Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Soils Newsletter

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To Our Readers

The new Soil and Water Management and Crop Nutrition Laboratory in the Yukiya Amano Laboratories (YAL)

The global COVID-19 pandemic continues to affect our daily lives as well as the implementation of our work, including meetings and training courses. Nevertheless, with the year ending, we take this opportunity to reflect on the achievements and activities of the Soil and Water Management and Crop Nutrition (SWMCN) Subprogramme carried out in 2020 and highlight activities planned for 2021.

The SWMCN Laboratory in Seibersdorf has recently moved into the new, modern Yukiya Amano Laboratories (YAL), which also hosts the Animal Production and Health, Food and Environmental Protection laboratories. You can read more on this in the Announcement section. The work of the SWMCN Laboratory continues in the laboratory, glasshouse and in the field. Many interesting activities are reported in this issue of the newsletter below.

On the work on nuclear emergency affecting food and agriculture and remediation of radioactive contamination in agriculture, a new development has been made on the online decision support system DSS4NAFA, i.e. when coupled with external modelling tools, it can help with the specific decision of where/when/how to remediate, based on expert judgements and multiple stakeholders' preferences (e.g. decision makers, farmers). In terms of remediation, some progress was also made on using mid-infrared spectroscopy-based soil property prediction in combination with artificial intelligence methods. Similarly, further progress was made on the use of zeolite amendments and potassium addition for remediating radioactive contamination in agriculture.

Studies carried out in the Laboratory showed that it is possible to combine the cosmic ray neutron sensing (CRNS) data with satellite imagery to provide a high-resolution soil moisture map. This was tested for both temperate and semi-arid environments. In addition, a new nuclear technology, Gamma Ray Spectrometer (GRS) was also being tested for soil moisture monitoring. The GRS has a smaller footprint of about 25 m radius, is lighter and can be mounted on a drone, facilitating suitability for small scale irrigation schemes.

Two studies carried out this year by the Laboratory relating to greenhouse gas emission were on the influence of different nitrogen process inhibitors on crop production and the influence of biochar on nitrous oxide and carbon dioxide emissions from vermicompost.

The Laboratory was able to conduct one in-person training course, which was FAO-funded, on mathematical processing of Mid-Infrared Spectral datasets. The training was successfully held in the Seibersdorf YAL and attended by staff from all FAO/IAEA Laboratories in Seibersdorf. We are grateful to FAO in Rome HQ for having funded this annual training event.

In the meantime, the Peaceful Uses Initiative (PUI) project on ‘Enhancing climate change adaptation and disease resilience in banana-coffee cropping systems in East Africa’ (started in 2019) has been extended for three years, during which two additional PhD studies will focus on coffee. PhD work will be on drought stress - to build on results already obtained - as well as coffee diseases. Both drought and diseases are predicted to become major issues in the East African region in light of climate change. This PUI project, funded by the Belgian Government, continues to address the urgent need for an improved resilience towards climate change and contributes to creating food security in a changing world.

I would like to inform readers who are analysing ^{15}N and ^{13}C isotopic abundance in plant materials that the SWMCN Laboratory provides free External Quality Assurance Proficiency Test. Please get in contact with us if you would like to join this annual proficiency test.

This issue’s feature article came from Gabriele Baroni, our CRP D1.20.14 counterpart. The work on ‘Boosting cosmic ray neutron sensing (CRNS) method for soil moisture estimation by means of new detectors and interdisciplinary collaborations’ provides a historical account of cosmic ray neutron sensing (CRNS) plus the need for new alternative detectors. The SWMCN will be involved through the Laboratory in field testing and through CRP D1.20.14.

Five Research Coordination Meetings (RCMs) are scheduled for 2021. Two of them, which were postponed from 2020, will be held virtually: 1^{st} RCM of the new CRP D1.50.20 ‘Developing Climate Smart Agricultural Practices for Mitigation of Greenhouse Gases’ and 2^{nd} RCM of D1.50.18 ‘Multiple Isotope Fingerprints to Identify Sources and Transport of Agro-Contaminants’. The other three RCMs for CRPs D1.20.14, D1.50.17 and D1.50.19 are scheduled for later in 2021.

All professional staff continued implementing new and ongoing TC projects. With travel not possible, all meetings, training and discussions were organized virtually to ensure timely implementation of activities. Despite all the restrictions, more success stories were published in the last six months, including one story to celebrate World Soil Day on 5 December.

During 2020, the Subprogramme continued to be very active in its publication activities; this includes the Springer open access book on ‘Measuring Emission of Agricultural Greenhouse Gases and Developing Mitigation Options using Nuclear and Related Techniques’ and a number of publications on sampling, analysis and modelling technologies for large scale nuclear emergencies affecting food and agriculture in the *Journal of Environmental Radioactivity*.

I would like to make a preliminary announcement that our decennial event, the FAO/IAEA International Symposium, will be held in July 2022, in Vienna, Austria, focusing on land and water management for climate smart agriculture. It will be held a week before the World Congress of Soil Science, in Glasgow, UK. More information will follow in the next newsletter; meanwhile please mark this event in your calendar.

We would like to bid farewell to several of our staff and intern: Ksenija Ajvazi, Team Assistant at the Section has joined the Plant Breeding and Genetics (PBG) Laboratory in Seibersdorf as of December 2020 for one year. We thank Ksenija for all the support she provided over the many years she was with us. We wish her the very best with the PBG Laboratory. We also want to thank Roman Gruber, who left us in October. Roman assisted in the large number of stable isotope analyses, as well as in R&D activities carried out in the Laboratory. We wish Roman success in his future career. We also wish Elden Willems the very best in his M.Sc. studies. Elden was an intern in the Laboratory for three months, helping in sample preparation and isotope analysis in experiments on water use efficiency in cassava, under the CIALCA extrabudgetary project. We take this opportunity to welcome Tamara Wimberger, who will join the Section in March 2021 as Team Assistant, replacing Ksenija Ajvazi.

Finally, I would like to thank all our readers for their continuous support. Stay safe and healthy. My very best wishes for 2021.

Lee Heng
Head
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	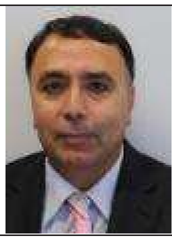		
L.K. Heng	M. Zaman	E. Fulajtar	J. Adu-Gyamfi
			
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Staff News

Ksenija Ajvazi (Austria), Team Assistant at the Soil and Water Management & Crop Nutrition Section (SWMCN) left on 1 December 2020 for her new assignment with the Plant Breeding and Genetics Laboratory in Seibersdorf. Ksenija has been supporting SWMCN for many years in her capacity as a Team Assistant. We would like to thank Ksenija for her dedication and support of the SWMCN Subprogramme and wish her all the best for her future.

Roman Gruber (Austria) left the Soil and Water Management and Crop Nutrition Laboratory (SWMCNL) in October 2020, as he followed his family to Spain. Roman joined the SWMCNL in October 2015, and assisted over the last 5 years in the stable isotope analysis conducted by the SWMCNL, essential for the development of its research and development activities. His continuous dedication has helped ensure the successful implementation of the large number of sample analyses, with often up to 10 000 analyses per year. Roman also contributed to field and greenhouse experiments together with the entire laboratory team, for the development of isotope techniques for climate-smart agriculture. His drive and enthusiasm to get things done has been well recognized by the entire team. We wish Roman success in the future and all the best for him and his family in this new step of their life.

Tamara Wimberger (Austria) will join the SWMCN Section on 1 March 2021 as a Team Assistant. Tamara was previously working in the Laboratories in Seibersdorf, providing administrative support to the Food and Environmental Protection Laboratory and Insect Pest Control Laboratory, which broadened her administrative skills in the Joint FAO/IAEA Division. We welcome Tamara to the SWMCN Section.

Elden Willems (Belgium) joined the SWMCN Laboratory as an intern in July 2020 for three months. He is a BSc graduate in Bioscience Engineering from KU Leuven, Belgium, with a specialisation in agriculture. During his internship, he assisted in the implementation of experiments on water use efficiency in cassava, under the Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA). His work included sample preparation as well as the analysis of isotope data. The opportunity of working in the SWMCN Laboratory of the Joint FAO/IAEA Division allowed him to gain practical experience about the use of stable isotopes in plant physiology and water management. After his internship he will start a Master of Bioscience Engineering at KU Leuven, specializing in soil and water management.

Feature Articles

Boosting cosmic ray neutron sensing method for soil moisture estimation by means of new detectors and interdisciplinary collaborations

Gabriele Baroni

Department of Agricultural and Food Sciences (DISTAL), Alma Mater Studiorum – University of Bologna, Italy

Cosmic-ray neutron sensing: from noise to a well-established method for non-invasive soil moisture estimation

Cosmic ray neutron sensing (CRNS) has been introduced as a new non-invasive large scale method for soil moisture estimation. It is based on the inverse relationship between natural neutrons created by cosmic-ray and the presence of hydrogen at the land-surface, which is predominantly stored as water in the soil (Zreda et al., 2012).

Noteworthy, this effect was well known by physicists with studies dating back more than half a century but it was considered as a noise (Hendrick and Edge, 1966). Only several years later, the use of natural neutron fluxes measured at the ground surface for quantifying soil moisture and snow water equivalent has been presented (Kodama et al., 1979). In these experiments, however, the neutron detector was installed below ground and the signal was strongly related to the hydrogen pools close to the probe. For this reason, this set-up probably did not provide relevant advantages in comparison to other point-scale soil moisture techniques (e.g., TDR) and it was considered for monitoring only extreme snowpack conditions (Morin, et al., 2012). In contrast, Zreda et al. (2012) showed that the signal of a neutron detector installed above-ground is sensitive to soil moisture within a large footprint of hundreds of meters horizontally and a soil depth of several decimeters. In such a way, they put CRNS in a new perspective proving to be a valuable technique to estimate soil moisture at an intermediate scale and showing to be a promising method with a range of applications.

Above-ground CRNS method for soil moisture estimation is now used by several research groups all around the world and several national networks have been established. Most of the applications focus on detecting temporal soil moisture dynamics but promising results have been shown also as a rover for covering larger areas, for estimation biomass, water interception and large scale snow observations.

From proportional gas tubes to alternative detectors

Helium-3 proportional gas tubes are the most effective method to measure neutrons and they can be relatively easily assembled (Peerani et al., 2012). A first prototype for hydrological applications was for instance developed at the University of Potsdam (Germany) by employing a Canberra detector (http://www.canberra.com/de/ (Figure 1, left). Nowadays, commercial CRNS probes embedded with data logging and telemetry solution have been developed and are distributed by Hydroinnova LLC (http://hydroinnova.com/main.html). The main components of these detectors have been described by Zreda et al. (2012). The detectors are available in several configurations, but they are all based on proportional gas tubes enriched with helium-3 (Figure 1, right), or alternatively, boron trifluoride. These probes showed to be reliable in several environment conditions and they are currently the standard for CRNS applications.

In the last decades, however, the need of helium-3 detector has grown significantly due to the increasing demand of instrumentation for, among others, homeland security. In contrast, helium-3 is a nuclide produced almost entirely in artificial contexts. For these reasons, the current storage is depleting and the price of this type of detector is relatively high and even increasing. The use of boron trifluoride tubes can be alternatively considered. The sensitivity, however, is lower than helium-3 and for this reason bigger tubes are needed. Moreover, Boron fluoride is a poisonous gas, and it might not be usable in some environmental conditions (Peerani et al., 2012).

Therefore, the need of alternative technologies for neutron detection became critical for many applications and it is now a relevant topic also in the framework of hydrological applications. Specifically, a new replacement for current CRNS probes has been developed by a collaboration between the University of Arizona (US) and Silverside Detectors Inc (Waltham, US). The detector is based on Lithium Foil Detectors embedded in a safety box. The probes are now distributed by the Lab-C start-up company (http://lab-c.co/). One configuration is shown in Figure 2 (left). The research group at the Department of Physics at Heidelberg University (Germany) in collaborations with several environmental scientific groups over Germany is now involved in the development of a new probe based on a large-area boron-lined neutron detector (https://www.uni-potsdam.de/en/cosmicsense/). The main components of this detector have been described by Weimar et al. (2020) and one configuration is shown in

Figure 2 (center). The probes are distributed by the company Styx-neutronica (https://www.styx-neutronica.de/). Finally, the research group of the Department of Physics and Astronomy at the University of Padova (Italy) has developed a new type of CRNS probe based on scintillators, in collaboration of the University of Bologna (Italy). The main components are described by Stevanato et al. (2019) and one configuration is shown in Figure 2 (right). The probes are distributed by the start-up Finapp (https://www.finapptech.com/#).

Figure 1. CRNS detectors (left) a commercial CRS1000 from Hydroinnva LCC; (right) a home-made assembly based on Canberra proportional gas tube.

Figure 2. Alternative to proportional gas tube CRNS probes from Lab-C (left), Stix-neutronika (centre), Finapp (right)

The need of inter-comparisons and interdisciplinary collaborations

The strong technical development of new alternative neutron sensors is a unique opportunity for boosting the applicability of CRNS method for new and wider applications. Comparisons of the characteristics of each detector is however an important aspect to be explored. First intercomparisons (Stevanato et al., 2019, Fersch et al., 2020) showed that all the detectors respond well to precipitation events and they reproduce well the soil moisture dynamics. The most sensitive detector showed to be, for this case study, the Lab-C detector. Promising results have been also reported for Stix-Neutronica. However, the dimension and the weight of these probes are relevant, providing some difficulties for some field applications. In contrast, Finapp probe is relatively more compact. For this reason, it can be a practical alternative in several field conditions and for wider agro-environmental applications. In addition, Finapp probes have the capability to measure additional particles like muons and gamma-rays. The use of these additional features is now under investigations.

In line with vision, the Soil and Water Management and Crop Nutrition Section of the Joint FAO/IAEA Division is contributing to these developments based on an important initiative (http://www-naweb.iaea.org/nafa/swmn/crp/swmcn-Cosmic-Ray-Neutron-Sensor.html) aiming at bringing together scientists from different countries and background. Within this framework, an intercomparison of Hydroinnova type detector and a new Finapp prototype is also planned by the beginning of 2021. The comparison will provide the scientific basis for further understanding of the specific characteristics and the advantages of the different detectors.

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Announcements

Opening of the new Soil and Water Management and Crop Nutrition Laboratory

On 5 June 2020, the third major new facility planned under the ReNuAL project was opened, named the Yukiya Amano Laboratories (YAL), in honour of the man who did more than anyone else to make it happen – the late Director General Yukiya Amano.

IAEA Director General Rafael Mariano Grossi, together with His Excellency Mr Alexander Schallenberg, Federal Minister for European and International Affairs of the Republic of Austria, unveils the dedication plaque at the official inauguration of the Yukiya Amano Laboratory (YAL) at the IAEA Laboratories in Seibersdorf, Austria. 5 June 2020 (Photo Credit: Dean Calma / IAEA)

The new building highlights our unique partnership with the Food and Agriculture Organization of the United Nations, giving fresh impetus to our efforts to help Member States address what are existential challenges in food and agriculture.

The Yukiya Amano Laboratories hosts three out of five laboratories of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. One of the three laboratories is the Soil and Water Management and Crop Nutrition Laboratory (SWMCNL).

The new SWMCNL, which has area of approximately 1800 m^2, will have greater capacity to help countries reduce greenhouse gas emissions, strengthen climate-smart agricultural practices, maximize crop yields, conserve soil and water resources and eventually improve farmers' livelihoods.

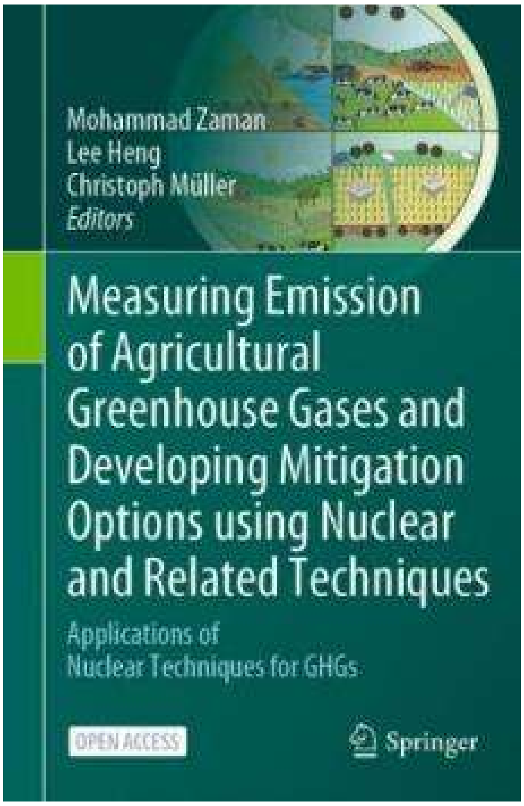
This wonderful modern laboratory complex would not have been possible without the continued generosity of Austria. The SWMCNL thanks the co-Chairs of the friends of ReNuAL, Ambassador Küntzle of Germany and Ambassador Molekane of South Africa, for their tireless efforts to raise funding for the labs. No fewer than 41 countries have contributed.

The new SWMCN Laboratory in the YAL building, with the first Subprogramme meeting in July 2020.

Open Access new Springer book "Measuring Emission of Agricultural Greenhouse Gases and Developing Mitigation Options using Nuclear and Related Techniques"

Climate change is real and happening for many years due to increased emission of greenhouse gases (GHGs) by man-made activities. We can see the negative impacts of climate change including the extreme weather events such as frequent heat waves, droughts, floods and uneven distribution of rainfall, rising sea levels and melting of glaciers. Recent data by the UN Intergovernmental Panel on Climate Change (IPCC) clearly showed that anthropogenic emissions of the three major GHGs including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) have increased significantly after the industrial revolution. Since 1900, the earth's average surface air temperature has increased about 0.8°C, with much of these increases taking place since the mid-1970s. It is therefore necessary to tackle the root-causes of climate change while fostering adaptation to its impacts.

In this regard, the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, through its Soil and Water Management and Crop Nutrition Section, published an Open Access book in Springer https://www.springer.com/gp/book/9783030553951 in strategic partnerships with world-leading research centre of the German Science Foundation research unit DASIM, and associated international leading experts. This book comprises of eight chapters covering GHG emission from soil fauna and plants, CH_4 production in ruminant animals, non-isotopic and micrometeorological methods, laboratory and field techniques, isotopic techniques to measure GHGs and identify their sources, and climate-smart agriculture practices for GHGs mitigation. This is a very important contribution to fostering and attaining the climate-smart agriculture "triple wins'' of reduced GHG emissions, enhanced adaptation and increased agricultural productivity. The material presented in this book should be useful for both, beginners in the field, to obtain an overview of the current methodology, and experienced researchers who need a hands-on description of current methodologies. The methods described in this book are written in such a way that they are easy-to-understand and applicable to a range of users with different expertise and backgrounds.



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
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
Colombia	COS5026	Enhancing Crop Productivity of Creole Potato Using Nuclear and Related Techniques	M. Zaman and PBG
Costa Rica	COS5035	Building Capacity for the Development of Climate-Smart Agriculture in Rice Farming	M. Zaman
Cuba	CUB5023	Strengthening National Capacities for the Development of New Varieties of Crops through Induced Mutation to Improve Food Security While Minimizing the Environmental Footprint	E. Fulajtar
Gabon	GAB5003	Building National Capacities for Monitoring Sedimentation of Dams and Harbors and the Management of Remediation Operations	E. Fulajtar
Gabon	GAB5004	Improving Soil Fertility Management for Enhanced Maize, Soybean and Groundnut Production	J.Adu-Gyamfi
Haiti	HAI5008	Strengthening National Capacities for Enhanced Agricultural Crop Productivity	J.Adu-Gyamfi
Indonesia	INS5044	Using Nuclear Technology to Support the National Food Security Programme	L. Heng and 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	Biocontrol of Striga asiatica (L.) Kuntze through the development of tolerant rice and maize lines and its impact on microbiological and ecological functioning of soil	J. Adu-Gyamfi and 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
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	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 lively hood 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

First Research Coordination Meeting of CRP D1.50.20. ‘Developing Climate Smart Agricultural Practices for Mitigation of Greenhouse Gases’, 8-12 February 2021, Vienna, Austria

Technical 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’, 1-5 March 2021, Vienna, Austria (virtual)

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

Regional Training Course of RLA5084 ‘Soil, nutrient and water management best practices for agricultural crops’, 8–19 March 2021, Seibersdorf, Austria

Technical Officer: J. Adu-Gyamfi

Regional workshop of RAS5084 ‘Assessing and improving soil and water quality to minimize land degradation and enhance crop productivity using nuclear techniques’ on ‘Fallout radionuclide (FRN) and stable isotope data processing, management and interpretation’, 4-5 May 2021 preparation meeting, (virtual) and 24-28 May 2021, (physical meeting), Mumbai, India.

Technical Officer: J. Adu-Gyamfi

Regional Training Course of RAF5081 ‘Enhancing productivity and climate resilience in cassava-based systems through improved nutrient, water and soil management (AFRA)’, 17-28 May 2021, Seibersdorf, Austria

Technical Officers: G. Dercon and M. Zaman

Second Research Coordination Meeting of CRP D1.20.14. ‘Enhancing agricultural resilience and water security using Cosmic-Ray Neutron Sensor’, 7-11 June 2021, Bologna, Italy

Technical Officer: E. Fulajtar

Final Research Coordination Meeting of CRP D1.50.17. ‘Nuclear Techniques for a Better Understanding of the Impact of Climate Change on Soil Erosion in Upland Agro-Ecosystems’, 5-9 July 2021, Vienna, Austria

Technical Officer: L. Heng

The FAO/IAEA International Symposium on Managing Land and Water for Climate Smart Agriculture, 25-28 July 2022, Vienna, Austria.

Scientific Secretary: L. Heng

Non-FAO/IAEA Events

International Conference on Soil Science and Plant Nutrition, 25–26 January 2021, Paris, France

International Conference on Sustainable Water Management and Pollution Control ICSWMPC, 4–5 March 2021, Rome, Italy

Second International Conference on Applications of Radiation Science and Technology (ICARST-2021), 19–23 April 2021, Vienna, Austria.

EGU General Assembly 2021 (virtual): vEGU21: Gather Online (#vEGU21). The General Assembly 2021 of the European Geosciences Union (EGU) will be held entirely online, 25-30 April 2021. https://www.egu21.eu/

26th UN Climate Change Conference (COP26), 1-12 November 2021, Glasgow, UK. https://www.ukcop26.org/

Past Events

FAO/IAEA Events

European Geosciences Union (EGU) 2020 on Session HS2.3.4 'Sources, transport and fate of contaminants in agricultural- and mining-impacted river catchments' 04–08 May 2020 (virtual)

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

The EGU General Assembly 2020 was converted into virtual event EGU2020: Sharing Geoscience Online, from 4 to 8 May 2020 due to the COVID-19 pandemic. The online submission focused on inter- and transdisciplinary sessions, disciplinary sessions, union symposia, and debates. The visibility of the current CRP D1.50.18 "Multiple Isotope Fingerprints to Identify Sources and Transport of Agro-contaminants" and a TC project RAS5084 "Assessing and Improving Soil and Water Quality to Minimize Land Degradation and Enhance Crop Productivity using Nuclear Techniques" was enhanced during the EGU 2020. Mr J. Adu-Gyamfi (IAEA, Austria) and Mr G. Imfeld (University of Strasbourg, France) were Co-conveners of Session HS2.3.4 "Sources, Transport and Fate of Contaminants in Agricultural- and Mining-impacted River Catchments" on 7 May 2020. Twenty-seven (27) abstracts were received and 20 online presentations were made on that day. Seven of the presentations in the session were given by Australia, Austria, China, France, Germany, IAEA, and Slovenia who are CRP participants from the CRP D.1.50.18 and TC project RAS5084. Overall, 66 scientists world-wide participated and contributed remotely to discussions during Session HS2.3.4. The online format sharing Geoscience online was a great success because there were 18,036 abstracts submitted to the programme with 701 scientific sessions, 11,380 presentation materials accompanied the abstracts and received 6,297 comments so far. Based on the combination of IP addresses and email addresses used for chat registration, 22,376 individuals were identified to have participated from 134 countries.

Regional training course of RAS5089 on 'Enhancing nutrient use efficiency of date palm using stable isotope ^{15}N Fertilizer', 17-18 August 2020 (virtual)

Technical officer: H. Said

The online RTC consisted of lectures on "Enhancing Nutrient use Efficiency of Date Palm using Stable Isotope ^{15}N Fertilizer". The RTC covered from fundamentals of ^{15}N fertilizer studies to practical uses of ^{15}N techniques in nutrient use efficiency on date palm cultivation. The training was attended by 14 participants from ARASIA members states.

6th International COSMOS Workshop, 8-10 October 2020 in Heidelberg (combined with online participation)

Project Officer: E. Fulajtar

The COSMOS Workshop is a paramount scientific event of international research community working on development and applications of Cosmic Ray Neutron Sensing technology for soil moisture assessment. This meeting was a foremost opportunity to present the preliminary results of CRP D1.20.14. The meeting was held physically at Heidelberg University, Germany but also on-line participation was arranged. This event was attended by five partners of CRP D1.20.14, Mr E. Fulajtar (Project Officer) and Mr H. Said Ahmed from Soil Lab in Seibersdorf. Two CRP partners Mr T. Franz and R. Rosolem were among the key-note speakers at this event. The CRP project partners and IAEA staff members gave several presentations discussing the results of the CRP.

International Conference on Phosphates (ICP): Fundamentals, processes and technologies" 15–17 October 2020, Benguerir, Morocco (virtual)

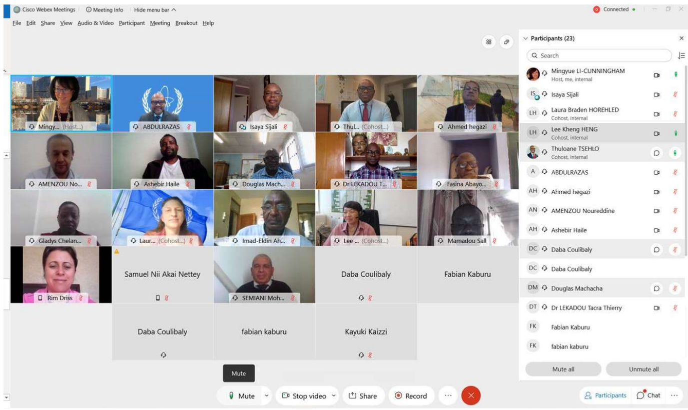
Technical Officers: Joseph Adu-Gyamfi and Lee Heng

The International Conference on Phosphates (ICP): Fundamentals, processes and technologies was a multidisciplinary scientific event covering a wide range of research areas around phosphates and related applications. The aim of the conference was to gather scientists and engineers from all over the world to exchange new findings to develop collaborations and partnerships and to discuss their new findings in the following research fields: (1) phosphates mining value chain, (2) complex fluids modelling (3) chemistry, processes & materials, (4) sustainable mining (5) agriculture and biotechnology and (6) industrial site & settlement planning. The conference was held through webinar (online) by the Mohammed VI Polytechnic University, Benguerir, Morocco. The Conference gathered national and international scientists and professionals in the field of phosphate and its derivatives. The SWNCN Section was invited to participate in the conference to give a keynote address on "Agriculture, biotechnology, fertilizers and food security" on 16th October 2020. A presentation "Phosphorus isotopes to investigate the positive and negative impacts of phosphorus fertilizers on agriculture and the environment" by Joseph Adu-Gyamfi and Lee Heng on (1) use of phosphorus radioisotopes to investigate soil phosphorus dynamics and cycling in soil–plant systems, (2) evaluation of phosphate rock sources for agricultural production using phosphorus isotopes, (3) development of protocols and guidelines using multi-stable isotope fingerprints for tracing the sources of the agro-pollutants, and soil and water management practices to reduce pollutants from phosphate fertilizers in the environment, was well received.

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', 27-29 October 2020 (virtual)

Project Officer: L. Heng

A virtual mid-term review meeting was held with 16 project counterparts from Algeria Benin, Botswana, Cote D'Ivoire, Egypt, Ethiopia, Ghana, Kenya, Mali, Morocco, Nigeria, Senegal, Sudan, Tunisia, Uganda and Zimbabwe, and two observers from Kenya. Mauritius did not manage to attend. The meeting was to evaluate the progress made towards achieving the results of the regional project since its inception in January 2018. The project was to contribute to the improvement of water and nitrogen use efficiency under small scale irrigation systems, with the long-term intent to contribute to improved agricultural productivity under climatic change and variability for sustainable food security. Overall, the project was making commendable progress towards improved efficiency of water and nitrogen use under small scale irrigation systems in the participating member states. The project delivered irrigation systems as well as equipment to support nutrient and water use efficiencies in participating countries and had trained up to 400 African professional scientists, students and farmers through national and regional training courses and in-country field-day initiatives by counterpart institutions. There was evidence of success from reported laboratory and field results, with several success stories on IAEA website. Two areas of improvement for the project were the use of ICT by member states as well as on more adoption of climate-smart practices by farmers and end-users.



Review Meeting of RAS5084 "Assessing and improving soil and water quality to minimize land degradation and enhance crop productivity using nuclear techniques", 28-29 October 2020 (virtual)

Technical Officer: Joseph Adu-Gyamfi

The purpose of this meeting was to review the implementation of the project in 2020, discuss and agree on the national and regional workplan and take measures to ensure an efficient way to achieve project objectives. Eighteen participants from eighteen countries: Australia, Bangladesh, Cambodia, China, India, Indonesia, Japan, Laos P.D.R, Malaysia, Mongolia, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Sri Lanka, Thailand and Vietnam made presentations online. Fiji, Korea, Palau and Singapore did not participate in the meeting. Prior to the meeting there was a preparatory and administrative session on 21 October 2020 to ensure that the IT platform was working well. The meeting on 28–29 October started with an IT roll call followed by welcome remarks by the PMO, Mr Sinh Van Hoang, the Lead Country Coordinator (LCC) Mr Tim Ralph and the Technical Officer, Mr Joseph Adu-Gyamfi. The TO presented the objectives and expected outcome of the meeting followed by an overview of the project implementation since the second coordination meeting in Tsukuba, Japan. There were country reports/presentations 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 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. Discussions focused on (1) the development of a regional database on soil erosion, soil and water quality, (2) national and regional fact sheets and/or e-learning materials. A database format was agreed by all participants to be completed within a week after the meeting.

Coordinated Research Projects

Project Number	Ongoing CRPs	Project Officer
D1.20.14	Enhancing Agricultural Resilience and Water Security Using Cosmic-Ray Neutron Technology	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	Remediation of Radioactive Contaminated Agricultural Land	G. Dercon and L. Heng
D1.50.20	Developing Climate Smart Agricultural Practices for Mitigation of Greenhouse Gases	M. Zaman and L. Heng

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

Project Officers: E. Fulajtar and J. Halder

This CRP which started in 2019 to 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 largescale 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 (Denmark, Netherlands and United Kingdom) 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 interpretations of soil water content datasets collected by the SWMCN Lab team at a stationary monitoring station in Petzenkirchen, Austria. In summer 2020 the progress reports summarizing the results of the 1st project year were submitted, evaluated and all contracts were renewed. Due to travel restrictions related to Covid-19 some activities, mainly the installation of cosmic ray neutron sensors and gamma ray sensors at some sites were delayed. Nevertheless, despite of these travel restrictions the major activities were successfully implemented and already in its first year the CRP brought significant scientific achievements:

- Proposing algorithm for filtering the noise and smoothening the signal of neutron counts;
- Developing approach for estimation of rainfall from soil water content data obtained by CRNS;
- Testing the procedure for estimating root depth soil moisture distribution from CRNS data.

These methodological issues were published in three research papers in international scientific journals and two oral presentations presented at the 6th International COSMOS Workshop on 8-10 October in Heidelberg, Germany. The Second Research Coordination Meeting is planned for 31 May – 4 June 2021.

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 δ^{13}C 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 were also published, in 2017 and 2019, i.e. 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 ^{7}Be (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 them 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 (δ^{18}O' δ^{2}H, δ^{13}C, δ^{15}N,' δ^{13}C-DIC, δ^{15}N-NO_3 δ^{18}O-NO_3 δ^{18}Op, δ^{34}S) techniques and compound specific isotope (CSSI)-based monitoring approach for evaluating in-situ degradation, transport, transformation and fate of pesticides.

The achievements from the CRP to-date include:
1) A 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 (CSSI) 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 2020) on 7 May 2020 where a Session (HS2.3.4) "Sources, transport and fate of contaminants in agricultural- and mining-impacted river catchments" was convened. A total of seven presentations were given by the CRP participants. This CRP will be featured for the third time in a European Geosciences Union (EGU) during the upcoming on-line EGU2021 General Assembly on 25–30 April 2021. The second RCM will be held virtual on 1–5 March 2021.

Remediation of Radioactive Contaminated Agricultural Land (D1.50.19)

Project Officers: G. Dercon and L. Heng

Innovative monitoring and prediction techniques present a unique solution to enhancing readiness and capabilities of societies for optimizing the remediation of agricultural areas affected by large scale nuclear accidents. In this CRP, new field, laboratory and machine-learning modelling tools will be developed, tested and validated for predicting and monitoring the fate of radionuclide uptake by crops and related dynamics at the landscape level, with the emphasis on those under-explored environments and related main crop categories. Laboratory, greenhouse and field-based research using stable caesium and strontium isotopes in combination with integrated time and space dependent modelling and machine learning will be used to predict radiocaesium and radiostrontium crop uptake and movement in the case of a large-scale nuclear accident affecting food and agriculture. Operation research will be applied to guide the use of remediation techniques at landscape level (i.e. selection, optimization and prioritization). Protocols will be developed and adapted for innovative spatio-temporal decision support systems for remediation of agricultural land, based on machine learning and operations research integrated with Geographic Information System (GIS) techniques.

The overall objective is to enhance readiness and capabilities of societies for optimizing remediation of agricultural areas affected by large scale nuclear accidents through innovative monitoring, decision making and prediction techniques.

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 in particular for under-explored agro-ecological environments such as arid, tropical and monsoonal climates and (2) to customize 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.
Eleven countries participate in this CRP: eight research contract holders from Belarus, Chile, Morocco, P. R. China (three institutions), Russia, Ukraine; two technical contract holders from France and Macedonia; and six agreement holders from Belgium (two institutions), Japan (three institutions) and India.

The CRP D1.50.19 was developed as a follow up to CRP D1.50.15. It was formulated based on recommendations from a consultants' meeting held at the IAEA, Vienna, 20-22 February 2019. Expert consultants from Belgium, Japan, Ukraine and Russia noted that the importance of optimization of remediation based on monitoring and prediction of the fate of radiocaesium and radiostrontium in agriculture is essential for returning the affected territories to normal environmental conditions. The First Research Coordination Meeting (RCM) –was held on 21-24 October 2019. During this meeting the objectives and experimental plans of the national research projects were discussed and adjusted to be in line with the objectives and work plan of the CRP. Common guidelines for implementing the national project activities and collaboration networks were established.

Since the beginning of the CRP a series of laboratory-experiments has been carried on improving remediation of radioactive contamination in farmland. The CRP team has designed the roadmap to develop new isotope techniques to better understand the dynamics of radiocaesium in the soil. 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. Further, decision-support tools are being developed to improve strategies for remediation of radioactive contamination in agriculture.

The second RCM of this CRP is planned to be held on 4-8 October 2021 in Japan.

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

Project Officers: 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) was initiated this year. The first Research Coordination Meeting (virtual) will take place on 8-12 February 2021, initiated from 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.

Twelve countries participate in this CRP: Nine research contract holders, one each from Argentina, Bangladesh, Brazil, China, Costa Rica, Ethiopia, India, Pakistan and Viet Nam and two agreement holders from China and New Zealand, and two technical contract holders from Germany and Spain.

Developments at the Soil and Water Management and Crop Nutrition Laboratory

High-resolution soil moisture map using Cosmic-Ray Neutron Sensors data and Sentinel-1 for temperate and semi-arid environments

Said Ahmed, H.[1], Mbaye, M.[2], Heng, L.K.[3], Weltin, G.[1], Franz, T.E.[4], Dercon, G.[1], Strauss, P.[5], Rab, G.[5], Saud Al-Menaia, H[6]

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[5]Institute for Land and Water Management Research, Federal Agency for Water Management, Petzenkirchen, Austria
[6]Kuwait Institute for Scientific Research, Kuwait City, Kuwait

Global climate change has a major impact on the availability of water resources for agricultural production. Sustainable agricultural productivity to ensure food security requires good agricultural water management. Soil moisture is an important variable in irrigation management, hydrological modelling, groundwater recharge, flood and drought forecasting.

Cosmic Ray Neutron Sensors (CRNS) have the capability to estimate field-scale soil moisture (SM) in large areas up to 20 to 30 ha and has demonstrated its ability to support agricultural water management, hydrology studies and land surface modelling. However, measurement of soil moisture at a global or regional scale can only be achieved from satellite remote sensing.

Recently, active microwave remote sensing Synthetic Aperture Radar (SAR) imaging has emerged as an effective tool to estimate surface soil moisture. The Sentinel-1 (SAR) satellite shows great potential for high spatial resolution soil moisture monitoring and for producing soil moisture maps. CRNS technology can be used for calibration and validation remote sensing imagery predictions at field and area-wide level.

Therefore, the SWMCN laboratory worked to create a conversion model to retrieve soil moisture from Sentinel-1 (SAR) using CRNS data from temperate (Austria) and semi-arid environments (Kuwait) (Figure 1). This model was then used to set up a soil moisture maps with high-spatial and temporal resolution. The study is performed using only the VV (vertical-vertical) polarization which is highly sensitive to soil moisture.

The first results from the test case in Kuwait showed that soil moisture measured by the CRNS and the radar backscattered signal (σ_{VV}) have a similar trend (Figure 2a). Therefore, a simple linear regression model could be made (R^2=0.77) (Figure 2b).

Once calibrated, the linear model was integrated into Google Earth Engine to convert VV polarization radar data into soil water content maps. In a next step, a web application was created for easy-access soil moisture estimation based on the satellite imagery data. Further, Normalized Difference Vegetation Index (NDVI) data from Sentinel-2 and rainfall data from Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) were also integrated in the prediction to take into account soil moisture and vegetation dynamics due to irrigation.

In Figure 3, an example of a derived high-spatial resolution soil moisture map and related soil moisture timelines, visible in the developed web application is shown. In this example, the impact of irrigation can be seen; soil moisture decreases down to a certain threshold (15 or 20%), and it increases again to 25 or 30% without any rainfall event. Such information is useful for irrigation management and can help the farmer decide when to irrigate.

This study is a major step in soil moisture monitoring at high spatial and temporal resolution by combining remote sensing data and the CRNS based nuclear technology. The CRNS technology bridges the critical gap between satellites and point-scale ground sensors and enables the calibration of satellites, such as Sentinel-1, to improve soil moisture data estimated by remote sensing.

However, the model is sensitive to vegetation density and further research will be conducted to incorporate this important parameter using advanced mathematical techniques, such as machine learning.

The developed web application is an important tool not only for agricultural water management, but also for hydrology, drought and flood prediction, and may be even useful in desert locust preventive management in the future.

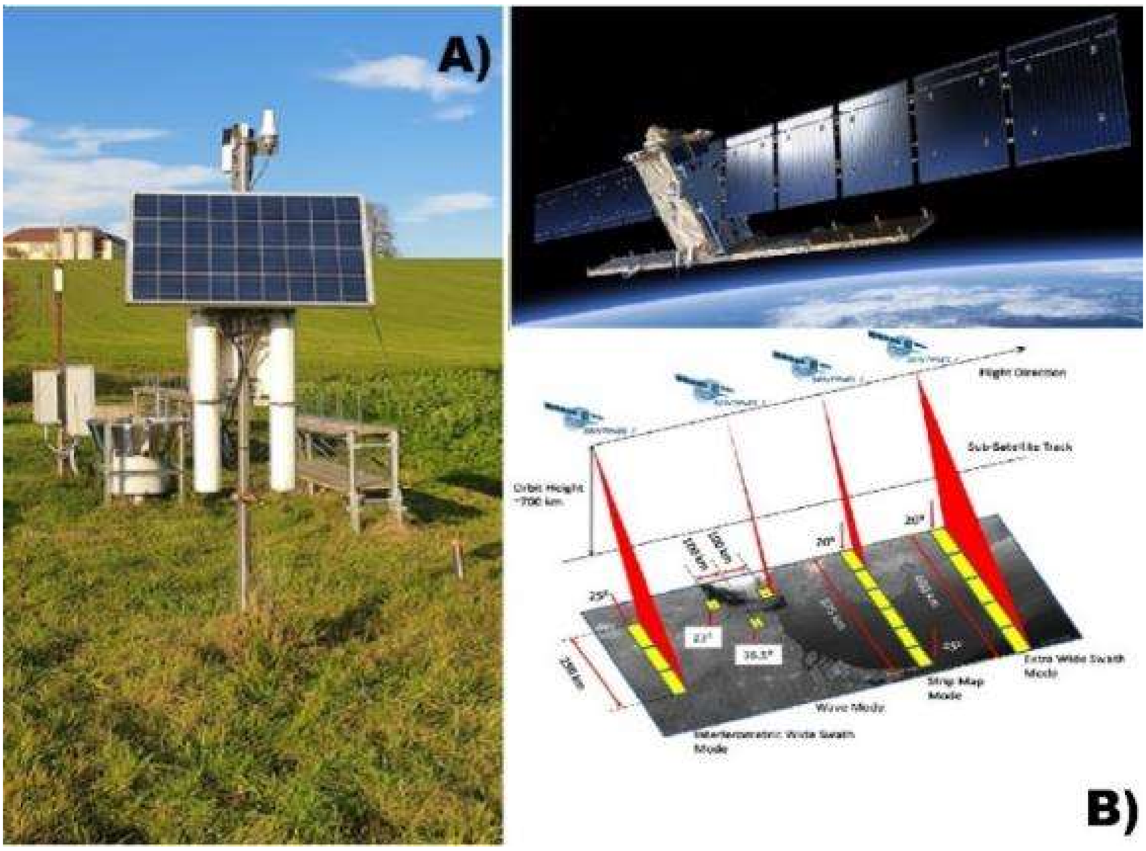

Figure 1. Cosmic ray neutron sensor in Petzenkirchen, Austria (a) and Sentinel-1 satellite (b).
https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar

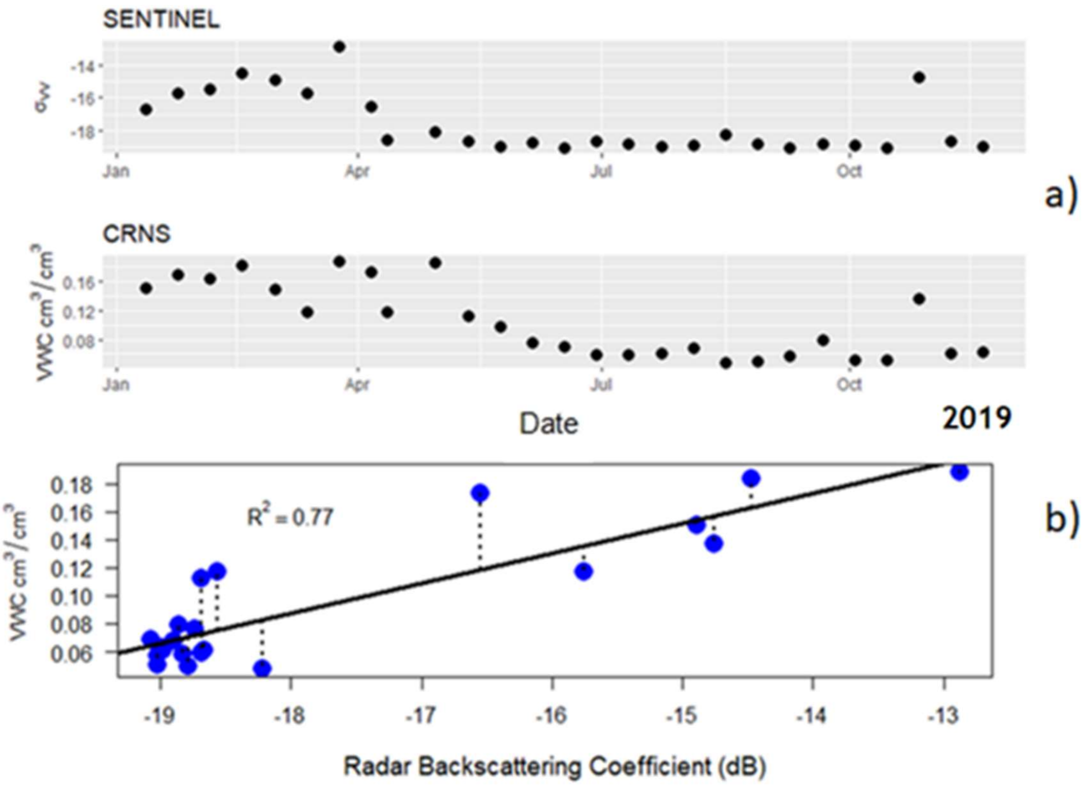

Figure 2. (a) Sentinel-1 radar backscattered coefficient (σ_{VV}) and soil moisture measured with Cosmic Ray Neutron Sensor in a test case in Kuwait and (b) Linear regression model between σ_{VV} and soil moisture for the same test case.

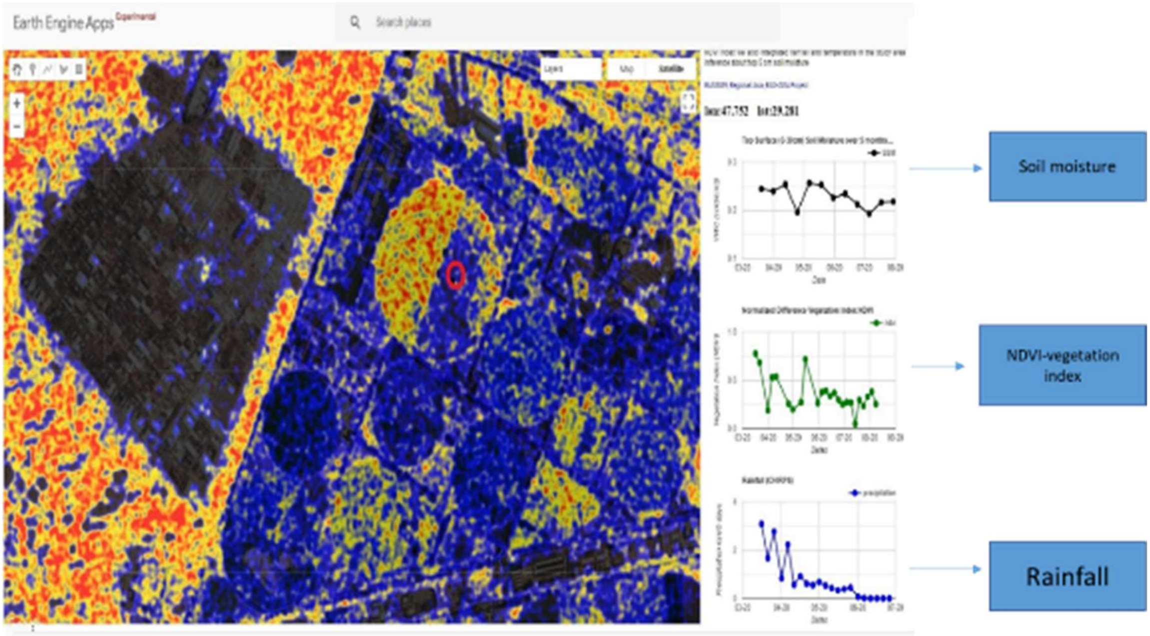

Figure 3. Screenshot of the web application for estimating spatial and temporal soil moisture data based on satellite imagery information, calibrated by cosmic ray neutron sensor technology, from the test case in Kuwait.

Field scale soil moisture monitoring with Gamma Soil Moisture Sensors

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With global climate change, water availability will be a problem for agriculture and food production. Agriculture production consumes more than 70 percent of the world's water resources, mainly for irrigation. With water use efficiency less than 50%, the challenge is to ensure adequate agricultural production while achieving maximum efficiency of irrigation water use.

Climate-smart irrigation practices, including effective soil moisture monitoring, can help to meet this challenge and ensure longer water availability when drought is hitting the farmlands.

Continuous monitoring of soil moisture at field scale with non-invasive methods can provide crucial information to help farmers decide when and how much to irrigate.

Nuclear technology, such as Cosmic-Ray Neutron Sensors (CRNS), has recently become a relevant method for measuring soil moisture content (SWC) over large areas of up to 20 to 30 ha and has become a robust and validated alternative to conventional devices, which measure soil moisture at point level.

Figure 1. Gamma Soil Moisture Sensors (GSMS), model GSMS100 in Seibersdorf, Austria

More recently a new nuclear technology, Gamma Soil Moisture Sensors (GSMS) (Fig.1) also emerged as non-invasive method for soil moisture monitoring at the smaller field level.

The GSMS approach for estimating soil moisture is based on the link between soil moisture and gamma-ray intensity.

With an estimated footprint of about 25 m radius, the GSMS can be suitable for soil moisture monitoring in small scale irrigation schemes.

This technology is relatively new and very few studies have attempted to estimate soil moisture through measuring gamma-radiation.

The SWMCN laboratory will work at its experimental fields in Austria on soil moisture monitoring using GSMS to evaluate its ability to measure soil moisture. The first results of this exploratory research are expected in 2021.

Refining drought stress measurement methods for banana – leaf temperature and $\delta^{13}C$ of leaf and phloem sap

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The year 2020 has been a year full of challenges. The COVID-19 pandemic has affected all of us, as well as hampered ongoing research. This was also the case for the PUI (Peaceful Uses Initiative) project on Enhancing climate change adaptation and disease resilience in banana-coffee cropping systems in East Africa (started in 2019). Planned research activities in Tanzania had to be called off. Fortunately though, KU Leuven (Belgium), partner in this research, allowed us to initiate last-minute research activities in Belgium, turning this drawback into an opportunity. KU Leuven hosts the world's largest banana gene bank and has proven experience and knowhow on assessing drought stress in banana. Against this background, an experiment was set up in an open-ground greenhouse, in cooperation with MSc student Joséphine Allaert. The purpose was to (1) evaluate different stress parameters and measurement methods under progressing drought conditions and (2) improve our understanding of the $\delta^{13}C$ signal as a proxy for water use efficiency in banana.

An optimal and a deficit irrigation treatment were applied to nine mature banana plants (cv. Cavendish). Treatments were initiated at the end of June 2020. The soil moisture availability was followed up with TDR sensors for every individual plant and the micro-environment (air temperature (°C), relative humidity (%) and light intensity (µmol $(m^2s)^{-1}$) was monitored with strategically placed sensors (Figure 1).

During the progressing drought, leaf temperature throughout the day was measured once per week with an infrared thermometer. Leaf growth was tracked, and every newly developed leaf was sampled for $\delta^{13}C$ analysis. Finally, phloem sap samples were taken in accordance to a method developed in early 2020 under this PUI project. Phloem sap contains recently assimilated sugars and could therefore prove a more short-term measure for drought stress than bulk leaf $\delta^{13}C$. Moreover, the combination of leaf and phloem sap samples may allow us to better understand the carbon dynamics in a banana plant.

Figure 1. Experimental set-up with TDR sensors inserted in the soil at different depths and RH and air temperature sensor attached to the plant.

We will analyze $\delta^{13}C$ of different fractions in the leaf samples, namely of the water-soluble organic matter (WSOM) and of the α-cellulose. The first one should express current stress levels and correspond well to the $\delta^{13}C$ measured in phloem sap, whilst the second one should express the stress level of the plant at time of the leaf development. As we constantly follow up soil water content, we can link the $\delta^{13}C$ levels in those different fractions to stress at specific times. This will finally make us understand what a bulk leaf $\delta^{13}C$ signal exactly entails. Is it merely dependent on immobile carbon and therefore represents the stress level at time of development or do currently produced sugars play a role? We can link those progressing drought conditions to leaf temperature as well. As such, we will eventually obtain drought stress parameters which can be interpreted unequivocally and have a well-defined applicability in terms of time and place.

In the meantime, the PUI-project has been extended with three years, during which two additional PhD studies will focus on coffee. Their work will be on drought stress and therefore build on the already obtained results, as well as on coffee diseases such as Coffee Berry Disease (CBD). Both drought and CBD are predicted to become major issues in the East African region in light of climate change. Isotope-based methods will be developed to create climate-smart adaptation measures. As such, the PUI-project, funded by the Belgian government, continues to address the urgent need for an improved resilience towards climate change and contributes to creating food security in a changing world.

Counteracting drought effects in cassava production systems: An update on the CIALCA activities at SWMCNL

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A simple system for extracting soil water for isotope analysis

Oxygen-18 (^{18}O) of plant tissues can provide information on the environmental conditions in which plants grow, because of its relation to stomatal conductance. Therefore, ^{18}O signatures can also be related to plant stress. In future experiments, ^{18}O will be used to assess whether fertilizer application or variety selection influences the reaction of plants to drought stress.

In order to understand the dynamics of ^{18}O isotopes in growing plants, it is necessary to know the isotopic signature of the water on which they are growing. This source water largely influences signatures which can be found in plant tissues. However, to analyze soil water, the first step is its extraction from the soil substrate. A popular way to extract soil water is cryogenic distillation. Here, soil water is almost completely extracted from the soil. However, plant roots are not able to extract all water from the soil with decreasing soil water contents. A method which samples water that resembles the water accessible for roots is centrifugation.

At the SWMCNL a simple system was made from 50 mL centrifuge tubes with inserts made from 20 mL syringes. Both ears of the syringes were cut off in order to fit in the 50 mL tubes. Small holes were made with a hot needle in the bottom of the syringe, which was then covered by a glass microfiber filter (Figure 1).

This system will now be used to centrifuge soil water at different speeds (coinciding with different soil water potentials) and compare the signatures of the different extract to the signature of the water taken up by plants. This will allow to evaluate which soil water pool needs to be extracted. Extracting the correct soil water pool will help improving drought stress assessment of cassava plants.

Image-based biomass estimation

At the end of October, a new batch of cassava cuttings arrived in the SWCMNL greenhouse. This batch, containing 120 cassava plants, was provided by Rwanda Agriculture and Animal Resources Development Board (RAB). The RAB works closely together with International Institute for Tropical agriculture in the Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA). The plants, grown in the SWMCNL greenhouse, will serve the purpose to develop models to estimate biomass of the growing plants. The estimates will be based on regular RGB images. Using this technique, the growing biomass can be assessed without the need to destroy the plants.

Figure 2. Soil water extraction tubes for centrifugation. The only materials needed are 50 mL centrifugation tubes, 20 or 30 mL syringes and a filter. The extracted water is collected in the space under the syringe and can be used for isotopic analysis of water.

In order to test the applicability of the model to different varieties and treatments, two varieties were selected: one local Rwandese variety, named Gacyaricyari, and one improved high-yielding variety, named NAROCASS1 developed by the National Agricultural Research Organization (NARO) in Uganda. Both varieties will undergo different fertilizer and irrigation treatments to test the robustness of the model to varying conditions.

Plants will be harvested at multiple time intervals; images will be captured in a photo booth after which the plants will be harvested and weighted. In the next step, 'virtual biomass' will be extracted from the images by a script made in R-studio and correlated to the actual biomass of the plants (Figure 2). Besides the biomass measurements, several physiological parameters (intrinsic leaf water use efficiency, chlorophyll fluorescence, leaf temperature,…) will be measured to assess drought stress response of cassava varieties with different fertilizer applications.

The developed models will both improve future drought stress experiments with cassava and provide the possibility to assess biomass-based water use efficiency on a weekly basis. The latter is very important as biomass-based water use efficiency can now only be determined at harvest. The greenhouse-based experiments are all helping to understand how cassava reacts under drought in a controlled environment. A next step planned for 2021 will be to validate the results in the fields.

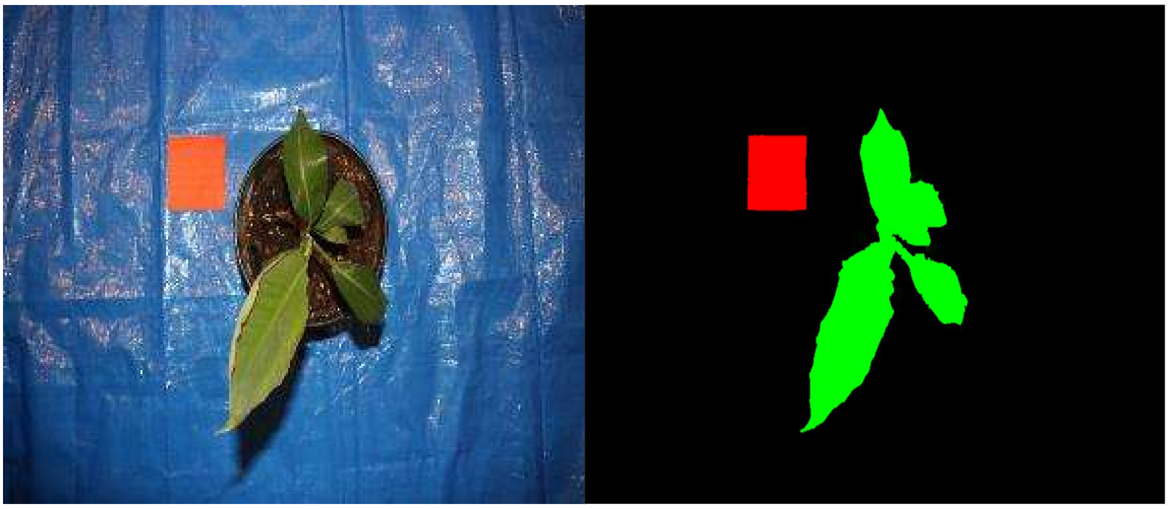

Figure 3. Example of how the biomass estimation works. A picture is taken (from above, and two sides), with a red reference surface. A script in R then divides the picture in red pixels (reference), green pixels (plant) and background pixels (black). The area of green pixels is then calculated by relating it to the area of the red reference surface

Influence of different nitrogen inhibitors on maize yield

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Nitrogen (N) fertilizer management is challenging due to the many factors that influence N use efficiency (NUE). Nitrogen losses from the soil reduce plant yield as well as have negative impacts on the environment. Nitrogen processes inhibitors, such as urease and nitrification inhibitors, are chemical compounds which reduce urea hydrolysis and nitrification respectively. Urease inhibitors (UI) (also known as 2-NPT or N-(2-nitrophenyl) phosphoric acid triamide) inhibit the hydrolytic action of the urease enzyme on urea, and nitrification inhibitors (NI) inhibit the biological oxidation of ammonium to nitrate. By coating ammonium based chemical fertilizers with N process inhibitors allows N to stay in a more stable form of ammonium (NH_4^+) thus minimising N losses as well as improving NUE and consequently enhancing crop yield. NI is further divided into MPA or N-[3(5)-methyl-1H-pyrazol-1-yl) methyl] acetamide (abbreviated as NI-1), and DMPP or 3,4-dimethylpyrazole phosphate (abbreviated as NI-2).

A field experiment was established at the SWMCN laboratory in Seibersdorf, Austria to determine the effect of different N fertilizers coated with N process inhibitors on maize yield in summer 2020 (Fig. 1). The field site is characterised by a moderately shallow Chernozem soil with significant gravel content.

Three combinations of N fertilizer (urea or NPK) with N process inhibitors (UI and/or NI)) were tested and compared with a control treatment (without N fertilizer) and a urea application without any inhibitor. All treatments received 60 kg ha^{-1} P_2O_5 and 146 kg ha^{-1} K_2O. The amount of nitrogen added to each treatment receiving N fertilizer was 120 kg N ha^{-1}. The inhibitors used were (i) UI, (ii) NI-1, and (iii) NI-2. DMPP, a nitrification inhibitor, was used in combination with NPK fertilizer, as the fertilizer contains besides nitrate-N also ammonium-N.

A randomized complete block design with four replications was used in this study. Treatments were: T_1 (control treatment - without N fertilizer), T_2 (Urea only), T_3 (Urea + UI), T_4 (Urea + UI + NI-1), and T_5 (NPK + NI-2). Urea was applied through two split applications in the T_2 treatment (at 20 DAP and 34 DAP). In T_3, T_4, and T_5 treatments, N fertilizers were applied only once (at 20 DAP). Supplemental irrigation was only applied in the early stages of growth, to ensure that the crop could establish. Harvest was carried out at 98 days after planting (DAP), before full maturity. Hence yield is expressed as dry matter (DM).

Figure 1. Field experiment in Seibersdorf

The preliminary results are shown in Table 1. The yield data showed that different fertilizer treatments had a significant ($p \leq 0.01$) effect on maize yield (dry matter production). There was no significant difference between treatments 4 and 5, which had the highest yield. A second group, with intermediate yield, was formed by the treatments 2 and 3. As expected, the yield under the control treatment, with only phosphorus and potassium but without N application, was the lowest. Based on the preliminary results, it can be concluded that nitrogen process inhibitors play a significant role in improving maize yields. In particular, the comparison between T_2 and T_3 shows that the application of a urease inhibitor avoids the need for a split application of urea, which decreases labour costs. Adding NI-1 (under T_4) further increases the yield. Also, the package of NPK, a common choice by farmers in Austria, in combination with the nitrification inhibitor NI-2 showed equally good results as urea combined with two inhibitors. Further analyses are now being carried out to understand the effects of different inhibitors on soil ammonia (NH_3) emission losses. Finally, a cost-benefit analysis will be carried out.

Table 1. Effect of different nitrogen fertilizers on maize dry matter yield, including the results of a Tukey's test (DM yields with similar letter indicate that there is no significant difference between the yields); results are expressed as mean ± SD.

Treatment		Yield - DM (t/ha)
T_1	Control treatment (without nitrogen fertilizer)	6.5 ± 0.7 ^{c}
T_2	Urea (in two splits)	8.2 ± 0.9 ^{b}
T_3	Urea + UI (2-NPT)	9.3 ± 1.0 ^{b}
T_4	Urea + UI (2-NPT) + NI-1 (MPA)	11.0 ± 0.6 ^{a}
T_5	NPK + NI-2 (DMPP)	11.6 ± 0.6 ^{a}

* 2-NPT: N-(2-nitrophenyl) phosphoric acid triamide (UI)
* MPA: N-[3(5)-methyl-1H-pyrazol-1-yl) methyl] acetamide (NI-1)
* DMPP: 3,4-dimethylpyrazole phosphate (NI-2)

Influence of biochar on nitrous oxide and carbon dioxide emissions from vermicompost

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Vermicomposting is the process of using worms to transform organic waste into a nutrient-rich fertilizer. The end product is called vermicast, which is used as fertiliser or as a soil activator. There are many advantages of vermicomposting, such as the improvement of soil aeration, enrichment of the soil with beneficial micro-organisms, and increased water holding capacity, leading to better root growth and structure. All these positive effects are well documented. However, there are some studies suggesting that worms produce potent greenhouse gases (GHG), in particular nitrous oxide. Biochar (BC) addition to the studied soil-worm systems reduce the emissions [1].

Biochar is similar to charcoal, basically it is pyrolysed biomass, specifically produced to be added to soil, as a soil conditioner-carbon sequestration measure. It has been recognised that vermicomposting could play a significant role in the circular economy, particularly tackling food waste recycling in peri-urban areas, whilst creating green business opportunities.

To confidently advocate these novel systems, knowledge of the pollution swapping risks must be assessed. Therefore, a study was proposed to determine the influence of vermicompost on GHG emissions and the impact of adding biochar into the mix.

This incubation experiment was conducted in collaboration with a local industrial worm farmer (VERMIGRAND Naturprodukte GmbH, Absdorf) and the Institute of Soil Research, University of Natural Resources and Life Sciences (BOKU), Tulln and the Soil and Water Management and Crop Nutrition Laboratory of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Seibersdorf.

The aim of this research is to quantify the GHG emissions from the entire worm composting process and to assess the impact of the addition of BC to the vermicompost, particularly its impact on nitrous oxide (N_2O) and carbon dioxide (CO_2) emissions, in addition to determining the influence of the timing of the BC addition (whether added before or after the initial hot composting process).

In this study two stages of composting and different types of vermicompost will be compared: In the first stage GHG's will be measured from regular feedstock hot composted normally (Comp) and feedstock pre-treated with 5% (v/v) BC added prior to hot composting (BC-Comp). Following hot composting an additional treatment where BC is added after, or post hot composting will be created (Comp+BC). For the second stage equal quantities of worms will be added to the replicated treatments and the GHG's measured regularly throughout the compost maturation process.

The following measurements will be conducted: compost temperature, pH, and salinity, N_2O and CO_2 concentrations and their corresponding isotopes, using off-axis Integrated Cavity Output Spectroscopy (OA-ICOS) in continuous flow mode. Concurrently compost properties of total nitrogen, total soluble nitrogen, soluble organic nitrogen, soluble inorganic nitrogen, total carbon, total soluble carbon, soluble organic carbon and soluble inorganic carbon will be measured using a combination of standard colorimetric methods and elemental analysis, using Elemental Analyser linked to an Isotope Ratio Mass Spectrometer (EA-IRMS).

The comparison of data gained from Comp and BC-Comp treatment as well as from Comp and Comp+BC treatment will be used to quantify the influence of BC addition at different stages of the vermicomposting process. It is hypothesised that there will be differences in GHG emissions due to the interaction of both the micro and macro organisms with the BC, as well differences in nutrient concentrations due to different adsorption characteristics of the BC and the influence of the BC on the nutrient cycling in the system.

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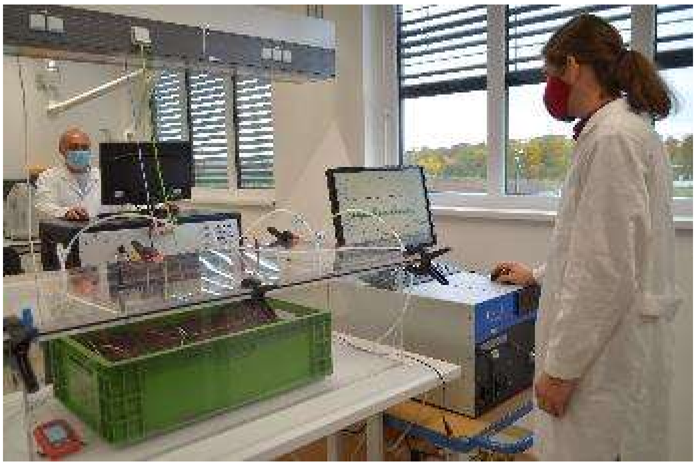

Figure 1. Measuring GHGs using isotope laser analyser (OA-ICOS)

Machine Learning-based Soil Property Prediction for Remediation of Radioactive Contamination in Agriculture

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The Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture launched a new Coordinated Research Project (D1.50.19) called “Monitoring and Predicting Radionuclide Uptake and Dynamics for Optimizing Remediation of Radioactive Contamination in Agriculture", in October 2019. Within the CRP, the high-throughput characterization of soil properties and the estimation of soil-to-plant transfer factors of radionuclides are of critical importance.

As already highlighted in Soils Newsletter Vol. 43, No. 1, July 2020**,** for several decades, soil researchers have been successfully using near and mid-infrared spectroscopy (MIRS) techniques to estimate a wide range of soil properties (Carbon, Nitrogen, CEC, Clay, Sand, pH, ...). In recent years, soil science researchers are increasingly shifting their focus from traditional modeling techniques such as PLSR (Partial Least Squares Regression) to new classes of algorithms, such as Ensemble Learning (Random Forest, Boosting, …) or Deep Learning (Convolutional Neural Networks), that have proven to outperform PLSR on most (if not all) soil properties prediction in a large data regime.

Indeed, till recently, only small (~100 samples) and region-specific MIR spectra libraries of soils were accessible. It is now realistic to envision a global MIR spectral library to characterize the world’s soils, thanks to the United States Department of Agriculture - Natural Resources Conservation Services (USDA-NRCS), which is maintaining a large and growing library (KSSL library) of MIR-scanned soil samples (~80K as of today), and the FAO GLOSOLAN – Soil Spectroscopy Workgroup (see: http://www.fao.org/global-soil-partnership/glosolan

In 2020, the SWMCN Laboratory obtained from the USDA-NRCS the KSSL database and reproduced the state-of-the-art modeling and cutting-edges MIR modeling techniques using advanced Machine Learning techniques.

Among the many interesting outcomes, these new classes of algorithms trained on the KSSL large database (all soil taxonomic orders included ~ 50K samples) make it possible to reach a quality of prediction for potassium so far unsurpassed with a Residual Prediction Deviation (RPD) around 3. Potassium is known for its difficulty of being predictable (RPD~1.5 on small and local datasets) but remains extremely important for the remediation of radioactive contamination after a nuclear accident. Potassium can help reduce the uptake of radiocaesium by crops, as it competes with radiocaesium in soil-to-plant transfer.

As part of our research agenda, thanks to these new MIRS-soils library and types of prediction algorithms, we aim to further address the challenges of predicting soil properties relevant to remediation and in particular: (i) Evaluate the performance of prediction algorithms in a simpler classification setup (e.g. low, middle, high levels) as this would already considerably inform decision making and (ii) Improve the interpretability of models developed by explaining individual predictions using methods such as Shapley Additive exPlanations (SHAP) values (i.e. how much specific MIRS wavenumber regions contribute to the prediction) - Fig 1.

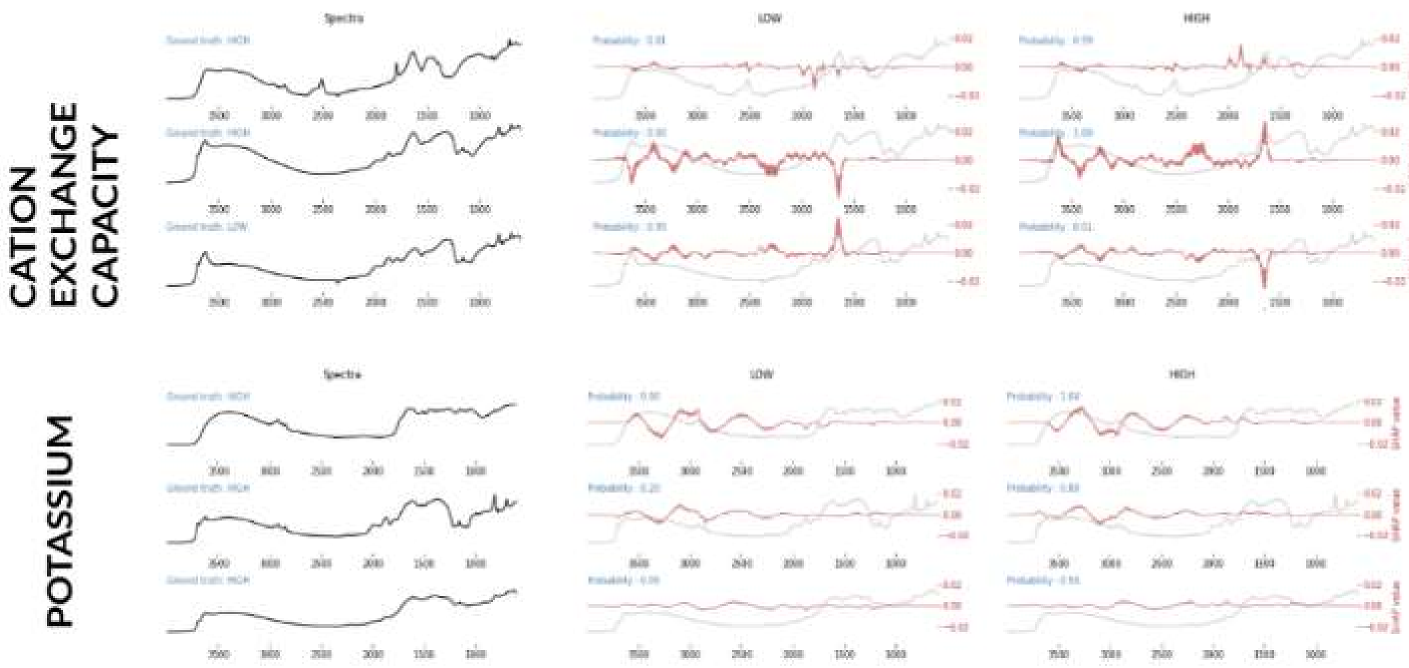

Figure 1. Explaining CEC and Potassium MIRS predictions using Shapley Additive exPlanations (SHAP) values

SWMCNL is now a member of the GLOSOLAN network, which helps enhance the usability of MIRS for soil monitoring worldwide. SWMCNL is further developing training packages on the use of traditional and advanced mathematical techniques to process MIRS data for predicting soil properties. This training package has been tested in October 2020 with thirteen staff members of the FAO/IAEA Laboratories in Seibersdorf, Austria.

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

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In the aftermath of a nuclear emergency, the development of remediation strategies for agricultural areas is crucial to ensure food safety within the affected regions. One of the key radionuclides that poses a concern for food safety is radiocaesium (RCs).

With the purpose to develop strategies to support remediation of radioactive contamination in agriculture, the SWMCNL aims to improve models predicting soil-to-plant transfer of radionuclides. This research activity is implemented under the Coordinated Research Project D1.50.19 on monitoring and predicting radionuclide uptake and dynamics for optimizing remediation of radioactive contamination in agriculture, launched in 2019.

Currently, potassium (K) fertilisation is being applied at increasing rates in the Fukushima Prefecture to further reduce the uptake of RCs by plant roots (Figure 1). Besides, zeolite minerals, which are economically affordable and progressively release K to the soil solution, were applied to decrease soil solution caesium (Figure 1), following topsoil removal. However, until present, there is some uncertainty on the specific role of zeolites in the uptake of RCs in Japanese soils.

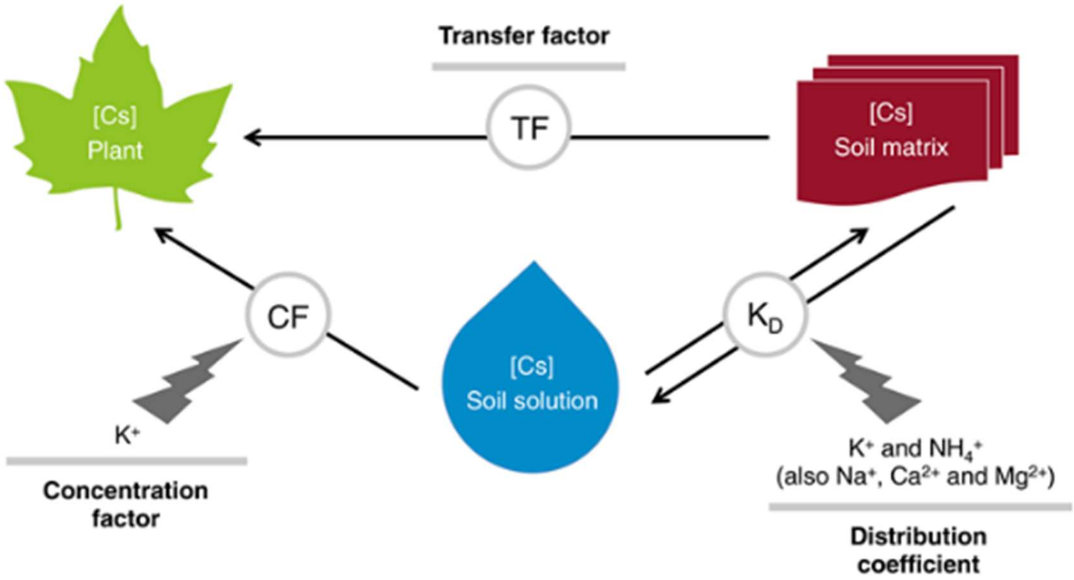
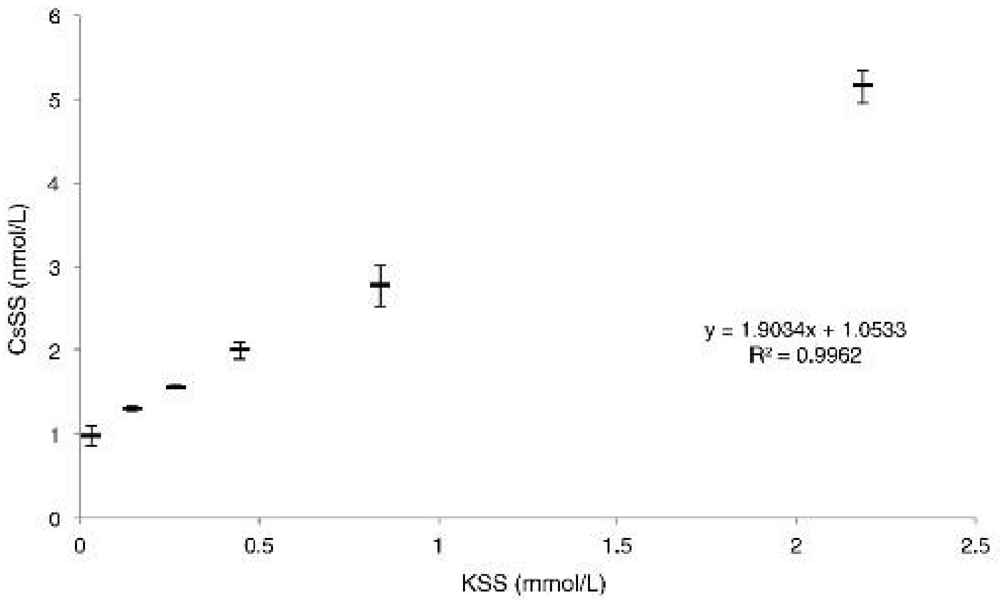


Figure 1. Relation between the distribution coefficient (KD), the transfer factor (TF) and the concentration factor (CF) in plant tissues and both soil solid and solution. Key cations affecting each parameter are shown below each parameter (Dengra i Grau et al., unpublished).

In this study we analysed the RCs behaviour in Japanese soils with major clay mineralogy differences: (i) a Cambisol rich in vermiculite that was chosen because of its ability to strongly retain monovalent cations such as potassium (K) and caesium (Cs); (ii) an Andosol with very low 2:1 phyllosilicate content which showed low K and Cs affinity; and (iii) a lowland smectitic Gleysol with high clay content and water holding capacity. We treated the Andosols with increasing doses of zeolites (cation exchange capacity of 130-180 meq.100g^{-1}) and all soils were also fertilised with K, at different levels, and further incubated. K and stable caesium (Cs-133) were analysed in soil solution and solid phase.

We presented intermediate results on K and Cs fixation capacities for each soil already in the previous newsletter. The final results provide evidence that zeolite addition diminished the soil solution caesium levels (Cs_{SS}), but also the K levels in the soil solution (K_{ss}) in allophanic Andosols (Figure 2). The K and Cs selectivity of the soil increased by zeolite addition, and further K_{SS}, a key parameter in the uptake of RCs, consequently decreased.



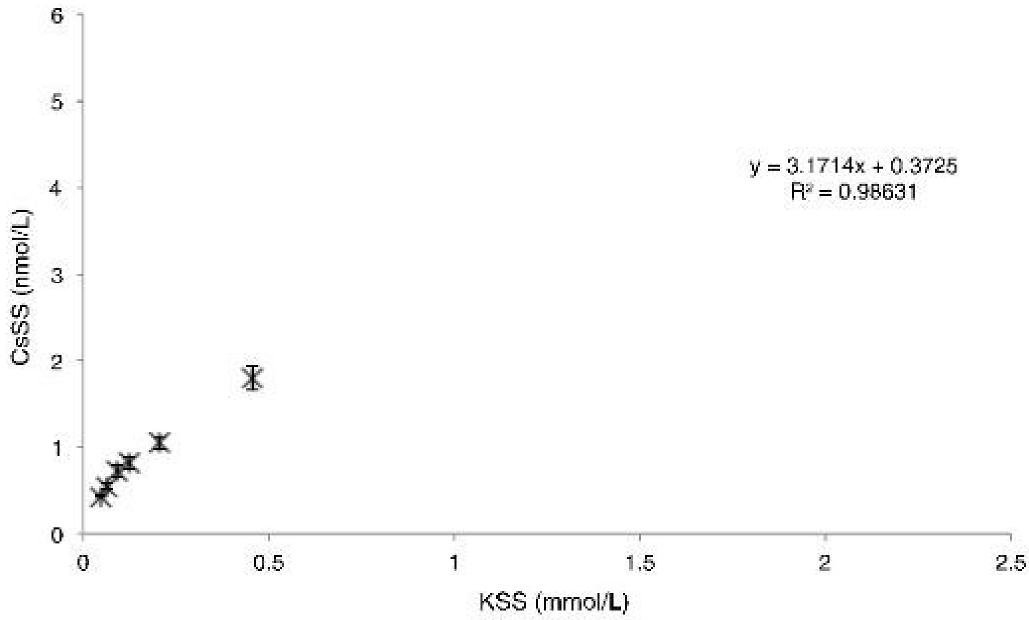


Figure 2. Caesium-133 in soil solution (Cs_{SS}) in relationship to the potassium concentration in soil solution (K_{SS}) for allophanic Andosol without zeolite (top) and allophanic Andosol with zeolite amendment at 4 kg·m^{-2} (bottom) (Dengra i Grau et al., unpublished).

A crucial finding is that the effectiveness of K fertiliser use to reduce RCs uptake was diminished by zeolite application. Zeolite application reduced predicted TF when K fertilizer was not applied (K target level of 0 in Figure 3). However, when K fertilizer was applied, higher TF can be expected in soils with zeolite (K target levels of 100 to 500 in Figure 3). So, it could be concluded that the effectiveness of zeolite application relies on its K depletion and on the soil K status to release this cation to the soil solution or to rather adsorb it in its outer surface.

These novel findings will be published soon and are already being considered in the Fukushima Prefecture, given its practical importance in the field. Our new insights will allow increasing accuracy in the fertiliser recommendations for farmers and to develop new actions to remediate radioactively polluted soils. Our next step is to enlarge datasets with other samples to keep improving the quality in prediction models for different soils from across the world.

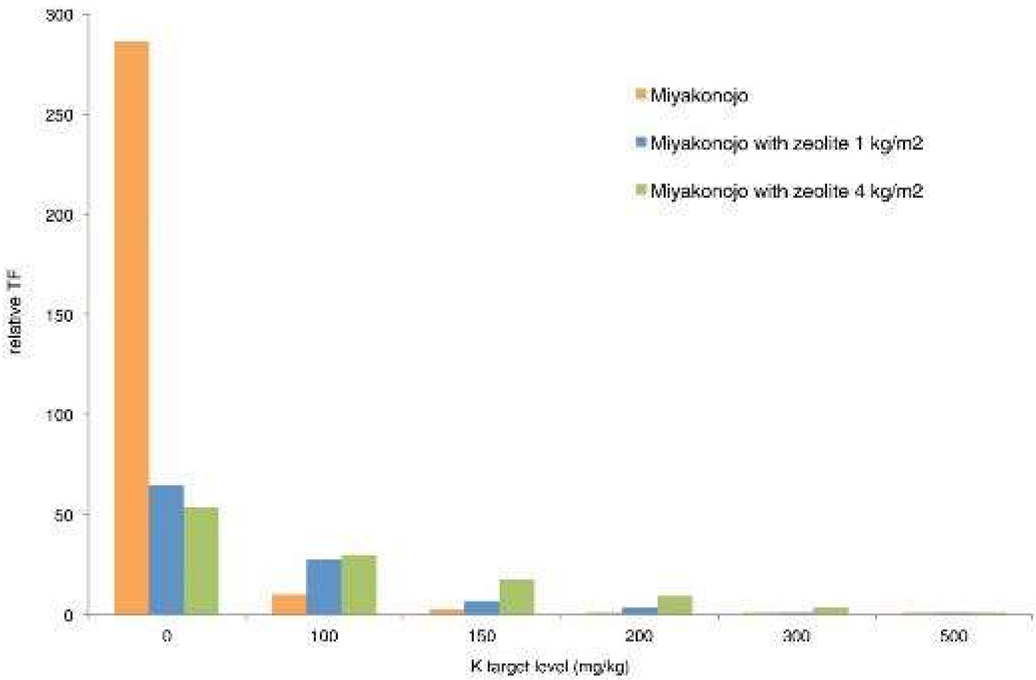


Figure 3. Expected increase in transfer factor (TF), relative to TF of soil with K target level of 200 mg K_2O·kg^{-1} (without zeolite application, value is 1), for one Andosol with and without zeolite

DSS4NAFA - New Developments

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Under the CRP D1.50.19 focusing on the optimization of remediation of radioactive contaminated agricultural land, one important objective is to update the existing decision support system DSS4NAFA to support data management during remediation activities in the aftermath of a nuclear emergency affecting food and agriculture. During remediation, the need exists for keeping an overview of the remediation activities and, in particular, where, when and how these activities are carried out. Further, it is imperative to keep track of the efficiency and effectiveness of remediation activities (e.g. reduction of soil and food contamination). At this moment the workflow for the remediation module is being developed in close collaboration with the CRP D1.50.19 research partners from across the world for addressing the above-mentioned needs for enhanced data management during remediation.

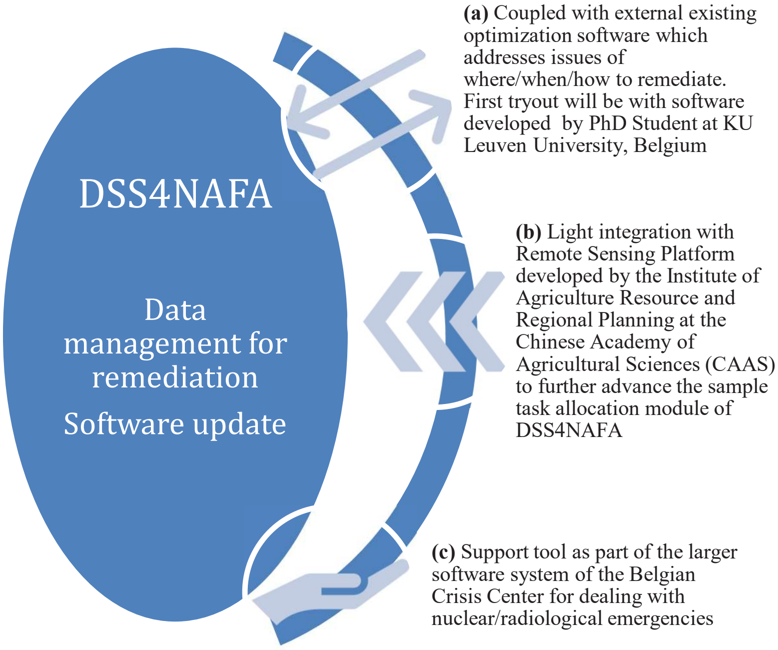

Figure 4. Envisioned activities to enhance and further develop DSS4NAFA, in particular for improving sampling task assignments and the follow-up of remediation intervention in case of radioactive

Further, as shown in Figure 1a, DSS4NAFA will be coupled with external modelling tools that help with the specific decision of where/when/how to remediate and will be based on expert judgments and multiple stakeholders' preferences (e.g. decision-makers, farmers). The principles of modularity and complementarity are at the heart of DSS4NAFA design choices. As a consequence, this new tool, heavily involving various mathematical optimization techniques and other methods is being developed as a new external module of the DSS4NAFA ecosystem. This tool is being developed by the Belgian Nuclear Research Centre in collaboration with the University of Leuven (Belgium).

A further activity related to DSS4NAFA is based on a new collaboration with the Chinese Academy of Agricultural Sciences (CAAS) (Figure 1b). Through assistance provided by the Chinese Institute for Agriculture Resource and Regional Planning at the CAAS, a remote sensing platform is being developed for identifying parcels with specific crop types. The main focus of this development is to assess the integration of large scale land use maps into DSS4NAFA to further optimize food and soil sampling during a nuclear emergency response. Possibilities of enhancing the currently existing advanced sample and task allocation (ASTA) module in DSS4NAFA are tested, to be further implemented under the CRP D1.50.19.

Finally, software packages in the core of DSS4NAFA are actively maintained, and each interested Member State is further welcomed to try out DSS4NAFA. Currently, DSS4NAFA has been adapted for the Belgian situation (through the PUI project on Global Networking for Improved Radiological and Nuclear Emergency Preparedness and Response in Food and Agriculture). In order to meet the Belgian needs, some developments had to be done to provide interoperability between the different applications used for the emergency preparedness and response in Belgium as well as to propose a user-friendly interface for the field extension of DSS4NAFA.

Optimizing remediation decisions in response to large-scale nuclear emergencies affecting food and agriculture

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A nuclear incident affects large territories through the deposition of radionuclides. This contamination can lead to long-term consequences for people and the economy. The subsequent data collection, data management and decision-making can become overwhelming with traditional methods, which inevitably increases the response time and effectiveness. A decision support system can aid with the efficient allocation of resources as well as the increase in transparency and robustness of the decision-making process. DSS4NAFA, a decision support system (DSS) jointly developed by the FAO and IAEA, can be used to manage and visualize this spatial data in real time. This research proposes a multi-criteria decision aiding system to optimize the remediation actions on a parcel basis, monitored by DSS4NAFA.

The optimal agricultural decontamination strategy starts with the localization of the most urgent clean-up sites. Thereafter, the most applicable remediation action should be performed on the identified prioritized parcels and finally the optimal combination of remedial actions in time is proposed.

To answer this first question - Where to act first? – The importance of an agricultural parcel is determined by a set of region-specific criteria and the corresponding decision makers (DM) preferences. The determination and importance of the criteria is completely dependent on the scale and stakeholders involved, it can range from a single farmer to an agricultural region with a multitude of decision makers.

The proposed tool ranks all agricultural parcels, from high to low priority based on the criteria shown in Table 1. All these criteria are found to be of equal weights as seen in table 1.

Table 1. The criteria used to visualise the importance for remediation of each field in the area of interest. The criteria weights can be changed in real-time to reflect the decisions maker preference.

Criteria	**Weight**	**Description**	**Unit**
^{137}Cs mobility in soil	0.25	Mobility of ^{137}Cs is dependent on the soil texture. The soil texture is determined from the soil map of the region. Unit:	[texture class]
^{137}Cs contamination level	0.25	The concentration of ^{137}Cs in the root zone of the agricultural parcel is determined from a soil sample.	[Bq/kg]
Radiological exposure from ingestion	0.25	Radiological exposure from ingestion of locally produced food. It is assumed that the food grown on contaminated parcels is consumed by the local population.	µSv
Parcel economic value	0.25	Economic value is based on the yield and the local market price of the crop. $Economic\ value = Parcel\ Yield \left[\frac{tons}{ha}\right] * Value \left[\frac{€}{\text{tons}}\right]$	$\frac{€}{\text{ha}}$

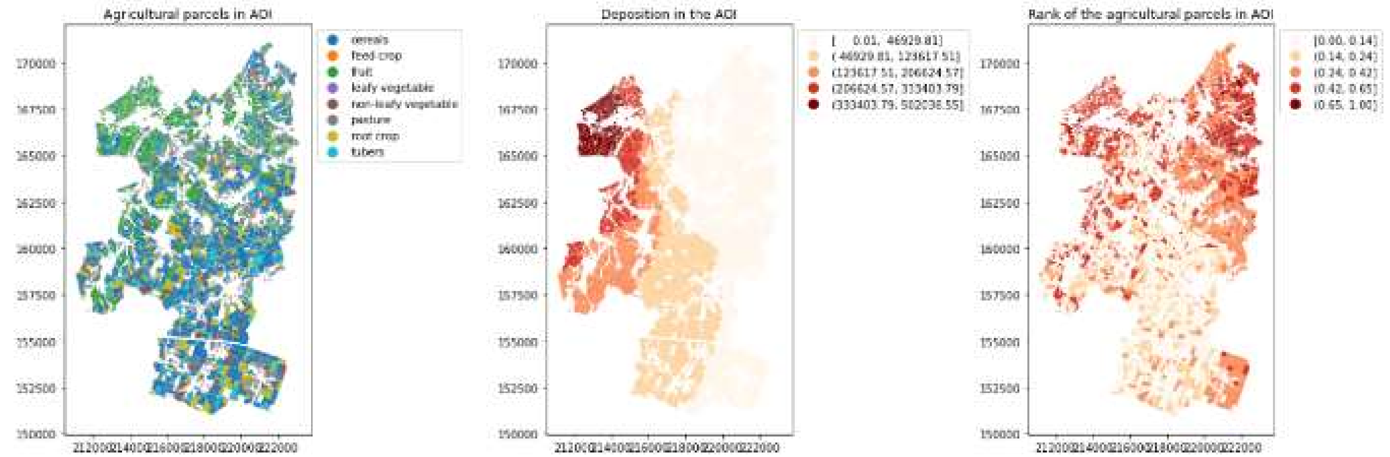

Figure 5. User interface of the optimization tool. The window shows the agricultural fields (Left), The ranking based on deposition (Middle) and the ranking based on MCDM (Right).

The tool output can be seen in Figure 1. The area of interest (AOI) consists of different agricultural parcels with varying soil conditions, crop type and contamination level. Multiple ranking algorithms have been used for ranking purposes (e.g. MAVT, AHP, TOPSIS, ELECTRE, PROMETHEE). The TOPSIS ranking algorithm is used below to determine the most urgent parcels, based on the mentioned criteria and DM preferences (Table 1).

We can see that remediation priorities change, when a multi-criteria approach is used. A remediation priority solely based on ^{137}Cs contamination levels (per parcel) would result in a sub-optimal ranking of parcels.

As part of the CRP D1.50.19 on remediation of radioactive contaminated agricultural land, a collaboration between members is set up to create a case study for optimizing the remediation of contaminated fields from the Chernobyl NPP accident. Based on the local spatio-temporal data, the dietary requirements and criteria preferences of the local population, a prioritization exercise can be established. In the proposed case study we want to provide an interactive visualization tool of decontamination priorities in the region, based on the preferred criteria of the decision makers.

A new format for virtual training courses in times of COVID-19

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Due to the COVID-19 outbreak, several planned training missions to the Himalayan and Andes region on the use of cosmic-ray neutron sensor technology were changed to a novel online teaching format, as part of the interregional project INT5156 on Building Capacity and Generating Evidence for Climate Change Impacts on Soil, Sediments and Water Resources in Mountainous Regions. In total 15 scientists from Bolivia, Chile, Peru and Ecuador participated on 17-19 August 2020 (Figure 1), and 25 scientists from China, Nepal, Pakistan and Afghanistan participated on 13-15 October 2020 (Figure 2). They learned how to install, calibrate and use the innovative cosmic-ray neutron sensor technology for better managing water resources in highlands.

To accomplish these online courses, Professor Trenton Franz from the University of Nebraska-Lincoln developed standard lectures, including training videos, and then used a flipped classroom format, meaning that all lectures and activities were prerecorded. The participants were then asked to watch the lecture and training videos ahead of the planned course activities. This way the participants could watch the material at their leisure or multiple times for increased comprehension. In addition, English Closed Captioning was provided to help overcome any language barriers. During the planned course times the participants received a quick summary of the lectures and activities, followed by more interactive discussion and active learning periods. The discussion periods for each day were limited to 2-3 hours to eliminate “zoom fatigue”. Finally, all discussion periods were recorded and made available to the participants after the training course. Course surveys indicated that the format was highly effective and enjoyed by the participants despite the challenging circumstances. Future work is planned to revise and expand the course content to be used by other Member States interested in the Cosmic-Ray Neutron Sensor technique for soil moisture and snow observations. The online training material will be a valuable resource during the pandemic as well as in future projects where international travel may be minimized. The experience gained during the development of this material will also be useful for future virtual training courses on other topics organized by the SWMCN Subprogramme.

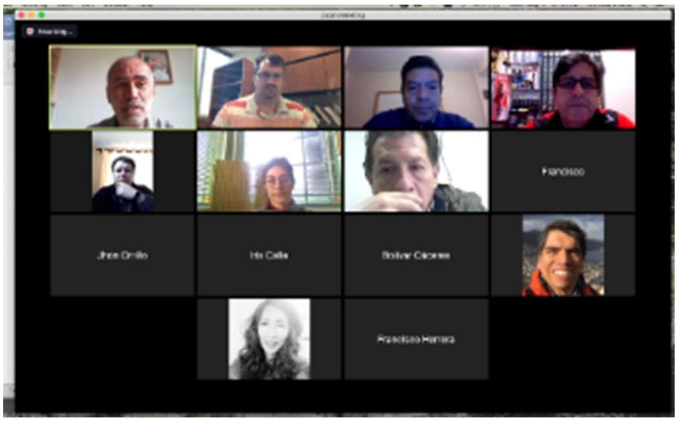

Figure 1. Zoom training for Andes Region.

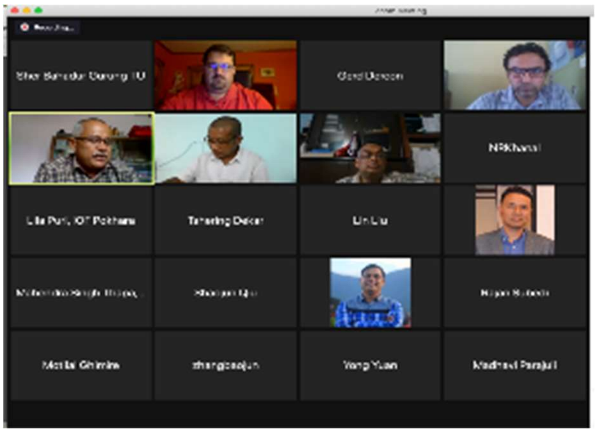

Figure 2. Zoom training for Himalayan Region

Training FAO/IAEA staff on Mathematical Processing of Mid-Infrared Spectral Datasets

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> *"This workshop gave me a clear and precise view on how mathematical processing and machine learning can help us in our research activities. Before attending this workshop, machine learning, deep learning seemed to me a complex and very difficult topic, although I knew that it was great tool for my research activities."*
>
> *Hami Said Ahmed, SWMCNL*

Our yearly Joint FAO/IAEA Division staff training at Seibersdorf, funded by the FAO Headquarters in Rome, was organized from 12-16 October 2020 by the SWMCNL. This time the staff training was about the theoretical and practical principles of mathematical processing of (mid-infrared) spectral datasets for the prediction of characteristics of soils, plants, food or insects. The focus of the training was on the use of traditional partial least squares regression and advanced machine learning approaches, with case studies in Python or similar open-source data analysis toolboxes.

During this training, case studies focusing mainly on the prediction of soil properties through Mid-Infrared Spectroscopy, were used due to an unprecedented large amount of data now available in this field, thanks to the SWMCNL's collaboration with the FAO Global Soil Laboratory Network (GLOSOLAN) and the Kellogg Soil Survey Laboratory (KSSL) of the United States

Department of Agriculture (USDA). However, the mathematical principles explained in the workshop can be used in the different fields of the Joint FAO/IAEA Division. The participants from four out of five Joint FAO/IAEA laboratories based at Seibersdorf presented how they can apply infrared spectroscopy for verifying food authenticity, analysing plant or soil properties, or identifying whether tsetse flies are male or female (Figure 1).

Further, personalized technical advice on spectral data analysis was given after the workshop, upon request (based on Python or similar software packages).

In total 14 FAO/IAEA staff members participated in the training, which is less than the previous years, as the organizers considered the IAEA guidelines for meetings in times of COVID-19.

Figure 1. Course participants visiting the FAO/IAEA laboratories for better understanding of infrared spectroscopy applications in our laboratories at Seibersdorf

The lecturer was Mr Franck Albinet, who has been providing his expertise to a wide range of United Nations agencies on the design, development and deployment of decision support systems for emergency responses, since 2005. His field of expertise also covers geospatial data science and machine learning applied, in particular, to complex environmental datasets for instance related to food safety and soil remediation.

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

Resch, C.

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

The 2020 Proficiency Test (PT) on ^{15}N and ^{13}C isotopic abundance in plant materials, organized by the University of Wageningen, the Netherlands, and funded by the SWMCN Laboratory has been successfully completed. The Wageningen Evaluating Programs for Analytical Laboratories (WEPAL, http://www.wepal.nl) is accredited for the organization of Inter-Laboratory Studies by the Dutch Accreditation Council.

Every year, one FAO/IAEA ^{15}N-enriched and three not ^{15}N-enriched test samples are included in one round of the WEPAL IPE (International Plant-Analytical Exchange) programme. A special evaluation report for IAEA participants on the analytical performance in stable isotope analysis is issued by the SWMCN Laboratory and sent to the participants together with a certificate of participation in addition to the regular WEPAL evaluation report. The participation fee for one round per year is covered by the IAEA.

In total seven stable isotope laboratories participated in the PT-round 2020: **Africa (1)**: Morocco, **Asia (1)**: Pakistan, **Europe (3)**: Austria, Belgium and France, **Latin America (1)**: Brazil and **South Pacific (1)**: New Zealand.

Due to the COVID-19 situation most laboratories were locked down for several months, therefore the deadline for reporting of results was extended. The laboratories, who were able to send the results before the new deadline, performed well regarding the C and N elementary analysis. However, as shown by the results below (Table 1), the ^{15}N and ^{13}C analyses were slightly below expectation, and less good than in other years. Nevertheless, it may be explained by the extended closure of the laboratories and the higher difficulty of isotope analysis. The lessons learned in these difficult times are of high importance to see what such extended closure may cause regarding the quality of isotope measurements.

Table 1. Number of results out of control limits

Sample	$\delta\ ^{15}N$	$\delta\ ^{13}C$	C-elementary	N-elementary	Number of reporting labs
203	0	0	0	0	7
235 (Enriched ^{15}N)	0	4	1	0	6
248	3	1	1	0	7
250	2	0	0	0	7

Analytical Services

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In 2020, 3141 samples were analysed for stable isotopes and 130 samples were measured for fallout radionuclides, respectively in the SWMCN Laboratory. Most analyses were carried out for supporting Research and Development activities at the SWMCNL focused on the design of affordable isotope and nuclear techniques to improve soil and water management in climate-smart agriculture.

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- Soil and Water Management and Crop Nutrition Section:
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- Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture:
  http://www-naweb.iaea.org/nafa/index.html
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  http://www.fao.org/about/en/
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  http://www.fao.org/ag/portal/ag-home/en/
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