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Nuclear Techniques in Food and Agriculture

Soils Newsletter

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Contents

To Our Readers

I am sending greetings from Vienna during this special time of lockdown in Austria and working remotely from home. At the IAEA, we are now in the phase of gradual return to office. As in almost every part of the world, it was a long and difficult period, especially for those living alone to be isolated for so long. Due to the inability to return to the Laboratory in Seibersdorf, a lot of the R&D activities were affected. Nevertheless, everyone in the Soil and Water Management and Crop Nutrition (SWMCN) Subprogramme has been busy and productive, with substantial output to report.

CRP D1.20.14 was represented at EGU General Assembly 2020 by the first results from Cosmic Ray Neutron Sensor soil moisture monitoring site newly established in Rutzendorf, Lower Austria.

A new coordinated research project (CRP) D1.50.20 on 'Developing Climate Smart Agricultural practices for carbon sequestration and mitigation of greenhouse gases' was approved in March 2020, and we have in the meanwhile evaluated all submitted proposals. Due to COVID-19 travel restriction, the 1st research coordination meeting (RCM) to be held in Vienna, Austria, is now rescheduled to November 2020, hoping there will be no further travel ban by then. You can read more about this CRP under Announcement on page 9. Similarly, the 2nd RCM of D1.50.18 on 'Multiple Isotope Fingerprints to Identify Sources and Transport of Agro-Contaminants' is also postponed to the 4th quarter, in Vienna, Austria. It was originally planned to be held in Accra, Ghana, in March.

With the initiation of the new Technical Cooperation cycle for 2020-2021, all our professional staff are busy implementing the new and on-going TC projects. Many online meetings and discussions were organized with project counterparts to ensure activities are implemented as scheduled. Two success stories were published during the lockdown period: *Benin Enhances Production and Export of Soybean Using Bio-fertilizers and Isotopic Technology* https://www.iaea.org/newscenter/news/benin-enhances-production-and-export-of-soybean-using-bio-fertilizers-and-isotopic-technology and *Nuclear Techniques Support Crop Production on Salt-affected Soils in Middle East* https://www.iaea.org/newscenter/news/nuclear-techniques-support-crop-production-on-salt-affected-soils-in-middle-east. In total seven stories have been published for the last six months, including: *Controlling Erosion and Land Degradation in Madagascar with the*

Help of Nuclear Techniques https://www.iaea.org/newscenter/news/controlling-erosion-and-land-degradation-in-madagascar-with-the-help-of-nuclear-techniques, *Radionuclide Technique Used to Update Serbia's Soil Erosion Map* https://www.iaea.org/newscenter/news/radionuclide-technique-used-to-update-serbias-soil-erosion-map-identify-conservation-needs; *Identify Conservation Needs: World Water Day 2020: Water and Climate Change... and Isotopes* https://www.iaea.org/newscenter/news/world-water-day-2020-water-and-climate-change-and-isotopes, *Malian Farmers Adapt to Climate Change, Improve Water Use, Crop Yield and Livelihood Using Nuclear Techniques* https://www.iaea.org/newscenter/news/malian-farmers-adapt-to-climate-change-improve-water-use-crop-yield-and-livelihood-using-nuclear-techniques and *World Environment Day 2020: How the IAEA Contributes to Soil, Plant and Animal Biodiversity* https://www.iaea.org/newscenter/news/world-environment-day-2020-how-the-iaea-contributes-to-soil-plant-and-animal-biodiversity.

This year's European Geosciences Union (EGU) General Assembly which took place in May went virtual due to the pandemic, it was an exciting experiment with every session carried out online. The Subprogramme was very productive with twenty-two oral or poster papers presented by our staff, consultants and interns. It was a new experience in terms of time allocation, participation in many live text chats and answering numerous messages posted online. Overall, it was an excellent opportunity to meet online, share findings and ideas and disseminate knowledge.

Meanwhile, research and development work continued albeit interruption at the Soil and Water Management and Crop Nutrition Laboratory in Seibersdorf. It is with immense pride that I present here the many contributions from the Laboratory. Interesting update has been obtained from the work on DNA sequencing analysis to investigate how the diversity and structure of bacterial and fungal communities in soil can be linked to soil quality and soil erosion, as reported in the article 'Characterizing bacterial and fungal community structure and diversity to complement soil erosion information derived from $^{239+240}$Pu determination'. Progress was made in determining the depth of measurement of soil water contents derived from cosmic ray neutron sensor, as well as predicting the root zone soil moisture. Good advances have been achieved in the extra-budgetary Peaceful Uses Initiative project on assessing the use of leaf δ^{13}C, phloem-derived δ^{13}C and leaf temperature as a measure for drought stress in bananas. Also, a very interesting piece of work undertaken in CRP D1.50.19 is to combine machine learning and operations research methods to optimize remediation efforts in response to large-scale nuclear emergencies affecting food and agriculture. Similarly, interesting results were achieved on ^{15}N labelling of cassava plants and possible implications for future nutrient management studies. Finally, further progress was made in the evaluation of zeolite amendments on radiocaesium selectivity in selected Japanese soils. It was observed that the influence of K addition on solution Cs concentration differ among Japanese soils, due probably to the difference in clay mineralogy.

Interesting preliminary results were also reported from the 4th Joint Danube Surveys carried out last summer, to determine the origin of water and nitrate sources in the Danube watershed. The results from the 64 samples collected indicated that major ion concentrations remained relatively constant within the mainstream but there was dilution and pollution 'hot spots' through tributaries and wastewater effluents due to higher sulphate and chloride concentrations which are often related to urban wastewater. The relatively low δ^{18}O values of nitrate and the presence of micropollutant indicate that nitrates in the Danube mainstream were mainly derived from wastewater effluents and is increasing in the lower parts of the stream. The results also indicate possible input of atmospheric nitrates, while fertilizer nitrate input was observed to be minor compared to mixtures of soil nitrate and nitrate derived from sewage.

The modernization of the IAEA's Nuclear Sciences and Applications Laboratories at Seibersdorf under the ReNuAL and ReNuAL+ project, which involved building several new laboratories, is coming to an end. The Yukiya Amano Laboratories (YAL) which houses the Animal Production and Health, Food and Environmental and our Soil and Water Management and Crop Nutrition Laboratories are nearing completion and the Laboratory team is now busy packing up and moving to the modern, brand new building. It is an exciting time ahead and we will update you in the next newsletter with news and pictures.

We would like to welcome our new team assistant Ms Julia Macrory who is filling in for Ms Ksenija Ajvazi who is returning this June after eight months away. We also extend our welcome back to Ksenija.

We are also very pleased to report here that four of our former interns, i.e. Amelia, Xavier, Yang and Annemie, have individually received full scholarship to start their respective PhD studies on topics related to carbon cycling, remediation of environmental contamination or microbial based resource recovery. They will soon start in Australia, Belgium and Germany. Our best wishes to them in their pursue of a PhD degree. To future interns, an additional motivation for doing your internship with us.

We would like to bid farewell to Mr Lionel Mabit, a strong contributor to our Subprogramme. Lionel contributed immensely to Member States in the current and previous seven years in the development and refinement of fallout radionuclide methods especially ^{137}Cs, ^{210}Pbex, ^{7}Be and

$^{239+240}Pu$ for assessing the magnitude and extent of soil degradation as well as evaluating the effectiveness of soil conservation strategies. He also contributed to the improvement of the use of Compound-Specific Stable Isotope (CSSI) technique using $\delta^{13}C$-Fatty acids for identifying areas at risk and the sources of sediment within agro-ecosystems. One more output from Lionel and his co-authors in the feature article section on 'Using ^{137}Cs measurements to estimate lateral mobilization of soil carbon induced by runoff along karstic slopes'. We will miss Lionel and big thanks to him for the great output to the SWMCN Subprogramme and we wish him the very best in his future undertaking.

Finally, I would like to take this opportunity to once again thank all our readers for their continuous support. Please stay safe and healthy!

Lee Heng
Head
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Staff News

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			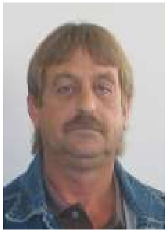
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R. Mirkhani			

Julia (Jules) Macrory (UK) joined the SWMCN team in April 2020 as a Team Assistant. She joined the IAEA in July 2018 and was previously with NSNS (Division of Nuclear Security). Prior to joining the IAEA, Jules worked for four years at the Institute for Austrian and International Tax Law at the WU (Vienna University of Economics and Business) and before that she served for 12 years as a British Army Officer in locations around the world. She has a BA (Hons) in Law and International Business and completed an MSc course in Food Logistic Management. She has lived in Vienna for 8 years now and is greatly looking forward to being part of the SWMCN team.

Lionel Mabit (France) soil scientist at the Soil and Water Management & Crop Nutrition Laboratory (SWMCNL) will be leaving the Agency on 7 September 2020 and finalize then his second 7-year of service at IAEA. Lionel received an MSc in Hydrology and a PhD in physical geography from the University of Paris I Sorbonne in January 1999. His PhD thesis was on soil degradation assessment using nuclear and conventional techniques. After performing research activities on similar scientific topics in Quebec (Canada), he joined as soil scientist the Soil Science Unit of the Joint FAO/IAEA Division in Seibersdorf from 2005 to 2012. After his first 7-year contract with IAEA, he has been working as a senior nuclear environmental scientist at Environmental Geosciences, University of Basel, Switzerland. Lionel then joined again the SWMCNL at the beginning of September 2013.

During his 14 years of cumulated service at IAEA, Lionel contributed significantly to develop and/or to refine fallout radionuclide (FRN) methods (i.e. ^{137}Cs, $^{210}Pb_{ex}$, ^{7}Be and $^{239+240}Pu$) to assess the magnitude and extent of soil degradation and to evaluate the effectiveness of soil conservation strategies. Moreover, he also contributed to the test and improve of the Compound-Specific Stable Isotope (CSSI) technique using $\delta^{13}C$-Fatty acids for identifying areas at risk and the sources of sediment within agro-ecosystems.

Through his involvement in IAEA TCPs and CRPs activities, Lionel played a key role in the development and transfer of the FRN and CSSI techniques to IAEA Member States to combat soil erosion and support soil conservation.

Along his carrier at IAEA, Lionel leaded and/or contributed to several group training activities at the SWMCNL Seibersdorf and organized training courses in IAEA Member States. He also supervised dozens of individual fellows and interns. As an IAEA staff member, he published several protocols and guidelines and authored or co-authored more than 60 peer-reviewed articles and book chapters.

For his output, dedication and support to the SWMCN Soil-Subprogramme, Lionel received two times IAEA merit awards (2010, 2015) as well as one IAEA team award that highlighted his significant contribution as part of the FAO/IAEA Food Safety Assessment Team sent to Japan in 2011 to provide advice and technical support to the Japanese authorities following the Nuclear Power Plant accident at Fuskushima Daiichi.

We would like to thank Lionel for his contribution to the SWMCN Subprogramme activities and wish him all the best for the future.

Feature Articles

Using ^{137}Cs measurements to estimate lateral mobilization of soil carbon induced by runoff along karstic slopes

Gaspar, L.[1], Mabit, L.[2], Lizaga, I.[1], Navas, A.[1]

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

This article is a summary of the major findings published in the peer-reviewed *Journal of Environmental Management* (Gaspar et al., 2020). The study was performed in summer 2019 under the IAEA CRP D1.50.17 on '*Nuclear techniques for a better understanding of the impact of climate change on soil erosion in upland agro-ecosystems*'.

The objective

Soil erosion induced by runoff is the main hydrological driver for surface or lateral transport of carbon in terrestrial agroecosystems. However, many questions still have to be answered to better understand the global significance of soil erosion in carbon cycling.

The purpose of this study was to determine the lateral mobilization of soil organic and inorganic carbon (SOC and SIC) in sub-humid Mediterranean mountain agroecosystem with karstic geological settings in northern Spain, over a period of 40 years. For this purpose, ^{137}Cs inventories and the characterization of terrain attributes were used to identify whether erosion or deposition is predominant in these lateral redistribution processes.

Study area

The investigation was performed around the *Estanque Grande de Abajo* lake near Estaña, in the northern part of Spain. This is a karstic area with abrupt topography and an intricate mosaic of land uses representative of Mediterranean mountain agroecosystems. There are no permanent rivers in the studied catchment and the only active erosional features are rills and gullies generated by surface water flows after rainfall events. The singularity of morphological landforms and other landscape linear elements (LLE) such as terraces, paths and vegetation strips, define the characteristics of the drainage system.

Methodology

Within the 1.3 km^2 catchment, five transects with different ranges of altitude, orientation and lengths between 200 and 1400 m were selected for sampling of a total of 58 soil profiles. In the investigated catchment a detailed analysis of the main runoff pathways was also performed (for more detailed information see Gaspar et al., 2020).

The SOC and SIC contents (%) were determined by the wet dichromate oxidation method and Barahona pressure calcimeter, respectively and were converted into contents per surface area expressed as inventories or stocks (kg m^{-2}), by multiplying the content by the mass of the fine fraction and dividing by the surface of the core sampler. Taking into account the thickness range of soil lost or gained (mm ha^{-1} yr^{-1}) in each sampling site, we derived an average value of carbon loss or gain (Mg ha^{-1} yr^{-1}) over the 40 years study period based on the percentage of SOC and SIC estimated from the topsoil samples. Finally, the soil loss or gain thickness and the related SOC and SIC for each profile was extrapolated along the hillslope by using a perceptual model, assuming that each transect represents a 1 m wide strip. In order to obtain sediment budgets for different sections along transects, the resulting areal estimates provided information on the total (gross) soil loss (kg yr^{-1}), total (gross) soil gain (kg yr^{-1}), net soil loss (kg yr^{-1}) and the sediment delivery ratio (%). Similarly, SOC and SIC budgets were calculated.

Major Outputs

Soil redistribution rates of each soil profile were estimated using the ^{137}Cs method. The thickness of soil gained and lost varied from +3.59 to -4.40 mm ha^{-1} yr^{-1}, respectively. The moderate values of soil loss and gain in uncultivated points (both did not exceed 1.6 mm yr^{-1}, even in steep areas) confirm the soil conserving effectiveness of the vegetation cover. The opposite effect occurs in cultivated steep slopes where soil loss doubled the values of uncultivated sites because runoff is not constrained by the vegetation cover. Concave areas and flat cultivated sites at the bottom part of transects also recorded twice the maximum soil gain as compared to uncultivated sites. Indeed, vegetation has a significant effect on water erosion processes, intercepts rainfall and protects soil from raindrop impacts by reducing the energy of raindrop through raindrop size fragmentation. The water erosion-induced carbon loss and gain was also highly variable ranging between -0.8 and +1.4 Mg of SOC ha^{-1} yr^{-1} and between -5.9 and +1.3 Mg of SIC ha^{-1} yr^{-1}. The general trends from lowest to highest flow accumulation values highlighted a significant increase in the loss of soil, SOC and SIC, reflecting the runoff effects on soil and carbon mobilization.

A significant portion of mobilised soil carbon is trapped along the hillslopes and only remaining portion reaches the Estanque Grande de Abajo lake (Figure 1). The extrapolation of transect showed that the overall catchment provides a Sediment Delivery Ratio of 59%. Therefore, around 41% of mobilized soil and carbon is deposited along the slopes. This implies that the net carbon loss in our catchment contributes to the carbon sinks in the Estanque Grande de Abajo lake. The marked differences between the gain and loss of soil and SOC in concave and convex areas that we have recorded in our study reveal how well-connected concave slopes with predominant inter-rill erosion deliver rich organic carbon sediment. Our results highlight the significant role of landform position in determining the location of erosion-induced terrestrial carbon sinks and understanding carbon sequestration in Mediterranean mountain agroecosystems.

Conclusions

The results of the study provide detailed information on the role of soil erosion as carbon source or sinks in the global carbon cycle. The use of ^{137}Cs inventories in addition to the characterization of terrain attributes allowed us to identify whether erosional or depositional processes have been predominant. This investigation reports detailed information on sediment and carbon budgeting along the five transects selected using a perceptual model in combination with ^{137}Cs inventories.

Despite the limitations of this approach, our findings improve the knowledge about contemporary sediment and carbon surface mobilization by sheet and rill erosion in complex karst catchments and also highlight the key role of the landscape topography, the effect of runoff related to different land uses and the importance of local storage of mobilized soil and carbon along the studied hillslopes.

References

Gaspar, L., Mabit, L., Lizaga, I, Navas, A. (2020). Lateral mobilization of soil carbon induced by runoff along karstic slopes. *Journal of Environmental Management*, 260, 110091. https://doi.org/10.1016/j.jenvman.2020.110091

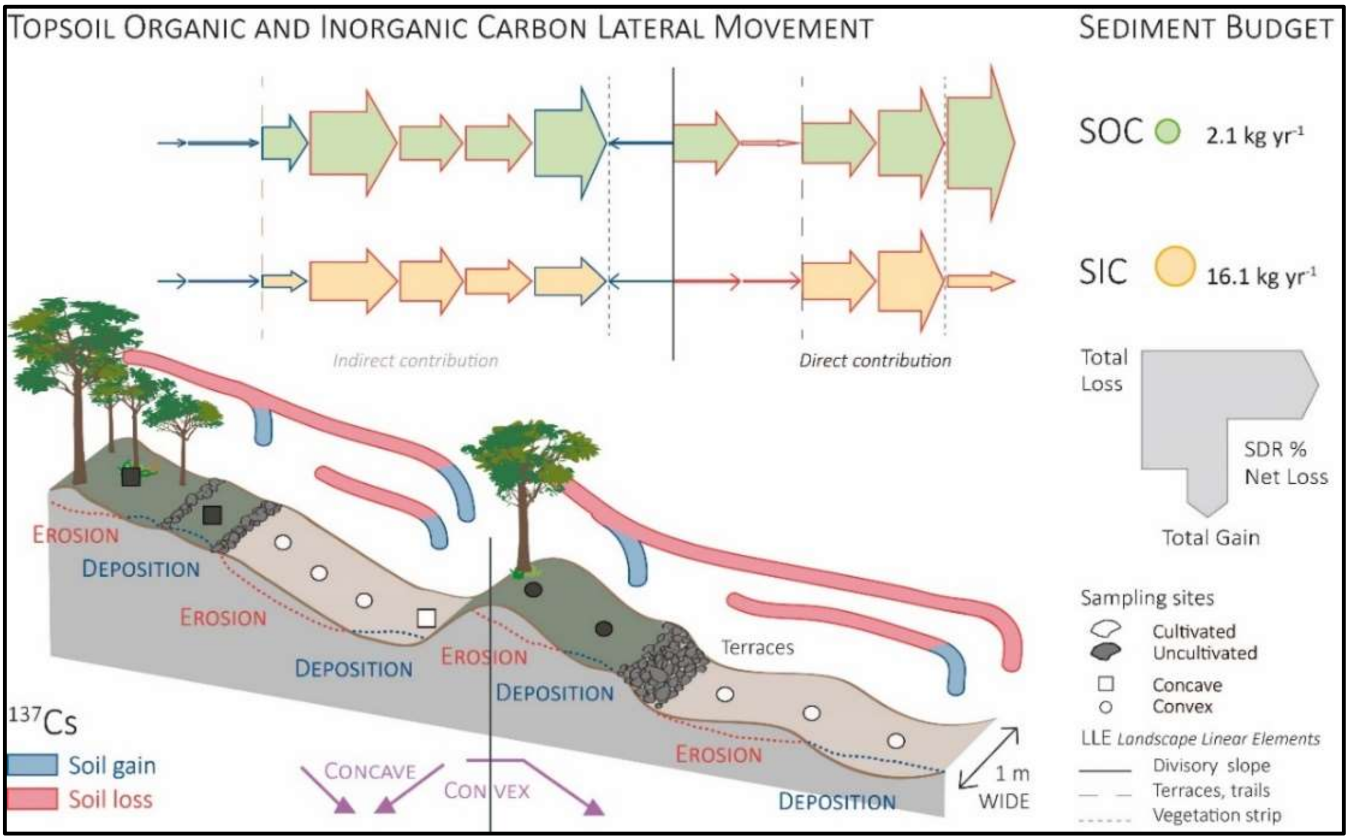

Figure 1. Example of schematic carbon budget obtained from one of the transect investigated (Adapted from Gaspar et al., 2020)

Preliminary results of the Joint Danube Survey 4

Halder, J.[1], Resch, C.[2], Gruber, R.[2], Heiling, M.[2]

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In the summer of 2019 the SWMCN Section and Laboratory participated in cooperation with the IAEA Isotope Hydrology Laboratory in the Joint Danube Surveys 4 (JDS4). The specific purpose of this collaboration was to gather information about the origin of water and nitrate sources in the Danube watershed.

In total IAEA performed the analysis of stable water isotopes, stable isotopic compositions of nitrate as well as a major ion analysis on 64 samples. For the ion analysis the SWMCNL could use the new Ion Chromatograph and its autosampler that was procured in 2019 for the analysis of environmental water samples. Water stable isotopes were analysed with laser equipment at SWMCNL and nitrate isotopes via Mass Spectrometry at the Isotope Hydrology Laboratory. In February 2020 all analyses were finalized, and the data are prepared for publishing.

Preliminary results indicate that major ion concentrations stay relatively constant within the main stream but indicate dilution and pollution “hot spots” e.g. through tributaries and wastewater effluents. An example is the sulphate and chloride concentrations, which are considered to be relatively conservative tracers and often related to urban waste water (See Fig. 1).

Results also indicate that water stable isotopes show differences in the snowmelt contribution in the Danube water and the dilution of pollutants (e.g. nitrate). The relatively low $\delta^{18}O$ values of nitrate clearly indicate that nitrate in the Danube mainstream mainly derives from waste water effluents, the input of which is increasing in the lower parts of the stream (see Fig. 2).

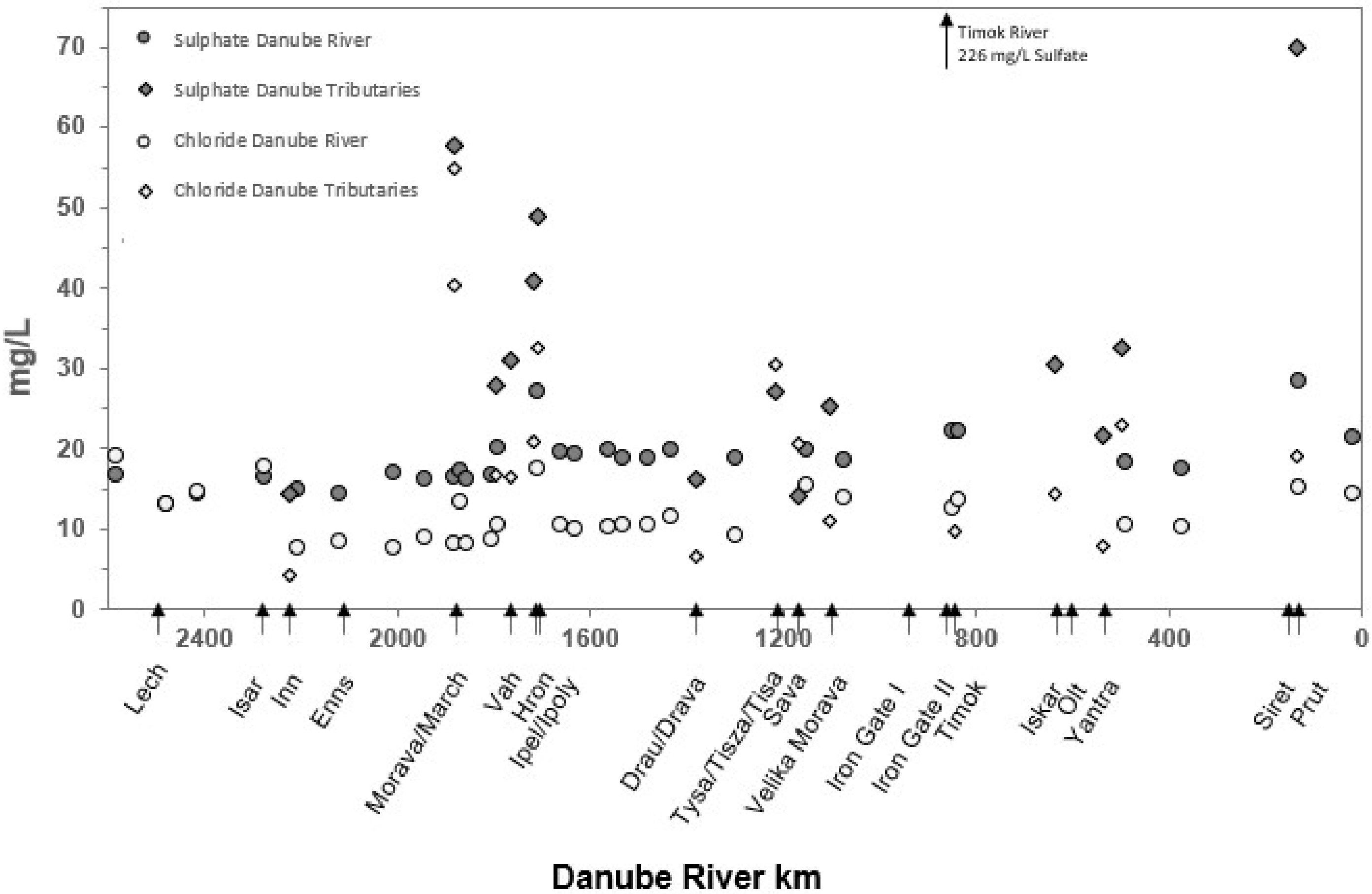

Figure 1. Sulphate and Chloride concentrations in the Danube and its tributaries

This can be further confirmed by results of micropollutant studies, performed by other participants of the JDS4, that demonstrate an increase of widely consumed pharmaceuticals (carbamazepine, diclofenac and caffeine) at different sections of the Danube River affected by tributary inflows and discharge from urban settlements. The $\delta^{15}N$ values indicate that input of atmospheric nitrate and fertilizer nitrate is minor in comparison to mixtures of soil nitrate and nitrate derived from sewage.

In summary, this study is an example of combining isotope techniques, general chemistry and hydrological methods as well as emerging compounds in order to approach the fate of anthropogenically-derived nitrate within the Danube Basin. The results of this study support the 2021 update of the Danube River Basin Management Plan and water monitoring practices in the Danube countries.

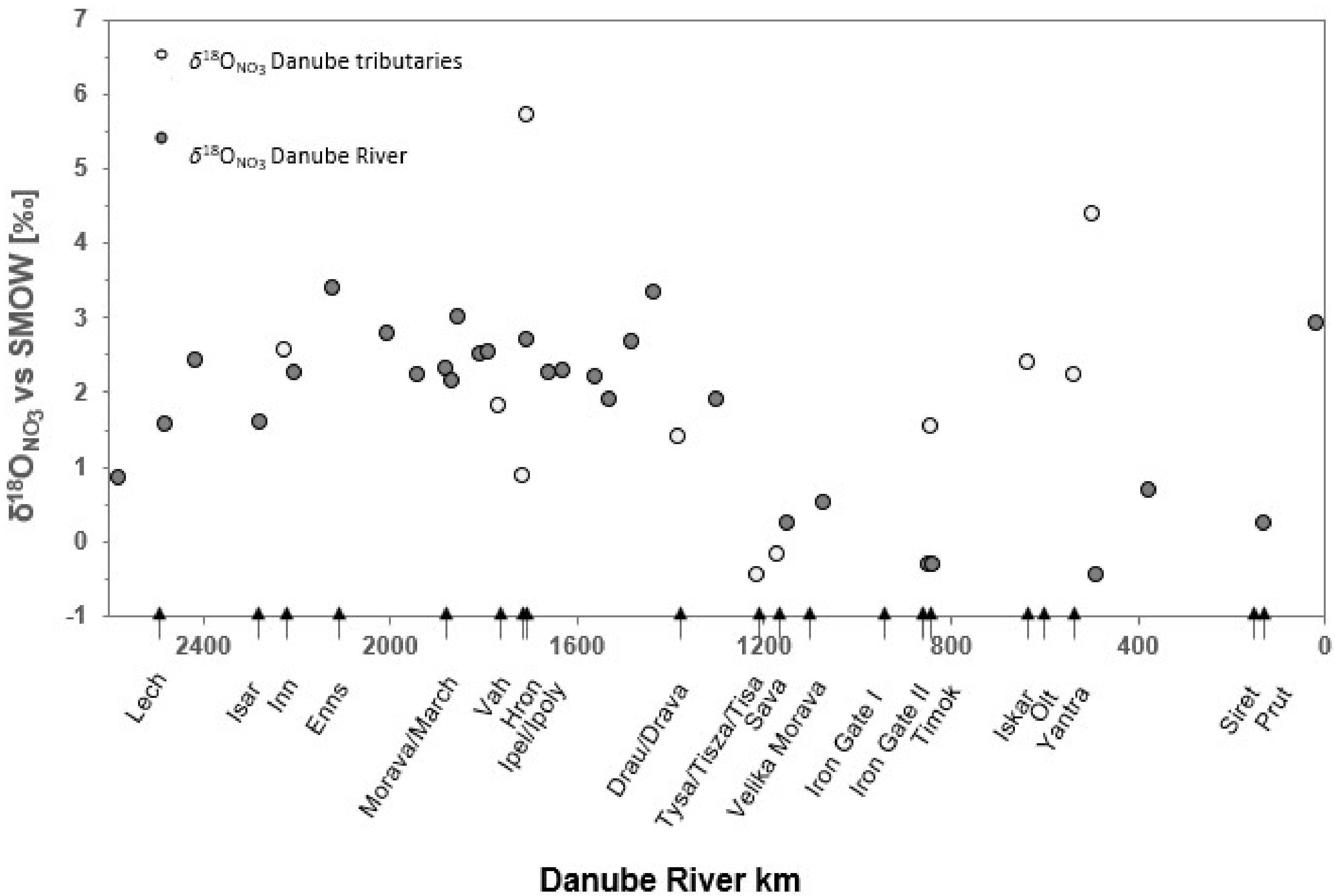

Figure 2. Stable oxygen isotope compositions of nitrate within the Danube and its tributaries

Announcements

New CRP:

Developing Climate Smart Agricultural practices for carbon sequestration and mitigation of greenhouse gases (D1.50.20)

Mohammad Zaman and Lee Heng

Soil and Water Management & Crop Nutrition Section

The Soil and Water Management & Crop Nutrition Section has launched a new five-year (2020-2025) Coordinated Research Project (CRP), titled 'Developing Climate Smart Agricultural practices for carbon sequestration and mitigation of greenhouse gases' (D1.50.20). This CRP's first Research Coordination Meeting is expected to take place on 23-27 November 2020, in Vienna, Austria.

Greenhouse gas measurements in the field

Background

Climate Change due to continued increased emission of greenhouse gases (GHGs) is a global threat. For many years, scientists were predicting that climate change would happen in the future, but that is no longer the case right now. Direct and indirect GHG emissions from agriculture, forestry and other land-uses changes contribute approximately 25% of the global anthropogenic GHG emissions. The GHGs with largest global warming potential are nitrous oxide (N_2O) and methane (CH_4), which predominantly originate from agriculture. Based on the outputs of the previous CRP (D1.50.16), climate-smart agricultural practices are a promising tool to enhance crop production with lower GHG emissions.

However, more quantitative data on the effect of soil processes (e.g. C- and N-dynamics) on emissions of GHGs in relation to land-use changes are urgently needed. Many farming practices such as soil cultivation, application of nitrogen (N) fertilizers, animal manure, crop residues, excreta from grazing livestock, and converting peatland to arable agriculture lead to GHG emissions to the atmosphere. Overall, a 70% increase in current agricultural production will be required, from existing natural resources of land and water, to meet the increasing demand of food (e.g. dairy and meat products) from the fast-growing population in developed and developing economies. This will lead to more GHG emissions. Agriculture production is at the same time a key contributor to climate change a primary victim of climate variability (heat, drought, changing rainfall patterns, extreme events) which cause major damages in terms of crop failure, soil erosion, fast decomposition of organic matter, overall nutrients cycling, etc. Thus, the development and validation of climate-smart agricultural practices are required to ensure food security while minimize GHG emission.

CRP Overall Objective:

To develop and validate climate-smart agricultural practices, based on isotopic and related techniques, to increase soil carbon (C) sequestration (based on C budgeting), mitigate GHG emissions (N_2O, CH_4, CO_2) and limit gaseous losses of ammonia (NH_3) and dinitrogen (N_2) from agricultural ecosystems, with the aim to enhance agricultural productivity and sustainability.

Specific Research Objectives:

1.1. To determine C budgets based on the quantification of C fluxes (CO_2 and CH_4) using nuclear and related techniques and devise soil C sequestration strategies in selected agroecosystems.

1.2. To quantify N_2O and N_2 emissions using ^{15}N technique to validate agricultural system-specific emission factors (EF).

1.3. To evaluate the effect of N process inhibitors and biochar on soil N transformation rates using ^{15}N tracing technique and to test their N_2O mitigation potential within specific agroecosystems (soil, plant and climate).

1.4. To develop guidelines on climate-smart agriculture practices for C sequestration, mitigation of GHG and improved N use efficiency.

Greenhouse gas emission study over rice

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 and PBG
Cambodia	KAM5005	Enhancing Soil, Water and Nutrient Management for Sustainable Rice Production and Optimized Yield	J. Adu-Gyamfi
Central African Republic	CAF5011	Building National Capacities for Improving the Efficiency of Biological Nitrogen Fixation for Food Security, Fertility Restoration and Rehabilitation of Degraded Soils	M. Zaman
Central African Republic	CAF5012	Building Capacities in Developing Best Agricultural Practices for Enhanced Production of Maize and its Quality – Phase I	M. Zaman
Cambodia	KAM5005	Enhancing Soil, Water and Nutrient Management for Sustainable Rice Production and Optimized Yield	J. Adu-Gyamfi
Chad	CHD5009	Developing Sustainable Water Resources Management through the Use of Nuclear Isotopic Techniques in Drip Irrigation Systems	J. Halder and L. Heng
Colombia	COL5026	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 Harbours and 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, 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
Laos	LAO5004	Enhancing National Capability for Crop Production and Controlling Trans-Boundary Animal Diseases	M. Zaman and APH
Lesotho	LES5009	Determining Soil Nutrient and Water Use Efficiency Using Isotope Techniques	J. Adu-Gyamfi
Madagascar	MAG5026	Enhancing Rice and Maize Productivity through the Use of Improved Lines and Agricultural Practices to Ensure Food Security and Increase Rural Livelihoods	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 and 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, 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 and 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 and 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 and PBG
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	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, 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 and PBG
Senegal	SEN5041	Strengthening Climate Smart Agricultural Practices Using Nuclear and Isotopic Techniques on Salt Affected Soils	M. Zaman
Seychelles	SEY5011	Supporting Better Sustainable Soil Management as Climate Change Adaptation Measures to Enhance National Food and Nutrition Security	J. Halder, L. Heng
Sierra Leone	SIL5021	Improving Productivity of Rice and Cassava to Contribute to Food Security	M. Zaman and PBG
Sudan	SUD5037	Application of Nuclear and Related Biotechnology Techniques to Improve of Crop Productivity and Livelyhood of Small Scale Farmers Drought Prone Areas of Sudan	J. Adu-Gyamfi and PBG
Togo	TOG5002	Improving Crop Productivity and Agricultural Practices Through Radiation Induced Mutation Techniques	E. Fulajtar and PBG
Zambia	ZAM5031	Improving the Yield of Selected Crops to Combat Climate Change	L. Heng and PBG

Forthcoming Events

FAO/IAEA Events

Workshop on Regional Project RAS5084 'Assessing and improving soil and water quality to minimize land degradation and enhance crop productivity using nuclear techniques' (RCA) on 'Land use and management practices to reduce sediments and agro-contaminants on trans-boundary rivers', 08-12 June 2020, Manila, Philippines. (Postponed)

Technical Officer: J. Adu-Gyamfi

Regional Training Course of RAS5089 Project 'Enhancing the sustainability of date palm production in states parties through climate-smart irrigation, nutrient and best management practices (ARASIA)' on the use of ^{15}N fertiliser to assess nutrient use efficiency in date palm plantations, 6-10 October 2020, Amman, Jordan.

Technical Officer: H. Said Ahmed

Workshop on Regional Project RAS5084 'Assessing and improving soil and water quality to minimize land degradation and enhance crop productivity using nuclear techniques (RCA) on 'Data management on FRN and stable isotope processing', 12-16 October 2020, Mumbai, India.

Technical Officer: J. Adu-Gyamfi

Regional Training Course of RAF5079 'Enhancing crop nutrition and soil and water management and technology transfer in irrigated systems for increased food production and income generation (AFRA)', 2-13 November 2020, Seibersdorf, Austria.

Technical Officers: L. Heng and H. Said

Regional Training Course of RAF5081 'Enhancing productivity and climate resilience in cassava-based systems through improved nutrient, water and soil management (AFRA)', 16-27 November 2020, Seibersdorf, Austria.

Technical Officers: G. Dercon and M. Zaman

First Research Coordination Meeting of CRP D1.50.20. 'Developing Climate Smart Agricultural practices for carbon sequestration and mitigation of greenhouse gases', 23-27 November 2020, Vienna, Austria.

Project Officers: M. Zaman and L. Heng

Second Research Coordination Meeting of CRP D1.50.18. 'Multiple isotope fingerprints to identify sources and transport of agro-contaminants', 30 November-4 December 2020, Vienna, Austria.

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

Mid-term review meeting of RAF5079 'Enhancing Crop Nutrition and Soil and Water Management and Technology Transfer in Irrigated Systems for increased Food Production and Income Generation', 7-11 December 2020, Vienna, Austria.

Project Officer: L. Heng

Non-FAO/IAEA Events

6th International COSMOS Workshop, https://cosmos.physi.uni-heidelberg.de/, 8-10 October, 2020, Heidelberg, Germany. Dates and deadlines of the workshop are kept until further notice. The committee will decide about a possible further postponement of the workshop in June.

International Conference on Dryland Agriculture 2020: Innovation and Collaboration: Building Resilient Dryland Ecosystem to Achieve SDG 2030. http://dryland.caas.cn/dryland2020/, 20-24 October 2020, Beijing, China.

EGU 2021: 25-30 April, 2021, Vienna, Austria.

Past Events

FAO/IAEA Events

Mid-term Coordination Meeting for Regional Project RAS5084 'Assessing and improving soil and water quality to minimize land degradation and enhance crop productivity using nuclear techniques, 2-6 December 2019, Tsukuba, Japan

Technical Officer: Joseph Adu-Gyamfi

The purpose of the mid-term project coordination was to bring all the national project coordinators (NPCs) from Asia and the Pacific together with the PMO, TO and the Lead Country Coordinator (LCC) to discuss progress to date, and to plan and refine both national and regional project workplans for 2020 and 2021. The meeting was attended by eighteen participants from eighteen countries:

Australia, Cambodia, China, Fiji, India, Indonesia, Japan, Laos P.D.R, Malaysia, Mongolia, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Sri Lanka, Thailand and Vietnam Bangladesh, Korea, Palau and Singapore did not have a representative at the meeting. The meeting was hosted by Prof. Yuichi Onda and his colleagues at the Centre for Research in Isotopes and Environmental Dynamics, University of Tsukuba, Tsukuba, Japan.

Participants visiting erosion plots at the Fukushima Prefectural Centre for Environmental Creation

Field visits to see water quality monitoring at the Fukushima Prefecture

The PMO, Mr Sinh Van Hoang, gave an overview of the objectives and expected outcome and was followed by an overview of the implementation of the project since the first Coordination Meeting in Vienna by Mr Tim Ralph, the LCC. The Technical Officer, Mr Joseph Adu-Gyamfi, made a presentation on recent developments and technical issues related to soil erosion and soil/water quality. There were country reports by each NPC to summarize their country's progress to date, including major achievements and outcomes, as well as obstacles or limitations. National workplans for 2020/2021 were discussed and agreement was sought to ensure the set objective/s of each country would be achieved at the closure of the project. The group discussed improvements that could be made for communication within the countries to identify and nominate correct personnel to attend RTCs and to develop adequate NPTs and projects. The participants travelled from Tsukuba to visit the Fukushima Prefectural Centre for Environmental Creation, to study on-going experiments aimed at monitoring soil erosion, sediments and water quality in the forest sites after the Fukushima Daiichi Nuclear Power accident. A small workshop was held to help with project design and workplan development. The participants debated and agreed to host: (1) an additional RTC from 8-12 June 2020 in Manila, the Philippines, on the use of FRNs and stable isotopes for soil erosion, and soil and water quality, (2) a workshop on data management and interpretation from 12-16 October 2020 in Mumbai, India.

Mid-term Coordination Meeting for Regional Project 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: Joseph Adu-Gyamfi

The mid-term project Coordination Meeting aimed to discuss progress to date, plan and refine both national and regional project workplans for 2020-21. It was attended by fourteen national project coordinators (NPCs) from fourteen countries: Bolivia, Brazil, Chile, Colombia, Costa Rica, Haiti, Dominican Republic, Ecuador, Mexico, Nicaragua, Panama, Paraguay, Peru and Venezuela. Argentina did not have a representative at the meeting. The IAEA was represented by the Technical Officer (TO) and the Project Management Officer (PMO) and the meeting was hosted by Ms Adriana Nario Mouat and her colleagues at the Research and Nuclear Applications Division, Chilean Nuclear Energy Commission (CCHEN), Santiago, Chile. The meeting was opened by Mr Oscar Enrique Díaz, Regional Director, Agriculture and Livestock Service (SAG). The TO - Mr Joseph Adu-Gyamfi - and the PMO - Ms Karla Molina Diaz - gave an overview of the objective and expected outcome of the meeting, and this was followed by an overview of the project implementation since the first Coordination Meeting in Mexico, given by Mr Eulogio de la Cruz Torres, the Lead Country Coordinator (LCC). Each National Project Coordinator (NPC) or their representative summarised their country's progress to date, including major achievements and outcomes, as well as any barriers or limitations to their progress since 2018. On the third day, the participants travelled outside Santiago to visit the Harmony Sustainable Company where different plant growth-promoting bacteria bio-fertilizers are manufactured for farmers. This was followed by a trip to the Villard Vineyard, Casablanca, where bio-fertilizers are being used to improve production and quality of grapes. The next day, there were discussions on the national workplans for 2020/2021. It became evident from the country reports and discussions that several countries had established National Project Teams (NPTs) and had applied the techniques learnt in the RTCs and expert missions to their national projects. Some have also initiated close collaborations between national institutions. The TO, however, realized that some countries did not have an adequate national project design, and that some did not attend some of the RTCs, which has led to knowledge gaps for theory and application of techniques in those countries. Therefore, the TO had one-to-one meeting with all the counterparts to review their field experimental designs.

Participants visited a vineyard to observe the use of bio-fertilizers on vine production

A visit to a factory where bio-fertilizers are produced for crop production in the suburb of Santiago

The group discussed improvements that could enhance communication within their countries. On the last day, all partners refined appropriate national workplans for 2020/2021. There was general discussion on the way forward and to highlight the achievements from the project through the creation of success stories. It was concluded that: (1) counterparts have created capacities in the application of nuclear and biotechnological techniques to study fertilizer dynamics and sustainable agricultural production; (2) promising genotypes of high productivity, tolerance to adverse conditions and efficient use of fertilizers have been obtained for the Latin American and Caribbean region; (3) optimal microorganisms have been typified to produce biofertilizers obtained from the microflora and from the crops in the regions of interest to the counterparts; (4) teamwork (multidisciplinary and inter-institutional incorporating students and technicians) both regionally and nationally was vital to achieving the project's objectives; and (5) the regional project has helped to share regional experiences and apply technical knowledge in different crops.

The counterparts recommended extending the project for another twelve months, in order to fully achieve the goals set and guarantee the transfer of the results to the farmers, and to organize a symposium at the end of the project as an activity to disseminate the achievements of the project.

National Training Course of PAK5051 'Developing isotope-aided techniques in agriculture for resource conservation and climate change adaptation and mitigation' on using nuclear techniques to measure greenhouse gases and to develop climate smart agricultural practices, 20–24 January 2020, Islamabad, Pakistan

Technical Officer: M. Zaman

Climate Change (CC), due to increased emissions of greenhouse gases, is a global threat which has been predicted by scientists for many years, but it is a reality now. Pakistan, where the population has increased exponentially during the past three decades, is losing its natural resources (soil and water) at a fast rate, and currently 25% of its current population is below the poverty line, meaning they are facing food insecurity and malnutrition problems. The changing climate, and lack of technical knowledge to increase agricultural production with lower environmental footprints (lower greenhouse gas emissions and nutrient losses to surface and ground water bodies) will further accelerate the negative impacts of CC in Pakistan. Investigation of these problems are an objective of PAK5051 technical cooperation project. The Technical Officer together with an expert, Mr. Christoph Müller, travelled to Islamabad to organize a five-day training course on the role of isotopic techniques in measuring greenhouse gas (GHG) emissions from agriculture and identifying the sources of GHG for developing mitigation measures. The training was held in Arid Agricultural University, Islamabad, from 20 to 24 January 2020. The training was inaugurated by the Vice Chancellor of Arid Agricultural University and was attended by 57 (15 female) researchers from different research institutes, universities, extension departments and fertilizer companies. The participants had no prior knowledge of GHG emissions and their measurements, therefore the Technical Officer introduced major GHGs emitted from agriculture, the sources of GHG production in soil followed by potential mitigation options to understand GHGs in the context of global elemental cycling and global change. The Technical Officer also highlighted the role of climate-smart agricultural which could offset the negative impact of climate change by capturing more carbon dioxide from the atmosphere and storing it in soil to build its resilience and increasing agricultural productivity contributing to food security. The field trip was aimed on GHG measurement. At the request of the Vice Chancellor, a half day workshop on climate change, GHG measurements and their mitigation was organized with assistance of the invited expert. More than 300 academic staff and students participated. The participants acknowledged the IAEA, the Pakistan Atomic Energy Agency and Arid Agricultural University, Islamabad, for hosting and organizing this training and committed to share their experience with fellow colleagues for further capacity building.

Training participants at Arid Agricultural University, Islamabad, Pakistan

Workshop of MLI5030 'Developing and strengthening climate smart agricultural practices for enhanced rice production' on 'Developing and strengthening climate smart agricultural practices for enhanced rice production', 17–21 February 2020, Bamako, Mali

Technical Officer: M. Zaman

The Technical Officer of MLI5030 met with project team, planned the project activities to ensure their timely implementation, sensitized key stake holders about the role of nuclear techniques in developing climate smart agriculture, and conducted a two-day-workshop on climate smart agriculture for enhancing rice production. The Technical Officer had several meetings with the senior managers, including National Liaison Officer (NLO), National Director of Ministry of Energy, Deputy Director General of the Institute of Rural Economics, Director Scientific (IER), and senior managers of IER and the Extension Department to sensitize them about the role of nuclear techniques in developing climate smart agriculture. The discussions with the project team members identified the key project activities to be implemented in 2020.

Training participants at Extension Directorate, near Bamako

To disseminate best practices of rice cultivation to farmers, the Technical Officer travelled to the Extension Directorate and discussed the objectives of demonstration field trials with the Deputy Director of Extension, his staff and farmers. The workshop with project team was aimed on best practices in soil, nutrient and water management and the role of nuclear techniques. The participants acknowledged the IAEA for hosting and organizing this workshop and committed to share their knowledge with fellow colleagues for further capacity building.

Technical meeting of PAL5008 'Reducing soil degradation by improving soil conservation using FRN' 2 to 6 March 2020, Vienna, Austria

Technical officer: Emil Fulajtar

The Technical Meeting of PAL5008 had two major objectives: 1) to finalize the data treatment and interpretation of the project results (including the drafting of a publication) and 2) to prepare a new national project proposal. The meeting was attended by three Palestinian representatives: Mr Ismail Ibrahim Hroub (Radiation Protection & Detection Unit, Ministry of Health), Ra'fat Fathi Mahmoud Odeh (Central Public Health Laboratory) and Orwa Jaber Houshia (Arab American University), as well as the expert in application of FRN techniques Mr Moncef Benmansour (CNESTEN, Morocco) and the representatives of the IAEA Gerald Cirilo Reyes (Project Management Officer) and Emil Fulajtar (Technical Officer). The meeting achieved both planned objectives.

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
D1.50.17	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 L. Heng
D1.50.20	Developing Climate Smart Agricultural practices for carbon sequestration and mitigation of greenhouse gases	M. Zaman

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

Project Officers: E. Fulajtar and J. Halder

This CRP (2019-2023) aimed to test the potential of a 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 on 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 the set of methodological tools applicable in irrigation scheduling, flood prediction and drought management.

This CRP was approved in March 2019. It involves ten partners: four research contract holders (two partners from Brazil, two 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, at the IAEA in Vienna, Austria. The major results of this meeting were: (1) reviewing the state of the art research on the use of CRNS and GRS for soil moisture assessment; (2) developing a detailed individual work plan and updating the overall workplan of the CRP; (3) establishing specific cooperation activities between technical contract holders and research agreement holders to support research contract holders through the provision of methodological guidance, help with data processing and using the collected data form soil moisture dynamics modelling and remote sensing validation.

In winter 2019-and spring 2020 the first results of the CRP were published in international scientific journals and as oral presentations and posters at the on-line EGU General Assembly (4-8 May 2020 in Vienna). These publications presented interpretation of soil water content dataset collected by the SWMCN Lab team at a stationary monitoring station in Petzenkirchen, Austria.

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

Project Officers: L. Mabit and L. Heng

This five-year CRP (2016-2021) aims to develop nuclear techniques to assess the impacts of changes in soil erosion occurring in upland agro-ecosystems, and to distinguish and apportion the impact of climate variability and agricultural management on soil resources in upland agro-ecosystems.

Nuclear techniques are used to achieve these two research objectives, including fallout radionuclides (FRN) such as ^{137}Cs, ^{210}Pb, ^{7}Be and $^{239+240}$Pu, Compound-Specific Stable

Isotope (CSSI) techniques as well as Cosmic Ray Neutron Sensor (CRNS).

The first Research Coordination Meeting (RCM) was held in Vienna, Austria (25 to 29 July 2016), the second RCM took place at the Centre National de l'Energie, des Sciences et des Techniques Nucléaires (CNESTEN) in Rabat, Morocco (16 to 20 April 2018) and the third RCM was held in Vienna, Austria (14 to 17 October 2019).

As reported in our previous soil newsletters , since the start of the project in April 2016, substantial achievement has been made in developing and refining FRN and CSSI techniques to deepen our understanding of erosion processes impacting upland agro-ecosystems. On 13 March 2019, the IAEA mid-term review of the CRP praised the output obtained.

So far, the CRP team has published more than 20 peer-reviewed publications acknowledging explicitly the CRP D1.50.17 and produced 4 manuals/guidelines. Indeed, key activities carried out within this CRP have led to the publication of:

Two IAEA TECDOCs providing detailed recommendations on how to perform soil moisture mapping using a portable 'backpack' cosmic-ray neutron sensor (IAEA-TECDOC-1845 published in 2018: https://www.iaea.org/publications/12357/soil-moisture-mapping-with-a-portable-cosmic-ray-neutron-sensor) and how to effectively use the CSSI technique based on $^{\delta 13C}$ signatures of fatty acids to determine the origin of sediment (IAEA-TECDOC-1881 published in September 2019; https://www.iaea.org/publications/13564/guidelines-for-sediment-tracing-using-the-compound-specific-carbon-stable-isotope-technique).

Two books that were respectively published in 2017 and 2019: an FAO handbook on the use of ^{137}Cs for soil erosion assessment (http://www.fao.org/3/a-i8211e.pdf) and a Springer open-access handbook on the assessment of recent soil erosion rates using 7Be (https://www.springer.com/gp/book/9783030109813).

Currently, an additional IAEA publication - which will be ready by the end of the CRP - is being prepared on the ^{137}Cs resampling method which appears to be the most suitable approach to fulfil the second challenging objective of the CRP. Moreover, as reported by some CRP contractors (e.g. MOR), this isotopic-based approach also allows us to evaluate the effectiveness of soil conservation measures.

The final RCM of the CRP will take place in Vienna, Austria from 21 to 25 June 2021.

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 achievements from the CRP to-date include:
1) The protocol for purifying ^{18}O-analysis in phosphate samples was developed and transferred to research contract holders. In addition, a silver phosphate comparison material (Ag_3PO_4) for measurement of the stable ^{18}O labelled phosphate composition has been prepared and distributed for an inter-lab [University of Natural Resources and Life Science (BOKU), the University of Western Australia (UWA), the ETH Zurich (ETH), the University of Helsinki (UH) and the Helmholtz Centre for Environmental Research (UFZ)] comparison.
2) In Jiangou catchment, China, Data from $\delta^{15}N$-NO_3 and $\delta^{18}O$-NO_3 showed that chemical fertilizers to maize farmland and dairy excrements of livestock contributed 38% and 37%, respectively, to nitrate pollutant sources in the water body and that the combined use of CSSI fingerprinting and stable isotopic techniques could quantitatively identify the source contribution of N pollutant in surface water and sediment, which is critical to the assessment and implementation of optimised agricultural and land management practices.
3) Under intensive fruit and vegetable production, soil N was the main source of nitrate in groundwater in Slovenia.
4) The compound specific isotope analysis (CSIA) was successfully used to track pesticide degradation and export at catchment scale and identify pesticide sources areas contributing to changes in carbon isotope stable signatures.
5) In the Nambeelup Brook catchment of Western Australia, sulphate concentrations ranged 6–140 mg/L and $\delta^{34}S(SO_4)$ 14.3–26.3 ‰, reflecting inputs from fertilisers, natural acid rock drainage and sulphur reduction.
6) The three sampling operating procedures (SOPs) produced in 2018 were evaluated and standardized in agricultural catchments by the CRP participants.
7) The visibility of the current CRP was enhanced during the European Geosciences Union (EGU 2019) on 9 April 2019 where a Session (HS2.3.3) "Identification of Agro-contaminants in Surface and Groundwater Using Stable Isotope Techniques" was convened. A total of 14 posters and **7** oral presentations were made. 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 on-line EGU2020 General Assembly on 4-8 May 2020. The second RCM to be held in Accra, Ghana on 2–6 March

2020 was postponed to 30 November – 4 December 2020 and it will be helg at IAEA in Vienna, Austria.

Remediation of Radioactive Contaminated Agricultural Land (D1.50.19)

Project Officers: G. Dercon and L. Heng

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.

Since its start at the end of 2019, a series of laboratory-based experiments has been implemented on how to improve remediation of radioactive contamination in farmland. Further, the CRP team has designed the roadmap to develop new isotope techniques to better understand the dynamics of radiocaesium in the soil. Finally, significant progress has been achieved in the application of advanced mathematical approaches for improving the prediction of soil properties based on Mid-Infrared Spectroscopy and enhancing the decision-making for the optimization of remediation of radioactively contaminated agricultural soils.

Developing Climate Smart Agricultural practices for carbon sequestration and mitigation of greenhouse gases (D1.50.20)

Project Officer: M. Zaman and L. Heng

A new five-year (2020-2025) Coordinated Research Project (CRP), titled 'Developing Climate Smart Agricultural practices for carbon sequestration and mitigation of greenhouse gases' (D1.50.20) will be initiated this year. It was approved in January and the first Research Coordination Meeting will take place on 23-27 November 2020, in Vienna, Austria. The overall objective of this CRP is to develop and validate climate-smart agricultural practices, based on isotopic and related techniques, to increase soil carbon (C) sequestration (based on C budgeting), mitigate GHG emissions (N_2O, CH_4, CO_2) and limit gaseous losses of ammonia (NH_3) and dinitrogen (N_2) from agricultural ecosystems, with the aim of enhancing agricultural productivity and sustainability.

Developments at the Soil and Water Management and Crop Nutrition Laboratory

Characterizing bacterial and fungal community structure and diversity to complement soil erosion information derived from $^{239+240}Pu$ determination

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As follow-up of the study initiated by Zhang *et al.* (2019) presented in the Soils Newsletter Vol. 41, No. 2, the high throughput DNA sequencing analysis was performed to investigate how information on the diversity and structure of bacterial and fungal communities in soil can be linked with and can complement data on soil quality and soil erosion. To achieve this objective the different soil quality parameters were analysed, such as pH, organic carbon (C_{org}, %), total nitrogen (N, %), aggregate stability, stable isotope analysis (i.e. $\delta^{13}C$ and $\delta^{15}N$) and soil erosion rates derived from $^{239+240}Pu$ analysis.

To figure out the responses of soil microbial communities to soil erosion processes, topsoil samples (i.e. 0-15 cm) were collected along a 63 m long transect located in an experimental agricultural field with Cambisols and Luvisols in Grabenegg, Lower Austria with (Figure 1).

The analysis show that the bacterial richness and diversity found in the soil at the top positions A and B are significantly higher than the lower positions C to E, whereas we observe no difference for the fungal communities (see Figures 2 and 3).

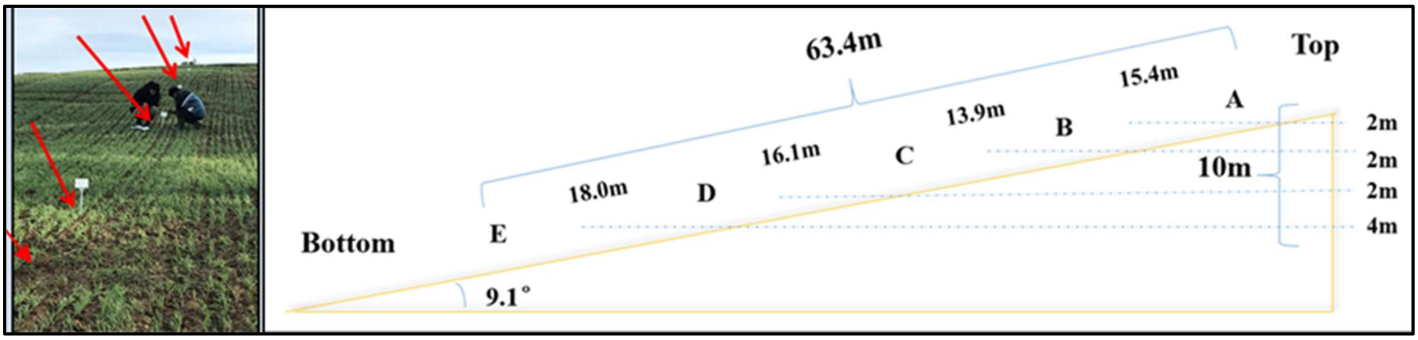

Figure 1. Soil sampling along the selected transect [5 bulk soil cores A to E; 4 replicas per core; n = 20] in Grabenegg (Adapted from Zhang et al., 2019)

Based on principal coordinate analysis (PCoA) of the five sampling points along the studied slope, the bacterial community structure is negatively correlated with pH, and positively correlated with soil aggregate stability indicators (i.e. Mean Weight Diameter [MWD] and Geometric Mean Diameter [GMD]).

The bacterial structure can be explained with pH, MWD and GMD by 65%. As it is t*he case for the bacterial community, the fungal community structure is also negatively correlated with pH, and positively correlated with soil aggregate stability (MWD, GMD), which, however, explained up to 90% of the fungal community structure.

In the same experimental field, soil loss rates derived from $^{239+240}Pu$ study (Mabit *et al.*, 2020) are significantly negatively correlated with bacterial diversity ($R^2 = -0.686$, $p < 0.05$), but not correlated with fungal diversity ($R^2 = 0.189$, $p > 0.05$).

The findings obtained under our experimental conditions and for the soils characterizing the region at northern footslopes of the Alps highlight that bacterial diversity can be a potential reliable soil quality parameter to investigate soil loss and its impact in case of soil degradation associated with soil erosion processes.

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Mabit, L., Meusburger, K., Toloza, A., Lee Zhi Yi, A., Alewell, C., Benmansour, M. (2020). Comparison of $^{239+240}Pu$ and ^{137}Cs derived soil erosion rates: a case study in an Austrian agricultural field (Grabenegg, Lower Austria). In: *IAEA-Soils Newsletter*, Vol. 42(2), pp. 25–27.

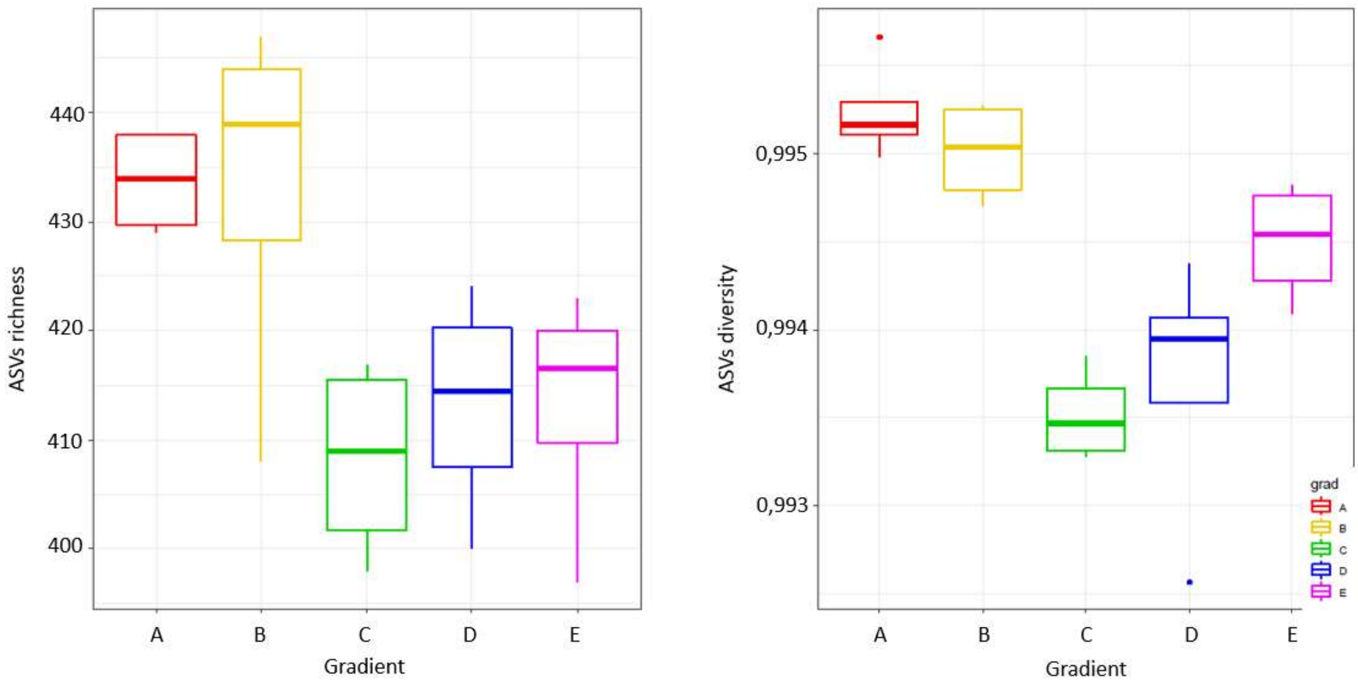

Figure 2. Bacterial richness and diversity along the transect

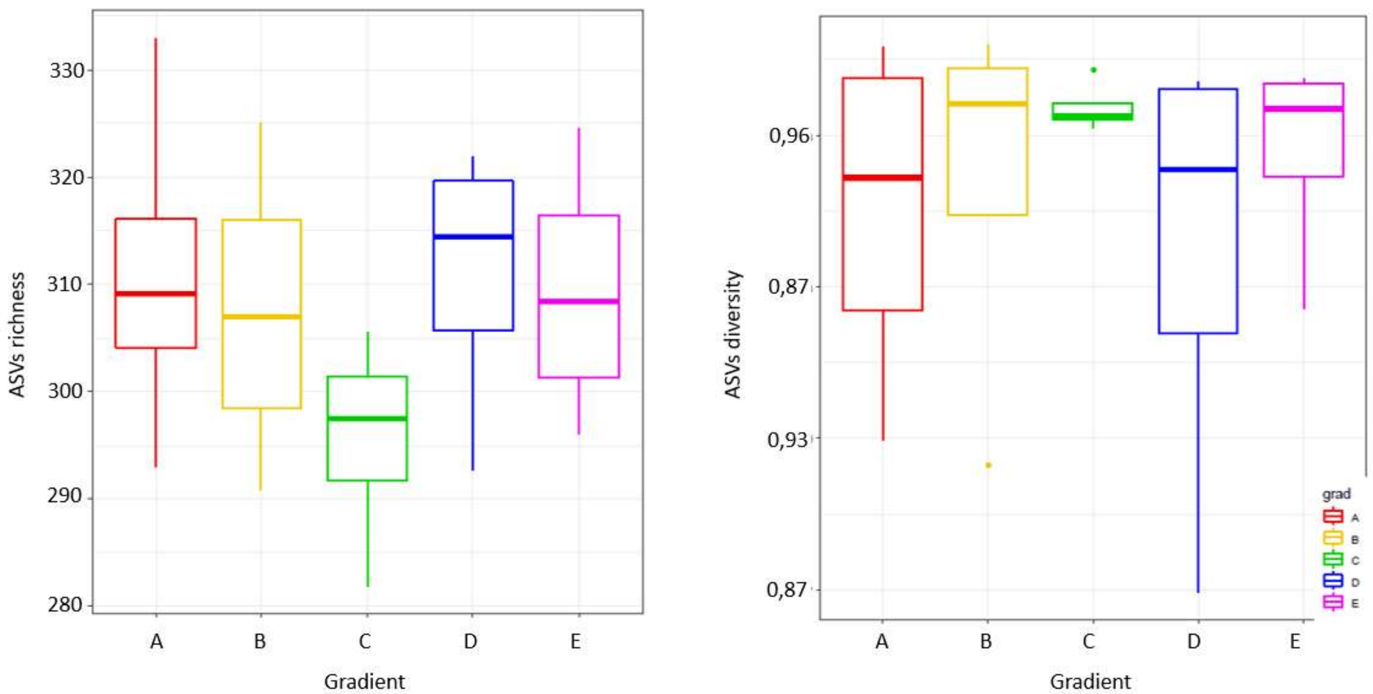

Figure 3. Fungal richness and diversity along the transect

Field scale root zone soil moisture estimation of cropped fields coupling cosmic ray neutron sensor with drill & drop capacitance probe

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Achieving efficient agricultural water use is essential for sustainable and productive agriculture. To improve the use of this resource in agriculture, it is imperative to measure the soil water content (SWC).

Cosmic Ray Neutron Sensors (CRNS) have the capability to estimate field-scale soil water content (SWC) in large areas up to 20 to 30 ha and appears to become a credible and robust alternative to traditional soil moisture monitoring techniques. However, a major limitation of the CRNS is its shallow penetration depth. The monitoring of the SWC over the whole rooting zone with CRNS is, and remains, a challenge. Therefore, since August 2019 the SWMCN laboratory started, to test extending the depth (up to 60 cm) of CRNS measurements by coupling them with drill & drop capacitance probes (D&D) in Rutzendorf, Lower Austria (Figure 1). A set of seven D&D was installed at 10, 60 and 120 m distances around the CRNS.

Collected data from both devices are now being processed, and mathematical processing of the CRNS derived SWC data (through a Savitzky-Golay filter) is carried out to reduce data noise and produce a smoothed SWC time series (Figure 2).

The preliminary results show that the CRNS measured soil water contents closely follow the measured rainfall pattern (Figure 3). The comparison between CRNS and D&D probe data show that D&D probes derived soil moisture information from 0 to 30 cm was fairly close to the CRNS derived data (Figure 4). More SWC profile data need to be collected in 2020.

Figure 1. Cosmic ray neutron sensor and drill & drop capacitance probe installed in Rutzendorf, Austria.

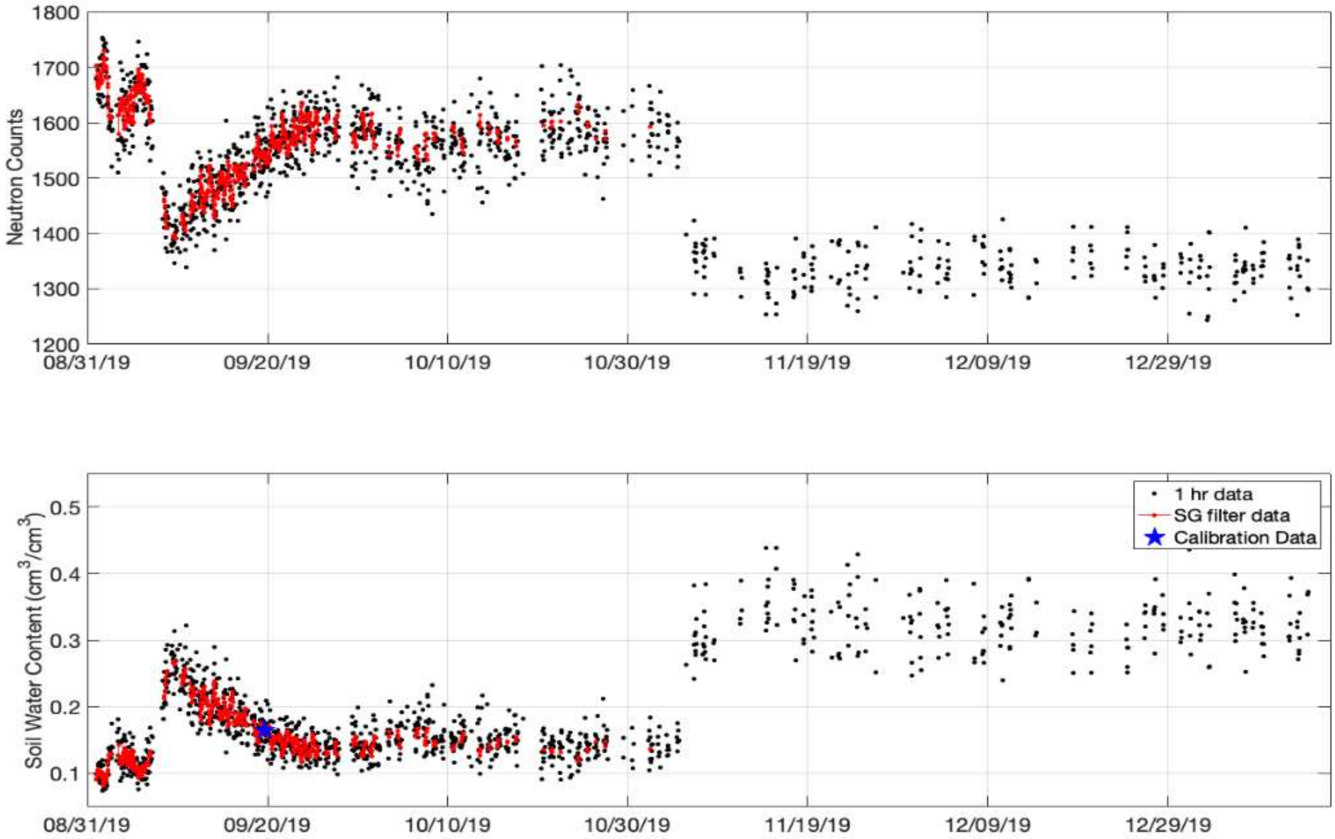

Figure 2. Time series of soil water content of Cosmic Ray Neutron Sensor in Rutzendorf, Austria; 1 hr corrected neutron counts (black dots), the Savitzky-Golay filter (red dot and line) and calibration measurements (blue star).

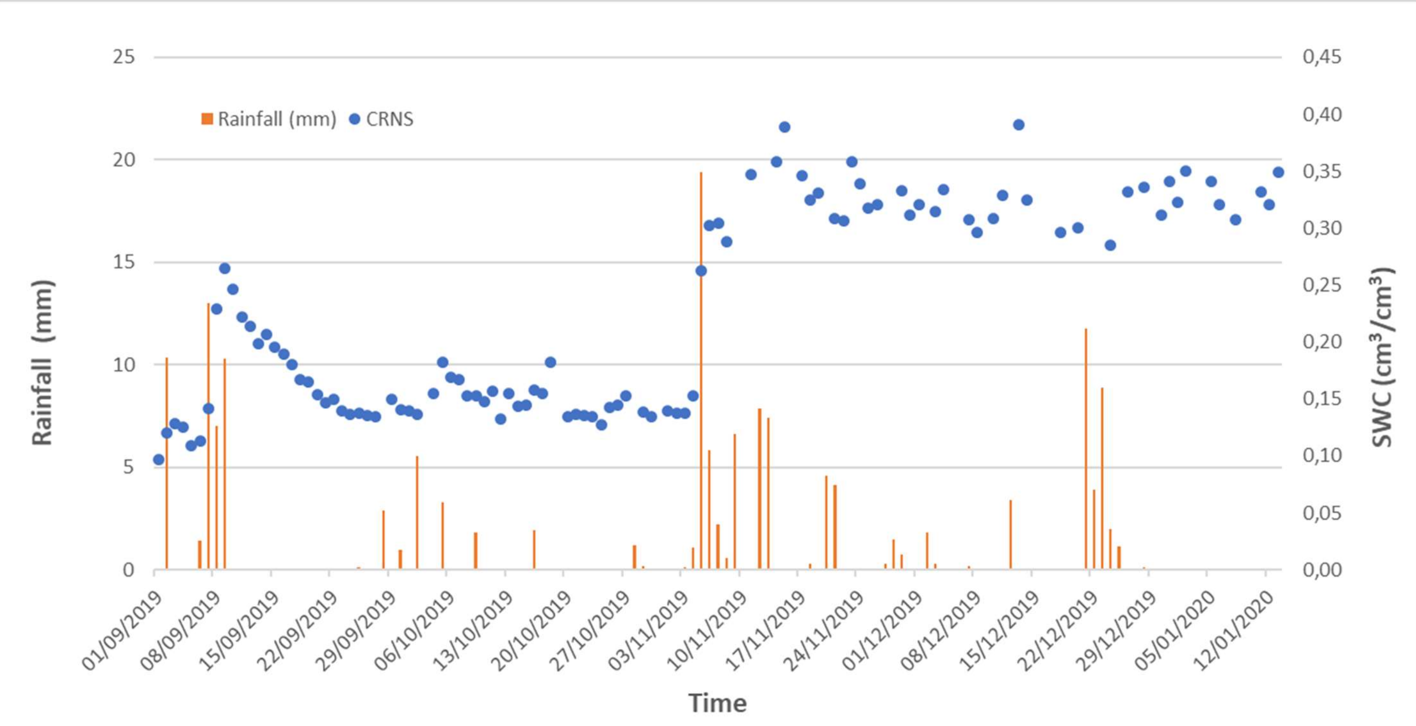

Figure 3. Time series of soil water content (SWC) of Cosmic Ray Neutron Sensor and rainfall in Rutzendorf, Austria

Further, an exponential filter model developed by Wagner et al. (1999) and improved by Franz et al. (2020) is being tested to predict root zone soil moisture (up to 60 cm) by using the field-scale surface soil moisture measurements of the CRNS (Figure 5). Calibration of this exponential filter model will be carried out in the summer of 2020. In order to calibrate the model to a root zone product, more profile SWC data will have to be collected from the D&D probes.

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Wagner, W., Lemoine, G., and Rott, H.: A method for estimating soil moisture from ERS scatterometer and soil data, Remote Sens. Environ., 70, 191–207, 1999

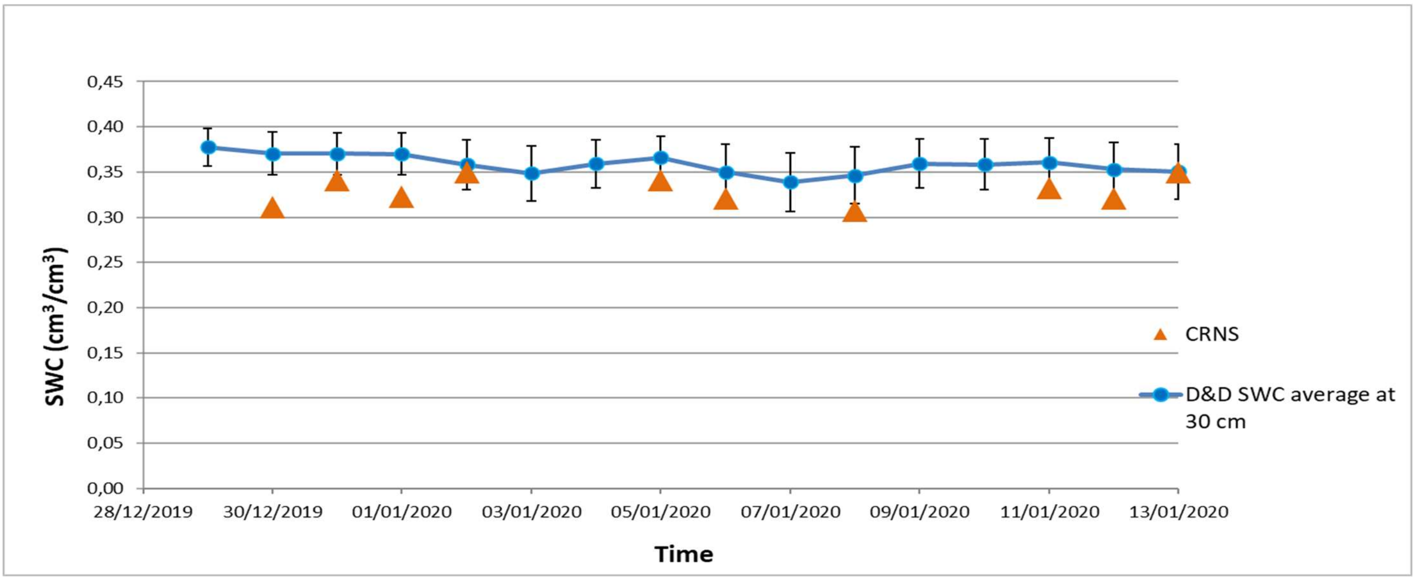

Figure 4. Time series of soil water content (SWC) of Cosmic Ray Neutron Sensor and drill & drop capacitance probe (Soil Water Content data from 0 to 30 cm) installed in Rutzendorf, Austria

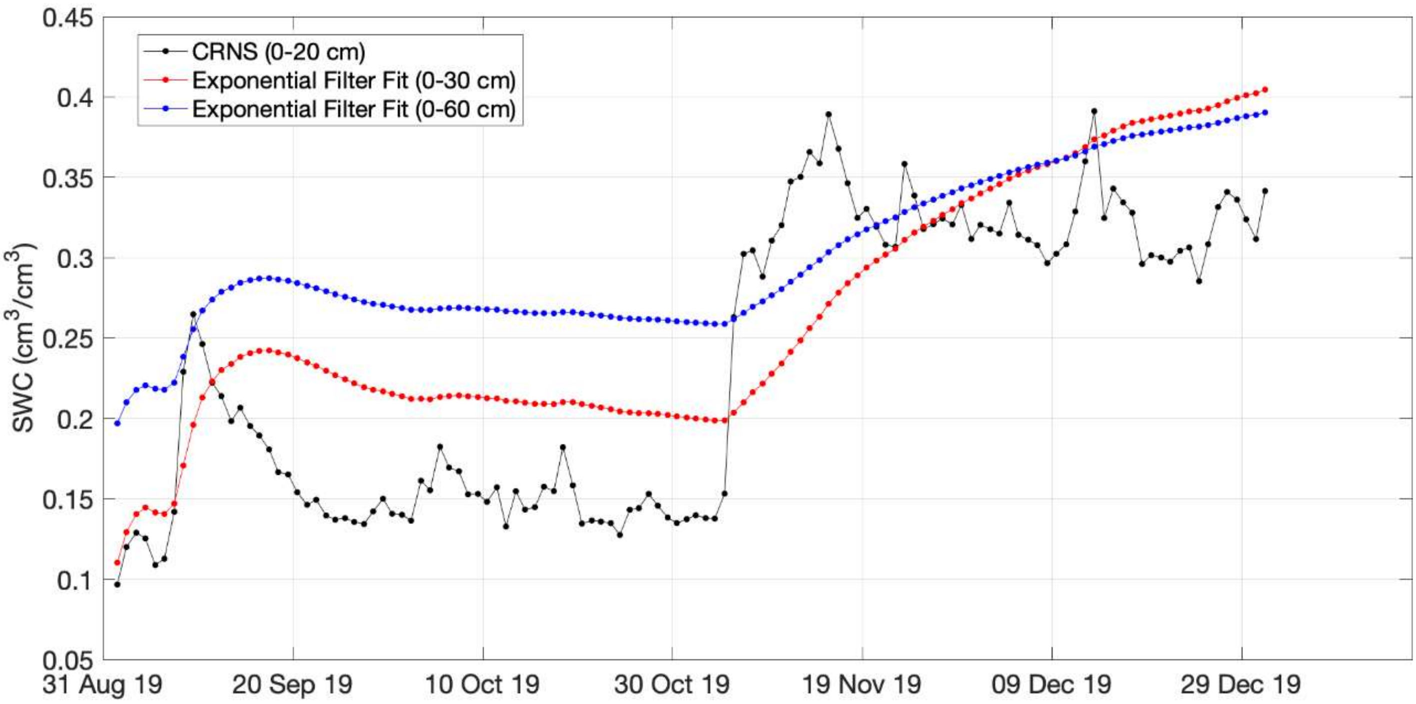

Figure 5. Time series of soil water content (SWC) of Cosmic Ray Neutron Sensor and estimated SWC with exponential filter in Rutzendorf, Austria

Developing and Evaluating Innovative Indicators for Drought Stress in Bananas

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In 2020, the work on the Peaceful Uses Initiative (PUI) project on coffee and bananas is continuing, with the main focus being on the development of isotope and related conventional indicators for drought stress in bananas. Climate change poses a large threat to banana and coffee production in East Africa. Climate smart practices and drought resistant varieties will be crucial to create an improved resilience, but quick assessment in field conditions is hindered by the lack of easy-to-use drought stress indicators.

Figure 1. Stomatal conductance measurement of a banana leaf with a porometer (Decagon SC-1).

Earlier results indicated that $\delta^{13}C$ signatures in banana leaves, as well as leaf temperature are good indicators for drought stress, the latter still being in the experimental stage. In February and March this year, leaf temperature measurements were repeated and validated by stomatal conductance measurements (Figure 1) in the joint research farm of the Nelson Mandela African Institution of Science and Technology (NM-AIST) and the International Institute of Tropical Agriculture (IITA) in Arusha, Tanzania. Repeated measures were required to create a robust leaf temperature parameter, as well as to optimize the method. However, irregular rainfall, which occurred in the entire East African region, during the dry season made it difficult to obtain clear results. Data analysis is still undergoing.

Figure 2. Sampling phloem sap through the 'bleeding' technique whereby a small cut is made in the banana leaf petiole and 1,5 ml of the spontaneously exuding phloem sap is captured with a tube

Simultaneously, new measurements and experiments are being prepared and initiated. One alternative method for immediate drought stress evaluation is to measure $\delta^{13}C$ signatures in phloem sap. A phloem-derived $\delta^{13}C$ signal should provide more instant information on drought stress than $\delta^{13}C$ in leaves, as phloem consists of recently assimilated carbon. The method is mostly used in trees, but looks promising for other - especially large herbaceous - species. Sampling methods are still lacking though. During the field visit in February and March 2020, different sampling methods were tested and evaluated (Figure 2). Analysis methods will be developed in the SWNCN laboratory in Seibersdorf and finally employed during the planned experiment in August of this year.

The purpose of this experiment is to test the physiological changes in banana plants during progressive water shortage and monitor the evolution of potential stress indicators phloem-derived $\delta^{13}C$, leaf $\delta^{13}C$ and leaf temperature. The field trial will consist of 80 banana mats. Initially, all will be irrigated optimally. After 6 months, irrigation will be interrupted for half of the plants. Growth, as well as all the indicators, will be assessed/measured over 3 months. It is expected that leaf temperature and phloem-derived $\delta^{13}C$ will react swiftly to the decreasing water availability, while leaf $\delta^{13}C$ is a time-integrated measure and is expected to change more gradually. Exactly how fast each indicator will react is still unknown, yet important when one wants to use these parameters to evaluate drought stress. The results of this experiment will give us an idea of the time frame each indicator provides information on. Finally, this will allow us to formulate clear recommendations on how and under which circumstances to use phloem-derived $\delta^{13}C$, leaf $\delta^{13}C$ and leaf temperature as a measure for drought stress in bananas. The experimental field is currently being established in the joint research farm of NM-AIST and IITA in Arusha, Tanzania.

Combining machine learning and operations research methods for optimizing remediation efforts in response to large-scale nuclear emergencies affecting food and agriculture

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As part of the CRP D1.50.19 (Remediation of Radioactive Contaminated Agricultural Land), a PhD research study will start in October 2020 at the Belgian Nuclear Research Centre. The research will contribute to the development of tools that identify and combine critical agricultural, environmental and agro-economic factors into priorities, upon which decisions regarding environmental remediation can be based.

Emergencies resulting from nuclear accidents may affect large areas through deposition of radionuclides as Iodine-131, Caesium-137 and Strontium-90. The subsequent data collection, data management and decision-making can become overwhelming with traditional methods. This inevitably increases the response time and reduces the decisiveness of the measures. In addition, during such events, the availability of technical and financial resources rapidly becomes a limiting factor. All of this is particularly applicable when large agricultural areas and subsequently the food system are affected.

Therefore, improved prediction - in space and time - of the accident's impact on the safety of agricultural food production and the future usability of the agricultural land is a key issue. Also, there is a need for optimisation of the post-accident decision-making process on where, how and when to remediate. All these issues are faced when facilitating the return of the agricultural production to normalcy as rapidly as possible, given the socio-economic constraints.

The research revolves around the integration of machine learning and operations research, each with their specific capabilities.

Machine Learning (ML)

We will use ML to attempt to improve estimations of the temporal and spatial behaviour of Cs-137 in the environment. ML has become the preferred approach for interpreting big spatio-temporal datasets in terms of functional information and recommended decisions. ML-techniques do not require statistical preconditions regarding the nature of the concerned data, making ML especially interesting in the context of rare and extreme events, such as a nuclear disaster.

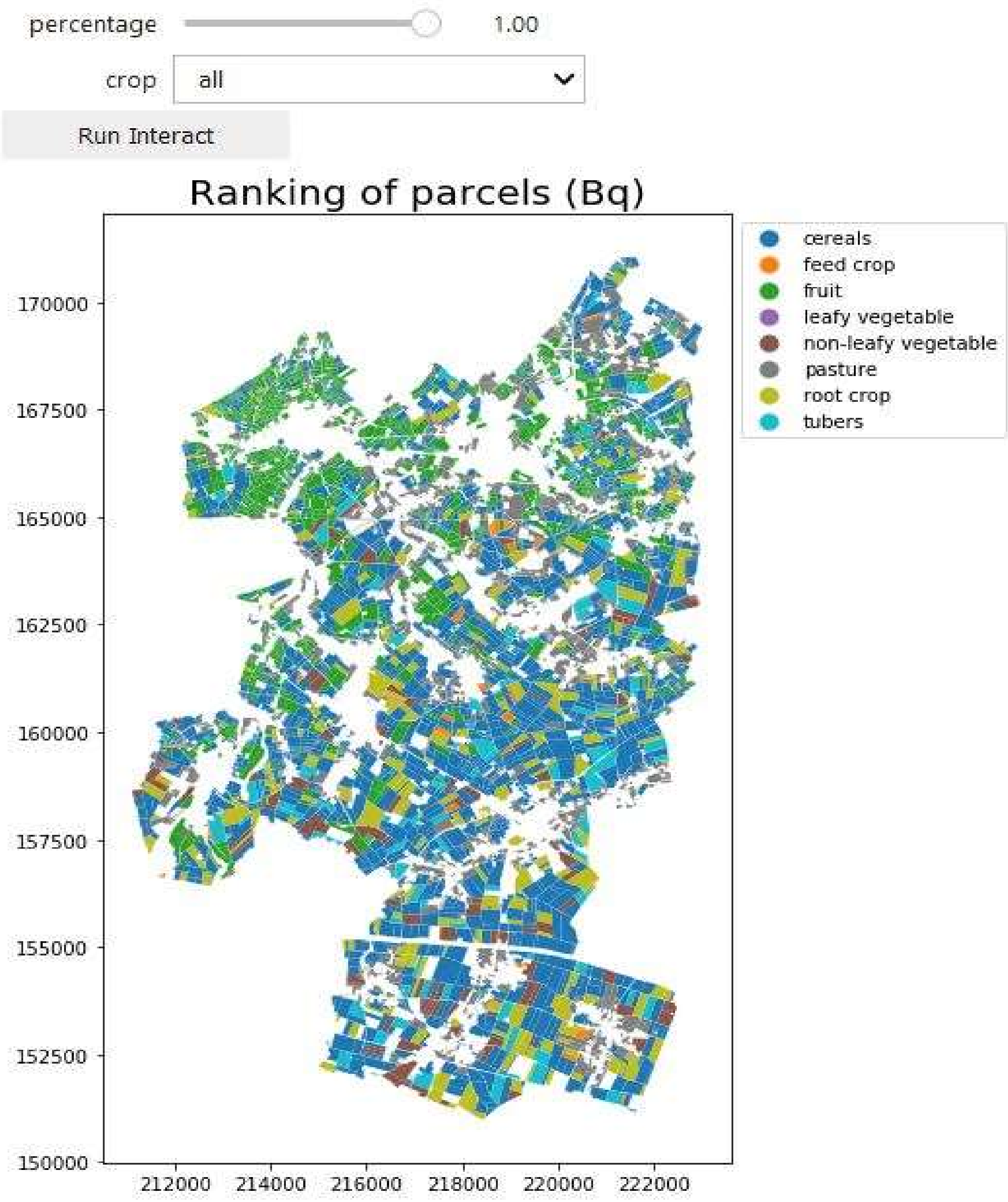
Operations Research (OR)

OR is the science behind objective and robust decision making, with algorithms such as Multi Attribute Decision Making (MADM). The ranking of possible alternatives, to make the overall best decision, is determined based on a set of predefined criteria and weights. These priorities should facilitate the response of decision-makers to questions on where and how to act first to minimise the overall damages for society and the time to return to normalcy. OR is not new in a nuclear disaster context. In 2005, Fesenko applied linear programming to optimise forest management countermeasures after the Chernobyl accident. The approach optimises the selection of countermeasure strategies and prioritises the most important parcels, based on the analysis of the main exposure pathways and application of radiological, socio-economic and ecological criteria.

Nevertheless, the combination of ML (for improved impact prediction from big geo-datasets) and OR (for finding the optimal locations, methods or timing to remediate radioactive contamination) is a promising avenue for improving response systems in case of nuclear emergencies affecting agriculture and food safety.

The research can contribute to further increase the functionalities of DSS4NAFA, a system which was developed by the SWMCNL for nuclear emergency response management and communication. DSS4NAFA assists in data management, visualization and risk communication, where it provides user-friendly spatio-temporal visualizations and communication materials for decision makers. The previously stated research can be integrated in DSS4NAFA.

Preliminary results from an MADM exercise using two criteria, income loss of the farmer and contamination of the agricultural products, can be seen below (Figure 1). The figure shows the interactive visualization of parcels for remediation. With the percentage slider, the user can regulate the percentage of highest ranked parcels to be visualized.



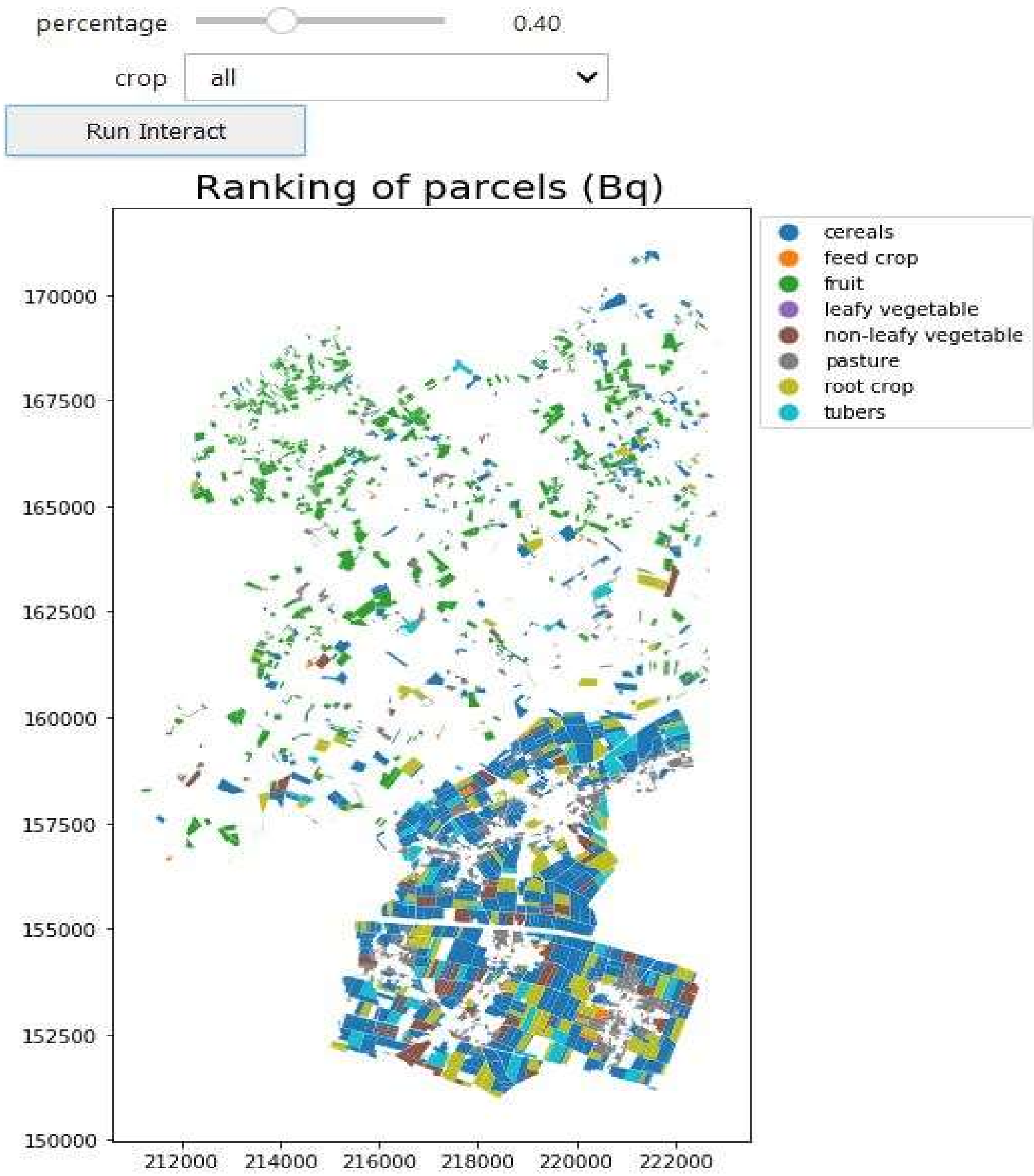


Figure 3.The MADM shows all the parcels per crop class in the area of interest (left) and the 40% most important parcels (right). The MADM process was based on 2 equally weighted criteria: income loss of the farmer and contamination of the agricultural products. The interface shows an interactive way to visualize the percentage of highest ranked parcels

Continuous ^{15}N labelling study: implications for nutrient management in cassava production systems

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Cassava (*Manihot esculenta Crantz.*) is a staple food for almost 800 million people worldwide. The starchy root crop is known for its relatively good yields under dry and nutrient poor soils compared to other important staple crops. Despite the worldwide importance of the crop, it has been neglected in research and by industries for a long time, as it was known as a self-subsistence crop. Given the consequences of climate change, the importance of cassava will increase even more.

In order to increase production in Africa from an average of 9 tonnes of fresh roots per hectare (FAOSTAT, 2018) to its potential of over 40 tonnes per hectare, best agricultural practices related to water and nutrient management should be proposed. With the goal of increasing cassava production, the SWMCN laboratory in Seibersdorf is developing stable isotope techniques for assessing water use efficiency (carbon-13 and oxygen-18) and fertilizer use efficiency (nitrogen-15) in collaboration with the Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA). These techniques will be implemented in the field to advise on variety selection and fertilizer application, amongst other practices.

In 2019, an experiment focusing on the application of potassium to alleviate drought stress was carried out in the SWMCNL greenhouses. Cassava plants, originating from the Democratic Republic of Congo, were grown in sand with nutrient solution either high (+K; 1.437 mM K^+) or low (-K; 0.359 mM K^+) in potassium. Additionally, sodium nitrate ($NaNO_3$), enriched in ^{15}N, was added to both solutions to continuously label the plants with ^{15}N during the whole experiment. Plants were harvested 59, 60, 69 and 83 days after planting (DAP), divided into different parts and analysed for ^{15}N and ^{13}C. In this article we focus on the results related to nitrogen uptake and cycling in cassava, using ^{15}N isotopes.

A summary of the data can be found in Figure 1. Although plants were continuously supplied with the solution containing the enriched nitrate (being the only nitrogen source in the solution), the plant material was not homogenously labelled. We can see a significantly decreasing trend in ^{15}N in the mean shoot from the upper parts (youngest fully expanded leaves at 59 DAP; 0.55 ± 0.04 atom% ^{15}N) to the lower parts (lower leaves at 59 DAP; 0.50 ±- 0.03 atom% ^{15}N). Secondly, storage roots, which were only visually distinguishable from fibrous roots at the last harvest, had a ^{15}N signature of 0.53 ± 0.02 atom% ^{15}N significantly different from the fibrous roots with a ^{15}N signature of 0.65 ± 0.04 atom% ^{15}N. Figure 2 shows a significant effect of the cutting weight on the ^{15}N signatures of the different plant parts. The heavier the cutting, the more diluted the ^{15}N in the plant parts. However, the effect was not significant for the fibrous roots (on day 59 and 60), lower leaves (on day 59, 60 and 68) and for the middle leaves (on day 59).

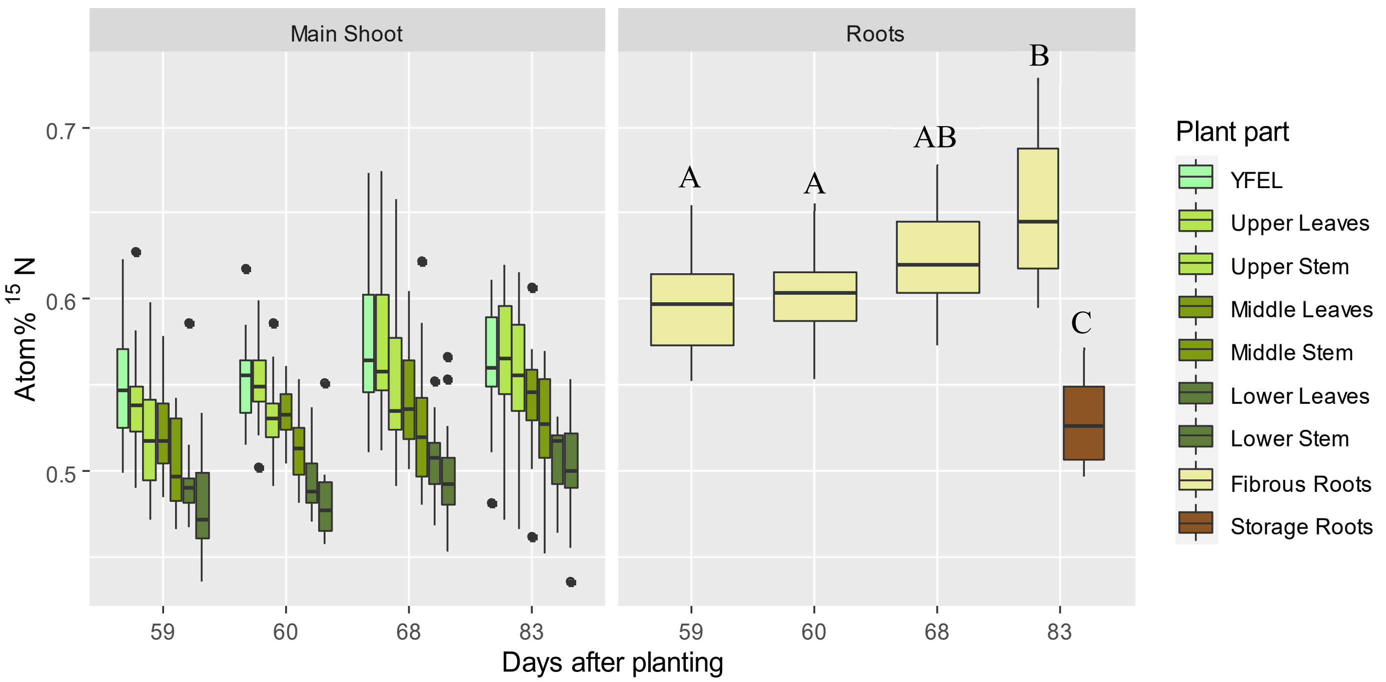

Figure 4. ^{15}N distribution (in atom% ^{15}N) in different parts of cassava plants at four different harvest times (59, 60, 68 and 83 DAP). Left: Data for the main shoot (YFEL = youngest fully expanded leaf); Right: Data for roots (Groups with a same letter in the label have no significantly different means)

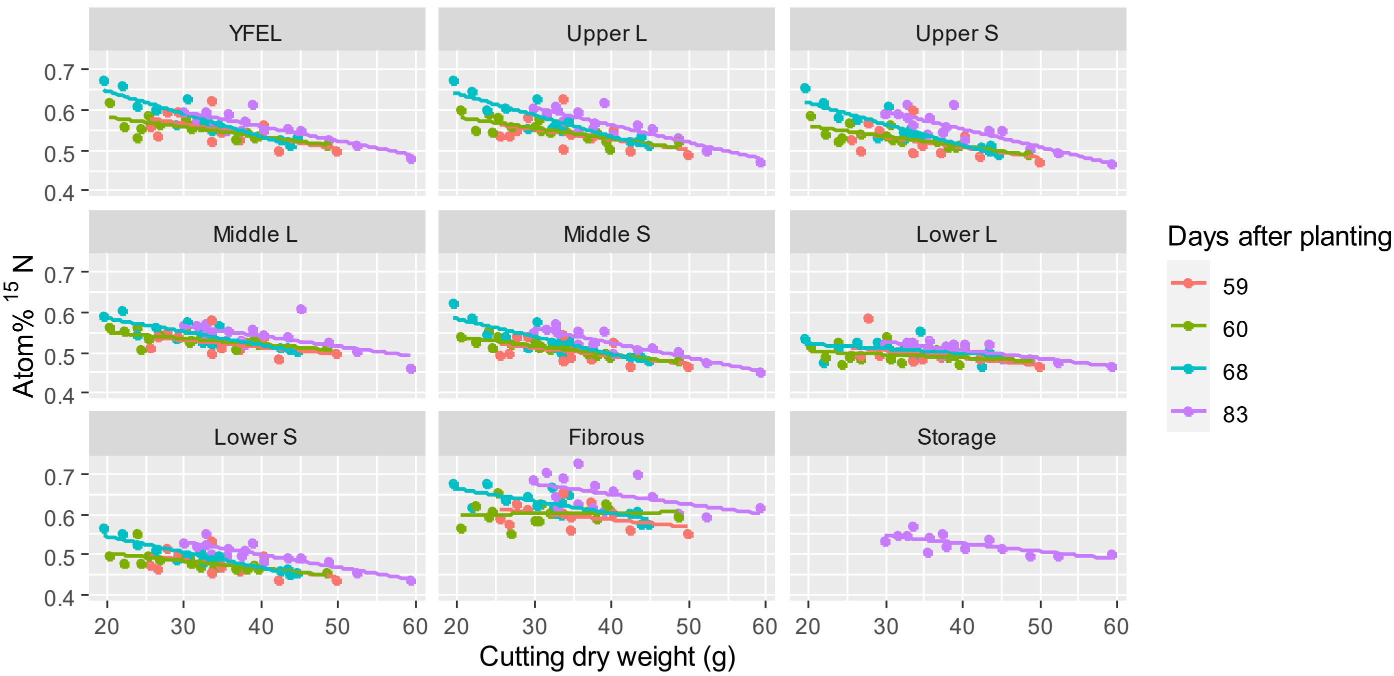

Figure 5. Influence of cutting weight on ^{15}N signatures (atom% ^{15}N) for the different plant parts; colors correspond to different harvesting dates (days after planting); lines through the data points represent the linear regression

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

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Agricultural production and food safety can become affected in the aftermath of a nuclear disaster. Therefore, remediation of agricultural land is often needed. Clay mineralogy plays a major role in adsorption of radionuclides, such as radiocaesium (RCs) in soils. Under the Coordinated Research Project D1.50.19 on monitoring and predicting radionuclide uptake and dynamics for optimizing remediation of radioactive contamination in agriculture, the Soil Water Management and Crop Nutrition Laboratory (SWMCNL) has been conducting collaborative research since 2019 to further develop the models of soil-to-plant transfer of radionuclides in Japanese soils and implement them in soils worldwide. This research will also help to better understand the role of clay mineralogy and clay amendments, such as zeolite, in the uptake of radionuclides by plants. In the first step the SWMCNL aims to gather datasets for these soil-to-plant transfer models and so to improve decision-making for remediation in radioactively polluted farmland. Japanese soils have been selected and investigated first. In future the comparative analyses of European soils will be done.

Three Japanese soils with different clay mineralogy were selected for this study; Yoshiki containing vermiculite, as major clay mineral, which retains monovalent cations (e.g. K and Cs) strongly; Ohgata containing smectite, which retains K and Cs less strong; and Miyakonojo dominated by allophane, which shows low K and Cs affinity. The soils were amended with a zeolite from clinoptlilolite (cation exchange capacity of 130-180 meq/100 g) and incubated for 3 days.

Potassium plays a significant role in the caesium behaviour in soil, given their cationic competition when taken up by plants. In addition, K application can influence the concentration of the Cs in soil solution, which plant roots take up directly using the same uptake mechanisms as for K. Thus, after an incubation of the soils with different potassium additions, potassium and stable caesium (Cs-133) were determined by the research team in soil solution and solid phase through ion chromatography (IC), atomic absorption spectrometry (AAS), and inductively coupled plasma mass spectrometry (ICP-MS).

The radiocaesium interception potential (RIP), which describes the solid-liquid distribution and mobility of radiocaesium, was measured using spikes of radiocaesium (Cs-134). Analysis of Cs-134 was carried out via a sodium-thallium iodide detector (NaI(Tl)).

The soil rich in vermiculite was able to fix K, which means K was strongly retained in soil and no longer exchangeable with another cation (Figure 1). In this soil, more than 90% of the potassium added was fixed. Smectitic soil was able to fix almost 65% of the K added, whereas allophanic soil showed a very low fixation, i.e. 70% of added K remained exchangeable. Andosol with K-containing zeolite amendments, however, showed higher levels of exchangeable K than natural soils, and similar rates of K were retained on the zeolite surface due to cation exchange.

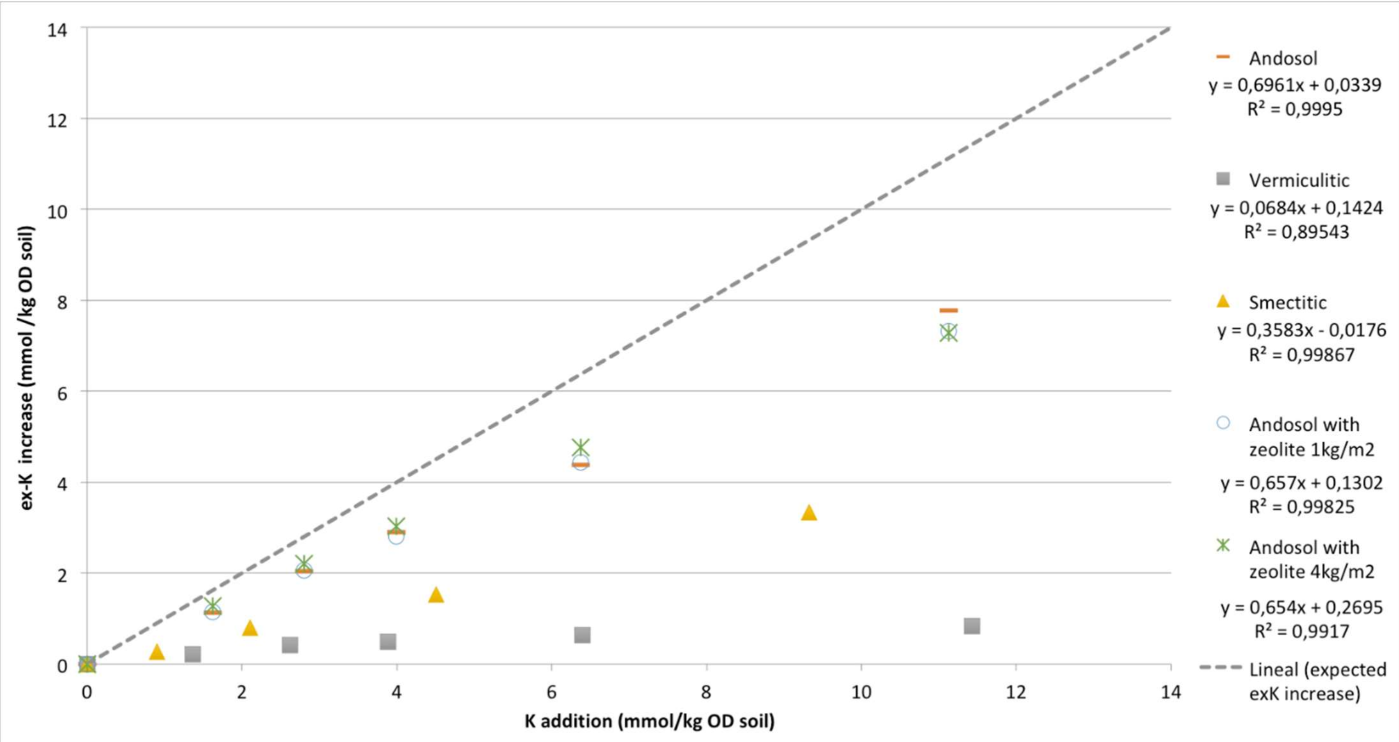
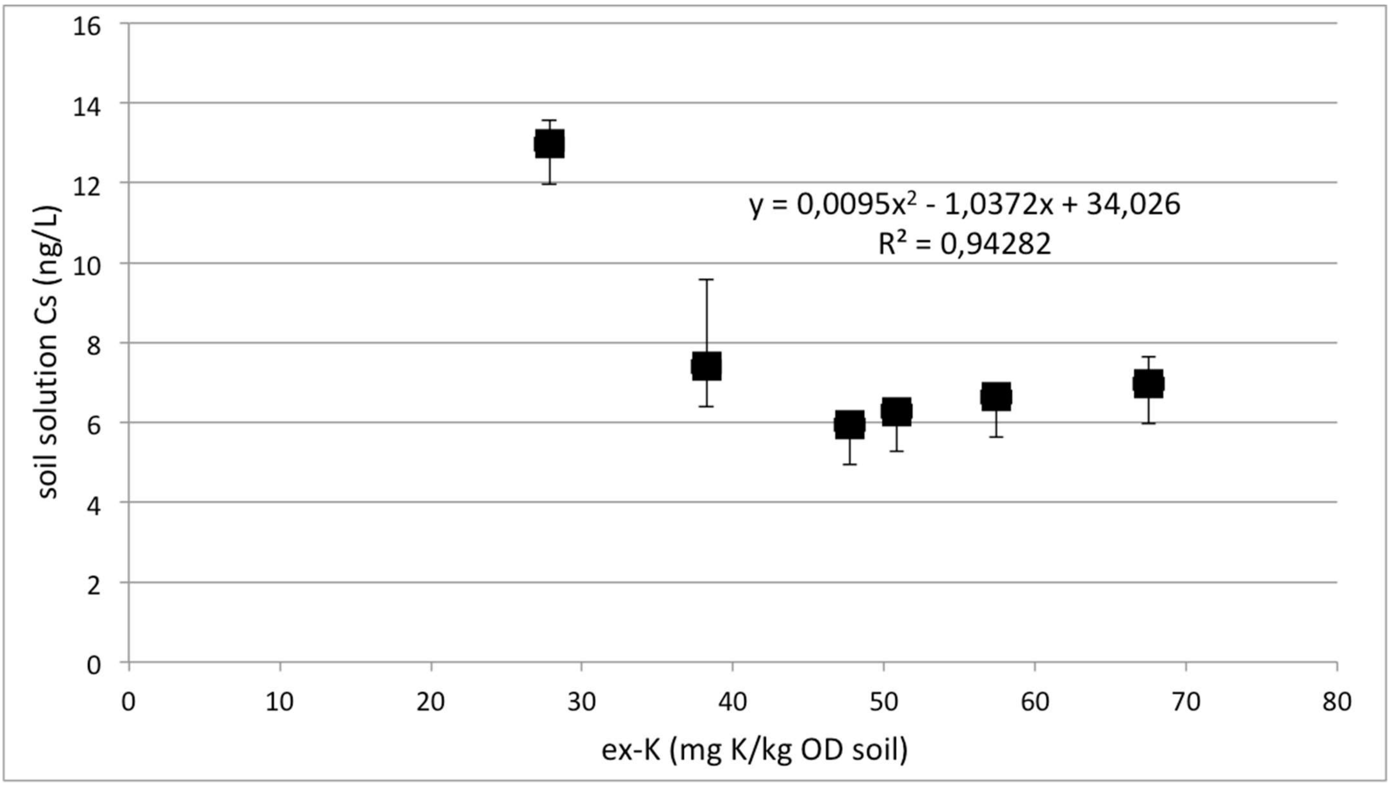


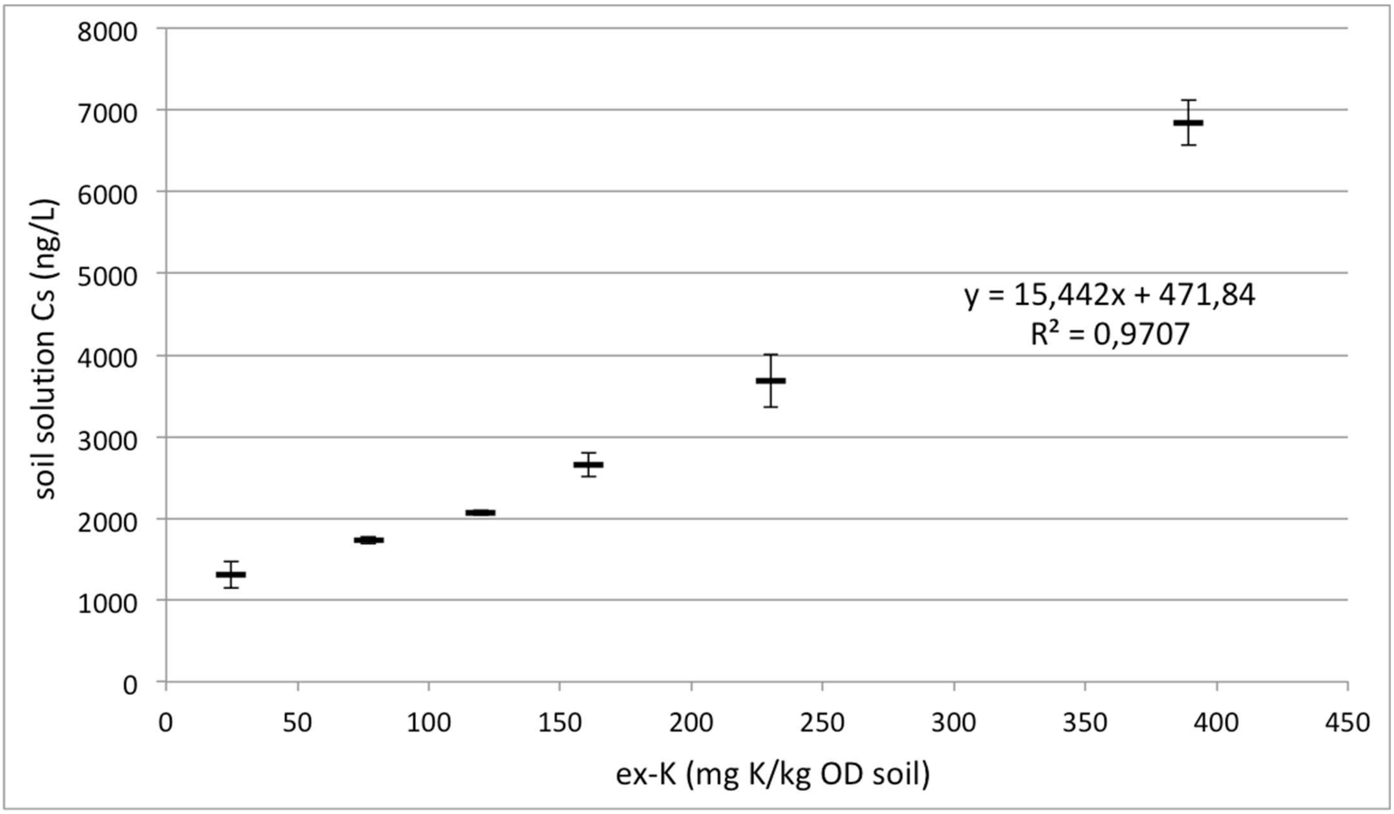
Figure 1. Increase in the exchangeable potassium level (ex-K) for the different potassium levels applied in five selected Japanese soils (The dashed line shows the expected increase in ex-K as all K addition remains exchangeable)-

The analysis of soil solution, focusing on stable Cs at different ex-K levels (Figure 2) suggests that some of the studied soils do not fit with the existing radiocaesium mobility models developed in the past for European soils, which expect increase in soil solution Cs due to K application. We observed a decreasing trend of soluble Cs with increasing ex-K in the vermiculitic soil followed by mobilisation at higher doses, this suggest that the low K doses induced a collapse of the interlayer and promoted Cs fixation. In the andosol, increasing K increased Cs mobility (Figure 2).

The RIP values were not affected or marginally affected by K supply in most of the studied soils (Figure 3). The zeolite application confirmed that zeolite enhanced RIP of the soil, i.e. that was able to significantly adsorb Cs.

At this point in our study, the most significant finding is that the influence of K addition on solution Cs concentration differ among Japanese soils. The variation in radiocaesium behaviour and mobility reflects the different clay mineralogy. The new insights gained might also have future implications regarding the fertilising recommendations for farmers and remediation actions for treating soils in radioactively polluted areas, showing the need for more site-specific recommendations considering soil type.


y = 0,0095x² - 1,0372x + 34,026
R² = 0,94282
soil solution Cs (ng/L)
ex-K (mg K/kg OD soil)
0
2
4
6
8
10
12
14
16
0
10
20
30
40
50
60
70
80


y = 15,442x + 471,84
R² = 0,9707
soil solution Cs (ng/L)
ex-K (mg K/kg OD soil)
0
1000
2000
3000
4000
5000
6000
7000
8000
0
50
100
150
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350
400
450

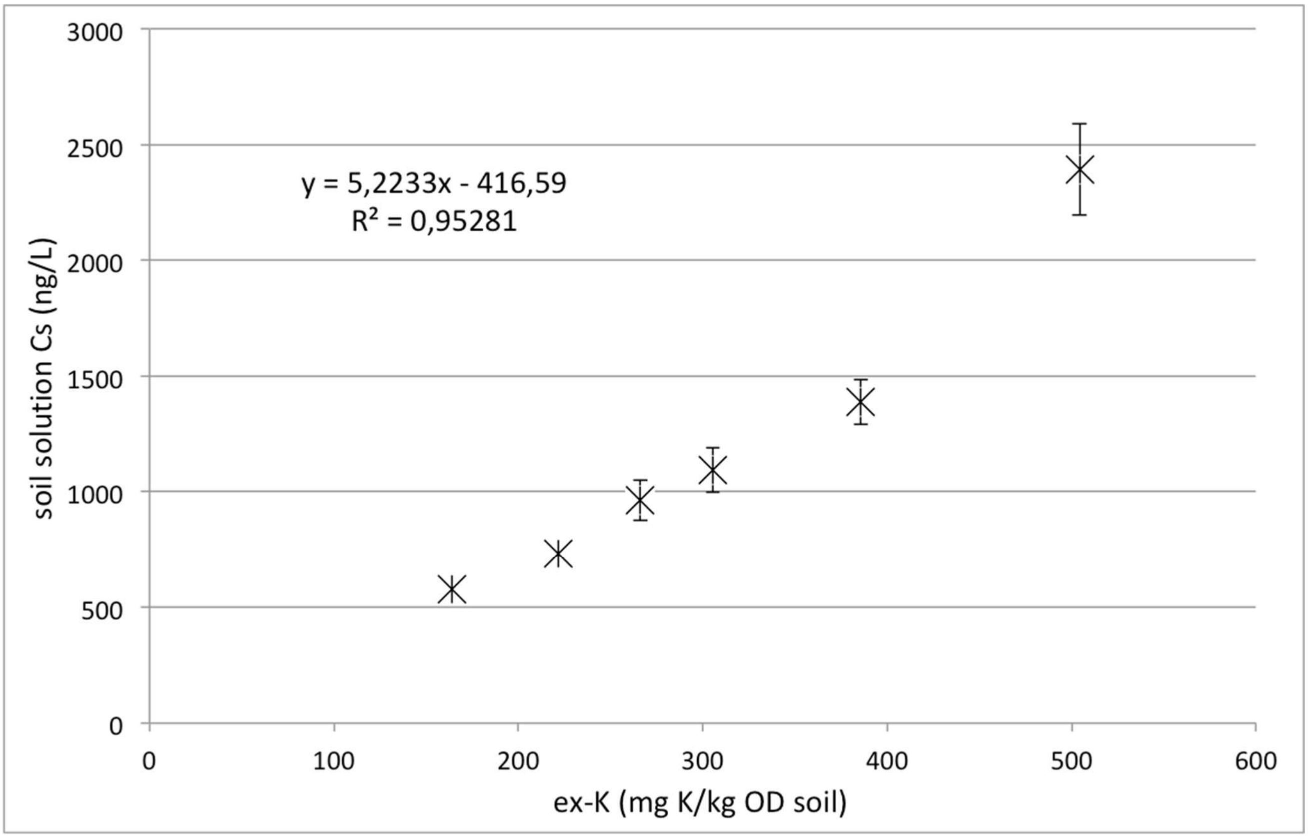

Figure 2. Caesium-133 in soil solution at different exchangeable potassium levels (ex-K) in three selected Japanese soils: vermiculitic (top), Andosol (center), and Andosol with zeolite amendments at 4 kg/m^2

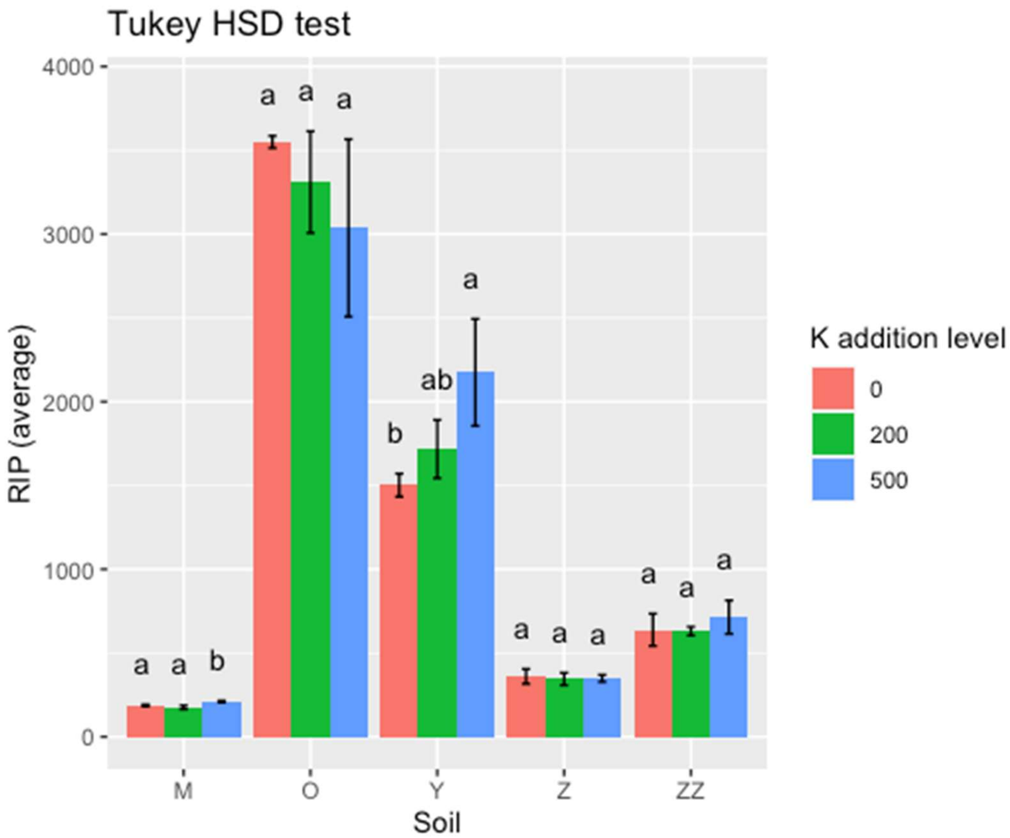

Figure 3. Statistical analysis (Tukey HSD post-hoc test) of the radiocaesium interception potential (RIP) analysis for selected Japanese soils at different amendment levels (no addition, 200 mg K/Kg oven-dried soil, and 500 mg K/kg oven-dried soil); From left to right: M (Andosol), O (smectitic soil); Y (vermiculitic soil), Z (Andosol with zeolite amendments at 1 kg/m^2), and ZZ (Andosol with zeolite amendments at 4 kg/m^2)

Exploring the potential of deep learning methods in mid-infrared spectroscopy for soil property predictions

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The Joint IAEA/FAO Division of Nuclear Techniques in Food and Agriculture launched a new Coordinated Research Project (D15019) in October 2019 called: "Monitoring and Predicting Radionuclide Uptake and Dynamics for Optimizing Remediation of Radioactive Contamination in Agriculture". Within this context, the high-throughput characterization of soil-to-plant transfer factors of radionuclides is of critical importance.

The usage of mathematical models and mid-infrared (MIR) spectral databases to predict the elemental composition of soil allows for rapid and high-throughput characterization of soil properties. The Partial Least Square Regression (PLSR) is a pervasive statistical method that is used for such predictive mathematical models due to a large existing knowledge base paired with standardized best practices in model application. Despite the successful use of PLSR over the last decades on many soil analytes, this popular approach fails to capture non-linear patterns and has poor prediction capacities for a wide range of soil analytes such as Potassium and Phosphorus, just to mention a few. In addition, prediction is highly sensitive to pre-processing steps in data derivation that can also be tainted by human biases based on the empirical selection of wavenumber regions. Thus, the usage of PLSR as a methodology for elemental prediction of soil remains time-consuming and limited in scope.

With major breakthroughs in the area of Deep Learning (DL) in the past decade, soil science researchers are increasingly shifting their focus from traditional techniques such as PLSR to using DL models such as Convolutional Neural Networks with higher capacity (ability to capture complex patterns). Very promising first results of this shift have been showcased, including increased prediction accuracy and reduced needs for data pre-processing. However, DL models still remain enigmatic (researchers still fail to understand why they work so well); they are notoriously data intensive, offering poor generalization properties in a small data regime, and are also computationally intensive. Whilst being aware of these limits, it would be unfortunate to overlook DL potential to increase: (i) the prediction accuracy on difficult analytes, (ii) the genericity and (iii) interpretability of models developed.

As part of our research agenda, our initial exploratory work on a small dataset (120 samples) confirms that machine learning models with higher representational capacity such as Random Forest (RF) outperform PLSR approaches on the prediction of difficult analytes such as Potassium with respectively average coefficients of determination R^2 of 0.75 (RF) against 0.43 (PLSR). Figure 1 showcases the interpretable nature of the Random Forest algorithm as it enables the determination of wavenumbers importance in terms of Potassium content prediction in soil. However, to avoid overfitting, more capacity must always go hand in hand with more data. The data collected over the duration of this CRP (a target of approximately 1000 samples over the next few months), in combination with a very large open database (about 80,000 samples as of today) of MIR soils spectra currently created and provided by USDA (United States Department of Agriculture) will enable:

- the comparison of the systematically traditional PLSR with DL approaches in different contexts of data variability and data regimes; and
- research to be conducted in applied mathematics (e.g Harmonic Analysis and Lie Groups) and soil sciences directed toward the development of DL models in small data regimes (e.g by systematically exploiting symmetries and invariants of input spectra) that meet the criteria (i), (ii) and (iii) above.

A better understanding of the potential for DL methods in soil composition prediction will greatly advance the work of soil sciences and natural resource management in general and would also enable the optimization of the remediation of agricultural lands in the aftermath of a large-scale nuclear accident.

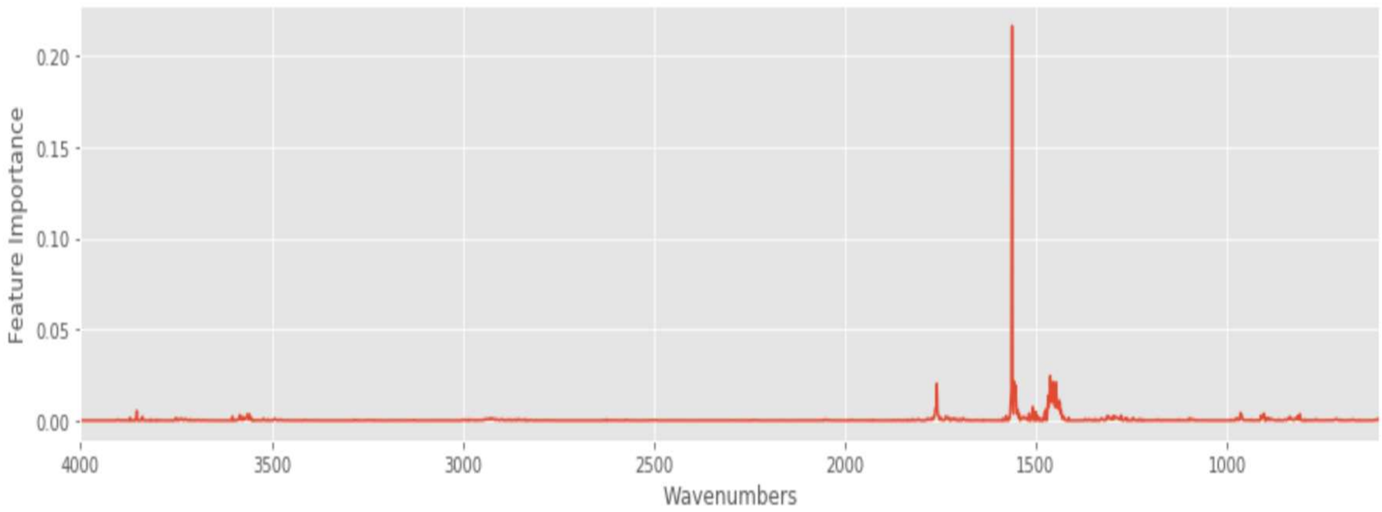

Figure 1. Determination of wavenumbers importance to predict Potassium content in soil using Random Forest learning algorithm using MIRS data (about 120 spectra) from Schmitter, P. et al. Sediment induced soil spatial variation in paddy fields of Northwest Vietnam. Geoderma 155, 298–307 (2010).

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Websites and Links

- Soil and Water Management and Crop Nutrition Section:
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  http://www.fao.org/land-water/home/en/
- New communication materials outlining successes in the area of nuclear techniques in food and agriculture:
  http://www-naweb.iaea.org/nafa/resources-nafa/IAEAsuccessIV_stories_Rev6.pdf
  http://www-naweb.iaea.org/nafa/resources-nafa/LabBrochure-2014.pdf

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