Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Soils Newsletter

https://www.iaea.org/topics/land-and-water-management
http://www.fao.org/home/en
ISSN 1011-2650
Vol. 44 No. 2 Jan 2022

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To Our Readers

In IAEA's Spotlight session on 18 March 2021, Gerd Dercon and Lee Heng gave an overview of how nuclear and isotopic techniques are being used in agricultural water management through climate-smart agriculture. In the above photo, SWMCN Laboratory staff Hami Said Ahmed and Georg Weltin were busy setting up a field experiment on a cold and windy day.

As we go into 2022, it is time to review the work of the Subprogramme on Sustainable Land and Water Management in 2021 and to look ahead to the events and activities planned for 2022 and beyond.

Over the last six months, three Research Coordination meetings (RCMs) were held in online/virtual mode due to COVID-19. These included the second RCM of the Coordinated Research Project (CRP) on 'Enhancing agricultural resilience and water security using Cosmic-Ray Neutron Sensor' (CRP D12014), second RCM on 'Remediation of Radioactive Contaminated Agricultural Land' (CRP D15019), and the last RCM on 'Nuclear Techniques for a Better Understanding of the Impact of Climate Change on Soil Erosion in Upland Agro-Ecosystems' (CRP D15017).

In addition, the National Agriculture and Food Organisation (NARO) of Japan, together with the Joint FAO/IAEA Centre, held its second International Joint

Symposium on 'Remediation of Radioactive Contamination in Agriculture: Next Steps and Way Forward'. The NARO symposium showed how remediation can be further optimized through new experimental methods, modelling techniques and decision-support systems. Two RCMs are planned for 2022, including the third RCM on 'Multiple Isotope Fingerprints to Identify Sources and Transport of Agro-Contaminants' (CRP D15018) and the first RCM of the new project on 'Isotopic Techniques to Assess the Fate of Antimicrobials and Implications for Antimicrobial Resistance in Agricultural Systems' (CRP D15022). You can read more about the new CRP on antimicrobial resistance in this newsletter. A consultants' meeting (CM) on 'Microplastics in agricultural soils – the application of stable isotopes' is planned for January 2022 to plan for a future CRP.

However, the biggest event in 2022 will be the FAO/IAEA International Symposium on 'Managing Land and Water for Climate-Smart Agriculture', which will be held from 25-29 July 2022. We encourage you to submit your abstract before the deadline end of January 2022. More information about the symposium is given in the newsletter.

In addition, the Subprogramme will be implementing more than 65 Technical Cooperation (TC) projects with more than 20 new projects in 2022.

We present two very interesting feature articles in this issue of the newsletter. The article on 'Climate Change's Effects on Mountain Regions: Insights from FAO/IAEA Scientific Expeditions' was an interview with Prof. Edson Ramirez, a glaciologist at the San Andrés University in Bolivia, about the impacts of climate change on the Andean mountain region, and how nuclear and isotopic techniques could be used in assessing the impacts. The second article on 'Absolute and relative expressions of ^{15}N and ^{13}C abundance' brings us back to the basics on the correct definitions of stable isotope abundance in terms of 'absolute' or 'relative' values. The article draws attention to the deprecated and non-standard usage of absolute and relative units of stable isotope abundance, and to highlight the consequences of non-compliance.

The Soil and Water Management and Crop Nutrition (SWMCN) Laboratory delivered many outputs as our research and development work continued. Due to space, only a few are mentioned here. The cosmic ray neutron sensor (CRNS) work continued to make good progress with the development of a near-real-time Web GIS tool for drought monitoring in combination with remote sensing data and estimating soil hydraulic properties in combination with the HYDRUS-1D model. In addition, a good overview article on microplastics – an emerging global change factor – is presented in this newsletter. The SWMCN Laboratory will be embarking on this important topic, studying the biogeochemical role of microplastics coming from biodegradable plastics in soils, measuring the carbon isotopic composition and concentrations of carbon dioxide (CO_2) and methane (CH_4) using a newly procured laser isotope analyser.

Good progress is also being made in the project of the IAEA Peaceful Uses Initiative (PUI) on 'Enhancing Climate Change Adaptation and Disease Resilience in Banana-Coffee Cropping Systems in East Africa', with the first journal publication of this work on new stable isotope techniques for assessing drought in banana plants. Also, the extrabudgetary 'Consortium for Improving Agriculture-based Livelihoods in Central Africa' (CIALCA) project on improving climate change resilience of cassava in Central Africa developed the first ever AquaCrop Cassava model using data from Africa and Latin America. Further work was implemented looking at the influence of ammonium fertilization and clay mineral amendments on caesium dynamics in European and Japanese soils. An interesting work was also carried out to understand the interaction between maize water use efficiency and nutrient uptake in irrigated cropping systems to predict and improve Zambia's crop productivity.

Several new interns and two new PhD students started in the SWMCN Laboratory and Section in the last few months. We welcome Prof. Jan Diels from KU Leuven University who is doing a six-month sabbatical at the SWMCN Laboratory. We also welcome Ms. Mumba Mwape from Zambia, Ms. Megan Asanza from the Philippines, Ms. Eline Beelen from Belgium, Ms. Abhishri Gupta from India, Ms. Maria Alejandra Martinez Maya from Colombia, and Ms. Janice Nakamya from Uganda. We wish them a good stay with us and hope their internship or PhD studies will provide them with the practical working experience to pursue their future careers. We bid goodbye to Mr. Norbert Jagoditsch who retired in September 2021 after 31 years of service to the SWMCN Laboratory. We wish him well in his retirement and thanking him for his contributions to the Laboratory.

Finally, I would like to take this opportunity to thank all our readers for their continuous support. Best wishes for a great year ahead!

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Staff News

Norbert Jagoditsch (Austria) retired in September 2021 after 31 years of service to the SWMCN laboratory. He assisted in greenhouse and field experiments of laboratory staff, prepared plant and soil samples for isotope and chemical analyses and maintained field and laboratory equipment and supplies. On behalf of the Section and the Laboratory, we thank Norbert for his long and excellent service.We wish him well in his retirement!

Jan Diels (Belgium) joined the SWMCN laboratory as a cost-free expert in August 2021 for a period of six months as part of his sabbatical leave from KU Leuven University in Belgium. Prof Jan Diels works at the Department of Earth and Environmental Sciences. In Seibersdorf he will be conducting research on the Cosmic Ray Neutron Sensing (CRNS) for measuring soil moisture content and using the isotopic mass balance technique to separate plant transpiration and soil evaporation using ^{2}H and ^{18}O signatures of water, in combination with HYDRUS model to investigate the potential and limitations of both techniques.

Mumba Mwape (Zambia) joined the SWMCNL team in September 2021 as an ICTP/IAEA STEP fellow. She is currently doing a PhD degree at the University of Zambia, working on water and nitrogen use efficiency in irrigated maize based cropping systems. The STEP fellowship allows Mumba to visit the SWMCNL three times over a periof of three years, to conduct experiments and data interpretation on fertiliser use efficiency and water stress. Mumba is also employed as an Agriculture Research Officer in the Zambia Agriculture Research Institute (ZARI) of the Ministry of Agriculture of Zambia.

Megan Asanza (Philippines) joined the SWMCN Laboratory as an intern in August 2021 for a year, working on radiocaesium mobility, determining the solid/liquid distribution coefficient of potassium, ammonium, and Mid−Infrared Spectroscopy, contributing to the CRP D15019 on remediation of radioactive contaminated agricultural land. The internship will provide Megan to gain practical working experience. She has a bachelor's degree in Biology at the University of Vienna.

Eline Beelen (Belgium) joined the SWMCN Laboratory as an intern in August 2021 for three months. She has a bachelor's degree in Bio-engineering at the KU Leuven and is doing the internship as part of her masters thesis on enhancing climate change adaptation and disease resilience in banana-coffee cropping systems in East Africa, looking at the carbon and water dynamics in banana mats using ^{13}C pulse labelling in which mother banana plants are exposed to ^{13}C enriched CO_2, to unravel the translocation of C-assimilates between mother and daughter plants in optimal and sub-optimal watering conditions.

Abhishri Gupta (India) Gupta joined the SWMCN section as an intern in September 2021 for one year. She is an MSc graduate in Global Change: Ecosystem Science and Policy from University College Dublin, Ireland and Justus Liebig University, Germany. Her internship at the Section is to assist with the International Symposium on Managing Land and Water for Climate-Smart Agriculture to be held in July 2022. She will also be involved in preparing SOPs for GHG measurements, carbon budgeting to assess agricultural carbon footprints.

Maria Alejandra Martinez Maya (Colombia) joined the SWMCN Laboratory as an intern in November 2021 for six months. Currently, she is pursuing her master's degree in agricultural sciences at the National University of Colombia. Alejandra will conduct her thesis research on the CIALCA project, in close collaboration with CIAT. Her thesis research will contribute to the development of carbon-13 for water use efficiency in cassava cropping systems, using samples of from fields in Colombia.

Janice Nakamya (Uganda) joined the SWMCN Laboratory as a Ph.D. Consultant in December 2021 for three years at BOKU (University of Natural Resources and Life Science), Austria. She has a master's degree in Soil Science from Makerere University, Uganda. She is working on the PUI project on "Climate change adaptation and disease resilience in banana coffee production systems in East Africa", aiming at developing stable isotope techniques to monitor drought stress and water use efficiency in coffee production system for enhanced climate change resilience.

Feature Articles

Climate Change's Effects on Mountain Regions: Insights from FAO/IAEA Scientific Expeditions to the Andes

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Figure 1. Edson Ramirez measuring morphometric changes in rivers in basins with glacier coverage in Nevado Illampu, Cordillera Real (Bolivia). (Photo: Abraham Machaca)

Since the 1950s, almost all of the world's glaciers have been retreating, according to the latest report by the Intergovernmental Panel on Climate Change. This is unprecedented in at least the last 2 000 years, scientists say, and is very likely caused by human activities contributing to climate change.

Since 2014, the IAEA in cooperation with the Food and Agriculture Organization of the United Nations (FAO) has supported 50 scientists from 12 countries to use nuclear and isotopic techniques to survey mountain ranges of up to 6 000 m altitude on six continents and assess the impact of climate change on soil and water resources. Thanks to an international network of laboratories created to analyse and share the results of these surveys, the decisions makers have access to timely, and accurate information to help them develop tailored climate-change adaptation and mitigation strategies.

To find out more, we spoke to Edson Ramirez, a glaciologist at the San Andrés University in Bolivia and the coordinator of the FAO/IAEA's studies in the Andes. Here are his insights into what the studies have revelated about the status of this range of mountains spanning seven countries and home to 85 million people:

How has climate change been impacting the Andes?

The state of glaciers in the Andes was assessed in December 2019 by glaciologists from the UNESCO Snow and Ice Working Group of the International Hydrological Programme for Latin America and the Caribbean, through the Declaration on Glaciers and Climate Change (Portillo-Juncal, Chile). They expressed their concern about the evidence of strong glacial retreat, thinning and even extinction of glaciers in the region. The retreat of glaciers has become noticeable, with particular intensity in the last four decades, due to climate change. On average, the glaciers in the Andean region (Bolivia, Colombia, Ecuador and Peru) have lost over 50 per cent of their coverage since the 1960s. And in the last decade, the rates of retreat and loss of ice thickness have further increased, notably in the arid and semi-arid Andes of Argentina and Chile.

The IAEA project has led to a better understanding of the impact of climate change on the cryosphere (glaciers, permafrost and snow) and its effects on soil and water resources. Why is such an assessment important?

This assessment enables us to find out whether the impacts of climate change in high mountain ecosystems, such as glaciers, wetlands and others may affect the availability of water resources. In the Andes region, mountain water resources are used for human consumption, hydropower generation and irrigation. Therefore, water availability is key to food security and energy production. Practically half of the regional electricity comes from the hydroelectric potential of the Andean rivers. Hydroelectric power supplies about 70-80 per cent of electricity needs in Colombia, 50 per cent in Peru, and 45 and 40 per cent in Ecuador and Bolivia, respectively.

Figure 2. Flow measurements in high altitude wetlands in Apolobamba, Bolivia, 2016. (Photo: Edson Ramirez)

What are the key findings of the surveys, so far?

In Chile, Bolivia and Peru, scientists have helped to better understand the impact of climate change on land and water resources in the high Andes. Through three major field campaigns in the three countries, with participation of local and international scientists, more than 800 soil, sediment and ice samples were collected.

Nuclear techniques helped trace the origins and pathways of sediments and calculate the sedimentation rate in lakes, reservoirs and wetlands. New sediments become exposed after the ice of the glacier retreats. When these are transported by rainwater, they can invade waterways and pollute rivers and fish with heavy metals. They can also be deposited in wetlands and causing their drying, which may then become less suitable for capturing and buffering water, and at the same time they can become a source of greenhouse gas emissions. Downstream, when the ice melts, at first the water availability increases. The water then reduces as the stock of ice available decreases, reducing the amount of water discharged into the river. Reduced water quality and availability impact local populations, crop production, livestock and tourism.

Studies carried out by Brazilian scientists linked to the project have also made it possible to better understand the impact of Amazonian forest fires on the melting of glaciers in the Andes. As smoke plumes from forest fires reach the glacier, they darken its surface causing it to then absorb more of the sun's energy, and therefore amplify the melting. Modelling combined with *in situ* measurements showed that this phenomenon may contribute to approximately five per cent of the surface melting of the Zongo glacier in Bolivia.

Further, the surveys in field and laboratory using isotope techniques helped to identify types of soils, land use and cover being most critical for emitting greenhouse gases when temperature further increases.

How are nuclear and isotopic techniques used and what makes them unique in assessing the impact of climate change in mountainous regions?

Conventional techniques and methods, such as sediment redistribution measurement, are no longer sufficient to assess, at a fine level of detail, the impacts of climate change on soil and water resources in mountainous regions. Thus, the application of isotopic and nuclear techniques – highly reliable and precise tools – open a new window of possibilities to decipher subtle changes in the ecosystems we are studying.

Nuclear techniques based on the measurement of carbon-13, carbon-14 and nitrogen-15 isotopes were used to determine the age of soil's organic carbon content and its stability. When organic carbon is not stable, soil can release CO_2 more easily. Various experiments were conducted in laboratories, using soil samples from the different study sites with varying climates, land use and soils. By changing temperature and soil moisture regimes in the laboratory, the scientists try to find out how changing climate conditions would lead to an increase in greenhouse gas emissions as well as whether the old or young carbon would be a source for greenhouse gases.

Climate change also has an impact on sediment distribution. Scientists measured sedimentation rates in natural and artificial water bodies, to find out how great is the impact of climate change and as retreating of glaciers on sediment dynamics. Nuclear techniques use various radionuclides present in soil and sediments, to assess soil degradation and sediment redistribution at a different time scales.

Nuclear techniques were also used along with conventional techniques to date sediments and understand past and current changes in climate and the landscape. Understanding the past allows to better predict future trends.

How can the kind of information gathered on the expeditions support the development of climate change adaptation strategies for ecosystems and local populations?

We expect to offer new, accurate science-based evidence for decision makers to establish tailor-made regional policies for climate change adaptation and mitigation. The United Nations Environment Programme and FAO support the science–policy dialogue resulting from the findings. Decision makers are involved and local populations also expressed clear support to our work, which is encouraging for us.

Our data are useful for developing water resource management plans and managing watersheds. For example, controlling erosion in hydrographic basins (the areas of streams where precipitation drains off into rivers or other bodies of water) will reduce the production of sediments that can compromise the storage capacity of reservoirs supplying water for human consumption and hydropower production.

Figure 3. A child from Tuni village helping the preparation of samples for analysis during an expert mission in Bolivia (May 2017). (Photo: Edson Ramirez.)

Also, comparing "signatures" between the current and the accumulated sediment in proglacial lakes, which are freshwater lakes formed behind ice dams or the soil and rock material left behind by a moving glacier, offers a perspective over time of the changes that have occurred during the glacial retreat stages. This helps in developing possible future scenarios, for which watershed management plans can be established.

David Choquehuanca, the Vice-President of Bolivia, and Bernardo Gurarachi, the first Bolivian to reach the top of Mount Everest, both expressed their full support for our project, as it responds to the need to generate scientific evidence on the impacts of climate change on water resources. The results obtained will be used by government institutions such as the Ministry of the Environment and Water and the Authority of Mother Earth in Bolivia to develop policies for adaptation to climate change.

How can scientists globally use the results of this work and what are the next steps?

A sharing platform on the IAEA's Cyber Learning Platform for Network Education and Training makes data available to experts for evidence-based decision making. It enables researchers and laboratories from different countries to have organized and systematized data to carry out their studies at a global scale.

The current FAO/IAEA project running until 2023 involves more regional participants from research institutes and universities, more decision makers and more members of the local population.

We expect now to gain a better understanding of the role played by high altitude wetlands as regulators of water flow, thanks to the use of Cosmic Ray Neutron Sensors, a new technology that can measure the moisture content of the soil in a wide area continuously. We will also strengthen and extend the interregional network of laboratories and competent institutions for the evaluation and prediction of climate change impacts.

This article was published on the IAEA website on 2 November 2021, Climate Change's Effects on Mountain Regions: Insights from FAO/IAEA scientific expeditions to the Andes | IAEA.

Absolute and relative expressions of ^{15}N and ^{13}C abundance

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Background

Guidelines for measurement and reporting of stable isotope abundance have been published by the IUPAC, the International Union of Pure and Applied Chemistry *(Coplen, 2011)*. However, these guidelines based on SI principles are being generally ignored in publications in the agricultural and biological sciences. We are not the first to draw attention to a disconnection between the end-users of stable isotope analysis and its origins in analytical chemistry, and the ramifications of this discontinuity *(Bond, 2012, Coleman, 2014, Chalk, 2015)*.

An issue addressed by the IUPAC through its Commission on Isotopic Abundances and Atomic Weights (CIAAW) is the widespread usage of non-SI units in reporting isotopic data, which are termed 'deprecated' units. However, lack of SI-compliance now appears to be only one of two pending issues.

Stable isotope abundance is defined in terms of either 'absolute' or 'relative' values *(Coplen, 2011, Chalk, 1995)*. Standard practice is to use absolute values for isotopically-enriched samples, and to use relative values to quantify small isotopic variations in samples close to the natural abundance of the element, the so-called *d* notation. However, the use of the relative unit to quantify both ^{15}N and ^{13}C-enriched samples instead of the absolute unit is a trend in the literature that has become apparent during the past two decades, which contravenes accepted practice.

The purpose of this feature article is to draw attention to the deprecated and non-standard usage of absolute and relative units of stable isotope abundance, and to highlight the consequences of non-compliance.

IUPAC guidelines for expression of stable isotope measurements

Absolute isotopic abundance

Deprecated: *atom %*, the amount of an isotope of an element divided by the total amount of atoms expressed as a percentage, and *atom % excess*, the *atom %* in excess of the natural abundance of the isotope.

Recommended: *atom fraction* (x), the ratio of the amount of an isotope of an element divided by the total amount of atoms, and excess atom fraction (x^E), the atom fraction in excess of the natural abundance of the isotope.

Relative isotopic abundance

Deprecated: $d\,(^{i}\mathrm{E}) \times 1000$

Recommended: $d\,(^{i}\mathrm{E})$

where $d\,(^{i}\mathrm{E}) = \dfrac{^{i}R_{\mathrm{sample}} - \;^{i}R_{\mathrm{reference}}}{^{i}R_{\mathrm{reference}}}$

and i denotes the mass number of the heavy isotope of the element E. R is the ratio of the number of heavier atoms (e.g ^{15}N or ^{13}C) to the number of lighter atoms (i.e. ^{14}N or ^{12}C) and subscripts $_{\mathrm{sample}}$ and $_{\mathrm{reference}}$ denote a sample and an international reference material, respectively. The international reference material for C is V-PDB which has an R_{standard} of 0.01117960, while the international reference material for N is N_2 in air which has an R_{standard} of 1/272 = 0.00367647 *(Coplen, 1992, Brand, 2014).*

Relationships between absolute and relative values of isotopic abundance

The general formula linking the two expressions of isotopic abundance is given by Eq. 2 *(Coplen, 2011).*

$$x(^{i}\mathrm{E})_{\mathrm{sample}} = 1 / \{1 + [1 / (\delta\,^{i}\mathrm{E}_{\mathrm{sample}} + 1) \times R_{\mathrm{standard}}]\}$$

However, linearity is only observed for samples close to natural abundance *(Brand, 2012),* where the precision of measurement for ^{15}N and ^{13}C is of the order of ± 0.1 to 0.2 ‰. For ^{15}N samples close to natural abundance, a simplified relationship (Eq. 3) was developed *(Chalk, 2015).*

$$d^{15}\mathrm{N}\,/\,‰ = 2740 \times x^{E}(^{15}\mathrm{N})_{\mathrm{sample/air}}\,/\,\%$$

In the following Section, examples of isotopically enriched samples that were reported as deprecated $d\,^{i}\mathrm{E} \times 1000$ values are tabulated. We present an equivalent $x(^{i}\mathrm{E})$ value based on the relationship given in Eqs. 2 and 3, but recognise that such derived values are subject to gross errors due to the deviation from linearity.

Examples of non-standard usage of relative isotopic abundance

Examples of ^{15}N- and ^{13}C-enriched materials expressed in the relative delta notation are given in *Table 1*. These examples represent a range of biological materials including plant foliage and litter, biochar and the soil fauna. d^{15}N values ranged from 1,234 to 76,200 ‰, while d^{13}C values were within the range of 392 to 14,455 ‰. Such data represent an unintended usage of the d notation, the purpose of which was to provide a precise measurement of small variations in the isotopic abundance of samples close to the natural abundance of the element. The range of absolute values corresponding to these d values for ^{15}N and ^{13}C were atom fraction 0.82 to 28.2 %, and 1.54 to 14.8 %, respectively *(Table 1).*

Conclusions

Scientists engaged in research in the agricultural and biological sciences generally do not observe the IUPAC guidelines on reporting isotopic data. This phenomenon seems rooted in an historical context where 'old habits die hard'. Until journal editors become aware of the problem and insist on SI nomenclature, the use of deprecated units will likely continue.

The curious outcome of the IUPAC recommendations to reform the expressions of stable isotope abundance to comply with SI standards, is that very little seems to have changed in a practical sense. For example, while an absolute abundance of ^{13}C in sample P of 1.5 atom % is deprecated, it is allowable to express the ^{13}C fraction, $x(^{13}\mathrm{C})$, of sample P as 1.5 % *(Coplen, 2011).* Whereas the IUPAC may regard such distinctions as important, others in the biological and agricultural sciences may not share this view. Similarly, while the definition of relative abundance ($d\,^{i}\mathrm{E} \times 1000$) is deprecated, it is permitted to express $d\,^{i}\mathrm{E}$ (Eq. 1), a dimensionless quantity *(Brand, 2012)*, as parts per thousand or per mil (symbol ‰), because $d\,^{i}\mathrm{E}$ values are typically small numbers. However, this traditional solution is regarded as unsatisfactory, and a new unit, the *urey* (Ur), has been proposed as a solution to the perceived problem *(Brand, 2012).*

We noted many examples of inconsistencies in the literature where the amounts of enriched N or C isotopes applied in experiments were given in absolute units, whereas the experimental results were reported in relative units. We suggest that such divergence from standard practice may reflect a fundamental lack of understanding of the respective roles of isotopic enrichment vs. natural abundance as tracers. The underlying reasons are undoubtedly complex, but perhaps can be traced back to the absence of cross-disciplinary education in nuclear science at the tertiary level. We agree with the observation of Bond and Hobson *(Bond, 2012)* that such problems are bound to arise when the end-users have little or no direct interaction with the analytical side of isotope-ratio mass spectrometry, relying on fee-for-service laboratories. The outcome is a misguided acceptance of the metrics in which the results are delivered, together with an apparent lack of knowledge of the relationships between the two expressions of isotopic abundance.

Absolute values vary within the atom fraction range of 0 to 99 %, while relative values of unenriched samples vary within a rather narrow range of *d* around the International Standard of the element. However, when isotopically-enriched samples are expressed as $d\,^{i}E$ values, the range of *d* may extend from hundreds to thousands. By ignoring the accepted yardsticks of measurement, an unfamiliar element is introduced into the way in which enriched isotopic data are viewed. Absolute values within a simple, well-understood scale, are replaced by meaningless δ values having an apparent open-ended scale.

Isotope	Year	Material	$\delta\,^{i}E \times 1000$ / ‰[a]	$x(^{i}E)$ / %[b]	Reference
^{15}N	2003	*Piper* sp. foliage	1,250	0.82	(Fischer, et al., 2003)
	2004	Beech litter	1,234 – 2,580	0.82 – 1.31	(Caner, et al., 2004)
	2011	Worker ants	16,000	6.21	(Defossez, et al., 2011)
	2012	Fungal hyphae	1,700 – 2,300	0.99 – 1.21	(Blatrix, et al., 2012)
	2016	Bromeliad tissue	8,200 – 14,700	3.36 – 5.73	(Gonçalves, et al., 2016)
	2016	Predatory ants	36,700 – 76,200	13.8 – 28.2	(Gonçalves, et al., 2016)
	2017	Maize litter	53,300 – 54,800	19.8 – 20.4	(Scheifele, et al., 2017)
	2020	Sugarcane tops	5,360	2.33	(Weng, et al., 2020)
^{13}C	2011	Worker ants	2,500	3.78	(Defossez, et al., 2011)
	2014	Rice straw	1,745	2.99	(Yin, et al., 2014)
	2015	Big bluestem	3,045	4.35	(Soong, Kotrufo, 2015)
	2016	Rice straw biochar	571	1.74	(Wu et al., 2016)
	2016	Maize straw	1,910	3.17	(Kerre, 2016)
	2016	Rice straw	14,455	14.8	(Pan, et al., 2016)
	2020	Rice straw	392	1.54	(Wang, et al., 2021)

Table 1. Examples of deprecated d values and derived atom fractions of ^{15}N-and ^{13}C-enriched materials

[a]All values are positive; Values calibrated against international standards (N_2 in air for $\delta^{15}N$; V-PDB for $\delta^{13}C$) [b]Eq. 3 for ^{15}N; Eq. 2 for ^{13}C

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Announcements

New CRP
Isotopic Techniques to Assess the Fate of Antimicrobials and Implications for Antimicrobial Resistance in Agricultural Systems (D15022)

Adu-Gyamfi, J.[1] and Heng, L.[1]

[1]Soil and Water Management & Crop Nutrition (SWMCN) Section, Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture, International Atomic Energy Agency (IAEA), Vienna, Austria

The Soil and Water Management & Crop Nutrition Section has launched a new five-year (2021-2026) Coordinated Research Project (CRP), titled ‘Isotopic Techniques to Assess the Fate of Antimicrobials and Implications for Antimicrobial Resistance in Agricultural Systems (D15022). This CRP’s first Research Coordination Meeting is expected to take place on 25-29 July 2022, in Vienna, Austria.

Background

Antimicrobials (AM) are widely used in agriculture, livestock, poultry, fisheries, and animal husbandry. In agriculture, antibiotics are most commonly used to prevent and cure various diseases in crops, whereas, in livestock and animal husbandry, these are most commonly used as growth promoting agents, and in preventing/curing infections. Because most antibiotics are not completely metabolized in the bodies of humans and animals, a high percentage of administered drugs is discharged into water and soil through municipal wastewater, animal manure, sewage sludge, and biosolids. The extensive use of AM in the veterinary fields has led to great selective pressure for the development of antimicrobial-resistant bacteria (ARB) and the acquisition of transmissible antimicrobial resistance genes (ARGs). Agriculture accounts for over 75% of annual antimicrobial consumption in the EU and the US.

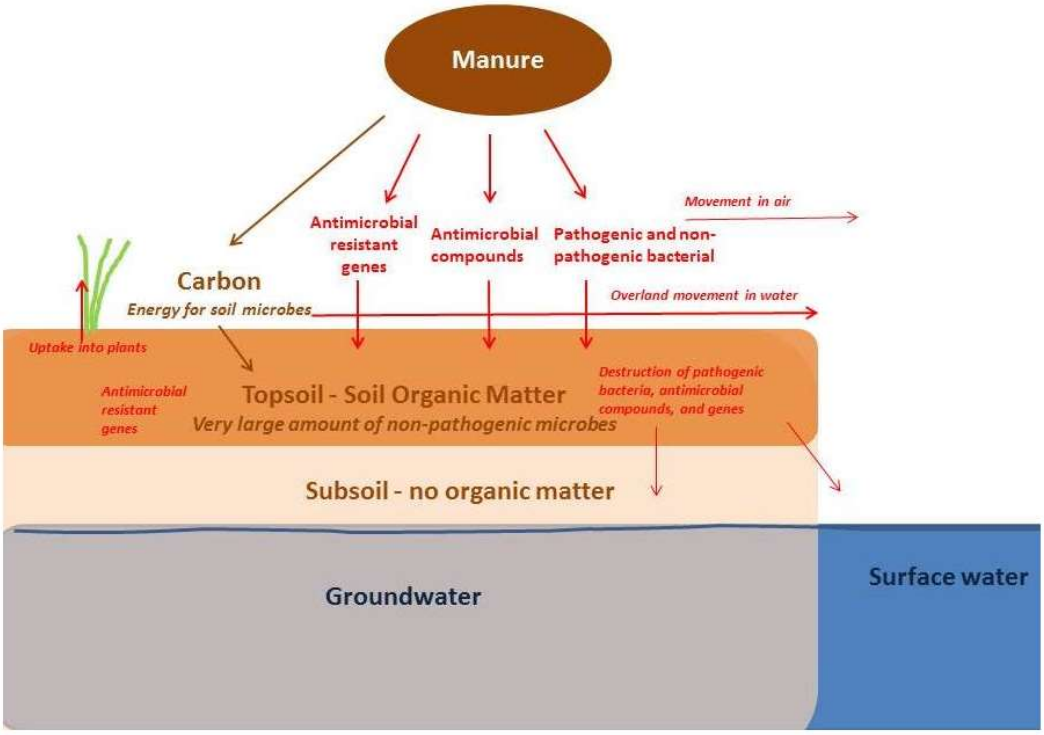

Figure 1. Pathway for antibiotics, antimicrobial resistance from manure to the environment and food chain

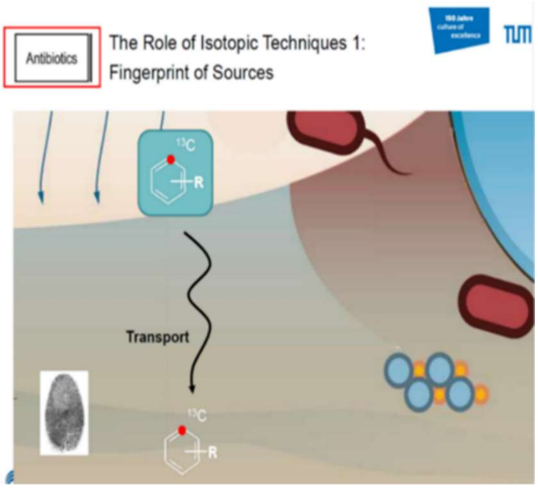

Figure 2. The role of isotopic techniques for fingerprinting the sources of antibiotics

While AMR has been widely studied from the view point of human and animal health, little is known about the impacts it has on the soil and water environment. The project proposes to use stable isotope-labelled AM to monitor their use and spread after agricultural applications, to assess the potential impact on the environment and initiate regional harmonization of nuclear analytical techniques through established networks. The need for such work is pressing because currently about 700,000 deaths/year worldwide is attributable to antimicrobial resistance (AMR) and is projected to increase to 10 million by 2050, and the spread of antimicrobial resistance (AMR) from soil and water, thereby having a potential impact on the food chain. A better understanding of how AM and AMR move from the source to the environment, and a cost-effective methodology for its detection and the management guidance to constrain the spread will help reduce the number of associated deaths related to AMR and evaluate their impact in the environment.

CRP Overall Objective:

To develop guidance for improving the understanding of the fate, dynamics and persistence of AM and AMR in agricultural systems based on nuclear and related techniques and support MS to develop common strategies to mitigate the spread of AM in agricultural systems.

Specific Research Objectives:

1.1. To develop, evaluate and standardize integrative isotopic and conventional approaches for tracing the sources and persistence of AM and AMR in agricultural systems

1.2 To apply isotopic and bioanalytical/molecular biological methods to different agricultural systems for assessing the fate and dynamics of AM and implications for AMR

1.3 To provide knowledge and guidance for informed decisions to help mitigate the spread of AM and AMR in agricultural systems

For further information related to this CRP: https://www.iaea.org/services/coordinated-research-activities/how-to-participate and https://www.iaea.org/projects/crp/d15022

Enhancing Climate Change Adaptation and Disease Resilience in Banana-Coffee Cropping Systems in East Africa

ELSEVIER

Agricultural Water Management
Volume 260, 1 February 2022, 107247

The potential of stable carbon isotope ratios and leaf temperature as proxies for drought stress in banana under field conditions

Mathilde Vantyghem [a, b, d], Roel Merckx [b], Bert Stevens [c], Rebecca Hood-Nowotny [d], Rony Swennen [b, e], Gerd Dercon [a]

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Highlights

- Large differences in $\delta^{13}C$ ratios and leaf temperature between drought stressed and optimally irrigated banana plants.
- $\delta^{13}C$ ratio and leaf temperature significantly correlated.
- Daughter plants less stressed than mother plants.
- Developed banana-tailored sampling approach for $\delta^{13}C$ analysis.
- Carbon allocation in banana proves to be complex and complicates interpretation of $\delta^{13}C$ ratio as a stress proxy.

Recommended articles

Development and application of a new package ...
Agricultural Water Management, Volume 260, 2022, Ar...
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After two years of research, the first results from the PUI (Peaceful Uses Initiative) project on Enhancing Climate Change Adaptation and Disease Resilience in Banana-Coffee Cropping Systems in East Africa (funded by the Belgian Government) have now been published in Agricultural Water Management. This journal, with current impact factor 4.5, publishes papers of international significance relating to the science, economics, and policy of agricultural water management.

In the paper, the authors investigate the use of stable carbon isotopes and leaf temperature as drought stress proxies for banana under field conditions. Both shown to have strong potential, being highly sensitive to changes in water availability. The paper further discusses the banana-tailored methods that were developed. These methods will enable a rapid development of climate-smart agricultural practices and varieties, thereby helping banana farmers cope with changing climate conditions. This is in accordance with the project goals, namely, to improve coffee and banana cropping systems for climate adaptation.

This paper is the first paper that describes in a comprehensive way the use of stable isotope techniques to assess drought stress in banana plants in the field.

https://www.sciencedirect.com/science/article/pii/S0378377421005242

International Symposium on Managing Land and Water for Climate-Smart Agriculture, 25-29 July 2022

The Soil and Water Management and Crop Nutrition Subprogramme will be organizing an 'International symposium on Managing Land and Water for Climate-Smart Agriculture', aiming to facilitate the exchange of information and knowledge among soil, water and environment professionals from developed and developing countries to advance the understanding, collaboration and capabilities to respond to the impact of climate change and rapidly changing global environment. It will also draw on lessons learnt, current status, with focus on new development of nuclear and isotopic techniques to enhance the resilience of livelihoods to threats and crises that impact agriculture and food security, such as emissions of greenhouse gases, climate change and nuclear or radiological emergencies.

The objective of the symposium is to provide information, share knowledge, review recent development and contributions of nuclear, isotopic and related techniques to improve land and water management practices, development of tools and technology packages to build soil resilience, adapting farming practices to the impact of climate change, as well as to nuclear or radiological emergencies. The objective is also to identify research needs, gaps and new opportunities to adapt to climate-smart agricultural practices.

The main topics of the symposium include

- Plant nutrition and nutrient cycling for enhancing crop productivity and on-farm ecosystem services
- Soil conservation, land management minimizing soil erosion, land degradation, improving soil health, increasing biodiversity and crop production.
- Agricultural water management for improving water use efficiency, threats/impact to agricultural water quality.
- Climate change and greenhouse gas emissions
- Tracing agricultural and industrial pollutants and assessing their threats to crop production and environmental sustainability.
- Advances of nuclear-based instrumental and analytical techniques applicable in soil and water research.
- Integrating nuclear techniques with other advanced techniques such as digital technology in agriculture, GIS, machine learning and modelling techniques.

You can get more information about the symposium, the scientific programme and submitting the abstract in the following link: https://conferences.iaea.org/event/270/

The abstract:

- should have a maximum of 500 - 600 words;
- should not include more than one or two figures, graphs or tables in two A4 pages;
- should be single spaced
- should only include a few pertinent references; and
- must be submitted through IAEA INDICO .

Deadlines & milestones (selection)

Abstract submission deadline: 31 January 2022
Grant application submission deadline: 28 February 2022

Technical Cooperation 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	O. Meniailo and E. Fulajtar
Azerbaijan	AZB5004	Strengthening Best Soil, Nutrient, and Water Agricultural Practices for Cotton Production	M. Zaman
Bangladesh	BGD5033	Using Nuclear Techniques in Assessing River Bank Erosion	E. Fulajtar
Belize	BZE5012	Use of Nuclear and Isotopic Techniques for Optimizing Soil-Water-Nutrient Management in Rainfed Agriculture Systems	J. Adu-Gyamfi
Bolivia	BOL0009	Strengthening National Capacities for the Development of Nuclear Technology Applications in Bolivia	M. Zaman
Bolivia	BOL5024	Strengthened National Capacities for the Identification of the Origin and Transport of Pesticides Compounds in Agricultural Watersheds	J. Adu-Gyamfi
Botswana	BOT5024	Improving Selected Legumes and Cereals against Biotic and Abiotic Stresses for Enhanced Food Production and Security	J.Adu-Gyamfi and PBG
Bulgaria	BUL5018	Improving Crop Water Productivity and Nutritional Quality of Orchards	J. Adu-Gyamfi
Burkina Faso	BKF5024	Improving Food Crops through Mutation Breeding and Best Soil and Nutrient Management to Ensure Food Security	J. Adu-Gyamfi and PBG
Burundi	BDI5005	Enhancing Productivity of Staple Crops Using Nuclear-derived Technologies	M. Zaman and PBG
Cambodia	KAM5008	Introducing a Digital Soil Information System and Remote Sensing for Sustainable Land Use Management	L. Heng
Central African Republic	CAF5014	Strengthening Capacity for Enhancing Cassava Production and Quality through Best Soil Nutrient Management Practices	M. Zaman
Chad	CHD5009	Developing Sustainable Water Resources Management through the Use of Nuclear Isotopic Techniques in Drip Irrigation Systems	L. Heng
Colombia	COL5026	Enhancing Crop Productivity of Creole Potato Using Nuclear and Related Techniques	M. Zaman and PBG
Congo Rep. of	PRC5003	Protecting Water and Fertility in Agricultural Soils	M. Zaman
Costa Rica	COS5035	Building Capacity for the Development of Climate-Smart Agriculture in Rice Farming	M. Zaman
Costa Rica	COS7006	Strengthening National Capacities to Identify Sources of Contamination that Affect Highly Vulnerable Aquifers Using Isotopic and Conventional Techniques	J. Adu-Gyamfi and IH
Cuba	CUB5024	Strengthening National Capacities for the Adaptation or Mitigation of the Negative Impacts of Climate Change and the Sustainable Management of Land and Water, Through the Integrated Use of Nuclear Techniques	E. Fulajtar
Egypt	EGY5027	Strengthening Capacities for Combating Soil Erosion and Restoring Soil Fertility to Support Sustainable Soil and Water Management Practices and Rehabilitation of Degraded Soils for Enhanced Production and Food Security	E. Fulajtar
Gabon	GAB5004	Improving Soil Fertility Management for Enhanced Maize, Soybean and Groundnut Production	J.Adu-Gyamfi
Ghana	GHA5039	Mainstreaming Nuclear Based Climate Smart Agriculture Technologies into Sustainable Production	J. Adu-Gyamfi and PBG
Haiti	HAI5008	Strengthening National Capacities for Enhanced Agricultural Crop Productivity	J.Adu-Gyamfi

Honduras	HON5011	Implementation of Soil, Water and Nutrient Management for Sustainable Coffee Production in Honduras using Nuclear Technologies	E. Fulajtar
Indonesia	INS5044	Using Nuclear Technology to Support the National Food Security Programme	L. Heng and PBG
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	L. Heng, 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
Lao PDR	LAO5006	Enhancing Crop Production with Climate Smart Agricultural Practices and Improved Crop Varieties	M. Zaman and PBG
Lesotho	LES5012	Improving Productivity of Potato and Sorghum through Mutation Breeding and Best Soil, Nutrient and Water Management Practices	M. Zaman and PBG
Madagascar	MAG5026	Enhancing Rice and Maize Productivity through the Use of Improved Lines and Agricultural Practices to Ensure Food Security and Increase Rural Livelihoods	J. Adu-Gyamfi 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	MLI5031	Improving Rice Productivity through Mutation Breeding and Better Soil, Nutrient and Water Management Practices	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	NAM5020	Enhancing Staple Crop Yields, Quality, and Drought Tolerance through Broadening Genetic Variation and Better Soil and Water Management Technologies	J. Adu-Gyamfi and PBG
Nicaragua	NIC2002	Strengthening of National Capacities in Energy Planning and Geothermal Resource Assessments through the Application of Isotopic Analytical Methods	E. Fulajtar
Pakistan	PAK5053	Strengthening and Enhancing National Capabilities for the Development of Climate Smart Crops, Improvement in Animal Productivity and Management of Soil, Water, and Nutrient Resources Using Nuclear and Related Techniques	M. Zaman with PBG and SIT
Palestine (T.T.U.T.J.)	PAL5011	Enhancing Food Security via Nuclear Based Approaches	E. Fulajtar
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
Panama	PAN5029	Strengthening National Capacities to Combat Land Degradation and Improve Soil Productivity Through the Use of Isotope Techniques	E. Fulajtar
Peru	PER5033	Application of Nuclear Techniques for Assessing Soil Erosion and Sedimentation in Mountain Agricultural Catchments	E. Fulajtar
Peru	PER5035	Improving Pasture Production Through Best Soil Nutrient Management To Promote Sustainable Livestock Production in the Highland Region	M. Zaman
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	RAF0056	Enhancing Nuclear Science and Technology Capacity Building through Technical Cooperation Among Developing Countries	E. Fulajtar
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 Africa	RAF5086	Promoting Sustainable Agriculture under Changing Climatic Conditions Using Nuclear Technology (AFRA) 2022-2023	H. Said Ahmed and L. Heng
Regional project Africa	RAF5090	Supporting Climate Change Adaptation for Communities Through Integrated Soil–Cropping–Livestock Production Systems (AFRA)	M. Zaman and APH

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 Asia	RAS5091	Assessing and Mitigating Agro-Contaminants to Improve Water Quality and Soil Productivity in Catchments Using Integrated Isotopic Approaches	J. Adu-Gyamfi
Regional project Asia	RAS5093	Strengthening Climate Smart Rice Production towards Sustainability and Regional Food Security through Nuclear and Modern Techniques	M. Zaman and Lee Heng
Regional project Asia	RAS5094	Promoting Sustainable Agricultural and Food Productivity in the Association of Southeast Asian Nations Region	M. Zaman with PBG and FEP
Regional project Asia and Pacific	RAS5099	Developing Climate Smart Crop Production including Improvement and Enhancement of Crop Productivity, Soil and Irrigation Management, and Food Safety Using Nuclear Techniques (ARASIA)	M. Zaman with PBG and FEP
Regional project Europe	RER5028	Improving Efficiency in Water and Soil Management	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	RLA5084	Developing Human Resources and Building Capacity of Member States in the Application of Nuclear Technology to Agriculture	J. Adu-Gyamfi, PBG and FEP
Regional Project Latin America	RLA5089	Evaluating the Impact of Heavy Metals and Other Pollutants on Soils Contaminated by Anthropogenic Activities and Natural Origin (ARCAL CLXXVII)	J Adu-Gyamfi
Rwanda	RWA5001	Improving Cassava Resilience to Drought and Waterlogging Stress through Mutation Breeding and Nutrient, Soil and Water Management Techniques	M. Zaman and PBG
Saint Vincent & the Grenadines	SVT0001	Building National Capacity in Nuclear Technology Applications	J. Adu-Gyamfi, NAHU and NAPC
Senegal	SEN5041	Strengthening Climate Smart Agricultural Practices Using Nuclear and Isotopic Techniques on Salt Affected Soils	M. Zaman
Seychelles	SEY5013	Developing and Promoting Best Nutrient and Water Management Practices to Enhance Food Security and Environmental Sustainability	L. Heng
Sierra Leone	SIL5021	Improving Productivity of Rice and Cassava to Contribute to Food Security	M. Zaman and PBG
Slovenia	SLO5005	Strengthening Agricultural Land Use and Management to Reduce Emerging Contaminants and Improve Water Quality	J. Adu-Gyamfi
Sri Lanka	SRL5051	Introducing Climate Smart Agricultural Practices to Mitigate Greenhouse Gas Emissions	M. Zaman
Sudan	SUD5041	Enhancing Productivity and Quality of High Value Crops through Improved Varieties and Best Soil, Nutrient and Water Management Practices	M. Zaman and PBG
Thailand	THA5057	Enhancing Capabilities for the Application of Isotopic Techniques for Enhanced Water Resource Management	E. Fulajtar
Zimbabwe	ZIM5026	Improving Soil Quality for Optimizing Selected Cereal and Legume Productivity in Smallholder Farms	O. Meniailo

Forthcoming Events

FAO/IAEA Events

First Coordination Meeting of TCP RER5025 'Improving Efficiency in Water and Soil Management', 4-8 April 2022, Vienna, Austria.

Technical Officer: E. Fulajtar

The FAO/IAEA International Symposium on Managing Land and Water for Climate Smart Agriculture, 25-29 July 2022, Vienna, Austria.

Scientific Secretary: L. Heng

Third Research Coordination Meeting of CRP D15018 'Multiple Isotope Fingerprints to Identify Sources and Transport of Agro-Contaminants, 25-29 July 2022, Vienna, Austria.

Project Officer: J. Adu-Gyamfi

First Research Coordination Meeting of CRP D15022 'Isotopic Techniques to Assess the Fate of Antimicrobials and Implications for Antimicrobial Resistance in Agricultural Systems, 25-29 July 2022, Vienna, Austria.

Project Officer: J. Adu-Gyamfi

NON-FAO/IAEA Events

EGU General Assembly 2022, 3-8 April 2022, Vienna, Austria https://www.egu22.eu/

World Congress of Soil Science, 31 July – 5 Aug 2022, Glasgow, United Kingdom https://soils.org.uk/wcss22/

Past Events

FAO/IAEA Events

Training course for Iraq under RAS5089 on 'Installation and use of Cosmic-Ray Neutron Sensor (CRNS) for stationary soil moisture assessment', 17-18 May 2021 (virtual)

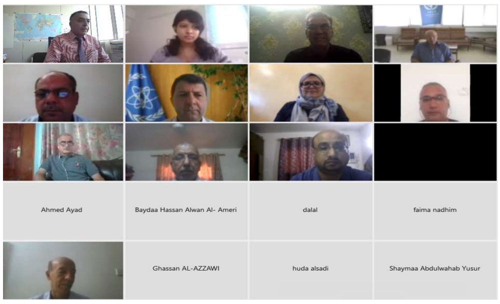
Technical officer: H. Said

The online training course 'Installation and use of Cosmic-Ray Neutron Sensor (CRNS) for stationary soil moisture assessment' consisted of lectures on providing guidance and technical assistance on CRNS installation in the field, calibration, data processing and designing field experiment for better use of the CRNS. on field. The training was attended by 14 participants from the Ministry of Science and Technology, Iraq.

National training course on nuclear and isotopic techniques to develop improved practices to enhance crop production in Iraq, 31 May to 04 June 2021 (virtual)

Technical Officer: M. Zaman

The purpose of this virtual training was to equip the participants with the knowledge and understanding of developing improved nutrient, and water management practices to grow crops under saline conditions, building soil resilience to climate change, and increasing crop production with lower environmental footprints using isotopic and related techniques. The training was attended by 19 researchers. The training event was opened by Mr Massoud Malek, the PMO of IRQ5022, who highlighted the key project activities. The technical officer described the objectives of the virtual training, and the role of climate smart agricultural practices. The technical officer along with two experts, Mr Mussaddak Janat and Ms. Habibah Al-Menaie, then provided virtual training covering a range of topics including best soil, nutrient and water management practices for mitigating soil salinity, improving soil fertility, enhancing nutrients and water use efficiencies, and the role of ^{15}N technique in assessing fertiliser use efficiency to minimise N fertiliser losses to the atmosphere and water bodies. The participants acknowledged IAEA for organizing this virtual training and committed to share their experience and knowledge with fellow colleagues for further capacity building.



Participants of the virtual training of Iraq

Second Research Coordination Meeting of CRP D12014 'Enhancing agricultural resilience and water security using Cosmic-Ray Neutron Sensor', 7-11 June 2021 (virtual)

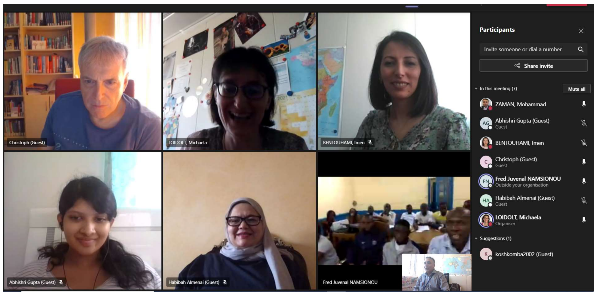
Project Officer: E. Fulajtar

The main purpose of this virtual meeting was to review the achievements of the CRP since its 1st RCM (in August, 2020). The project partners presented the case studies and methodological achievements. The important achievement of this meeting was reviewing the publishing strategy and initiating the preparation of the methodological handbook which should be among the major outputs of the CRP. There was agreed team of co-authors and particular contributions of each chapter. This meeting also contributed to preparation of the CRP for mid-term review.

National training on improved soil, water and nutrient management for cassava, sorghum and sugarcane and the role of nuclear and isotopic techniques in Central Africa Republic, 16-18 June 2021 (virtual)

Technical Officer: M. Zaman

A virtual training was arranged under the national TCP (CAF5011) to equip the participants with the advanced knowledge and understanding of the improved soil, nutrient, and water management practices to increase cassava production and the role of stable isotopic technique of ^{15}N to assess fertiliser use efficiency. Eighteen researchers, extension workers and academic persons participated in this virtual training to enhance cassava, sorghum and sugarcane production in Central Africa Republic using nuclear and related techniques. The experts also provided basic training on performing ^{15}N tracing experiments, the interpretation of ^{15}N data, and an easy-to-use spreadsheet for nitrogen use efficiency (NUE) calculations.

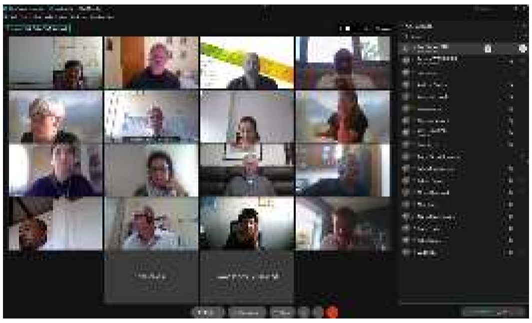


Participants of the CAF5011 virtual training

Final Research Coordination Meeting of CRP D15017 'Nuclear Techniques for a Better Understanding of the Impact of Climate Change on Soil Erosion in Upland Agro-Ecosystems', 5-9 July 2021 (virtual)

Project Officer: E, Fulajtar and L. Heng

The final RCM evaluated the results of this CRP. It was a very successful CRP, with the participants achieved excellent results in developing new techniques. Most of the result were already published in research papers among which the most successful is the review paper on 20 years of IAEA in the field of soil erosion assessment using FRNs. However, the major achievements of the CRP are the methodological handbooks. Four handbooks were already published and the last one aimed on ^{137}Cs resampling is already in preparation.



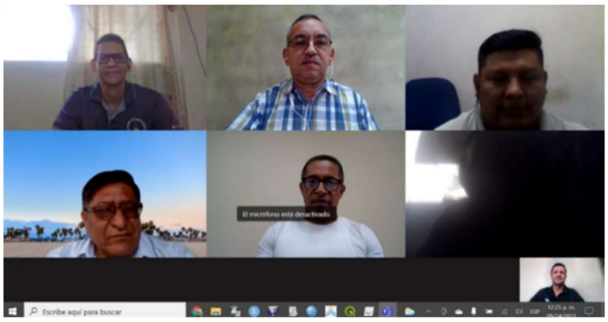
Participamts of the Final RCM of D15017

National Training Course on Remediation techniques in soils with high concentration of cadmium, PAN5028, 20–24 September 2021 (virtual)

Technical Officer: J. Adu-Gyamfi

The province of Bocas del Toro, in north western Panama, is home to 90% of the country's organic white cocoa with gourmet quality. The export of cocoa beans represents an important source of income that helps alleviate poverty of 1, 400 farmers. As new European Union (EU) import regulations on the cadmium (Cd) levels of less than 0.8 milligram per kilogram in chocolate products entered into force in 2019, Panama's cocoa exports came under threat as most of the cocoa-growing areas has tested very high in Cd. The objective of this TC Project is to support farmers in soil and water management technologies to increase the production of high-quality organic cocoa for export, as well as for its use in the national value-chain.

This national training course was organized to train scientists and technicians on how to develop soil and water management practices to help reduce Cd levels in cocoa beans and chocolate. Eight scientists and technicians from the Agricultural Research Institute of Panama (IDIAP) participated in the virtual training which was conducted by IAEA Expert Prof Alfredo Huamaní Yupanqui, (Universidad Nacional Agraria dela Selva, Peru). The participants received theoretical and practical training on (i) mechanisms of uptake, translocation and accumulation of Cd by cocoa and mitigation strategies to reduce the concentrations of Cd in crops, (ii) experimental designs to understand Cd uptake by cacao plants using Cd isotopes ($\delta\ ^{114}/^{110}Cd$): spiking from the soil with Cadmium isotopes, data analysis and interpretation.

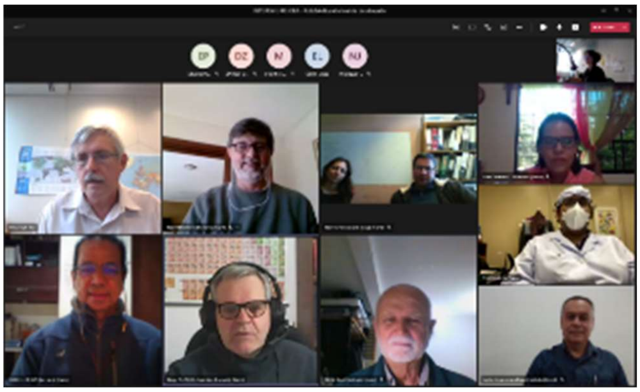


Participants of the PAN5028 national training course

Final Coordination Meeting of TCP RLA5076 “Strengthening Surveillance Systems and Monitoring Programmes of Hydraulic Facilities Using Nuclear Techniques to Assess Sedimentation Impacts as Environmental and Social Risks”, 5-7 October 2021 (virtual)

Technical Officer: E. Fulajtar

The online final meeting of this project was to summarize the results achieved by the project partners in 14 Latin American countries participating in RLA5076. It was a very challenging project because of the high number of participating countries and because the objectives are very broad. Integrated approach involves three very different methodological groups (FRNs, CSSI and water isotopes). The additional problems caused by the lockdown and home office periods, slowing down especially the analysing of the samples. Despite that this project achieved very good results. All countries combined two techniques and several countries managed all three techniques. The interpretation of collected data is still continuing and the whole group of project partners is still in constant communication. This project brought also interesting methodological experience which will be pressented in methodological handbook used for integrating the three method groups and will pay special attention to adapting the methodological approaches to specific needs of Latin America (tropical environments and great diversity of geographical conditions and landuses (from small subsistence family farming to large mechanized land management by huge agricultural enterprices.

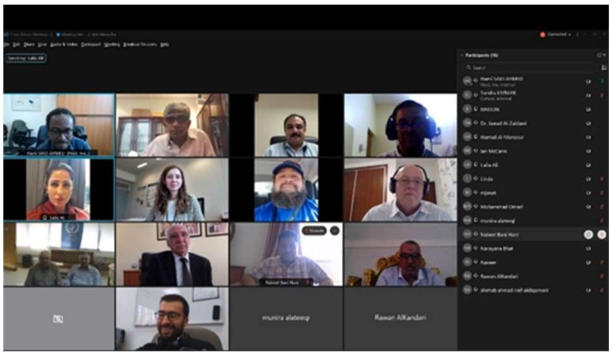


Final coordination meeting of TCP RLA5076

Regional Training course of RAS5089 on ‘Enhancing the Sustainability of Date Palm Production in States Parties through Climate-Smart Irrigation Practices (ARASIA)’, 18-21 October 2021 (virtual)

Technical officer: H. Said

The online course ‘Enhancing the Sustainability of Date Palm Production in States Parties through Climate-Smart Irrigation Practices (ARASIA)’ consisted of providing training on precision irrigation strategies for date palm. The training was attended by 14 participants from 5 ARASIA Member States.



Participants of the RAS5089 Regional Training Course

Technical Meeting on Artificial Intelligence for Nuclear Technology and Applications, 25-29 October 2021 (virtual)

Technical officer: G. Dercon

The event aimed to provide an international, cross-cutting forum to discuss and foster cooperation on artificial intelligence applications, methodologies, tools and enabling infrastructure that have the potential to advance nuclear technology and applications. With collaboration of SWMCNL team, Mr. Modou Mbaye and Mr. Franck Albinet respectively presented the work on the use of AI for calibration of Cosmic ray Neutron Sensor and for improving soil property prediction using Mid-Infrared Spectroscopy and improving radioactivity mapping in the landscape.

AI4Atoms Technical Meeting

2021 IEEE International Workshop: Metrology for Agriculture and Forestry, 3-5 November 2021 in Trento-Bolzano (combined with online presentation)

Technical Officer: H. Said

The MetroAgriFor workshop is an international event where academics, researchers, and industry experts in the field of measurement and data processing techniques for agriculture, forestry and food can meet and share new advances and research results. The meeting was held physically at Trento-Bolzano, Italy, but also online participation was arranged. Mr H. Said Ahmed from the SWMCNL presented virtually the research results on the link between cosmic-ray neutron sensoring and remote sensing: ‘High-Resolution Soil Moisture Retrieval Using C-Band Radar Sentinel-1 and Cosmic-ray Neutron Sensor Data’.

Coordinated Research Projects

Project Number	Ongoing CRPs	Project Officer
D12014	Enhancing Agricultural Resilience and Water Security Using Cosmic-Ray Neutron Technology	E. Fulajtar and H. Said Ahmed
D15017	Nuclear Techniques for a better understanding of the Impact of Climate Change on Soil Erosion in Upland Agro-ecosystems	E. Fulajtar and L. Heng
D15018	Multiple Isotope Fingerprints to Identify Sources and Transport of Agro-Contaminants	J. Adu-Gyamfi and L. Heng
D15019	Remediation of Radioactive Contaminated Agricultural Land	G. Dercon and L. Heng
D15020	Developing Climate-Smart Agricultural Practices for Mitigation of Greenhouse Gases	M. Zaman and L. Heng
D15022	Isotopic Techniques to Assess the Fate of Antimicrobials and Implications for Antimicrobial Resistance in Agricultural Systems	J. Adu-Gyamfi and L. Heng

Enhancing Agricultural Resilience and Water Security using Cosmic-Ray Neutron Sensor (D12014)

Project Officers: E. Fulajtar and H. Said Ahmed

This CRP (2019 to 2024) is aimed on testing the potential of using a cosmic ray neutron sensor (CRNS) and gamma ray sensor (GRS) for agriculture and environment protection, especially on irrigation scheduling and management of extreme weather events. CRNS provides soil moisture data at a large scale and in real time, which has a great value for land and water management.

The objectives of the CRP are to: (1) Advance the capabilities of CRNS for Best Management Practices (BMP) in irrigated and rainfed agriculture; (2) Integrate CRNS, GRS, remote sensing and hydrological modelling for improving agricultural water management and its resilience; and (3) Develop approaches using CRNS and GRS for long-term soil moisture monitoring in agroecosystems. The final output of the CRP will be a set of methods and guidelines applicable in irrigation scheduling, flood prediction and drought management.

This CRP was approved in March 2019. It involves eleven partners: with five research contract holders (two from Brazil, two from China and one from Mexico), two research agreement holders (Denmark and UK) and four technical contract holders (Italy, Netherlands, 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 the project partners. In autumn 2019 the installations of CRNS and their calibration began at selected study sites of project partners and the stationary soil moisture measurements began. It was a good luck that the project started about half year before the problems with traveling emerged in spring 2020. At that time all partners had established already some CRNS monitoring sites and the first soil moisture time series were collected.

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 online EGU General Assembly (4-8 May 2020 in Vienna). These publications presented interpretations of soil water content datasets collected by the SWMCN Laboratory team at a stationary monitoring station in Petzenkirchen, Austria.

In spring and summer 2020 the field work limitations emerged due to travel restrictions, lockdowns and home office. Soil moisture monitoring was interrupted at some sites. Also the installation of CRNS and GRS at some sites were delayed. Nevertheless, in late summer and autumn the measeurements and installations of new sites continued and 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 rooting depth soil moisture distribution from CRNS data.

These results 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 was held virtually from 7 - 11 June 2021. Main achievement of this meeting was initiating the preparation of the methodological handbook. The time during the lockdowns and home office periods was exploited very efficienty for writing a number of publications and also preparing inputs for the major handbook which will be major output of the project. The draft manuscript is almost ready now and it will be submitted in winter 2021/22.

In autumn 2021 the work on testing GRS for soil moisture management began and the great achievement is especially testing the newly constructed CRNS (FINAPP Probe) in comparison with traditionally used CRNS (Hydroinnova). The most important methodological achievements presented in this handbook are: neutron signal noise filtering, CRSPy tool (neutrone counts processing using Python language), agriculture soil moisture products (rooth zone depth estimation and precipitation estimation) and approach using CRNS for remote sensing soil moisture products (SENTINEL, ASCAT) validation. Apart of that the results were presented at 2021 IEEE International Workshop: Metrology for Agriculture and Forestry, 3-5 November.

Nuclear Techniques for a Better Understanding of the Impact of Climate Change on Soil Erosion in Upland Agro-ecosystems (D15017)

Project Officers: E. Fulajtar and L. Heng

This CRP (2016-2021) develop nuclear techniques for assessing 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. Three groups of nuclear techniques have been used: fallout radionuclides (FRN) such as ^{137}Cs, ^{210}Pb, ^{7}Be and $^{239+240}$Pu; Compound-Specific Stable Isotope (CSSI) techniques; and the Cosmic Ray Neutron Sensor (CRNS).

The first RCM was held in Vienna, Austria from 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 from 16 to 20 April 2018. On 13 March 2019, the IAEA mid-term review of the CRP praised the output obtained.and the third RCM was held in Vienna, Austria from 14 to 17 October 2019. The final RCM of the CRP took place in Vienna, Austria, in a hybrid format (virtual and in-person), from 5 to 9 July 2021.

The CRP achieved substantial improvements in developing and refining FRN and CSSI techniques to deepen our understanding of erosion processes impacting upland agro-ecosystems. The CRP team has published 25 peer-reviewed publications and 4 guidebooks. The IAEA TECDOC-1845 was aimed on soil Moisture Mapping with a Portable Cosmic Ray Neutron Sensor and the IAEA TECDOC-1881 on CSSI technique based on δ^{13}C signatures of fatty acids to determine the origin of sediment. Two books were also published, as FAO handbook on the use of ^{137}Cs for soil erosion assessment and a Springer open-access handbook on the assessment of recent soil erosion rates using ^{7}Be.

Currently, the last guidebook is in preparation, which is about 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 allowed them to evaluate the effectiveness of soil conservation measures.

Multiple Isotope Fingerprints to Identify Sources and Transport of Agro-Contaminants (D15018)

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 second RCM of this CRP was held virtually from 1–4 March 2021. The purpose of the meeting was to review the progress made since the first RCM, develop a workplan and activities to realize the project outputs, and formulate recommendations for future work. Fifteen-member states including eight research contract holders from China, Ghana, India, Morocco, Romania, Sri Lanka, Slovenia and Viet Nam, six agreement holders from Austria, France, Germany, Ireland, Switzerland and United Kingdom, and one technical contract holder from Australia participated. Ten observers from Romania, India, Morocco, Costa Rica, France, and FAO (Italy) participated. The mid-term review for the project was submitted on 8 September 2021 and was approved by the CCRA with a further extension of the CRP till 31 December 2023 to enable the participants complete the work on the respective research projects.

The CRP achieved two of the three specific objectives namely to (1) develop, evaluate and standardize an integrative isotope approach for identifying and apportioning sources of contaminants in agro-ecosystems, (2) apply the combined approach to different agro-ecosystems to control contaminants. It was recommended to focus on the third specific objective 'to provide guidelines and decision trees for adapting and applying the toolbox' The achievements from the CRP to-date include:

(1) $\delta^{18}Op$ developed and modified after field applications as surrogate of P to distinguish between P from agriculture and sewerage disposal causing eutrophication [Kothmale reservoir in Sri Lanka, Pearl River Basin in China and Viet Nam and Weija reservoir in Ghana]. A new reference material for calibration was developed
(2) The CSIA ($\delta^{13}C$ and $\delta^{15}N$) for assessing the fate of pesticides successfully tested in the field. A new passive sampler for detecting pesticide isotope signature developed and tested in India
(3) $\delta^{34}S(SO_4)$ and $\delta^{18}O(SO_4)$ for partitioning different sources of pollutants from household waste and from mining areas in the catchment tested [Nambeelup Brook, W. Australia]
(4) Combined use of ($\delta^{18}O$ and $\delta^{2}H$) and FRN-based sedimentary geochronology was used to assess the contribution of sediment source apportion to pollution [UK, Tanzania, China and Chile]
(5) A success story from Viet Nam "Nuclear Techniques and Improved Resource Management Help Reduce Pollution in Viet Nam's Nhue River (https://www.iaea.org/newscenter/news/nuclear-techniques-and-improved-resource-management-help-reduce-pollution-in-viet-nams-nhue-river) and 2 journal articles were published.

A special issue on Agro-contaminants sources, transformation, and transport in agroecosystems (2021) was published in Agriculture, Ecosystems & Environment Journal (Elsevier).

The Third RCM is planned to be held on 25-28 July 2022 in Vienna, Austria.

Remediation of Radioactive Contaminated Agricultural Land (D15019)

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 D15019 was developed as a follow up to CRP D15015. 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 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. The second RCM was held online on 4-8 October 2021, which was combined with the NARO-FAO/IAEA International Joint Symposium on *"Remediation of Radioactive Contamination in Agriculture: Next Steps and Way Forward"* (4 October 2021). This meeting allowed to show the significant progress by the CRP participants in all fields of the project and based on theses advances individual and project work plans were revised and adjusted where needed.

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 and radiostrontium in the soil. The first steps have now been made for stable isotope techniques that allow stable caesium and stable strontium to mimic the behaviour of their radioisotope equivalents. Significant progress has also 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. It has been planned to present in 2022 the first CRP results in scientific conferences and symposiums.

Developing Climate Smart Agricultural practices for carbon sequestration and mitigation of greenhouse gases (D15020)

Project Officers: M. Zaman and L. Heng

Climate Change due to continued increased anthropogenic emission of greenhouse gases (GHGs) is a global threat to food security. Direct and indirect GHG emissions from agriculture, forestry and other land-uses changes contribute approximately 25% of the global anthropogenic GHG emissions. Data by the Intergovernmental Panel on Climate Change (IPCC) clearly show that anthropogenic emissions of the three major GHGs including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) have increased significantly since the industrial revolution and as a result, the Earth's average surface air temperature has increased about 1.2°C. This warming of the Earth has led to extreme weather events such as frequent heat waves, droughts, floods, and uneven distribution of rainfall, rising sea levels and melting of glaciers. The GHGs with the largest global warming potential are N_2O and CH_4, which predominantly originate from agriculture. Based on the outputs of the previous CRP (D15016), climate-smart agricultural practices are a promising tool to enhance crop production with lower environmental footprints. However, more quantitative data on the effect of soil processes (e.g. carbon- and nitrogen-dynamics) on emissions of GHGs in relation to land-use changes are urgently needed. Therefore this new CRP as phase-2 was started with the objective to develop and validate climate-smart agricultural practices, based on isotopic and related techniques, to increase soil carbon (C) sequestration, mitigate GHG emissions (N_2O, CH_4, CO_2) and limit gaseous losses of ammonia (NH_3) and dinitrogen (N_2) from agricultural ecosystems, with the aim to enhance agricultural productivity and sustainability. The 1st RCM took place virtually on 8-12 February 2021. After the 1st RCM, all CRP participants have started establishing field trials to develop and validate climate-smart agricultural practices, to increase soil C sequestration, mitigate emissions of GHG and NH_3 from agricultural ecosystems, with the aim to enhance agricultural productivity and sustainability. Measurements of gaseous emissions of GHGs and collection of soil and plant samples for chemical analyses are currently underway.

Isotopic Techniques to Assess the Fate of Antimicrobials and Implications for Antimicrobial Resistance in Agricultural Systems (D15022)

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

A new five-year (2021-2026) Coordinated Research Project (CRP), titled 'Isotopic Techniques to Assess the Fate of Antimicrobials and Implications for Antimicrobial Resistance in Agricultural Systems' Agricultural practices for carbon sequestration and mitigation of greenhouse gases' (D15020) was initiated this year. The first Research Coordination Meeting will take place on 25-29 July 2022 in Vienna, Austria. The overall objective of this CRP is to develop guidance for improving the understanding of the fate, dynamics and persistence of AM and AMR in agricultural systems based on nuclear and related techniques and support MS to develop common strategies to mitigate the spread of AM in agricultural systems. This CRP was approved in September 2021. It involves eight partners: four research contract holders (Brazil, China, South Africa, and Vietnam), three agreement holders (China, Norway and USA), and two technical contract holders (Australia and Germany). The first research coordination meeting will be held on 25–29 July 2022.

Developments at the Soil and Water Management and Crop Nutrition Laboratory

Near-real-time Web GIS tool for Climate Smart Water Management (CSWM) by combining Cosmic-Ray Neutron Sensor data and remote sensing data (Sentinel 1 & 2 and MODIS)

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

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[6]*Kuwait Institute for Scientific Research, Kuwait City, Kuwait*

Climate change and its impact on water resources is a major problem for agricultural production. To enhance agriculture production in a sustainable way, there is a need to develop climate-smart agricultural practices to improve water-use efficiency.

For agricultural water management, crop evapotranspiration (ET) and soil moisture are the key indicators for crop water requirement. Many remote sensing based methods have been developed to measure ET at a global scale using satellite and airborne imagery. For large scale soil moisture monitoring, nuclear technology, such as Cosmic-Ray Neutron Sensors (CRNS), bridges the critical gap between satellites and point-scale ground sensors. It can enable the calibration of satellites such as Sentinel-1 (S1) to improve soil moisture data estimated by remote sensing *(Said et al., 2021)*.

In 2020 the SWMCN laboratory started to work on the development of a near-real-time Google Earth Engine Web GIS tool for estimating soil moisture by combining CRNS data and remote sensing data (Sentinel 1 & 2 and MODIS), using highly spatial resolution (10 m) and highly temporal resolution (5 days) data, provided by Model 1 in *Figure 1*. An example of the output of the Model 1 is given in *Figure 2* for the long-term SWMCNL study site in Petzenkirchen (Austria), showing a time sequence of high-resolution soil moisture maps.

This year the team included an additional model and drought monitoring:

- Evapotranspiration by combining the WAPOR (Water Productivity Open access of Remotely sensed data) database and temperature data from MODIS (Model 2)
- Drought water stress by using the Normalized Difference Drought Index (NDDI) which is obtained from a combination of Normalized Difference Vegetation Index (NDVI) and Normalized difference Water Index (NDWI), which are sensitive to vegetation and water content of vegetation, respectively.

The NDVI and NDWI are obtained from Sentinel-2 (S2) with high spatial resolution (10 m) and high temporal resolution (5 days) (Fig. 1). The intensity of the NDDI index scale ranges from -1 (no drought) to 1 (highly droughty condition). This was applied to produce a highly spatial resolution (10 m) drought map for date palm fields in Kuwait, linked to one of the IAEA Technical Cooperation projects supported by the SWMCNL. The drought monitoring map for October 2021 showed that date palm field is under severe drought water stress *(Figure 3)*.

For the first time, in a semi-arid region, important parameters such as soil moisture, crop water requirement, crop greenness and drought status were made accessible and combined for agricultural research organizations through a Web GIS platform combining nuclear technology and satellite imagery. Farmers and scientists may freely use this platform to gather important information to develop climate smart agriculture (Figure 4).

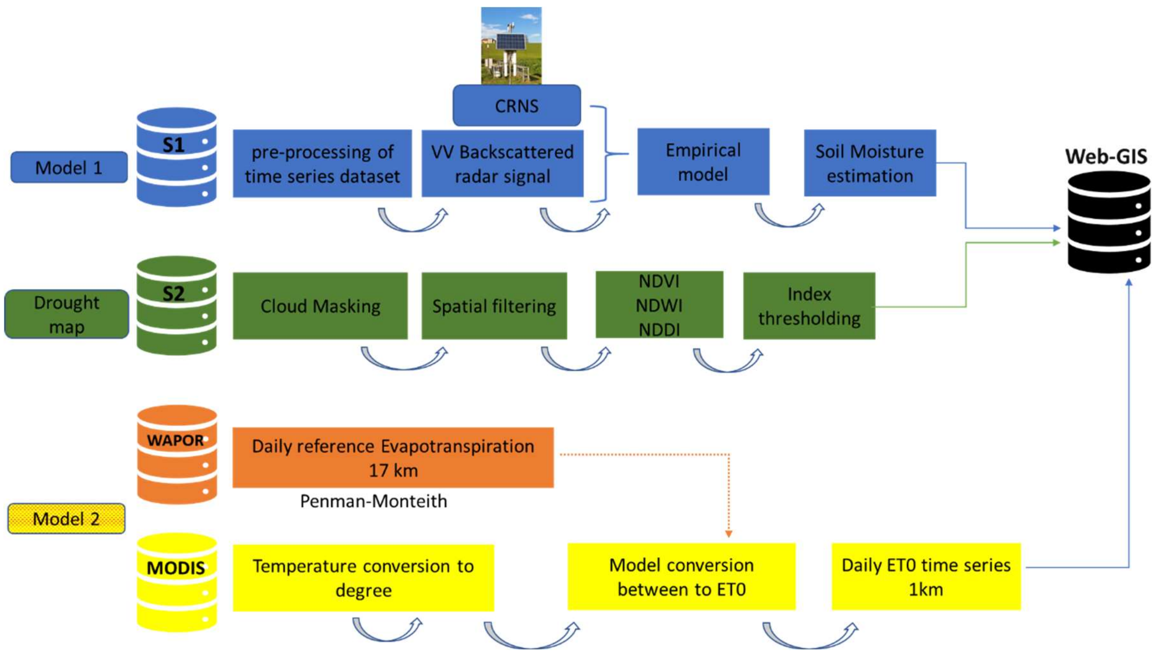

Figure 1. Flowchart of building the web-GIS platform using remote sensing datasets: Sentinel-1 (S1), Sentinel-1 (S2), MODIS (Moderate Resolution Imaging Spectroradiometer) and WAPOR (Water Productivity Open Access of Remotely Sensed Data).

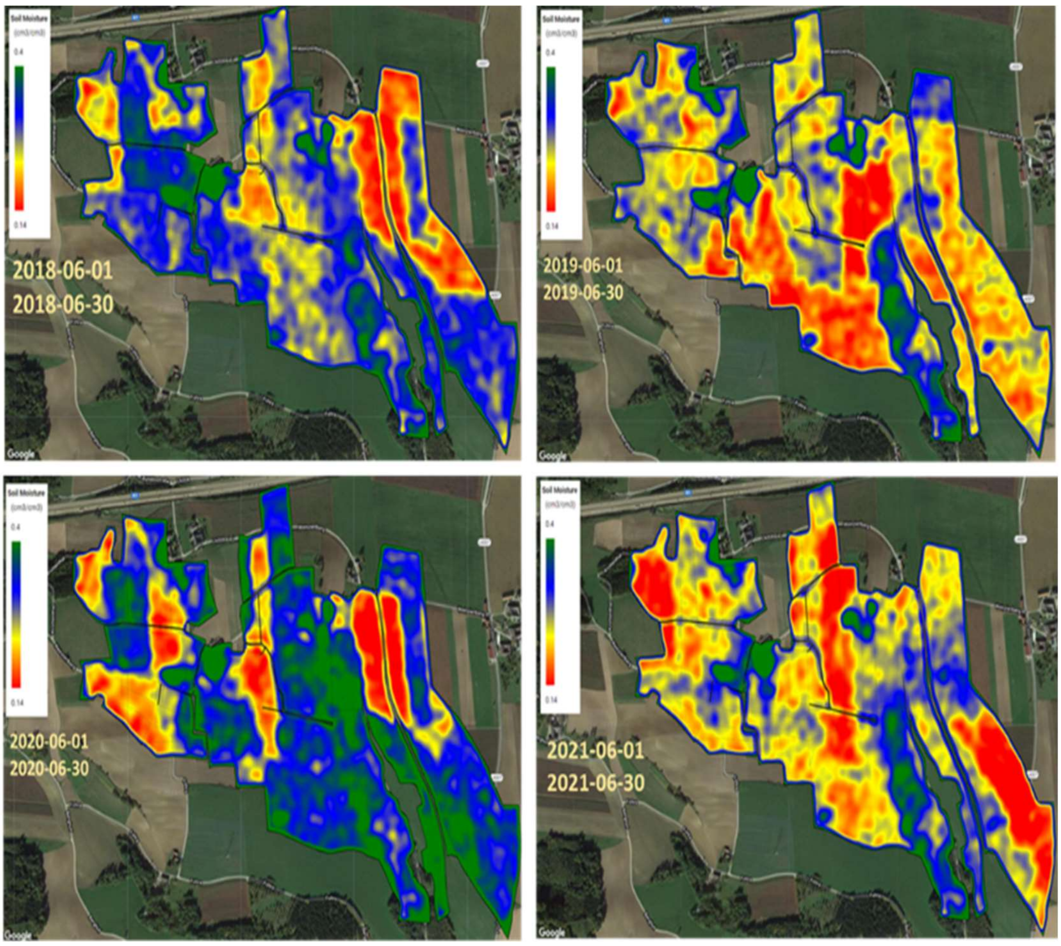

Figure 2. Soil moisture map retrieved using the Sentinel-1 imagery combined with CRNS data in Petzenkirchen (Austria).

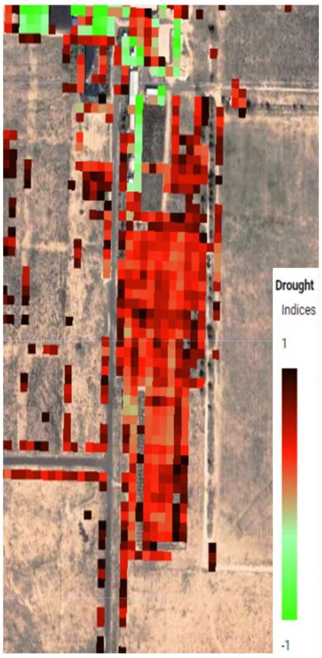

Figure 3. Drought stress map in date palm field in Kuwait during field in the semi-arid area, Kuwait

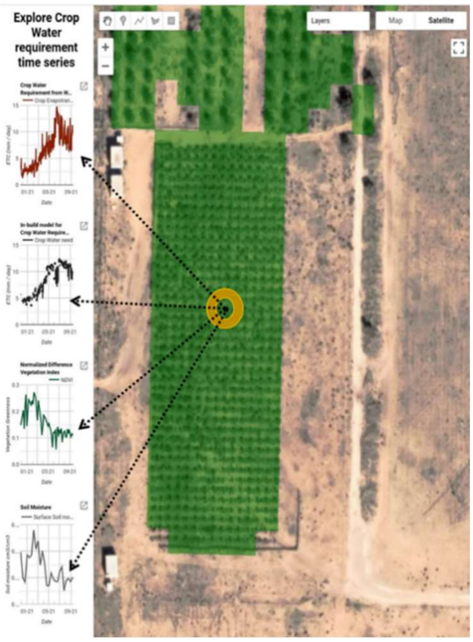

Figure 4. Screenshot of the Web GIS platform for date palm October 2021.

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Estimation of area-wide soil hydraulics properties by using Cosmic-Ray Neutron Sensor technology and HYDRUS-1D modeling

Said Ahmed, H.[1], Diels, J.[1,2], Weltin, G.[1], Toloza, A.[1], Dercon, G.[1]

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[2] Division of Soil and Water Management, Department of Earth and Environmental Sciences, KU Leuven, Leuven, Belgium

Cosmic Ray Neutron Sensing (CRNS) is an *in-situ* nuclear technology developed to estimate soil moisture content in a large area of up to 20 to 30 ha. The CRNS has been used in agricultural water management and hydrology studies. This technique is based on the detection of natural neutrons with high-energy that came from cosmos, penetrate the soil and then scatter back into the atmosphere. These scattered neutrons lose energy due to collisions mainly with hydrogen atoms – which come mostly from soil moisture – and become low-energy neutrons (epithermal neutrons). The CRNS measures these low-energy neutrons near the soil surface that are spatially distributed and scatter across large distances in the air which helps monitor soil moisture over large areas.

The movement of water in the soil and its availability are regulated by soil hydraulic properties, which is mainly the relationship between volumetric soil water content, pressure head and hydraulic conductivity. The determination of those properties at field scale is mainly based on labor-intensive soil sample collection and analysis in the laboratory which is time consuming. Area-wide soil moisture data from CRNS combined with soil water simulation models, such as Hydrus-1D, could be used to infer field-scale soil hydraulic parameters and depth-resolved soil moisture dynamics. This approach is largely unexplored except for one study *(Brunetti et al., 2019)*.

At the SWMCNL a study is being carried out to assess the performance of estimating soil hydraulic properties at the field scale with the Hydrus-1D model by coupling to the COSMIC code which translates soil moisture content in a neutron flux *(Shuttleworth et al., 2013)*. For this study, the data obtained by the CRNS installed in an agricultural field near Vienna *(Figure 1)* will be used. First sampling campaigns have been carried out, results are expected by the beginning of 2022.

Figure 1. Cosmic Ray Neutron Sensor (CRNS) installed in agricultural field in Marchfeld area east of Vienna (Austria) and field sampling campaign in Marchfeld area

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Microplastics – an emerging global change factor

Menyailo, O.

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Microplastics pollution of soils is a serious issue. The FAO/IAEA SWMCN Laboratory aims to contribute to this issue using nuclear techniques, especially stable isotopes, which could advance our understanding of the ecological role of microplastics in soils.

Research on microplastics (plastic particles <5 mm) has initially focused predominantly on marine and aquatic ecosystems. With the lag of approximately one decade, research on microplastics in soils has started. The early research agenda on microplastics in both aquatic and terrestrial systems was mainly ecotoxicological. Many of their effects appear to be mediated by physical parameters, such as particle shape and size, rather than overt chemically mediated toxicity. The effects of microplastics are mostly sublethal or even nominally positive.

The concept of “plastic cycle” acknowledges that microplastics can move between different large-scale compartments, including the air, terrestrial habitats, rivers and other freshwater bodies, and the ocean, including its sediments *(Rillig, Lehmann, 2020)*. The cycle framework places these movements in the context of the pools and fluxes that are inherent to ecosystem ecology. The current challenge is to understand how microplastic flows affect such pools and fluxes in terrestrial ecosystems.

Microplastics are mostly composed of carbon. Microplastic addition to ecosystems thus represents a source of carbon independent of photosynthesis and net primary production. This polymer carbon has a slow turnover, because the material is mostly inert *(Rillig, Lehmann, 2020)* however, the behavior and residence time of microplastics in soil are currently unknown. Originally, most of this carbon is of fossil origin, rather than having recently been fixed from the atmosphere. Because of the resistance of microplastic to decomposition, it would be expected to accumulate in soils, increasing soil carbon stocks.

Effects of microplastics on soil are likely to be indirect and depending on particle shape and size. For example, for microplastic fibers, effects on soil aggregation, a key process governing soil structure, are quite well established. Soil aggregates are the crumbs contributing to soil structure and have a central role in shaping the habitat of soil organisms. Additionally, carbon compounds are stored within aggregates, where they are physically protected from being rapidly decomposed. Soil aggregates also determine the overall pore space in the soil, which in turn influences the movement of gases and water, and the activity of associated microbial communities. A completely different indirect effect occurs because of lower soil bulk density in the presence of fibers. This can lead to enhanced plant growth, probably because roots experience less resistance when growing *(de Souza Machado, et al., 2019)*. However, negative effects on plants, likely related to plastic additives, are also possible *(van Kleunen, et al., 2020)*. What types of microplastics could promote or inhibit plant biomass production is an important area for future research.

Effects of microplastics on other element cycles remain uncertain. Direct effects will likely be minimal, because microplastics contain mostly negligible amounts of nitrogen and phosphorus. However, alterations to soil structure would be expected to change the rates of many microbial processes, including those in the nitrogen cycle. An example is denitrification, a process that occurs anaerobically, within the center of soil aggregates, which reduces nitrate and nitrite to gaseous forms of nitrogen, including nitrous oxide and nitrogen. Effects on emissions of nitrous oxide and other important greenhouse gases are only now being examined *(Ren et al., 2020)*. One study *(de Souza Machado, et al., 2019)* found an increase in arbuscular mycorrhizal fungi, a key symbiont group that associates with plant roots. If this is true, this could affect phosphorus cycling, because these symbionts transport nutrients, including phosphorus, to their plant hosts. There are no published data so far on microplastics effect on ectomycorrhizal fungi (EM). Probably because EM fungi are mostly attributed to forest ecosystems in which microplastics were not yet studied.

Plastic films, and likely fibers, may alter the flow of water in soils, including evaporation *(Wan et al., 2019)*. Thus, the effects on ecosystem water dynamics and energy balance, mediated by direct effects in soils or indirectly through plants, are also likely. Other possible ecosystem-level effects include altered rates of erosion owing to changes in soil aggregate stability. Altering water flows the plastics can also alter soil aeration, affecting diffusion of greenhouse gases. The least soluble among greenhouse gases is methane (CH_4), therefore CH_4 fluxes could be strongly affected by microplastics pollution.

There are some critical unknowns that need to be addressed before the impacts of microplastic pollution on terrestrial ecosystems and the subsequent feedbacks can be understood. Using nuclear techniques such compound specific stable isotope technique could improve our understanding of the effects on turnover and transformation processes in soil.

So far the research has focused mainly on agricultural systems, which are expected to contain the largest amount of microplastics *(Weithmann, et al., 2018)* because of input pathways (sewage sludge, compost, and plastic mulching). We know much less about microplastics in other ecosystems, such as drylands or forests, where the microplastic dynamics might be quite different because of the different ecosystem structures. It is clear that agricultural soils are more polluted with microplastics than forest soils. However, agricultural soils in many parts of the world are afforested. Conversion of agricultural land into forests may also alter the behavior of microplastics in soil.

At the SWMCNL, we are preparing to study the biogeochemical role of microplastics in soils. For this we invested in equipment. A Picarro analyzer has been purchased, that measures isotopic carbon composition and concentrations of CO_2 and CH_4. The instrument is equipped with a small sample introduction module and a 16 port multiplexer. Besides that, a Memmert's Peltier cooling incubator is purchased as well, which operates in the temperature ranges between 5 and 70 °C. We intend to assemble an automated incubation system, where soil samples will be incubated for days or weeks, unattained by operator, with constantly monitoring the CO_2 and CH_4 fluxes and their isotopic composition.

A Coordinated Research Project (CRP) proposal is in preparation, to be submitted in 2022. The consultant meeting is planned for early next year. The meeting will gather international experts on microplastics, who would help to sharpen the research agenda, and who would possibly collaborate with us in the new CRP.

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Temporal patterns of ammonia volatilization from different nitrogen fertilizers in maize cropping systems

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The release of large amounts of NH_3 after the application of urea is a serious problem, which not only reduces economic returns to farmers, at the same time has a negative impacts on environment. Mitigating ammonia losses from nitrogen (N) fertilizer application thus provides a double benefit for farmers and environment.

In this study, our objective was to understand the effect of nitrogen process inhibitors on daily NH_3 volatilization. Nitrogen inhibitors are products that temporarily retard conversion of fertilizers to the forms that can be lost through different pathways and can improve nitrogen use efficiency (NUE) and consequently enhance crop yield and reduce environmental emissions. There are two main types of inhibitors that can be added to N fertilizers:

- Urease inhibitors (UI) slow down the hydrolysis of urea
- Nitrification inhibitors (NI) inhibit the biological oxidation of ammonium to nitrate

A field experiment was established at the SWMCN laboratory in Seibersdorf, to determine the effect of different N fertilizers coated with N process inhibitors on maize yield and NH_3 volatilization in summer 2020. The field site is characterised as a moderately shallow Chernozem soil with significant gravel content. A randomized 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). NI-1 referred to MPA: N-[3(5)-methyl-1H-pyrazol-1-yl) methyl] acetamide while NI-2 is DMPP: 3,4-dimethylpyrazole phosphate. Urea was applied through two equal split applications in the T_2 treatment (at 20 days after planting (DAP) and 34 DAP). In T_3, T_4, and T_5 treatments, N fertilizers were applied only once (at 20 DAP). All treatments received 120 kg of N ha^{-1}, except of treatment 1, 60 kg ha^{-1} of P_2O_5 and 146 kg ha^{-1} of K_2O. Supplemental irrigation was only applied in the early stages of growth, to ensure that the crop could establish. Ammonia volatilization was measured with semi-static chambers. Measurements were taken every two days during the first month, then every three days for the second month.

The first results were reported in previous newsletters (January and July 2021), showing a clear impact of the N process inhibitors on maize yield and cumulative NH_3 emissions. The emphasis is on the temporal patterns of ammonia volatilization from nitrogen fertilizers coated with inhibitors.

Figure 1 shows that all treatments resulted in a sharp increase in NH_3 emissions after addition of fertilizers. In T_1 (U), the emissions after the first and second splits showed similar time course and reached a peak on day 4 after the application of the fertilizers. The pattern of daily NH_3 losses from urea applied alone in the first and second splits were similar, confirming that the majority of NH_3 losses occurred during the first few days following urea application. By contrast, the emissions in treatments T_2 (U+UI) and T_3 (U+UI+NI-1) were lower and the increase persisted longer than urea alone treatment (T_1). The addition of UI to urea in T_2 and T_3 treatments reduced the peaks of the NH_3 loss, delaying them until day 8. As T_4 treatment (PK+NI-2) is composed of nitrate and ammonium, the volatilization losses of NH_3 from this treatment should theoretically be lower than other urea treatments. This was confirmed by our results.

In urea alone treatment (T_1), measurements of the daily NH_3 emission showed that about 80% of NH_3 losses occurred within seven days after each split application and dropped quickly. For U+UI (T_2) and U+UI+NI-1 (T_3) treatments, the majority of NH_3 losses (between 76-77%) happened within two weeks after adding nitrogen fertilizer. In NPK+NI-2 treatment (T_4), about 63% of NH_3 losses occurred within the first week.

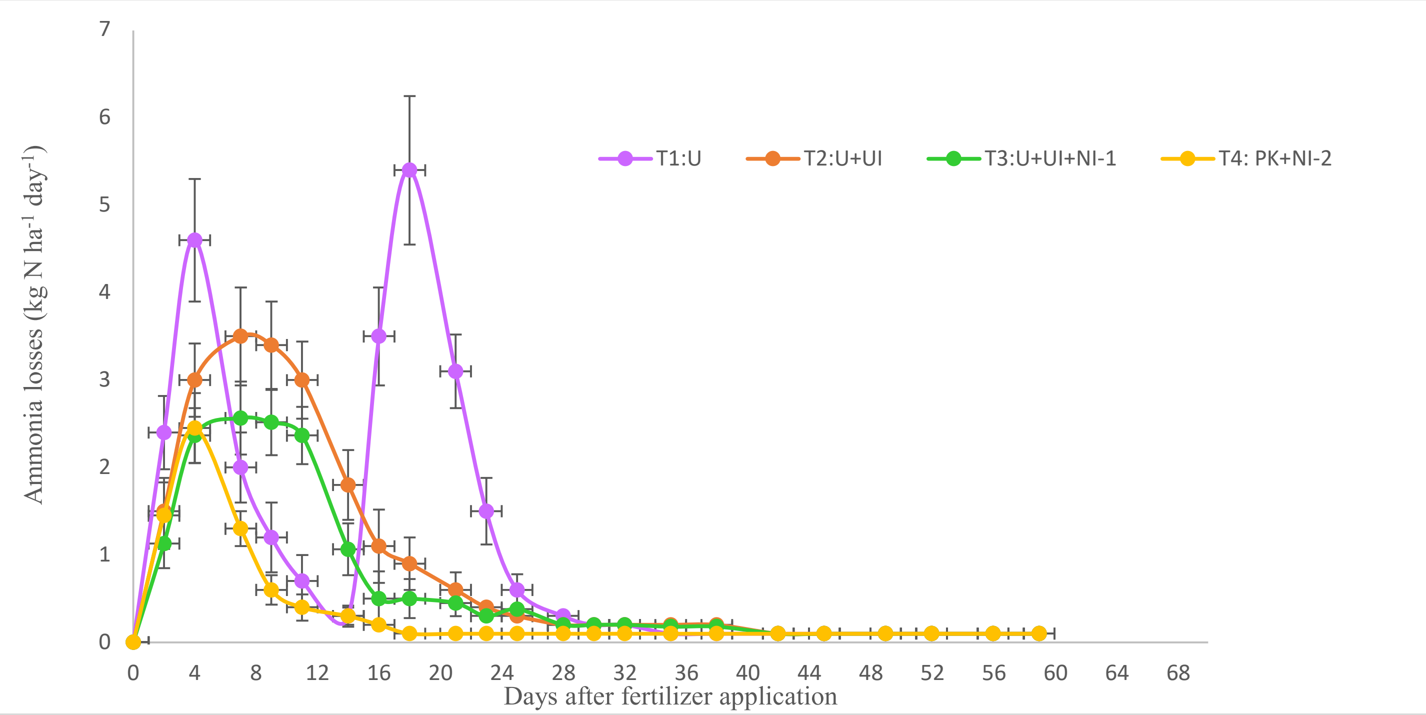

Figure 1. Daily NH3 emissions of different fertilization treatments (U: urea-in two splits; U+UI: urea+2-NPT; U+UI+NI-1: urea+2-NPT+MPA; NPK+NI-2: NPK+DMPP). Each value represents a mean of four replicates with standard deviation shown by vertical bars.

** 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)*

** NPK (Total Nitrogen 15%: 6.9% Nitrate + 8.1% Ammonium)*

Unraveling carbon and water dynamics in banana mats through a ^{13}C labelling experiment

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Following earlier steps in the PUI (Peaceful Uses Initiative) project on *Enhancing climate change adaptation and disease resilience in banana-coffee cropping systems in East Africa*, funded by Belgium, a more in-depth experiment was performed in the SWMCNL greenhouses to investigate the translocation of carbon-assimilates in banana mats under different watering treatments. Earlier findings showed the potential of the $\delta^{13}C$ signature as a short-term indicator for drought stress. In this experiment, enriched $^{13}CO_2$ label was used as a tracer to quantify carbon (C) fluxes from source to sink within the plant. The major emphases were the measurement of the carbon transfer from mother to daughter plant and determination of the potential influence of drought stress on this process.

Twenty-four banana plants were subjected to two different water treatments (optimal, 100% field capacity and suboptimal, 50% field capacity). Half the plants consisted of a sole mother plant and half of the plants had a daughter plant attached to the mother plant. After a $^{13}CO_2$ pulse labelling of 16 minutes (400 ml/min) in the SWMCNL growth chamber, where the soil and daughter plants were covered to avoid direct uptake of the ^{13}C enriched CO_2 *(Figure 1),* plant samples were taken from different plant parts at specified time moments *(Figure 1)* for $\delta^{13}C$ analysis. Extractions are done on the plant samples to isolate the major C pools, such as water-soluble organic matter (WSOM), cellulose and starch.

Figure 1. Preparation of plants before entering the growth chamber for the ^{13}C pulse labelling where the daughter plant and soil are packed in a vacuum bag in polyethylene and the opening is sealed with tyrosine clay, and taking a phloem sample from a petiole of the mother plant for water soluble organic matter extraction.

The focus is on the WSOM in phloem and leaf samples and on bulk C in leaf samples. WSOM consists of mobile carbon, which is a good indicator for short-term changes, whereas bulk C represents the entire carbon pool present. α–cellulose is a highly immobile fraction, thus representing conditions at time of leaf development, which makes this C pool interesting to compare between leaves differing in age to visualize the incorporation of newly assimilated C.

Additionally the WSOM and starch fractions in the corm are of interest. All C-assimilates moving between mother and daughter plant are expected to pass through the corm. On the other hand, the corm serves as a reserve organ full of starch. Whether recent carbon assimilates from the mother plant are directly passed on to the daughter plants or rather stored (temporarily) in the form of starch, is yet to be determined. Analyzing the $\delta^{13}C$ signal on the WSOM and starch fraction in the corm, will help us unravel the complex processes in this organ.

Finally, we will be able to quantify the speed of carbon allocation from mother to daughter plants in banana. This will allow us to formulate better recommendations for farmers with regards to plant management under drought stress, considering the energy or carbon budget of the plant. In addition, this experiment will contribute to a better understanding of carbon movement in banana crops, which are historically understudied, yet highly relevant under changing climate conditions.

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

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Climate change is affecting weather patterns all over the world. One of the effects of climate change in Central Africa is expected to be an increase in dry spells. These dry spells will decrease the production of staple crops such as cassava *(Daryanto, et al., 2016)*, affecting millions of people in that region. The Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA, www.cialca.org) is therefore aiming to increase cassava yields with the predicted climate change in mind. Several agronomical practices are being investigated to make cassava cropping systems more resilient against climate change. Variety selection and fertilizer application are the two main components in the battle against climate change which are being investigated in the SWMCN lab under the CIALCA project.

In the Soils Newsletter *(Soil Newsletter, July 2021),* an introduction was given on a cassava greenhouse experiment, which was conducted in the framework of CIALCA (www.cialca.org). This experiment was mainly focusing on the influence of variety selection and potassium application on drought tolerance of cassava. For a better description of the experiment, the reader is referred to the Soils Newsletter of July 2021. Shortly, a one month period of drought was imposed on one improved (*NAROCASS1*) and one local variety (*GACYARICYARI*) 5 months after planting (W+ and W- treatment). Of these plants, half received optimal potassium nutrient solution (K+ treatment), while the other half received suboptimal quantities of potassium (K- treatment).

In the previous newsletter, it was shown how potassium and variety play an important role in the morphology of cassava plants, as well as in their water use. However, it was not clear yet which effects these factors have on the transpiration efficiency. Here, we give more information about transpiration efficiency, its relation to carbon-13 and how fertilizer application and variety selection play role in that.

Based on ANOVA results, we can see that *NAROCASS1*, which is the improved variety, has a significantly better transpiration efficiency ($p<0.001$) compared to the local variety. With the same amount of water transpired, 85% more root biomass is produced in the improved variety. When we zoom in to the improved variety, we can also see that plants receiving the K+ solution, produced 79% more biomass per liter transpired water ($p<0.05$). The same effect of potassium could however not be seen in the local variety. Overall, there was no significant effect of the induced drought on the transpiration efficiency in both varieties.

Isotopic composition of leaves was also measured to assess its relationship to transpiration efficiency (linked to root biomass). Bulk $\delta^{13}C$ in leaves which were the youngest fully developed leaves just before the start of the drought, seemed to be better estimators ($R^2 = 0.53$) of transpiration efficiency (linked to root biomass) compared to leaves which were youngest fully developed at the moment of harvest (1 month after drought was induced). Plants using water less efficiently for root growth, showed leaf tissue which was less depleted in ^{13}C. This shows that $\delta^{13}C$ can be used as a proxy for transpiration efficiency.

Currently, a method for leaf sugar extraction is being fine-tuned and isotopic composition of cellulose is being analyzed. Both components will help interpreting isotopic data of the bulk samples, as $\delta^{13}C$ of cellulose remains stable after leaf formation (and thus giving information on the plant's status during the time of leaf formation), while sugars, produced at the moment of sampling, could give a better idea on present status of stress, regardless of which leaf is taken. It is still under investigation whether extracting sugars and cellulose and analyzing for $\delta^{13}C$ will give better estimates for transpiration efficiency.

To validate results from this greenhouse experiment, a collaboration with CIAT (Colombia) was initiated and fields were planted with 14 different varieties having different tolerances to drought. Samples from this experiment are currently being analyzed in the SWMCN laboratory.

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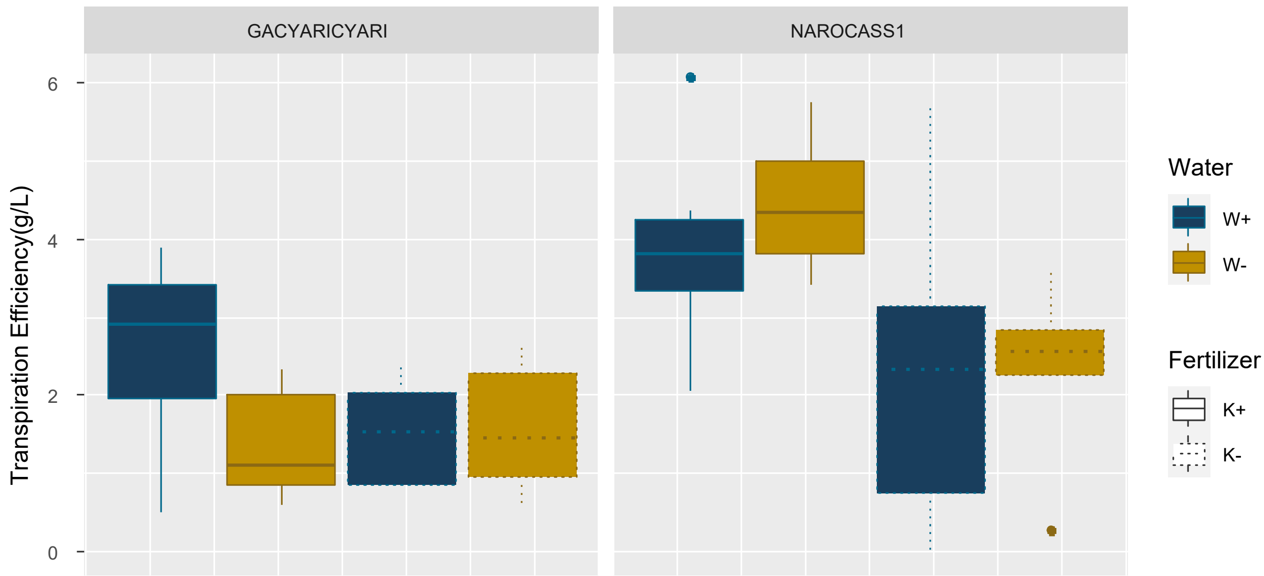

Figure 1. Transpiration efficiency of the storage roots (W+ treatment at 90% of pot capacity – blue color, W- treatment at 50% of pot capacity – brown color. K+ treatment - full line boundary, K- treatment – dotted line boundary, 6 replicates per group)

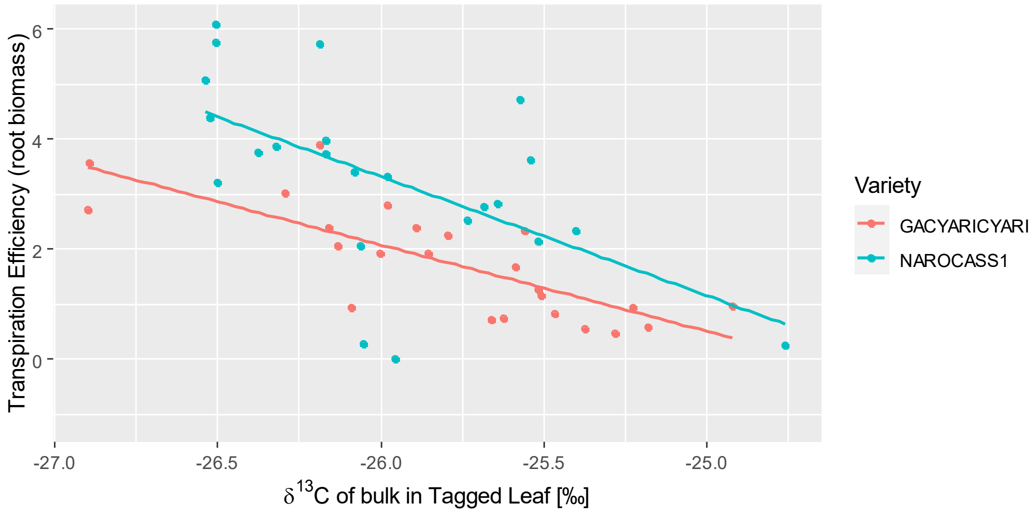

Figure 2. Relation between $\delta^{13}C$ in the bulk of the tagged leaf and the transpiration efficiency of the root biomass. R^2 is the correlation coefficient of a multiple linear regression with following formula: $TE = \beta_0 + \beta_1 * \delta^{13}C + \beta_2 * variety + \beta_3 * \delta^{13}C * variety + \varepsilon$. *Total number of observations is 48.*

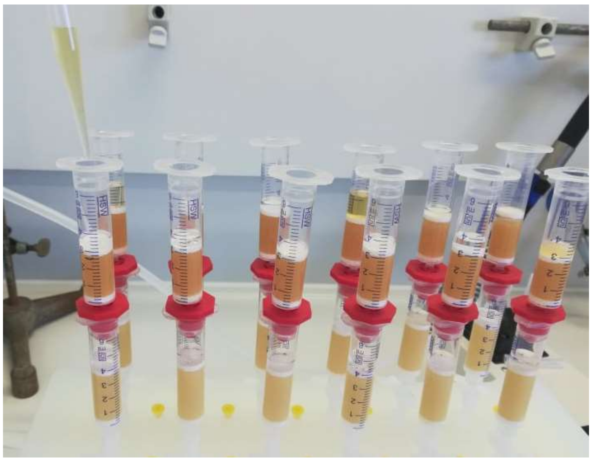

Figure 3. Sugar extraction from dried leaf samples. Anion and cation exchange resins are used to obtain the neutral fraction from the water soluble compounds after a sample solution is being added on top of the column

Understanding the interaction between maize water use efficiency and nutrient uptake in irrigated cropping systems, a basis for predicting and improving Zambia's productivity under a changing climate

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The agriculture sector is a key contributor to the Zambian economy and essential to ensure food security in the country. Overtime, climate change has had a negative impact on Zambian agriculture production. In line with its Vision 2030 to have an efficient, competitive, sustainable and export-led agriculture sector, Zambia is making efforts to improve irrigated agriculture through investments in various irrigation projects. Irrigated agriculture has the potential to secure farmers income but at the same time may impact the environment if resources are not properly managed. This study aims to improve irrigation management by optimizing water and nitrogen use efficiency for maximum crop water productivity at field levels while improving production. This will be used to predict and compare the effects of climate change on different water and nutrient application levels. To achieve this goal, the research will use and adapt nuclear and isotope techniques for the Zambian agro-ecological conditions. Drip irrigation will be the targeted system. The experimental design is as follows:

a. Water application levels for maize (deficit [50% and 75%] versus optimal irrigation versus farmer practice)

b. Nitrogen levels for maize (140 kg N/ha, 112 kg N/ha and 84 kg N/ha, optimal and widely practiced being 112 kg N per hectare)

Maize was grown as a sole crop, under the drip irrigation *(Figure 1),* during the 2021 dry season (April-October) with four levels of water application: (i) optimal (required amount as per crop water requirement), (ii) deficit (50% of optimal) (iii) deficit (75% of optimal) and (iv) farmers practice (which is leaving to the farmer to decide when to irrigate) and three levels of nitrogen applications. The rates of water (deficit and optimal) applied were determined by calculating the evapotranspiration using local climate data, FAO's New LoClim, CROPWAT software and root-zone soil water balance approach. Data collected include soil moisture monitoring with nuclear technology such as neutron probe *(Figure 1),* growth rate and punched samples of leaves of plants, which received ^{15}N enriched fertilizer, as well as ground grains and stalk samples *(Figure 2 a and b).*

Figure 1. Experimental field with maize, and Neutron probe for soil moisture monitoring

These data will be compiled and analyzed at the SWMCN laboratory *(Figure 2 c).*

This study will help Zambia and also countries with comparable agro-ecological conditions using nuclear and isotope techniques to increase crop water productivity under the drip irrigation system and to mitigate the impacts of climate change.

This project has been supported through the ICTP/IAEA Sandwich Training Educational Programme (STEP). Through this fellowship, the fellow Mumba Mwape can join the SWMCNL team three times over the next three years. You can find more information about ICTP/IAEA STEP opportunities on the following website: ICTP - ICTP/IAEA Sandwich Training Educational Programme.

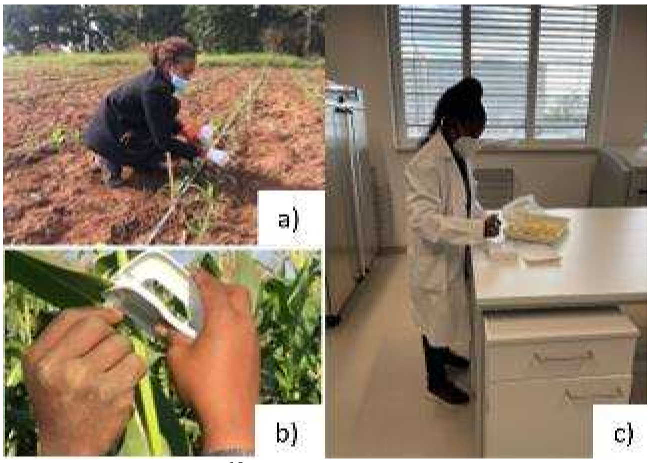

Figure 2. a) Applying ^{15}N labelled fertilizer on a subplot in the experimental field, b) Collecting punched maize leaf samples for ^{15}N analysis, and c) Labelled leaf sample preparation for ^{15}N analysis in the SWMCN laboratory.

AquaCrop cassava assessment

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Introduction

To enhance food security and income of cassava farmers through increased productivity, resource use efficiencies and climate resilience, the SWMCN Laboratory and Section launched the initiative to develop a cassava crop-file for the AquaCrop model. This initiative was supported by the Regional TC project RAF5081 on Enhancing Productivity and Climate Resilience in Cassava-Based Systems through improved Nutrient, water and Soil Management, and the Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA, www.cialca.org).

FAO's field-crop-water-productivity model, AquaCrop, was calibrated and validated for the case of cassava. The model simulates attainable crop biomass in response to soil moisture variations. Although based on basic and complex biophysical processes, the model uses a relatively small number of parameters to be adjusted according to the case and crop. AquaCrop balances accuracy, simplicity and robustness, and it is particularly well suited to conditions in which water is a key limiting factor in crop production.

Several climate, soil, canopy cover and biomass datasets were: i) retrieved from the *Decision Support System for Agrotechnology Transfer (DSSAT)* model (a software application program that comprises crop simulation models for over 42 crops; as of Version 4.7.5) for the CIAT site in Colombia, ii) shared by the *International Fertilizer Development C (IFDC)* in Togo and iii) the *African Cassava Agronomy Initiative (ACAI)* project of *International Centre for Tropical Agriculture International Institute of Tropical Agriculture (IITA)* in Nigeria; covering several varieties, years and regions.

Cassava simulations

A single crop file was created for the ensemble of South American and West-African experiments. Simulation performance was assessed by comparing observed and simulated dry total biomass. Results gave an overall R^2 of 0,90; RMSE of 2,0 t/ha and rRMSE of 3,5%. Final yield is not yet implicated, since harvest indices were too cultivar specific and ranged from 45 to 60%; and not enough final yield observations were available for each variety. An example for the MPtr-26 variety in Palmira (Columbia) is given in *Figure 1*.

Conclusions

The resulting cassava crop-file will be added in the upcoming updated AquaCrop version 7. A detailed article on the calibration and validation procedure and results is under revision for publication in Agricultural Water Management.

Acknowledgements

A special thanks goes to Luis Augusto Becerra and Michael Selvaraj from CIAT-CGIAR, Kodjovi Senam Ezui from the International Plant Nutrition Institute (APNI), Nigeria, and IFDC, and Joy Geraldine Adiele from the National Root Crops Research Institute (NRCRI), Nigeria, for sharing their cassava experiences and guidance through the extensive datasets.

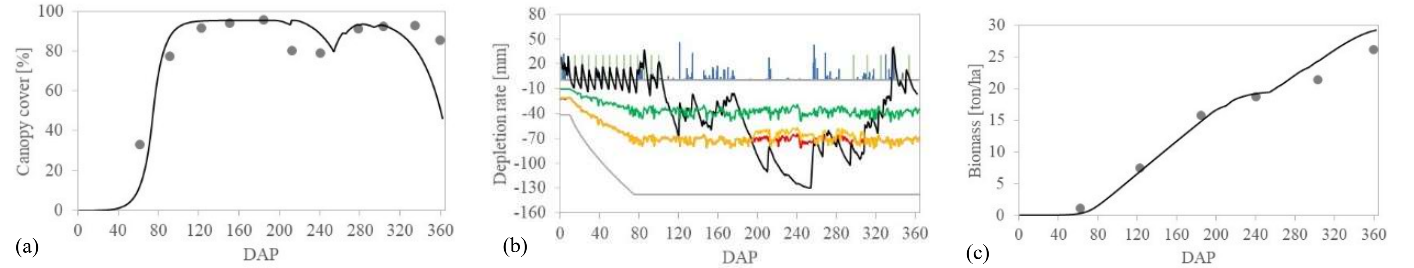

Figure 1. AquaCrop cassava simulation for the MPtr-26 variety for Palmira (Columbia, 1980); From left to right: a) simulated (line) vs observed canopy cover (dots); b) root zone water depletion (black line), depletion at saturation and permanent wilting point (grey dashed lines), and different water stress thresholds (green: canopy expansion; red: stomatal closure; orange: early senescence); c) cumulated biomass (line) vs observed biomass (grey dots).

The influence of ammonium fertilization and clay mineral amendments on caesium dynamics in different soils

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In the aftermath of a nuclear emergency, remediation of radioactive contamination is crucial to ensure food safety within affected regions. It is important to investigate soil properties and consider specific agricultural practices in planning remediation. Radiocaesium is one of the key radionuclides that raises concern for food safety.

The implementation of this research activity is under the Coordinated Research Project D15019 launched in 2019 which aims to enhance readiness and capabilities to optimize remediation. It emphasizes on under-explored agro-ecological environments to design an optimal remedial model. The SWMCN Laboratory, in close collaboration with the National Agriculture and Food Research Organization (NARO-Japan) and BOKU (University of Natural Resources and Life Sciences-Austria), has been evaluating the influence of ammonium (NH_4^+) fertilization and clay amendment in soil-to-plant transfer of radiocaesium, since the beginning of 2021.

Nitrogen (N) fertilizers are used widely around the world to improve crop yield. They are applied mostly as NH_4^+ since it is retained in soils due to its ability to occupy the negatively charged sites of organic matter and clay. However, NH_4^+ and caesium (Cs^+) compete for positions in these negatively charged sites. The release of Cs^+ into soil solution, from which plant roots directly take up nutrients and pollutants, can be caused by NH_4^+ fertilization and consequently facilitate Cs^+ plant uptake.

Results presented in the July 2021 newsletter showed that although initial addition of clay minerals to soil decreases NH_4^+ in soil solution, retained NH_4^+ was released afterwards (5 weeks incubation). This research focused on the behavior of NH_4^+ in connection with soil solution Cs^+ in Austrian, Belarusian, and three Japanese soils with strongly varying clay quantities and characteristics.

The results shown below elucidate the effect of a 300 kg NH_4^+-N fertilization and clay amendments on Cs^+ dynamics in the case of one of the investigated soils. This soil is an Allophanic Andisol, a typical Japanese soil with low selectivity for NH_4^+ and Cs^+ formed on volcanic ash. All obtained results indicated similar patterns of NH_4^+ and Cs^+ dynamics over time, whereby Cs^+ concentrations are up to 1000 times smaller than NH_4^+ concentrations.

NH_4^+ fertilization led to drastically raised NH_4^+ as well as Cs^+ concentrations in the beginning of the observation period *(Figure 1 and 2).* Without zeolite amendments, NH_4^+ concentrations reached 184 mg/L while Cs^+ raised up to 16 µg/L after one day. A strong NH_4^+ decrease could be observed between 8 and 22 days. This can be explained by nitrification processes, which cause a decrease in NH_4^+ and a simultaneous increase in NO_3, which is supported by further results of this experiment.

The application of 40t/ha zeolite caused a significant (α = 0.001) reduction of NH_4^+ as well as Cs^+ concentrations in soil solution after day 1 and 8, whereby effects on day 22 and 36 were small. Cs^+ was stronger adsorbed than NH_4^+ on the first day, as its concentration decreased almost 14-fold while NH_4^+ concentration decreased only threefold. An explanation for this could be the strong Cs^+ selectivity of zeolite. Previous results, which suggested an increase of NH_4^+ concentration after 22 days could be confirmed but occur on a low concentration level and did not affect Cs^+ concentrations in soil solution. Paradoxically, Cs^+ concentrations were in this case even lower despite higher NH_4^+ concentrations. As slow release of NH_4^+ after initial NH_4^+ fertilization can be beneficial for optimal plant growth, particularly under humid climate in which NO_3^- is easily lost from topsoil due to leaching, a synergy between remediation and agricultural practice can be assumed.

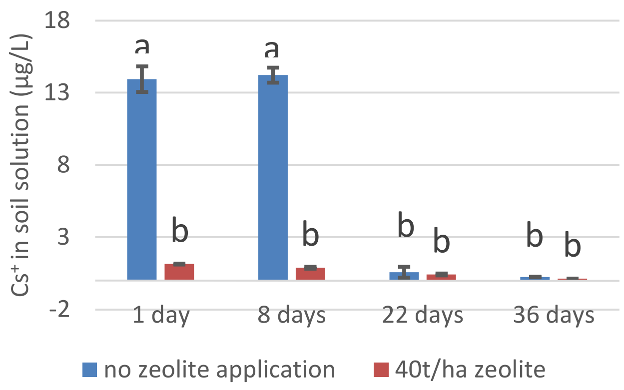

Figure 1. Cs^+ dynamics with and without zeolite amendments after NH_4^+ fertilisation. Different letters indicate significant differences between different days and treatments, with significance level of α = 0.05 (Tukey-Test).

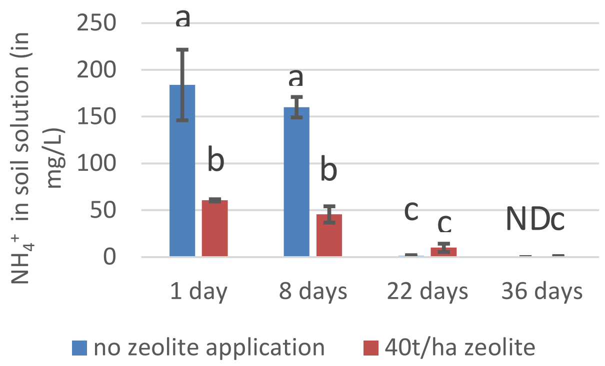

Figure 2. NH_4^+ dynamics with and without zeolite amendments after initial NH_4^+ fertilisation. Different letters indicate significant differences between different days and treatments, with significance level of α = 0.05 (Tukey-Test). ND values were below detection level.

Summarizing, zeolite application can display a useful measure to decrease Cs^+ in soil solution and thereby the probability of radioactive contamination of crops. However, it needs to be considered that it also leads to an increase of negative charges in soils and can remove positively charged plant nutrients as NH_4^+ from soil solution. Furthermore, a decrease in K^+ in soil solution provokes less selective uptake mechanisms in plant roots and so enhances the risk of Cs^+ uptake, as could be seen in investigations of Dengra I Grau (2020). A further step of this experiment will be the determination of K^+ in soil solution to better understand its interplay with NH_4^+ and Cs^+. Another focus will be on the differences among the investigated soils and the effects of different applied clay minerals and application rates. Future research should focus on actual plant uptake of Cs^+ to calculate even better the risk of radiocaesium contaminated soils and therefore the risk for human health.

SWMCNL hosted two group training courses for the staff of the Joint FAO/IAEA Centre

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As every year, FAO Headquarters in Rome funded training courses for the staff of our Joint FAO/IAEA Centre. In 2021, a total of four group training courses were held in Seibersdorf, in different fields, from scientific English up to modelling skills. The SWMCNL organized two of these four courses, described below.

Theoretical and practical principles of mathematical processing of (mid-infrared) spectral datasets for the prediction of characteristics of soils, plants, food or insects (6-10 September 2021).

> Franck guided us fluently through the jungle of machine learning. With well explained lectures combined with hands-on exercises, Franck prepared us to handle our own datasets in a very short amount of time.
>
> Jonas Van Laere, Joint FAO/IAEA Centre

This was the second edition of a training on theoretical and practical principles of mathematical processing of (mid-infrared) spectral datasets for the prediction of characteristics of soils, plants, food or insects.

During this training course, participants learned how to process mid-Infrared spectral datasets step by step: from data import, preprocessing, to modeling with traditional partial least squares regression and advanced machine learning approaches such as ensemble learning and Convolutional Neural Networks.

Theoretical sessions allowed to cover the fundamental themes of machine learning and justify the use of different classes of algorithms with respect to the volume of data available. During practical sessions, participants could harness the rich ecosystem of Python open-source packages through the implementation of an entire modeling pipeline to predict the clay content of soils using MIRS spectra from the KSSL spectral library. Indeed, through the collaboration with the FAO Global Soil Laboratory Network (GLOSOLAN) and the Kellogg Soil Survey Laboratory (KSSL) of the United States Department of Agriculture (USDA), the SWMCNL has gained access to a game changing MIRS spectral library of more than 80K scanned soil samples.

However, it is important to note that the machine learning principles explained, and techniques deployed in the workshop are also relevant to all of the research fields of the Joint FAO/IAEA Centre.

In total ten FAO/IAEA staff members participated in the training provided by Mr. Franck Albinet, who has been providing his expertise in Data Science 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.

Experimental Design and Data Interpretation (Biostatistics) through R (September – October 2021)

For five days spread over five weeks in September and October, the course on "Experimental Design and Data Interpretation (Biostatistics) through R" was held, with a total of 20 participants of the Joint FAO/IAEA Centre.
The workshop focused on how to design and carry out experiments in the context of food and agriculture and analyze the data, with examples in R, an open-source software with multiple data analysis capacities. The workshop included the possibility for personalized technical advice on statistical analysis on request.

> The guidance and support provided by Juan Carlos during the course is very much appreciated, he changed our perspectives of the "paranormal distribution" or a more appropriate "normal distribution".
>
> Chantel De Beer, Joint FAO/IAEA Centre

The first workshop session (5 days, spread over 5 weeks) focused on advanced statistics for food and agriculture, including design and implementation of experiments focusing on advanced experiments, with a variety of experimental designs such as completely randomized,

randomized complete and incomplete blocks, as well as split-plot designs. Furthermore, techniques to analyze long-term trials and experiments that executed repeated measurements on a specific subject/plot were included.

The workshop started by reminding the assistants the most basic, although often overlooked, statistical concepts such as correlation, confounding variables, randomization, and replication, as well as how strongly these concepts influence data analysis later on. The participants then started to familiarize themselves with R, and how it responds, stores, and displays information. Exercises in R for data management, data ingestion, descriptive and inferential statistics were undertaken allowing participants to experiment with basic data sets and create reproducible scripts that could help as template to later analyze their own data sets.

The second part of the workshop (3 additional days) included the possibility of requesting personalized and technical advice, focusing on the statistical analyses of NAFA's (Joint FAO/IAEA Centre for Nuclear Techniques in Food and Agriculture) related experiments and databases. This support was provided on-site (Seibersdorf) as well as remotely through email and video support.

The range of data sets discussed included, for example, the analysis of different methods to separate mosquito populations, the comparison of different irrigation and nutrient levels and COVID-19 methods of detection, as well as potential use of incomplete block designs for trials with many treatments. The participants were encouraged to further explore the software keeping in mind key statistical design concepts that enable meaningful inferential analyses.

This training was provided by Mr. Juan Carlos Laso Bayas. Juan Carlos joined the International Institute for Applied Systems Analysis (IIASA) in September 2015 as a research scholar. He currently works with the Novel Data Ecosystems for Sustainability (NODES) group in the Advancing Systems Analysis (ASA) program and his current scientific interests include the use of GIS and spatial statistics, more specifically mixed models, to analyze remote sensing data, aiming to contribute to agricultural production, food security, disaster management and community resilience.

Analytical Services

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In 2021, 4123 samples were analysed for stable isotopes 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.

Publications

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Websites and Links

- Soil and Water Management and Crop Nutrition Section:
  https://www.iaea.org/topics/land-and-water-management
- Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture:
  https://www.iaea.org/topics/food-and-agriculture
- Food and Agriculture Organization of the United Nations (FAO):
  http://www.fao.org/home/en
- New communication materials outlining successes in the area of nuclear techniques in food and agriculture:
  https://www.iaea.org/sites/default/files/cb5847en.pdf

Impressum

Soils Newsletter Vol. 44, No. 2

The Soils Newsletter is prepared twice per year by the Soil and Water Management and Crop Nutrition Section, Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture and FAO/IAEA Agriculture & Biotechnology Laboratories, Seibersdorf.

International Atomic Energy Agency
Vienna International Centre, PO Box 100, 1400 Vienna, Austria
Printed by the IAEA in Austria, January 2022

21-04494