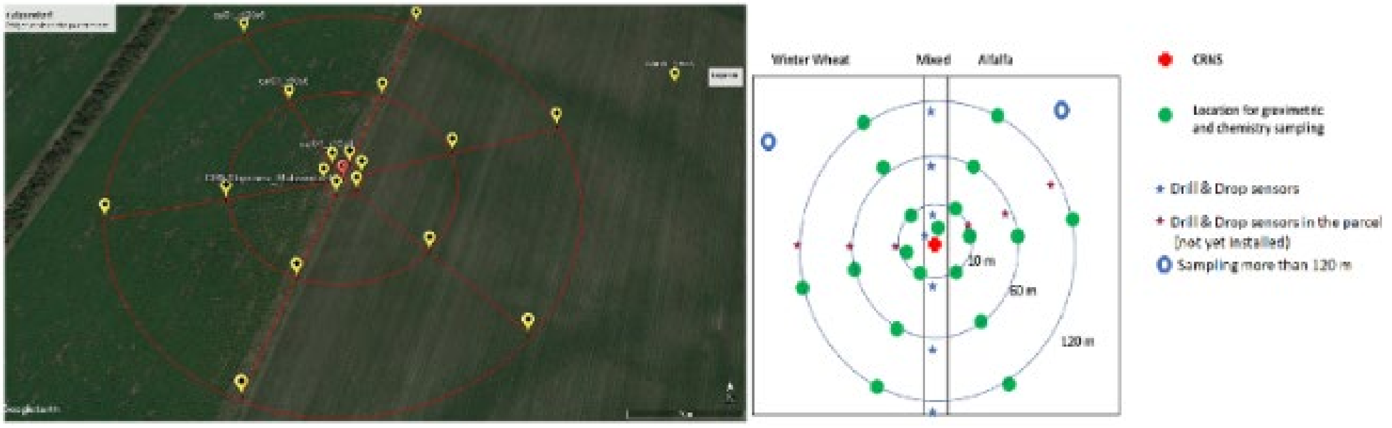

Figure 2. Sampling pattern for calibration of the Cosmic Ray Neutron Sensor (left) and schema of the installation device (right) in Rutzendorf Austria

A set of seven Drill & Drop probes was installed in the mixed range at 10, 60 and 120 m of the CRNS in each direction and one installed closer to the CRNS. Six more capacitance probes will be installed inside the two parcels later, between planting and harvesting period (Figure 2).

For field calibration of the CRNS, the SWMCN Laboratory team already carried out the first sampling for gravimetric analysis (121 samples) and chemical analysis (14 samples). The sample design for CRNS calibration is on Figure 2. Two more sampling campaigns are planned for the CRNS calibration and for Drill & Drop calibration.

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Potassium application to alleviate drought stress in cassava production: a pulse labelling experiment

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Cassava (*Manihot esculenta Crantz*) is a tropical root crop important for almost 800 million people worldwide. Due to climate change and an increasing year-round demand from starch processing industries, farmers are forced to grow their crops during less favourable dry periods. To cope with problems of drought stress, stable isotope techniques based on ^{13}C (related to water use efficiency) and ^{18}O (related to stomatal conductance) are being developed by the SWMCN laboratory in Seibersdorf in collaboration with the Consortium for Improving

Agriculture-based Livelihoods in Central Africa (CIALCA), led by the International Institute of Tropical Agriculture (IITA). Once these techniques are established, they will help in decision making processes related to variety selection and fertilizer application.

In July, a new experiment focussing on the application of potassium to alleviate drought stress was carried out in the SWMCN greenhouse. Cassava plants, originating from Democratic Republic of Congo, were grown on nutrient solution with either high (+K) or low (-K) in potassium. Water use was monitored every other day by weighing the pots and water content adjusted to field capacity. At two months after planting, a dry spell was simulated by lowering the irrigation amounts for half of the plants for 17 days. To follow the translocation of new assimilates and compare the different treatment combinations, plants were put in an airtight walk-in growth chamber. The air inside the growth chamber was enriched with ^{13}C-CO_2 so the plants assimilate the heavier carbon isotope.

First results of the water use data (Figure 1) indicate a higher water use for plants that received the nutrient solution low in potassium (-K) at the periods where both received the same amount of water. These results will be checked against the biomass production and $\delta^{13}C$ and $\delta^{18}O$ values of the same plants to see whether this difference in water use also leads to a difference in water use efficiency.

This potassium effect on water use will be further validated through field trials in Burundi, the Democratic Republic of Congo and Rwanda, where in total 121 nutrient omission trials were implemented to better understand how varieties and fertilizer management can help make cassava production more climate-resilient.

Further ongoing is the ^{13}C analysis of the enriched cassava plants. With this data we expect to extract information on the translocation speed from shoot to root and compare the different treatments with the main question being: "Can potassium application increase the translocation speed of assimilates from shoot to roots?" ^{18}O levels will also be analysed and will be used as a proxy for stomatal conductance, an important factor in water use efficiency.

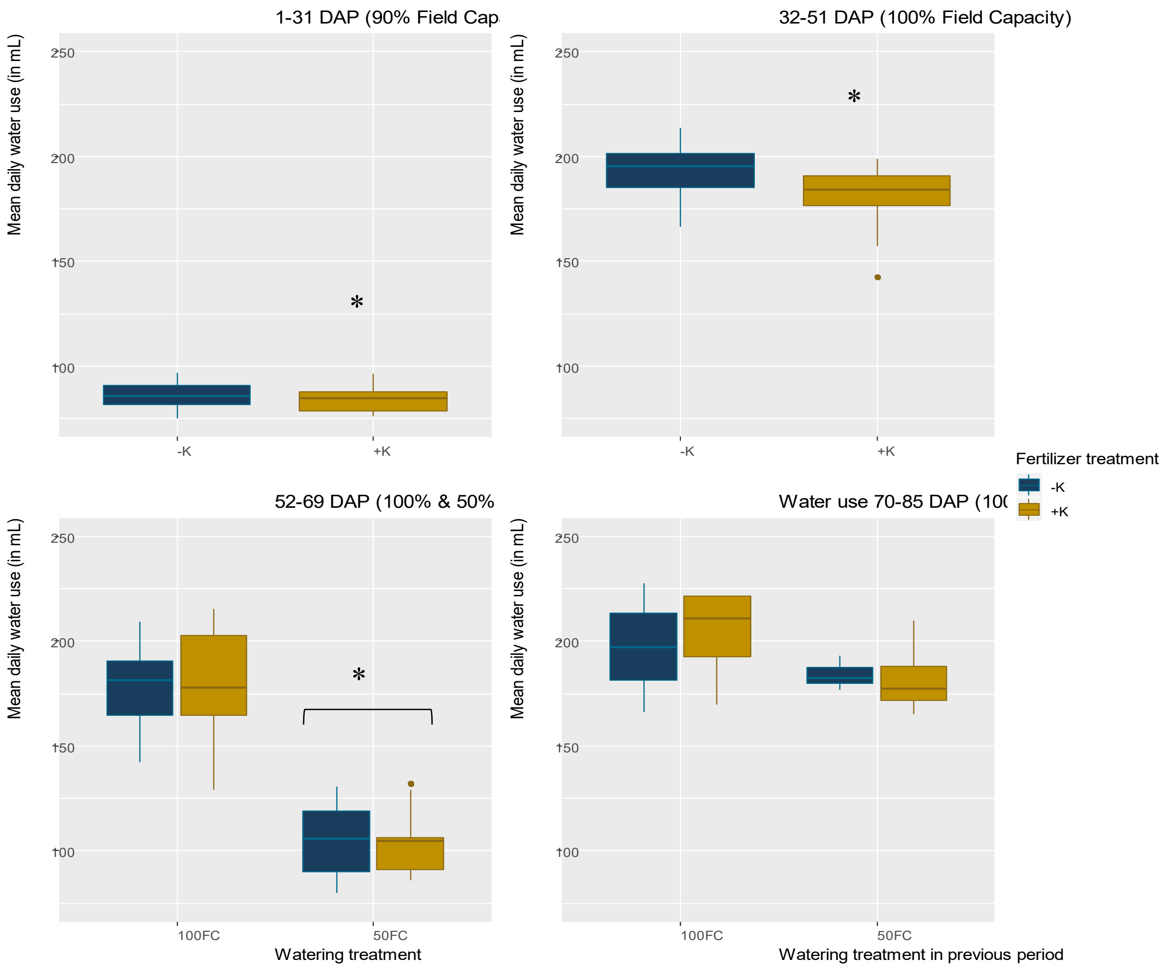

Figure 1. Mean daily water use for four given periods at given days after planting (DAP). Fertilizer treatments are either high (+K) or low (-K) in potassium. Watering regimes are either field capacity (100FC) or 50% of field capacity (50FC). Groups with the same letters are not significantly different from eachother (p>0.05), while groups with a different letter show a significant difference (p<0.05). "Sample sizes for each group are n = 31-32 for 1-31 DAP and 32-51 DAP, n = 13-15 for 52-69 DAP and n = 5-8 for 70-85 DAP

Climate change adaptation of banana in East-Africa: first observations from the field

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Under the Peaceful Uses Initiative (PUI) project on coffee and banana, co-organized by the Plant Breeding and Genetics (PBGL) and the Soil and Water Management & Plant Nutrition (SWMCNL) Laboratories, a first data collection campaign was organized during July and August 2019 in Arusha, Tanzania.

In an ongoing field-trial, two banana varieties (Grand Nain and *Mchare,* local variety) were investigated under different watering treatments in the dry season (rainfed and optimal irrigation). Hence, the effects of drought stress could be monitored. The main purpose of the campaign was to assess the usefulness of stable isotope techniques for the evaluation of water use efficiency (WUE) and drought stress. Isotope signatures have been proven to strongly correlate with WUE. Their relationship is however not straightforward. Isotope signatures are affected by many different parameters, both environmental and plant-related. As such, the variability in isotope signals should first be explored and correlated with potential influencing factors, to distinguish their effect from the effect of drought. This will allow us to comprehend isotope signatures in banana plants and use them for the purpose of WUE evaluation.

Figure 1. Sampling and temperature measurements in the field

Variability in carbon signatures ($\delta^{13}C$) was investigated at field-, plant- and leaf level. Samples were taken from both varieties under the different watering treatments (Figure 1). Both mother plants and on-growing suckers were sampled. Within every plant, leaves of a different age were sampled. Finally, the within-leaf variability was explored by taking 6 or 10 samples per leaf (depending on the size) according to a predetermined pattern. Environmental conditions were carefully monitored with a weather station and the soil water content in every treatment was followed up daily, using time time domain reflectometry (TDR) sensors. As an additional measure for water stress and stomatal closure, leaf temperature was evaluated over the course of a day. Typically, stomata close when water supply becomes insufficient, leading to an increase in leaf temperature. Temperature was measured in a large number of plants and on both sides of the leaf, to account for the large variability. A contactless infrared thermometer was used, allowing for fast data collection.

Preliminary results indicate that rainfed plants in the dry season clearly heat up more during the day than irrigated (and presumably non-stressed) plants (see Figure 2). The difference in temperature between rainfed and irrigated mother plants becomes as large as 6°C at 14:30. Interestingly, sucker plants, which are protected from direct sunlight by the canopy, show a lesser increase in temperature. This demonstrates the importance of canopy protection for optimal sucker development.

Carbon isotope analysis confirms the occurrence of water stress in the rainfed treatment (Figure 3). Rainfed plants express δ-values up to -24. The effect of drought is visible in both varieties, although more pronounced is in *Mchare*.

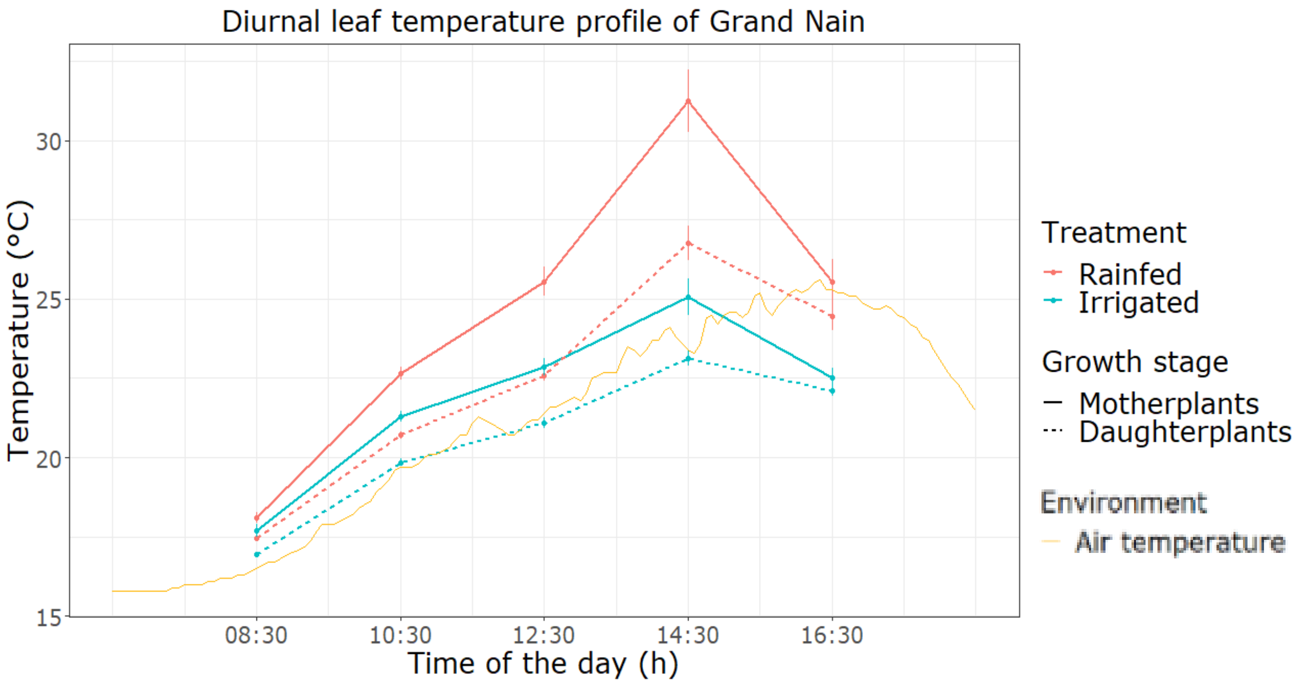

Figure 2. Diurnal temperature profile of Grand Nain banana in different growth stages and under different irrigation levels. Error bars indicate the standard error of the mean, with n = 36 for irrigation treatments in mother plants and n = 42 for treatments in daughter plants

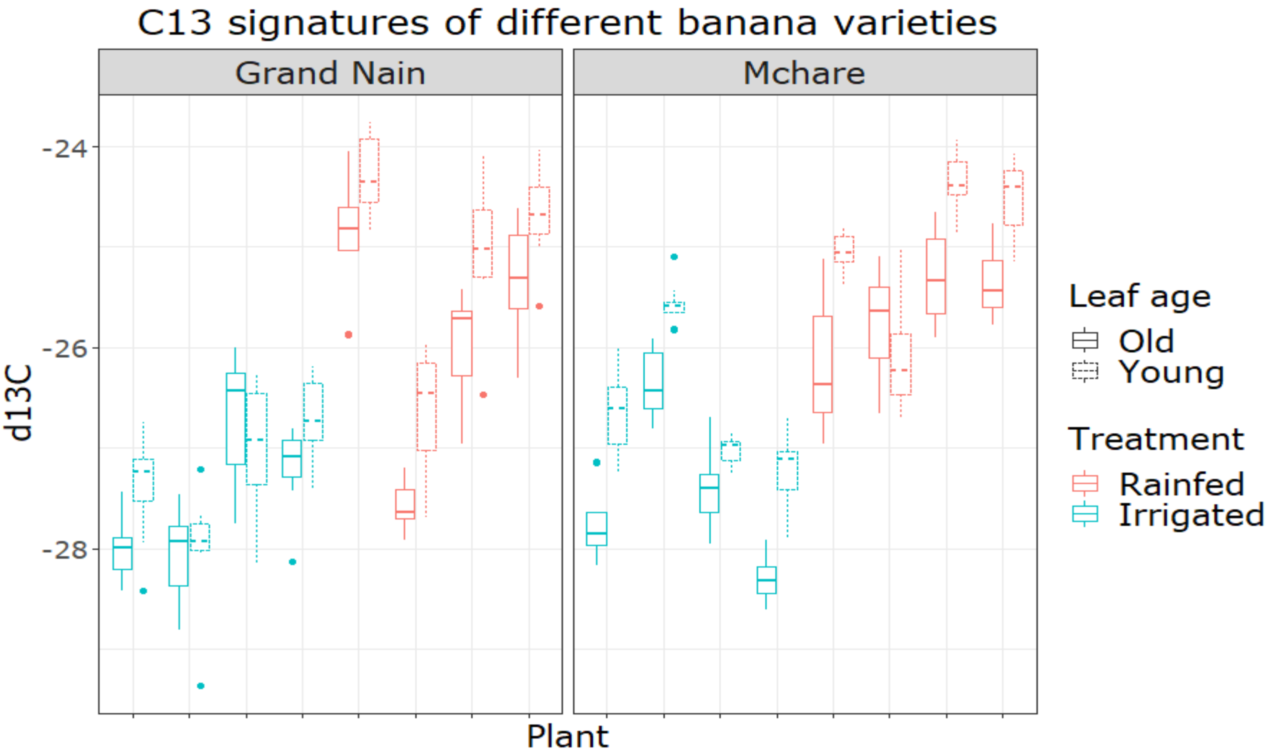

Figure 3. Boxplots representing the distribution of carbon isotope (^{13}C) signatures of 2 banana varieties under different irrigation levels, measured in 4 plants per treatment x variety and 10 samples per leaf. "Old" and "young" leaf respectively imply the 3rd and 2nd or 4th and 3rd leaf, depending on the treatment.

As could be expected, the younger leaves have less negative δ-values. They were formed more recently and thus at a time when water reserves have already become more limited, due to the progressing dry season. Interestingly, this effect is also visible in the irrigated plants. However, under optimal irrigation, the water level should be constant and leaves formed at a different time should have similar isotope signatures. In terms of variation, it becomes clear that individual plant and location effects play an important role. The variability from plant-to-plant is rather large. Within the leaf, variation is limited, yet present. Further investigation on the individual samples in the leaf will allow for the development of an optimal sampling methodology for isotope analysis, facilitating further research. The temperature measurements as well, need further analysis. In particular, other meteorological variables like vapour pressure deficit and solar radiation could provide better insight in the trends seen in leaf temperature. In the near future, fieldwork will be continued, and measurements will be scaled up, both geographically, as well as temporarily. Exciting opportunities like thermal infrared remote sensing will be explored and eventually, fast methods for drought stress monitoring in banana will be developed and optimized, allowing for a better response and increased resilience of the system.

Participation in the Joint Danube Survey 4

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The Danube is Europe`s second longest river, stretching from Germany to the Black Sea. Water quality in the Danube River Basin is regularly monitored by the national authorities of all riparian countries to evaluate contaminant sources and to reduce the pollution loads to the Danube River and the Black Sea.

In summer 2019 the SWMCN Section and laboratory participated in cooperation with the IAEA Isotope Hydrology laboratory in the Joint Danube Surveys 4 (JDS4). The survey was organized by the International Commission for the Protection of the Danube River (ICPDR). Its main purpose is to gather specific water quality data, which are not covered in standard monitoring campaigns, across the entire length of the Danube River and its major tributaries. The water sampling is implemented by the national authorities, but water analyses are performed through cooperation with external institutions in order to cover a wide range of parameters.

As no nuclear components are measured routinely along the entire Danube River, IAEA provided sampling material and performed the analysis of stable water isotopes, stable isotopic compositions of nitrate as well as major ion analysis. In total 51 sites from 13 different countries across the Danube River Basin and 7 groundwater samples were sampled and analysed in IAEA laboratories. The results provide information about the origin of water and nitrate sources in the Danube watershed. The results will contribute to an official report of the ICPDR and the outcome will support the 2021 update of the Danube River Basin Management Plan as well as water monitoring practices across the Danube countries.

DSS4NAFA beta testing in Belgium

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On 23-24 May 2019, the SWMCNL in collaboration with the Belgian Ministry of Defense and Belgian Federal Agency for Nuclear Control (FANC) successfully performed a first testing of an SWMCNL developed IT-tool, the Decision Support System for Nuclear Emergencies Affecting Food and Agriculture (DSS4NAFA). The IT-tool was designed to strengthen Member State abilities to respond to nuclear emergencies affecting food and agriculture through optimized data management and data visualization. This testing was organized under a PUI Project titled “Global Networking for Improved Radiological and Nuclear Emergency Preparedness and Response in Food and Agriculture”.

The emergency response exercise simulated a radionuclide contamination event and involved 22 civil protection personnel from the Federal Public Service (Ministry of the Interior), as well as six local coordinators from the Belgian Nuclear Research Center (SCK-CEN), the National Institute for Radioelements (IRE) and

Federal Agency for the Safety of the Food Chain (FASFC).

Testing was repeated over two days – one day for the French-speaking Civil Protection group, one day for the Flemish-speaking Civil Protection group. As part of the exercise, DSS4NAFA was utilized on its desktop and mobile based interface to assign sampling tasks, digitize data input in the field, and update stakeholders on the contamination status in real-time. The principles, as well as end-user and strategic level usage of the DSS4NAFA system was explained. After, IRE, FASFC, SCK-CEN personnel were appointed as local coordinators and utilised the web-based interface of DSS4NAFA to assign tasks and oversee the response exercise on a strategic level. Meanwhile, civil protection personnel utilised the mobile-based interface of DSS4NAFA to receive tasks and input in-situ measurements.

This testing and adaptation experience serves as a platform for improved adjustment and implementation of DSS4NAFA for other Member States in the future. The general feedback was constructive and points towards further customization and improvement in DSS4NAFA's user interface and system set up. A list of improvements and proposed solutions were drafted and agreed upon by all counterparts in Q3 2019, and will be further implemented in 2020.

Members of the Belgian Civil Defense Force tested DSS4NAFA while undergoing training in Nuclear Emergency Response (Photo credit: Mr Jürgen Braekevelt, Belgian Ministry of Defense)

Evaluation of the use of zeolite amendments on radiocaesium selectivity in Japanese and European soils

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In the aftermath of a nuclear emergency, radioactive contamination can severely affect agricultural production and food safety. Top soil removal and potassium fertilizer application are used as major countermeasures to reduce the transfer of radioactive elements, such as radiocaesium, from soil to crop. Additionally, clay amendments, such as zeolite, known to adsorb effectively radiocaesium, are also applied to some extent. Field studies in the areas affected by the Fukushima Nuclear Power Plant accident showed that amendment of clays can reduce the radiocaesium uptake by crops being planted on contaminated soils.

To better understand the precise role of such clay amendments in radionuclides behaviour, the SWMCNL started in 2019 a collaboration with Austrian, Belgian and Japanese research institutes. Through this partnership, a set of experiments has been initiated to compare the Radiocaesium Interception Potential (RIP) of Japanese and European agricultural soils with different clay mineralogy.

RIP is a key parameter for understanding the dynamics of radiocaesium in the soil. This parameter is used in mathematical models that can assist in the prediction of radionuclide mobility in soils. Such modelling approaches may help optimize the use of remediation countermeasures.

First the selected soils are being characterised by X Ray Diffraction (XRD) analysis to identify their clay mineralogical composition. Secondly, incubation of Japanese and European soils with different clay mineralogy is being conducted for determining the RIP. As caesium competes with potassium for binding sites in soils, their content in soil solution and solid phase will both be determined with the support of a range of analytical techniques including atomic absorption spectrometry (AAS), inductively coupled plasma - mass spectrometry (ICP-MS) and sodium iodide detector, and this for different levels of potassium addition. Soils characterised by low RIP values will be further studied by considering different levels of zeolite addition.

From left to right: (1) Preparation of soils; (2) Dialysis bags with soil samples for RIP analysis; (3) Zeolite minerals

This study falls under the new Coordinated Research Project D1.50.19 on “Monitoring and predicting radionuclide uptake and dynamics for optimizing remediation of radioactive contamination in agriculture”.

The research team expects the main outcomes of this study to contribute in the decision-making on agronomic countermeasures for radioactively contaminated soils, as well as provide primary data that can improve existing models and elucidate the role of RIP in radiocaesium behaviour in agricultural soil.

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

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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 an important tool for external quality control.

The 2019 Proficiency Test (PT) on ^{15}N and ^{13}C isotopic abundance in plant materials, organized by the University of Wageningen, the Netherlands, and funded by the SWMCN Laboratory has been successfully completed. The Wageningen Evaluating Programs for Analytical Laboratories (WEPAL, http://www.wepal.nl/) is accredited for the organization of Inter-laboratory Sudies 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 2019: **Africa (1)**: Morocco, **Asia (3)**: Pakistan and Philippines (2 labs), **Europe (3)**: Austria, Belgium and France, **Latin America (3)**: Argentina, Brazil and Chile, and **South Pacific (1)**: New Zealand.

Nine out of nine laboratories participating in the nitrogen analysis reported ^{15}N-data within the control limits for the enriched plant sample (Figure. 1) and seven out of nine participating laboratories in carbon analysis reported ^{13}C

isotopic abundance results within the control limits (Figure. 2).

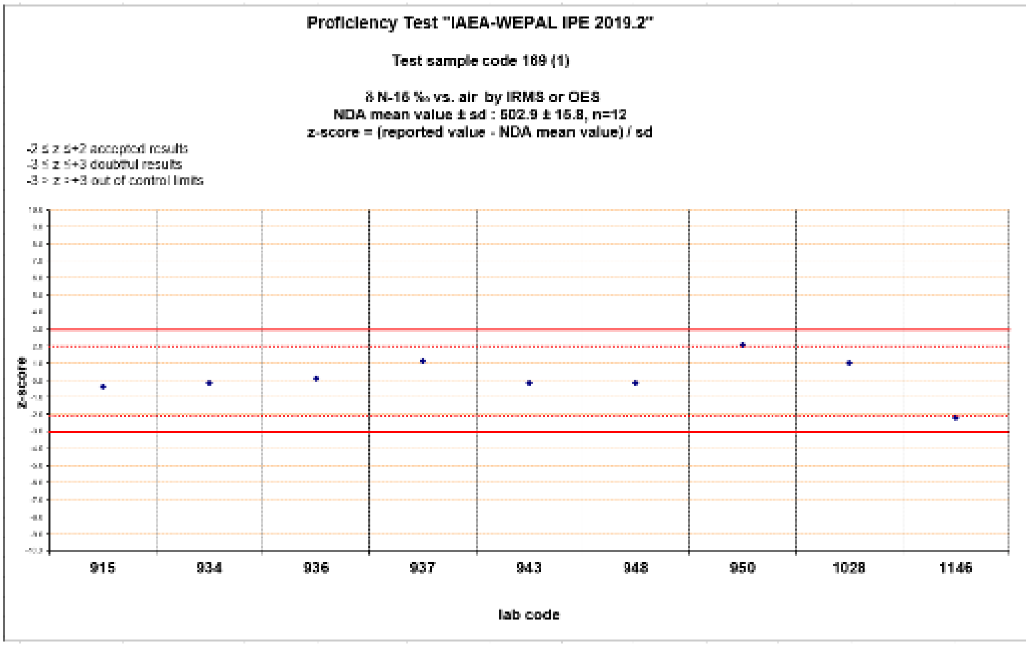

Figure 1. Z-score evaluation of the ^{15}N analysis

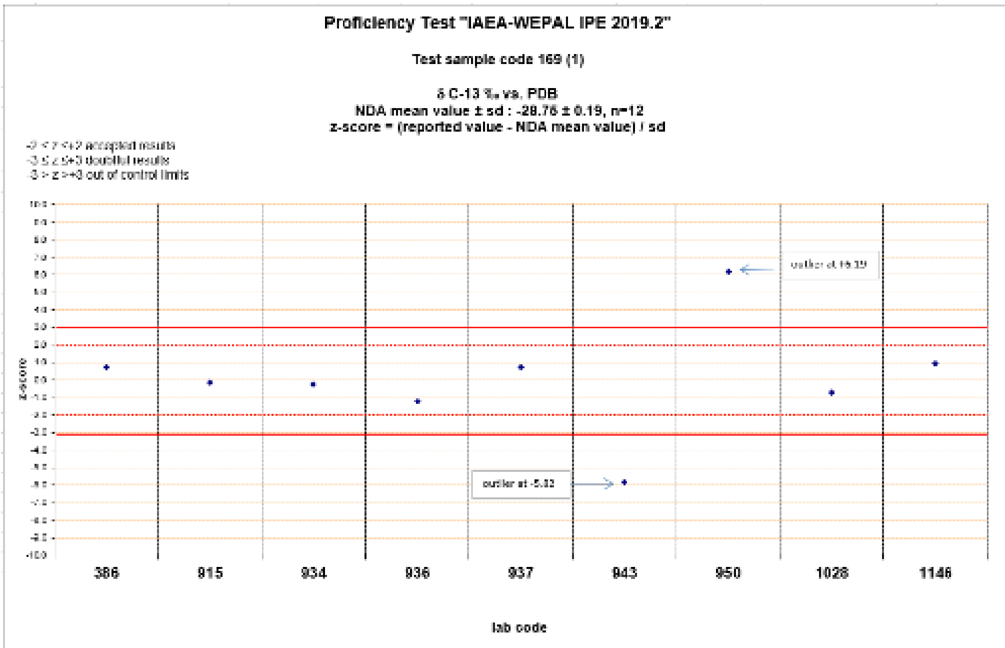

Figure 2. Z-score evaluation of the ^{13}C analysis

Analytical Services

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In 2019, 3780 samples were analysed for stable isotopes and 300 samples were measured for fallout radionuclides respectively in the SWMCN Laboratory. Most analyses were carried out for supporting Research and Development activities at the SWMCNL focused on the design of affordable isotope and nuclear techniques to improve soil and water management in climate-smart agriculture. Analytical support has also been given to the Insect Pest Control Laboratory with about 180 samples analysed.

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Websites and Links

- Soil and Water Management and Crop Nutrition Section:
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- FAO Land & Water:
  http://www.fao.org/land-water/en/ l
- 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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