



Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Soil Science Unit

Activities Report 2008



FAO/IAEA Agriculture & Biotechnology Laboratory
IAEA Laboratories Seibersdorf
International Atomic Energy Agency
Vienna, Austria

This document is an internal FAO/IAEA report and is intended only for limited distribution. The material contained is of preliminary nature, and therefore, the report should not be quoted or listed as a reference in publications.



The Soil Science Unit (SSU) of the FAO/IAEA Agriculture and Biotechnology Laboratory develops and tests nuclear techniques in the field of crop nutrition, soil erosion and sedimentation as well as water management. During the past years the research and development work of the Unit have had major impact through the transfer of nuclear technology to developing Member States.

Major progress has been achieved during 2008 on the use of fallout radionuclides (FRN) in quantification of soil erosion and sedimentation. Our experimentation in collaboration with Boku University in Mistelbach (Austria) using ^{137}Cs and ^{210}Pb and conventional runoff plots has been completed demonstrating the reduction of soil loss by a factor of 10 when adopting direct seeding in conservation agriculture; in the same time conservation tillage (20 cm instead of 30 cm) and direct seeding were effective in reducing sedimentation rates on the average by 65% under the experimental condition. Collaborative research investigations and technical supports in the use of radioisotopic approaches have been provided to two Member States: Nigeria and Slovenia. Also, in 2008 with the involvement of fellow, a preliminary test has been conducted in Seibersdorf on the use of ^7Be as short term soil tracer. Through a major review paper published this year in the Journal of Environmental Radioactivity in association with two international well known experts, recent and future trends in the use of ^{137}Cs , ^{210}Pb and ^7Be for documenting soil redistribution was completed. This paper also provided clear recommendations to Member States for an accurate selection of the most appropriate FRN for agroenvironmental investigation.

Drought, salinity and declining soil fertility underscore the need for expanding the availability of plant varieties that can be productively grown in harsh environments due to the emerging climate change. Methodologies for using the stable isotopes of carbon (carbon isotope discrimination techniques) were tested and fine-tuned to effectively evaluate rice and wheat genotypes with high agronomic water and nutrient (nitrogen and phosphorus) use efficiency. In addition, a modified laboratory methodology and protocols to use radioisotopes of phosphorus (P) to estimate the differential ability of cereals and legumes to grown in low-P soils were developed and validated. The practical application of the validated carbon isotope discrimination technique is currently used in collaboration with Soil Scientists and Plant Breeders in Bangladesh, Pakistan, and Sudan through a Coordinated Research Projects (CRP) and Technical Cooperation Projects (TCPs) to select wheat and rice lines tolerant to drought and salinity. In collaboration with the Pennsylvania State University, a field root methodology that is capable of discerning variations for root traits important for efficient phosphorus and water uptake with minimum labour and expense has been developed and effectively used to identify and evaluate efficient rice, maize and beans lines adapted to low soil P environments in parts of Cuba, Mozambique and Mexico.

Nine fellows from developing Member States received individual fellowship training at the Soil Science Unit during 2008 a total of 29 man-months of training. The fellows were trained in a range of isotope and nuclear techniques related to integrated land, water, and crop management for high crop-water productivity and environmental sustainability. The collaboration between the Plant Breeding Unit and the Soil Science Unit were further strengthened through joint fellowship training in the use of stable isotopes to identify crops with increased resilience to abiotic stress. Eight scientific visitors received furthermore training by the Soil Science Unit during the year in the field of crop nutrition, water management and soil erosion and sedimentation for a total of 35 days.

A total of 12024 stable isotope measurements were performed during 2008. Most analyses were for supportive research as well as for training with some 3700 for CRPs and 100 for TCPs. Furthermore the Soil Science Unit performed 788 radioisotopes measurements for supportive research in 2008.

The External Quality Assurance of isotope analyses was outsourced during 2008 with Wageningen Evaluating Programs for Analytical Laboratories (WEPAL) looking after the proficiency test for the FAO/IAEA. Eleven laboratories reported isotope abundance data within the deadline. The big advantage of comparing analytical data to those of a large and increasing number of analytical laboratories worldwide will provide high confidence in the laboratory's analytical performance and is an invaluable tool for external quality control. It is hoped that in the future more stable isotope laboratories will make use of this opportunity to assess their analytical performance and provide evidence of the sustainable high quality of their analytical data.

The SSU coordinates a CRP on Selection and Evaluation of Food (Cereal and Legume) Crop Genotypes Tolerant to Low Nitrogen and Phosphorus Soils through the Use of Isotopic and Nuclear-Related Techniques. In addition the SSU coordinated 13 TC projects (Angola, Bangladesh, Chile, Eritrea, Kenya, Madagascar, Mali, Mongolia, Ivory Coast, Sierra Leone, Slovenia, Sudan, and Yemen).

Total of 15 publications were produced by the Soil Science Unit and co-authors during 2008.

Table of Contents

Executive Summary.....	i
1. PROGRAMMATIC AND UNIT OBJECTIVES.....	1
2. STAFF.....	3
3. RESEARCH AND DEVELOPMENT ACTIVITIES.....	5
3.1. Update of Previous Investigations on the Use of Fallout Radionuclides (^{137}Cs & ^{210}Pb) in Mistelbach-Austria	5
3.2. Preliminary Test in Slovenia to Assess Erosion and Sedimentation Processes Using Radio-Isotopic Approach	7
3.2.1. Description of the Study Site	8
3.2.2. Soil Sampling, γ -laboratory Measurements and Preliminary Results	9
3.3. Selection of the Most Appropriate FRN (^{137}Cs , ^7Be , ^{210}Pb) for Agroenvironmental Investigation in Member States	11
3.4. State of the Art, Research Needs and Analysis of Recent and Future Trends in the Use of FRN for Documenting Soil Erosion and Soil Redistribution.....	14
3.5. First Investigation in Seibersdorf Laboratory of a Promising Short Term Soil Tracer: ^7Be	16
3.5.1. Basic Information and Principles	16
3.5.2. Testing of the Methodology under Field Conditions at the Seibersdorf Laboratory	16
3.6. The First Application of Nuclear Techniques (FRN) in the Derived Savanna of Nigeria for Estimating Medium-Term Soil Redistribution Rates: Preliminary Results.....	19
3.7. Summary of the Results on the Use Carbon Isotope Techniques in the Quest for Higher Productivity in Nutrient, Salt and Water Stressed Environments	22
3.7.1. Implications for Using the Carbon Isotope Discrimination Techniques to Select Wheat and Rice Genotypes for Higher Agronomic Water Use Efficiency under Nutrient Stress Environments.....	22
3.7.2. Carbon Isotope Discrimination Techniques to Select Wheat and Rice Genotypes for Higher Agronomic Water Use Efficiency under the Combined Effect of Water and Salt Stress Environments	23
3.8. Variations in Phosphorus Acquisition from Sparingly Soluble Forms by Maize and Soybean in Low and Medium-Phosphorus Soils Using ^{32}P	25
3.8.1. The Challenge	25
3.8.2. Experimental Design.....	25
3.8.3. Plant and Soil Sampling and Analyses.....	26
3.8.4. Results.....	28
3.8.5. Main Findings	30
3.9. Investigation of the Plant Response to Irrigation Water with Conventional Methods and ^{18}O	32
3.9.1. Introduction.....	32
3.9.2. Objective of the Study	32
3.9.3. Material and Methods	32
3.9.4. Irrigation System and Soil Preparation	33
3.9.5. Preliminary Results	33
3.9.6. Soil Characteristics	34

3.9.7.	Conclusion	35
3.10.	Can Efficient Irrigation and Nitrogen Management Practices Contribute to Nitrate Reduction in Groundwater under Intensive Farmer-Managed Vegetable Fields in Slovenia Catchments?	36
3.10.1.	The Challenge	36
3.10.2.	The Project	36
3.10.3.	Main Findings	37
3.10.4.	A 2-day Round Table Discussion to Mark the Culmination of TC project SLO/ 5002	38
3.11.	Selection and Evaluation of Food (Cereal and Legume) Crop Genotypes Tolerant to Low Nitrogen and Phosphorus Soils through the Use of Isotopic and Nuclear Related Techniques	40
3.11.1.	A Mid-Term Review	40
3.12.	Roots for Crop Productivity	42
3.13.	Stable Isotope Analyses	43
3.14.	Radioisotope Analyses	44
3.15.	External Quality Assurance	46
3.15.1.	Evaluation Criteria for IAEA-participants	46
3.15.2.	Conclusions	47
4.	TRAINING ACTIVITIES	50
4.1.	Individual Fellowship Training	50
4.2.	Scientific Visits	51
5.	ACKNOWLEDGEMENTS	52
6.	APPENDICES	53
6.1.	Staff Publications	53
6.1.1.	Journal Articles	53
6.1.2.	Conference Proceedings/Abstracts /Reports	53
6.2.	Staff Travels	55
6.3.	External Collaborations and Partnerships	58
6.4.	Trainees, Fellows and Scientific Visitors	60
6.5.	Co-ordinated Research Projects (CRP) and Technical Cooperation Projects (TCP).....	63
6.6.	Abbreviations	64

1. PROGRAMMATIC AND UNIT OBJECTIVES

Management practices and technological packages which conserve natural resources, minimize environmental degradation and mitigate climate changes are becoming increasingly vital to improving or even maintaining food security and environmental sustainability. Understanding transformation processes that influence soil health, including the efficient use of water and nutrients, and developing and delivering technological packages through various networks will be essential to enhance the sustainability of agricultural systems. Through the development and improvement of stable and radioactive isotopic techniques, the Soils subprogramme assists Member States (MS) to monitor and predict the impacts of climate change and agricultural land use aimed at addressing the land-water-nutrient issues in the individual countries.

The Soil and Water Management and Crop Nutrition (SWMCN) Section of the Joint FAO/IAEA Division and the Soil Science Unit (SSU) of the FAO/IAEA Agriculture & Biotechnology Laboratory assist in developing and delivering a range of isotopic and nuclear technological packages to MS, which will help conserve natural resources, minimize environmental degradation and mitigate climate change aimed at improving food security and soil health.

Nuclear techniques used in the field of land-water-nutrient management complement conventional techniques and provide unique information which other techniques often cannot provide. This includes:

- Quantitative information on the flow and fate of fertilisers in soils and uptake of nutrients by plants. Such information is essential in identifying efficient fertiliser management practices that minimizes movement of soil nutrients into ground waters where they become potential pollutants.
- Identification of sources of soil water and its availability to plants, essential in identifying crop plants tolerant to environmental stresses (drought, salinity, nutrients) brought about by climate or other changes to the agri-ecological system.
- Measurement of soil water storage in cropping systems, indispensable in developing novel irrigation and soil management strategies aimed at assessing and mitigating the impact of water scarcity.
- Measurement and quantifying land degradation and soil erosion by the use of fallout radionuclides.
- Identification of sources of soil carbon vital in and estimating the contribution of organic carbon sources to global warming
- Quantification of biological nitrogen fixation in cropping systems, enabling also discrimination between soil and atmospheric nitrogen usage by agricultural crops.

The main roles of the SSU are to:

- To develop and validate the use of stable- and radio isotope applications in the plant-soil-water-atmosphere continuum,
- To train technical staff and scientists from Member States in the analyses of stable isotopes and the use of nuclear and related techniques to address land-water and nutrient issues,

- To provide isotope analyses to projects where analytical facilities are not currently available,
- To supply reference materials and quality assurance services to Member States.

The Soils Newsletter published two times annually by the IAEA provides details on current and future programmes.

2. STAFF

IAEA Laboratories

Name	Title	E-mail	Extension
Voigt, Gabriele	Director	G.Voigt@iaea.org	28200

FAO/IAEA Agriculture & Biotechnology Laboratory

Name	Title	E-mail	Extension
Busch-Petersen, Erik	Laboratory Head	E.Busch-Petersen@iaea.org	28267
Makovicky, Kyoko	Clerk	K.Makovicky@iaea.org	28362
Kizhakkekara, Smitha	Clerk	S.Kizhakkekara@iaea.org	

Soil Science Unit

Name	Title	E-mail	Extension
Hardarson, Gudni	Unit Head	G.Hardarson@iaea.org	28277
Adu-Gyamfi, Joseph	Soil Scientist / Plant Nutritionist	J. Adu-Gyamfi@iaea.org	28263
Mabit, Lionel	Soil Scientist	L.Mabit@iaea.org	28271
Mayr, Leopold	Senior Laboratory Technician	L.Mayr@iaea.org	28305
Arrillaga, José Luis	Senior Laboratory Technician	J.L.Arrillaga@iaea.org	28306
Aigner, Martina	Senior Laboratory Technician (50%)	M.Aigner@iaea.org	28212
Heiling, Maria	Senior Laboratory Technician (50%)	M.Heiling@iaea.org	28272
Gludovacz, Doris	Laboratory Technician	D.Gludovacz@iaea.org	
Toloza, Arsenio	Laboratory Technician	A.Toloza@iaea.org	28203
Jagoditsch, Norbert	Technical Attendant	N.Jagoditsch@iaea.org	28422
Macaigne, Peggy	Consultant	P.Macaigne@iaea.org	26843

Soil Science Unit



Joseph
ADU-GYAMFI



Gudni
HARDARSON



Lionel
MABIT



José Luis
ARRILLAGA



Martina
AIGNER



Leopold
MAYR



Doris
GLUDOVACZ



Arsenio
TOLOZA



Maria
HEILING



Peggy
MACAIGNE



Norbert
JAGODITSCH

3. RESEARCH AND DEVELOPMENT ACTIVITIES

3.1. Update of Previous Investigations on the Use of Fallout Radionuclides (^{137}Cs & ^{210}Pb) in Mistelbach-Austria ¹

Collaborative work of Boku University (Austria) and the Soil Science Unit

The investigation performed in 2007 by the SSU in collaboration with Boku University in Mistelbach-Austria and previously partly presented in the **2007 SSU Activities Report** has been updated and submitted to publication to the peer-reviewed journal *Geoderma* by the following authors Mabit, L, A Klik, M Benmansour, A Toloza, A Geisler and UC Gerstmann under the title: ‘*Combined assessment of erosion and deposition rates within an agricultural watershed in Mistelbach, Austria, using ^{137}Cs , $^{210}\text{Pb}_{\text{ex}}$ and conventional erosion plots measurements*’. During 2008, the results were also presented during three international conferences.

The main objective was to assess the magnitude of deposition rates using fallout radionuclides ‘FRN’ (^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$) and the mid-term (13 years) erosion rates using conventional runoff plot measurements in a small agricultural watershed under conventional and conservation tillage/cropping practices. The main results of this first test of the use of ^{137}Cs and ^{210}Pb in Austria can be summarised as follow:

- i) Long-term erosion measurements (1994-2006) from runoff plots located in the upper part of an agricultural field just up-slope from a deposition area was $29.4 \text{ t ha}^{-1} \text{ yr}^{-1}$ in the conventional tilled plot, $4.2 \text{ t ha}^{-1} \text{ yr}^{-1}$ in the conservation tillage plot and $2.7 \text{ t ha}^{-1} \text{ yr}^{-1}$ in the direct seeding treatment. Soil losses were reduced significantly by a factor of 10 using no tillage, direct seeding treatment.
- ii) Using the ^{137}Cs data that integrate the 1954-2007 period, the sedimentation rates down slope of the field containing the runoff plots were estimated at:
 - $26.1 \text{ t}^{-1} \text{ ha}^{-1} \text{ yr}^{-1}$ using the ^{137}Cs depth distribution profile
 - $20.3 \text{ t}^{-1} \text{ ha}^{-1} \text{ yr}^{-1}$ using the Mass Balance Model 2 (MBM2)
- iii) The erosion rates under conventional tillage are in agreement with the sedimentation rates estimated down slope of the field by the ^{137}Cs depth distribution profile and MBM2.
- iv) In the lowest part of the watershed sedimentation rates of $50.5 \text{ t}^{-1} \text{ ha}^{-1} \text{ yr}^{-1}$ were highlighted by the ^{137}Cs depth distribution profile. These rates were greater than the average erosion rates measured by the erosion plots because this area is more representative of sedimentation processes occurring in the study area due to its topographical position and the basin geomorphology.
- v) While ^{137}Cs produced exploitable results, the ^{210}Pb method was not applicable due to very low concentrations of $^{210}\text{Pb}_{\text{ex}}$ associated to a high uncertainty in the measurements.

¹ Project 2.1.1.1. Soil Management and conservation for sustainable agriculture and environment – Task 2: Improve FRN methodologies to measure soil redistribution rates at a range of scales in agricultural landscapes with the use of geostatistic approach.

It is well known that to control soil erosion and associated land degradation, there is a need to assess the impact of major land use and the effectiveness of specific soil conservation technologies. FRN as well as runoff plots can be associated to assess the environmental impact of soil conservation and the magnitude of soil redistribution.

3.2. Preliminary Test in Slovenia to Assess Erosion and Sedimentation Processes Using Radio-Isotopic Approach ²

Collaborative work of the Centre for Agricultural Land Management and Agrohydrology of the University of Ljubljana (Slovenia) and the Soil Science Unit

Soil quality is decreasing worldwide due to erosion and lost of nutrients, and as a result the cost of producing food is rising. Water erosion is one of the major sources of soil degradation on the continental temperate plains. Growing evidence of the cost of soil erosion on agricultural land and off site impact of associated processes has emphasized the need for quantitative assessment of recent erosion rates to develop and assess erosion control technology and to allocate conservation resources and development of conservation regulation, policies and programmes.

Slovenia, with only 8.5% of arable land, is not spared from this phenomenon, with more than 70% of its territory affected by major soil degradation problems mainly linked to water erosion process. Associated environmental impacts such as surface water eutrophication and groundwater pollution by nitrate are serious problems in Slovenia, mainly in the most intensive agricultural regions.

Soil erosion in Slovenia has been studied since the mid 1950's but few data are available. Existing soil erosion reviews clearly demonstrate the mobilisation of the Slovenian scientific community including geomorphologists, geographers, hydrologists and soil scientists to gain information on erosion and sedimentation rates and processes at various scales. Investigations have been done mostly using field observation and using different conventional tools:

- i) Rainfall erosivity assessment;
- ii) Field measurement of visible erosion features and morphometric measurements;
- iii) Runoff erosion plots with and without rainfall simulation;
- iv) Erosion risk assessment using surface morphology combining GIS, DEM and radar photos;
- v) Sediment loading measurements;
- vi) Empirical sediment transport models;
- vii) Satellite remote sensing approach in combination with other data.

Such measurements and/or model calibration have to be carried out over several years to integrate inter-annual and mid-term climatic variability and land use evolution. However, the use of nuclear techniques especially Fallout Radionuclides (e.g. ¹³⁷Cs) can complement the information provided by conventional approach.

To obtain quantitative estimates of soil erosion and deposition rates from radionuclide measurements, the first major step is to determine the baseline value of the area investigated

² Project 2.1.1.1. Soil Management and conservation for sustainable agriculture and environment - Task 2: Improve FRN methodologies to measure soil redistribution rates at a range of scales in agricultural landscapes with the use of geostatistic approach.

to which the ^{137}Cs contents of the agricultural fields will be compared. This first contribution presents the evaluation of the reference inventory of ^{137}Cs in an undisturbed Slovenian forest chosen as reference site.

3.2.1. Description of the Study Site

The study site is located in Pomurje – the sole Slovenian macroregion in which agricultural landscape still prevails – in Goričko, a hilly area close to the Hungarian and Austrian borders at the beginning of the Pannonian plains, East Slovenia (**Figure 1**).

The area under investigation has a moderate inland continental climate with mild winters and cool summers with an average annual temperature of 9 °C. Precipitation reaches 870 mm yr⁻¹ with most of the rainfall occurring during summer, winter being the driest season.

After compilation of available documents coupled with farmers enquires and the absence of permanent pasture, an undisturbed forest situated a few meters from the future agricultural study area in Šalamenci (46°44'N, 16°7'E) (**Figure 1**) was selected as reference site. This forest covers approximately 1.9 ha with a flat topography (slope < 2%) for an average elevation level of 242 meters.

However, a sharp contrast can be observed in the topography of the surrounding agricultural fields as in the upper half of Goričko hills slopes reach 20%, while in the lower part slopes generally do not exceed 3%. Around the forest, the landscape consists of semi-dry and dry meadows, which are now disappearing due to land abandonment and subsequent forestation. The average field size is 1.5 ha, predominantly covered by forage crops (silage corn, barley and wheat) that occupy up to 80% of the cropped area. Agricultural fields are ploughed till 20 cm in the direction of the slope.

The study site is located on the edge of the alluvial Pleistocene terrace consisting of silty clayed sediments deposited by the river Ledava and the subsidiary affluent. Developed on noncarbonated substratum, the soil of the Šalamenci forest can be classified as Haplic Stagnosol according to the FAO classification. Based on the physico-chemical analysis, the top-soil of the forest investigated is a silt loam strongly acidic with high organic matter content.



Figure 1. Location and aerial photography of the forested studied site and adjacent agricultural fields near Šalamenci in East Slovenia.

3.2.2. Soil Sampling, γ -laboratory Measurements and Preliminary Results

In the forest, a homogenous area of 1200 m² was selected with reduced canopy and roots occurrence. The area of concern was sampled using a 'Systematic grid sampling' on the basis of a rectangular grid (40 x 30 meters). The origin and direction for placement of the grid was selected by using an initial random point located within the forest. Soil samples were collected at each intersection of the grid lines using bulk density cylinder (**Figure 2**). A total of 20 sampling points have been collected at 4 different depth increments (0-10, 10-20, 20-30 and 30-40 cm) for a total of 80 samples. Soil samples were oven-dried for 48 hours at 70°C, sieved through a 2 mm mesh and homogenized. The fine material was analysed for ¹³⁷Cs activity content by γ -spectrometry using the gamma detector of the SSU. Each soil sample for ¹³⁷Cs determination was counted for a period of 50 000s to reach an acceptable level of detection limit.



Figure 2. Ms. Vesna Zupanc - SSU previous fellow - performing soil sampling using bulk density cylinder.

A high level of ¹³⁷Cs was detected in the first 0-10 cm soil increment and the activity of the ¹³⁷Cs measured in 20-30 cm layer and especially the 30-40 cm layer was most of the time close or under the detection limit of the detector with a high measurement error (**Table 1**).

The ¹³⁷Cs profile distribution in this forested site is typical of an undisturbed soil. An exponential decrease of the ¹³⁷Cs activity across the soil profile can be noticed with 84% of the total caesium inventory in the 0-10 cm increment and 97% in the first 20 cm. With a maximum areal activity of 11 302 Bq m⁻² and a maximum mass activity of 147 Bq kg⁻¹ in the first 10 cm (**Table 1**), the values are very high in comparison with our previous investigation

Table 1. ¹³⁷Cs summary statistics per soil depth increments.

	Depth interval 0-10 cm		Depth interval 10-20 cm		Depth interval 20-30 cm		Depth interval 30-40 cm	
	¹³⁷ Cs content (Bq kg ⁻¹) (Bq m ⁻²)		¹³⁷ Cs content (Bq kg ⁻¹) (Bq m ⁻²)		¹³⁷ Cs content (Bq kg ⁻¹) (Bq m ⁻²)		¹³⁷ Cs content (Bq kg ⁻¹) (Bq m ⁻²)	
Mean	70.1	6127	7.6	972	1.0	145	0.47	70.4
SD	33	2514	6.3	719	0.78	110	0.27	40
Kurtosis	0.2	-0.5	3.3	2.8	4.7	4.9	-0.16	-0.47
Skewness	0.7	0.5	2.0	1.9	2.0	2.0	0.9	0.8
Minimum	22	2230	2.6	369	0.3	41	0.1	20
Maximum	147.5	11302	24.7	2863	3.4	489	1.1	156
CV (in %)	47	41	84	74	76	75	58	56

in Mistelbach (Austria) where the base level of ^{137}Cs was 1954 Bq m^{-2} . This is probably due to an additional Chernobyl contribution.

The activity of ^{137}Cs at the Šalamenci site reached $7315 \pm 1255 \text{ Bq m}^{-2}$ with a coefficient of variation (CV) of 34 %. This value is within the range of CVs results – 19 to 47 % – reported on forested reference sites.

This estimated ^{137}Cs base level will be used in future investigations in Slovenia to assess the soil redistribution in neighbouring agricultural fields. During 2009, inventories and depth distribution of other gamma emitters (^{40}K , ^{226}Ra , ^{232}Th , ^{235}U and ^{238}U) from the same undisturbed forested soil will be investigated.

3.3. Selection of the Most Appropriate FRN (^{137}Cs , ^7Be , ^{210}Pb) for Agroenvironmental Investigation in Member States³

The FRN cesium-137 (^{137}Cs), excess or unsupported lead-210 ($^{210}\text{Pb}_{\text{ex}}$) and beryllium-7 (^7Be) have been used successfully as tracers of soil redistribution, because they are non-exchangeable, and on delivery to the land surface as fallout they are rapidly and strongly fixed by the surface soil or small sediment particles. Examples of the vertical distribution of ^{137}Cs , $^{210}\text{Pb}_{\text{ex}}$ and ^7Be in undisturbed and non-cultivated (e.g. pasture and rangeland) and cultivated soils are presented in **Figure 3**.

Their subsequent redistribution within the landscape occurs primarily through physical processes and they thus provide a very effective tracer of soil and sediment redistribution. The FRN inventories found in agricultural areas are generally reduced on convex slopes, which constitute eroding areas and increased in depressions or small valleys and at the base of the slopes (depositional areas). Assessment of erosion and deposition rates is commonly based on a comparison of the FRN areal activity density or inventory at individual points in the landscape with that for a representative 'stable' landscape position known as the 'reference site', where neither erosion nor deposition has occurred and the FRN inventory reflects the total fallout input and its subsequent radioactive decay.

Erosion and sedimentation rates estimated using FRN measurements have been validated against other more conventional data provided by erosion plots, erosion pins, erosion-sedimentation modelling and catchment sediment yields, in a range of environments. Furthermore, many studies undertaken to date provide a basis for identifying the likely advantages and limitations associated with individual FRN.

An in depth review suggested by the participants of the Coordinated Research Project D1.50.08 "*Assess the effectiveness of soil conservation techniques for sustainable watershed management using fallout radionuclides*" during the fourth and final Research Coordination Meeting (RCM) of this CRP was performed in 2008 by the SSU in collaboration with the Centre National de l'Énergie, des Sciences et des Techniques Nucléaires (CNESTEN) in Rabat-Morocco and the Department of Geography of the Exeter University of UK to identify key knowledge gaps linked to the use of FRN to assess erosion and sedimentation processes. In addition, guideline materials for selecting the most appropriate FRN and associated approach, in order to deal with a range of spatial and temporal scales and to investigate specific sets of agro-environmental problems, were provided. The selection and application of a particular FRN for documenting or investigating soil erosion and redistribution should reflect the user's objectives, the advantages and limitations of each approach, and, the human and material resources available in Member States.

Table 2 synthesizes the present state of knowledge regarding the use of FRN in soil erosion investigations, by summarizing and comparing the advantages and limitations of the ^{137}Cs , ^{210}Pb and ^7Be methodologies. The full paper was published in 2008 in «*Journal of Environmental Radioactivity*» (Ref: L Mabit, M Benmansour, DE Walling (2008).

³ Project 2.1.1.1. Soil Management and conservation for sustainable agriculture and environment - Task 2: Improve FRN methodologies to measure soil redistribution rates at a range of scales in agricultural landscapes with the use of geostatistic approach.

Comparative advantages and limitations of Fallout Radionuclides (^{137}Cs , ^{210}Pb and ^7Be) to assess soil erosion and sedimentation. *Journal of Environmental Radioactivity*, 99 (12), 1799-1807) and can also be obtained upon request from the SSU.

Table 2. Comparison of the advantages and limitations of ^{137}Cs , $^{210}\text{Pb}_{\text{ex}}$ and ^7Be for documenting soil erosion and sediment redistribution (Adapted from Mabit *et al.*, 2008).

	Radionuclide origin	Energy emission (keV)	Half life	Time span	Erosion assessment	Sample collection	Area studied	Equipment needs	Laboratory measurements	In situ measurement	Sediment dating
^{137}Cs	Man-made	662	30.2 years	50 years	Medium-term ^a	Simple	Plot to large watershed	Normal HPGe γ detector	Easy	Easy	Possible
$^{210}\text{Pb}_{\text{ex}}$	Natural geogenic	46.5	22.3 years	100 years	Long-term	Simple	Plot to watershed	Broad energy range HPGe γ detector	More difficult	Limited and unreliable	Possible
^7Be	Natural cosmogenic	477.6	53.3 days	≤ 6 months	Short-term	Requires fine depth incremental sampling	Local scale, plot to field	Normal HPGe γ detector	Easy	Requires at least double the counting time in the field needed by ^{137}Cs ^b	Possible ^c

^a In some European countries the Chernobyl reactor accident provided the main input of ^{137}Cs into the landscape. In these areas it is possible to document soil erosion and redistribution occurring since 1986. This represents a time scale of ca. 20 years which is significantly shorter than that provided by bomb fallout.

^b Based on the in situ measurement survey implemented by the IAEA SSU and CU in 2007 and 2008 in the Mistelbach watershed (Austria).

^c ^7Be analysis can also provide information regarding recent and seasonal sedimentation processes.

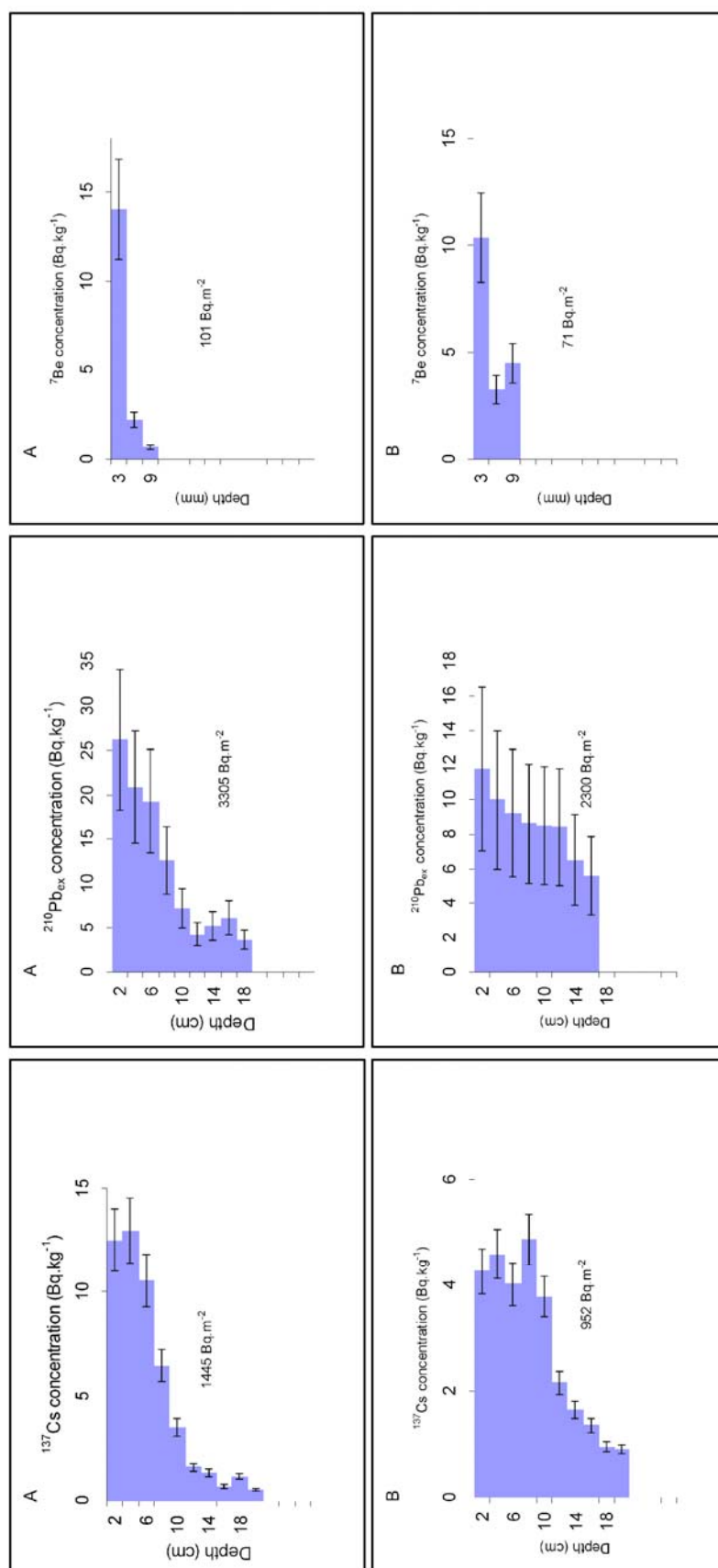


Figure 3. Example of typical depth distributions of ^{137}Cs , ^{210}Pb and ^7Be in an undisturbed (A) and a cultivated (B) soil in Morocco with an uncertainty expressed at 2σ (Adapted from Mabit *et al.*, 2008).

3.4. State of the Art, Research Needs and Analysis of Recent and Future Trends in the Use of FRN for Documenting Soil Erosion and Soil Redistribution ⁴

Although in many investigations a single radionuclide will be selected to meet the requirements of the study, the conjunctive use of two or even three radionuclides can frequently provide valuable information on the erosional history of a site, by generating information for different timescales. The conjunctive use of FRN must be seen as offering considerable future potential. Based on their half-life and origin (**Table 2**), ¹³⁷Cs and ²¹⁰Pb can provide a basis for establishing the erosional history of a site over long and medium-term periods and the inclusion of ⁷Be provides the opportunity to also consider short timescales. The choice of FRN should reflect the requirements of the study, in terms of both the timescales involved and its overall objectives.

Taking account of the information presented in **Table 2** and existing experience, the transfer of FRN methodologies to Member States within the framework of the FAO/IAEA programme aims to focus initially on ¹³⁷Cs. Other FRN are introduced later, once experience has been gained with ¹³⁷Cs, in order to broaden the scope and potential afforded by the initial work with ¹³⁷Cs.

Interest in using nuclear techniques to assess the impact and effectiveness of soil conservation practices has focused attention on the use of ⁷Be for documenting soil redistribution, because, when tested in the normal way, ¹³⁷Cs and ²¹⁰Pb_{ex} can only be used to provide estimates of longer- and medium-term average soil redistribution rates. Recent work supported and promoted by IAEA Coordinated Research Project D1.50.08 “*Assess the effectiveness of soil conservation techniques for sustainable watershed management using fallout radionuclides*” has demonstrated the potential for using ⁷Be to assess the effectiveness of soil conservation measures in Chile, the U.S.A, the UK, Australia, Morocco and Vietnam. In addition, ⁷Be can provide a useful tool for investigating erosion associated with individual extreme events, which are expected to become more frequent as a result of climate change. The sequential or repeat sampling of ¹³⁷Cs inventories could provide another approach for quantifying recent soil redistribution in response to both climate change and modification in land use and land management, as demonstrated by work in Canada undertaken within the same CRP. However, the application of this approach is constrained by the need for periods of sufficient duration between sampling to ensure that the change in inventory is greater than the uncertainty associated with both sampling and laboratory measurement procedures.

Several other important issues, linked to refining the application of FRN, are also currently being addressed by the scientific community. These include:

- testing assumptions relating to the initial distribution of fallout reaching the soil surface;
- developing an improved understanding of the post fallout behavior of FRN in soils and related environments (e.g. plant interception, preferential adsorption /desorption mechanisms);
- provision of more rigorous guidelines for reference site selection;
- the wider application of in situ measurements for ⁷Be and ¹³⁷Cs;

⁴ Project 2.1.1.1. Soil Management and conservation for sustainable agriculture and environment - Task 2: Improve FRN methodologies to measure soil redistribution rates at a range of scales in agricultural landscapes with the use of geostatistic approach.

- refinement of sampling methods for documenting FRN depth distributions, especially for ^7Be and ^{210}Pb ;
- improvement of laboratory procedures for measuring $^{210}\text{Pb}_{\text{ex}}$;
- improvement of the conversion models used to derive estimates of soil redistribution rates from measurements of FRN inventories;
- the use of spatial interpolation and geostatistical tools to assist in the spatial extrapolation and mapping of results at different scales;
- investigating the relationship between FRN activities and soil quality indicators;
- the use of FRN as fingerprints in sediment source tracing studies.

Soil and water resources must be managed in an integrated way, in order to promote their sustainable use and to promote environmental protection. It is increasingly clear that the impacts of agricultural practices on the landscape and downstream communities need to be investigated at the watershed scale, which encompasses links between both upstream-downstream and upland-lowland environments. One of the major requirements for further development of the application of FRN in studying soil and sediment redistribution within watersheds relates to the fact that to date most studies have been conducted at the scale of individual fields, although some work has been undertaken in small basins ranging in scale from a few hectares to several km^2 . An important and logical next step, which has to date been taken by only a few researchers using FRN, is to upscale the assessment of the impact of agricultural activity on soil erosion and redistribution from the field to the watershed scale. This will require different sampling strategies and approaches. One of the possible options is to analyze the watershed under investigation using GIS tools and then to subdivide it into sub-areas or classes representing similar agro-environmental conditions (soil, slope, land use). Representative fields can then be selected in each class, and sampled for application of FRN measurements. The results can then be generalized to the different classes and to the entire watershed. This should permit the establishment of a sediment budget, including an assessment of the net sediment output and therefore the sediment delivery ratio (SDR). However, this approach needs to be developed further and validated under a range of different agro-environmental conditions (climate, soils, topography and cropping systems).

If, in the future, FRN are to be used more widely and at a larger scale and to contribute more directly to decision making, another important challenge will be to promote a transition in their application from research tools to readily-applied decision support tools and to promote their use as a key soil quality indicator.

3.5. First Investigation in Seibersdorf Laboratory of a Promising Short Term Soil Tracer: ^7Be ⁵

3.5.1. Basic Information and Principles

Beryllium-7 is a natural cosmogenic radionuclide produced in the upper atmosphere by cosmic ray spallation of nitrogen and oxygen. This radionuclide has a short half life ($t_{1/2}=53.3$ days), which means that it offers potential for investigating soil erosion processes occurring over shorter timescales, particularly individual storm events or short periods of heavy rainfall. This in turn can provide an opportunity to assess the effectiveness of changes in crop type or tillage practice in reducing erosion.

^7Be is generally fixed rapidly by the upper few millimeters of the soil. Its short half life means that there is insufficient time for the radionuclide to move deeper into the soil. If it is found deeper, this is generally linked to the downward movement of soil particles through fissures, bioturbation and/or cultivation processes.

The examples of the vertical distribution of ^7Be in soil presented in the previous **Figure 3** indicate that significant concentrations of ^7Be may be limited to a depth of approximately 3 cm and that activity decreases rapidly and exponentially with depth.

^7Be activity can be readily determined using an HPGe “P type” detector by measuring the counts at 478 keV. To convert ^7Be inventories into soil redistribution rates, a variant of the profile-distribution conversion model developed for ^{137}Cs is generally applied.

The potential to document the erosion rates associated with individual events and to thereby investigate the effectiveness of different soil conservation practices represents the major advantage of ^7Be over the assessments of longer-term erosion rates provided by ^{137}Cs or ^{210}Pb .

3.5.2. Testing of the Methodology under Field Conditions at the Seibersdorf Laboratory

In 2008 a literature review on ^7Be has been conducted. ^7Be has been used since the late 1990s to estimate soil erosion and sedimentation processes associated with individual periods of heavy rain, mainly at scales ranging from plots of a few square meters, to fields of a few hectares. Studies employing ^7Be have been reported from Australia, UK, USA and Chile. ^7Be has been also successfully used to document soil erosion associated with forest harvest operations in central-southern Chile and to assess the effectiveness of trash barriers with different spacings in reducing soil loss. Around 50 papers on this isotope have been published including radio-environmental investigations that represent more than 90% of the papers. To date only 10-15 major papers have been written on the use of this isotope as soil tracer.

Based on the information collected during this review it was decided to conduct a test in Seibersdorf concerning two majors point:

- Local information on the temporal distribution of the ^7Be deposition flux

⁵ Project 2.1.1.1. Soil Management and conservation for sustainable agriculture and environment - Task 2: Improve FRN methodologies to measure soil redistribution rates at a range of scales in agricultural landscapes with the use of geostatistic approach.

Production of ^7Be in the upper atmosphere is relatively constant, although it may vary seasonally and in response to sunspot activity. However, fallout is dependent on the incidence of rainfall and inventories may be very low in arid and semi-arid areas. This could also be a problem in temperate or continental climates with extended dry periods. So additional information on the temporal distribution of the ^7Be deposition flux is required involving its measurement in precipitation especially on events basis.

- Field validation of the Fine Soil Increment Collector (FSIC) at Seibersdorf laboratory.

There is a need to collect soil samples from shallow depths, because the occurrence of ^7Be is restricted to the immediate surface layer of the soil and there is commonly a well-developed exponential depth distribution. If the sample is not collected to a sufficient depth, it will not contain the full ^7Be inventory. Equally, however, if the sampling depth is too great, the inclusion of soil with a ^7Be activity below the level of detection may reduce the concentration of ^7Be in the overall sample to a low level or even to below the level of detection. In addition, the need to characterize the exponential depth distribution at the reference site for use in the conversion model means that there is a need to section the core into small depth increments or to collect samples from small depth increments. A very fine resolution of 2-3 mm is required. Various devices have been used to meet this requirement. For this purpose, the SSU in collaboration with the IAEA Mechanical Workshop has developed a prototype – presented in the SSU activities report 2007 – the Fine Soil Increment Collector (FSIC). This soil collector is being tested under field condition.

To summarise, the aim of the experimentation conducted in Seibersdorf laboratory is to try to answer to the following questions:

- i) At a same location, is the activity level of ^7Be in rain water variable with time?
- ii) Has the ‘type’ of precipitation (rain/snow) any influence on the ^7Be radioactivity level?
- iii) Is it possible using the FSIC to perform in field soil sampling for future use of ^7Be approach and if so what is the fine depth distribution of ^7Be and also $^{16}\text{O}/^{18}\text{O}$ in soil profile?
- iv) What are the ^7Be activities and associated measurement precisions in shallow depths soil samples before and after rain events?
- v) What is the ^7Be soil depth redistribution after known rainfall events?
- vi) Is there any linkage between ^7Be and $^{16}\text{O}/^{18}\text{O}$ in rain water and then/afterwards in soil water?

In 2008, a small undisturbed area was selected in the forested part of Seibersdorf Laboratories to implement this test. As the depth distribution of ^7Be measured at the reference site is a key parameter for the conversion model, soil samples were collected using the SSU-FSIC.

Three soil profiles were collected on the 15/05/2008 and three other two weeks later on the 26/05/2008 (**Figure 4**). During the experimentation – from 15 to 26th May 2008 – rain water (3 major events) was collected using a 3 times 1m² rain collector developed by the SSU in collaboration with the IAEA Mechanical Workshop (**Figure 5**). The rain was analysed quantitatively and qualitatively for its content in ^7Be and $^{16}\text{O}/^{18}\text{O}$. The information recorded

will be associated with the data provided by the SSU Seibersdorf weather station's and with soil physico-chemical parameters.

Data analyses for stable isotope signatures – $^{16}\text{O}/^{18}\text{O}$ in soil water samples and rain water – are still on going. The γ -measurements of the soil samples and rain water have been made but the spectra should be reanalysed using a new geometry calibration of the SSU gamma detector for small soil sample quantity ($\approx 80\text{-}100\text{ g}$ with a bulk density of $1.2\text{-}1.3\text{ g cm}^{-3}$). This task will be performed in the 1st quarter 2009.



Figure 4. Mr Solonjara Asivelo Fanantenansoa - SSU previous fellow - collecting soil samples per 2.5 mm increment using the SSU-FSIC prior to ^7Be gamma analysis.

Preliminary results should be available at the end of the summer 2009 and the findings of this experimentation will be reported in the 2009 SSU annual activities report.



Figure 5. The SSU/IAEA Mechanical Workshop rainfall collector.

3.6. The First Application of Nuclear Techniques (FRN) in the Derived Savanna of Nigeria for Estimating Medium-Term Soil Redistribution Rates ⁶: Preliminary Results

Collaborative work between the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria and the Soil Science Unit

Nigeria has experienced rapid political, socio-economic, demographic and agricultural changes. Population growth has increased from 88 million in 1991 to 140 million in 2006 leading to an average density of 155 inhabitants per km². This growth has led to an increased demand for cereals, legumes, and livestock products and an intensification of urbanization. The consequence is a change in land use and land cover, the intensification of farming, the shortening or elimination of fallows, the loss of forests, the reduction of animal and plant species and increased land degradation. In Nigeria, human-induced soil degradation is very high for an estimated 54% of the area (495 662 km²).

Soil erosion is the most widespread form of soil degradation in the country and has been recognized for a long time as a serious problem. Soil erosion can cause a 30 to 90% yield reduction in some root-restrictive shallow lands of southern Nigeria and off-site problems linked to erosion/sedimentation processes are other common impact effects of soil loss in the country.

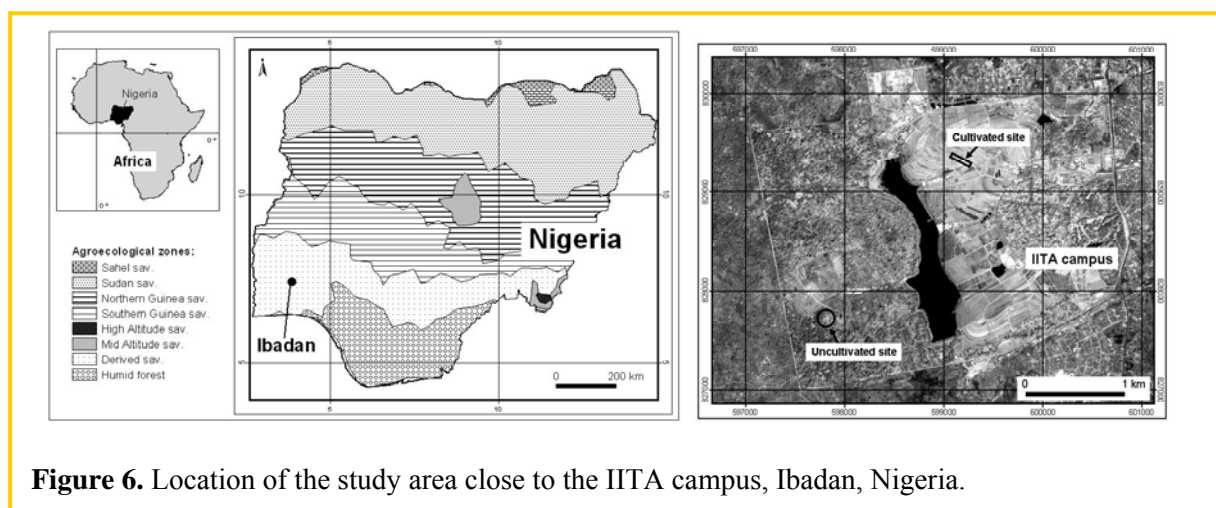
To develop an effective management strategy reliable quantitative data on soil loss and deposition are necessary. In Nigeria, measurements of erosion have been conducted by using different conventional techniques (runoff plots, erosion pins and sediment traps). But these approaches are time-consuming, labor-intensive, expensive, and if not conducted for at least during 15 years to integrate the climatic variability do not represent realistic erosion rates. Nuclear techniques are an alternative approach to overcome many problems of these conventional methodologies for documenting rates and pattern of soil redistribution in the landscape. The relatively simple sampling procedure makes also the FRN technique cost-effective and less time-consuming than any other conventional approaches.

FRN such as ¹³⁷Cs have been increasingly used to investigate soil redistribution all over the world, but the application of this technique on the African continent is still limited and until now no FRN study has been implemented in Nigeria.

In collaboration with the International Institute of Tropical Agriculture (IITA) a first investigation to test FRN to evaluate soil degradation in West Africa was initiated. The objective of this join study was to test the applicability of the ¹³⁷Cs method in the forest savanna transition zone of Nigeria and to provide information on erosion/deposition rates in a cassava sloped field.

The study site is located on the research farm of the IITA in Ibadan, approximately 150 km north of Lagos in Nigeria (**Figure 6**).

⁶ Project 2.1.1.1 Soil Management and conservation for sustainable agriculture and environment - Task 2: Improve FRN methodologies to measure soil redistribution rates at a range of scales in agricultural landscapes with the use of geostatistic approach.



The climate in the forest savanna transition zone or derived savanna is sub-humid. The average precipitation on the research farm is 1280 mm yr^{-1} and the average annual temperature is 26.7°C . The landscape is characterized by a gently undulating relief. Most soils developed from metamorphic parent materials are characterized by a sandy loamy topsoil over a gravelly layer and clayey subsoil. They are classified as ferric Luvisols due to the development of an argic horizon with increased clay content, high base saturation, and high cation exchange capacity.

An undisturbed site ($7^\circ48' \text{ N } 3^\circ88' \text{ E}$) a secondary flat forest of 10 ha was selected. The cultivated site ($7^\circ50' \text{ N } 3^\circ89' \text{ E}$) an agricultural field of 1.75 ha with a slope of 6° has been conventionally tilled by regular ploughing up to a depth of 30 cm down the slope since 1970. It has been mainly used for growing new varieties of cassava (*Manihot esculenta*) only interrupted by short periods with natural fallows or velvet beans to restore the soil fertility.

Soil samples were collected by using a cylindrical metallic core (**Figure 7**). Twelve samples were taken randomly for describing the activity level and the spatial variability of ^{137}Cs in the reference site and in the cultivated site, samples were taken along four parallel transects running downslope on ridges and in trenches.

On each transect, 11 samples were taken. The distance between each sampling point of the same ridge/trench was 30 m and the distance between transects was 10 m. The cores were collected to a depth of 60 cm. In total, 44 bulked core samples were taken on the cropland.

The ^{137}Cs content of the fine fraction was measured by gamma spectrometry and the MBM2 was used to convert the inventory of ^{137}Cs into quantitative rates of soil loss and deposition.

The first results showed an average ^{137}Cs inventory in the uncultivated site of 567 Bq m^{-2} . In the agricultural field the ^{137}Cs activities were generally higher in the ridges than in the trenches. Using MBM2 the gross erosion was evaluated at $34 \text{ t ha}^{-1} \text{ yr}^{-1}$ highlighting a very high erosion in the cassava field. The high rate of soil loss is caused by several factors, one of these factors is the rain erosivity which is very high in tropical West Africa.

A joint paper is being written to report the results obtained through this fruitful collaboration established between IITA, the SSU and the SWMCN section.



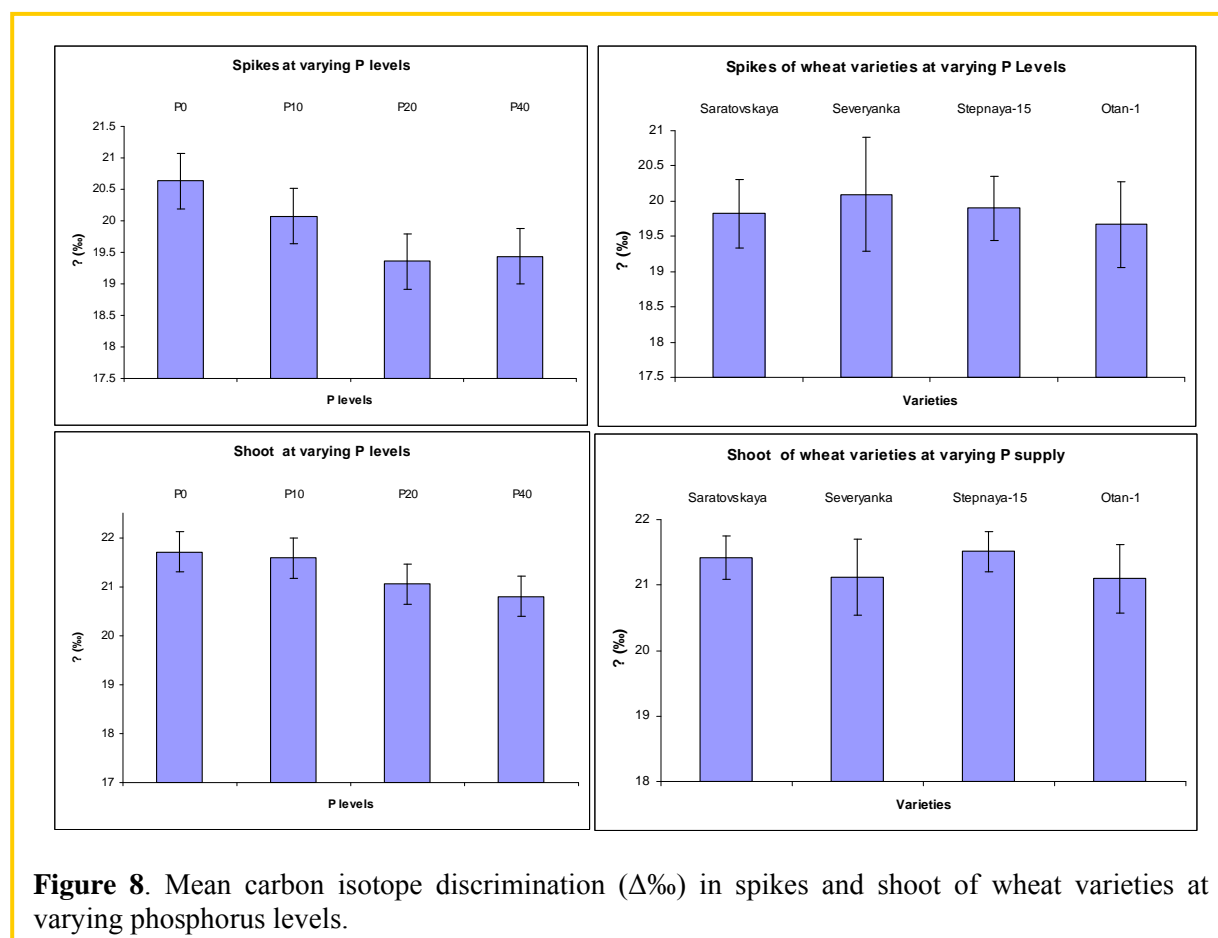
Figure 7. Samples collection in the cassava field using soil column cylinder.

3.7. Summary of the Results on the Use Carbon Isotope Techniques in the Quest for Higher Productivity in Nutrient, Salt and Water Stressed Environments⁷

A detail report was presented in the **SSU Activities Report 2007**. Below are summaries and implications on the use of the carbon isotope discrimination techniques under nutrient stress and the combined effect of water and salt stress environments.

3.7.1. Implications for Using the Carbon Isotope Discrimination Techniques to Select Wheat and Rice Genotypes for Higher Agronomic Water Use Efficiency under Nutrient Stress Environments

Nutrient (particularly N and P) deficiencies are principal constraint to low yields of wheat and rice in drought-prone (semi-arid and arid) environments. Although the carbon isotope discrimination (Δ) has been proposed as useful trait for selecting C₃ cereal crops in drought and salinity stressed environments, low bioavailability of soil nitrogen (N) and phosphorus (P) could hinder the accuracy and effectiveness of using the Δ as a selection tool for high yield in nutrient-stressed environments. Greenhouse pots experiments conducted to assess the effect of N and P supply and their combined effects on carbon isotope discrimination (Δ) in vegetative and reproductive parts of wheat and rice under well watered conditions showed that P supply significantly reduced the value of Δ under controlled conditions but the effect was not visible under the salinity treatment (**Figure 8**). The results showed that both N and P



⁷ Project 2.1.1.5. Integrated soil-plant approaches to increasing crop productivity in harsh environments - Task 3.

significantly affected the Δ in wheat in well-watered, and rice under salinity conditions suggesting that environmental conditions such as nitrogen and phosphorus availability in soil must be considered in future research on the relationship between yield and carbon isotope discrimination of C_3 cereals. In addition characterization of the environment for using the carbon isotope discrimination techniques should not mainly focus on the timing of water availability (pre-anthesis, post anthesis and residual moisture stress) but should include N and P bioavailability since P deficiency could affect CO_2 fixation and the translocation of assimilates from vegetative to the reproductive parts.

3.7.2. Carbon Isotope Discrimination Techniques to Select Wheat and Rice Genotypes for Higher Agronomic Water Use Efficiency under the Combined Effect of Water and Salt Stress Environments

Crop yield in salt-affected areas in the semi-arid environments is frequently limited by salinity and low moisture availability. A two year greenhouse experiment assessed the performance of carbon isotope discrimination technique to evaluate and select wheat and rice varieties in combined soil salinity and water deficit environments. Four wheat varieties (Saratovskya-29, Severyanka, Stepnaya-15 and Otan-1), obtained from Kazakhstan and two upland rice varieties (WAB 5650 and ROK 3) from Sierra Leone were used. Six treatments including: (i) control (water applied at field capacity throughout the experiment without salt treatment); (ii) drought 1 (**D1**, water applied at 30% FC 8 d after thinning); (iii) drought 2 (**D2** water applied at 70% FC at 50% booting); (iv) salt (**S** 50 mM or 10 dSm⁻¹ applied 8 and 10 days after thinning in 2 splits); (v) drought 1 x salt interaction (**D1 x S**) and (vi) drought 2 x salt (**D2 x S** water stress and salt applied at 50% booting for wheat but at 60 days after sowing for rice and maize). The combined effect of water and salt stress resulted in a less discrimination or low Δ values in comparison with the control (well-watered and no salt treatment) and the individual water and salt stress treatments. High DM was associated with high Δ suggesting a positive correlation between shoot DM and Δ (**Figure 9**). For rice, whereas water stress (D1 and D2) resulted in a decrease in Δ values compared to the control (19.5‰ to 18‰), the application of salt resulted in higher Δ values compared to the control (19.5‰ to 20.4‰). The results suggest that selecting crop plants for their greater agronomic efficiency in a combined salt stress and water deficit environments is complex and require further investigations in the field with more cultivars.

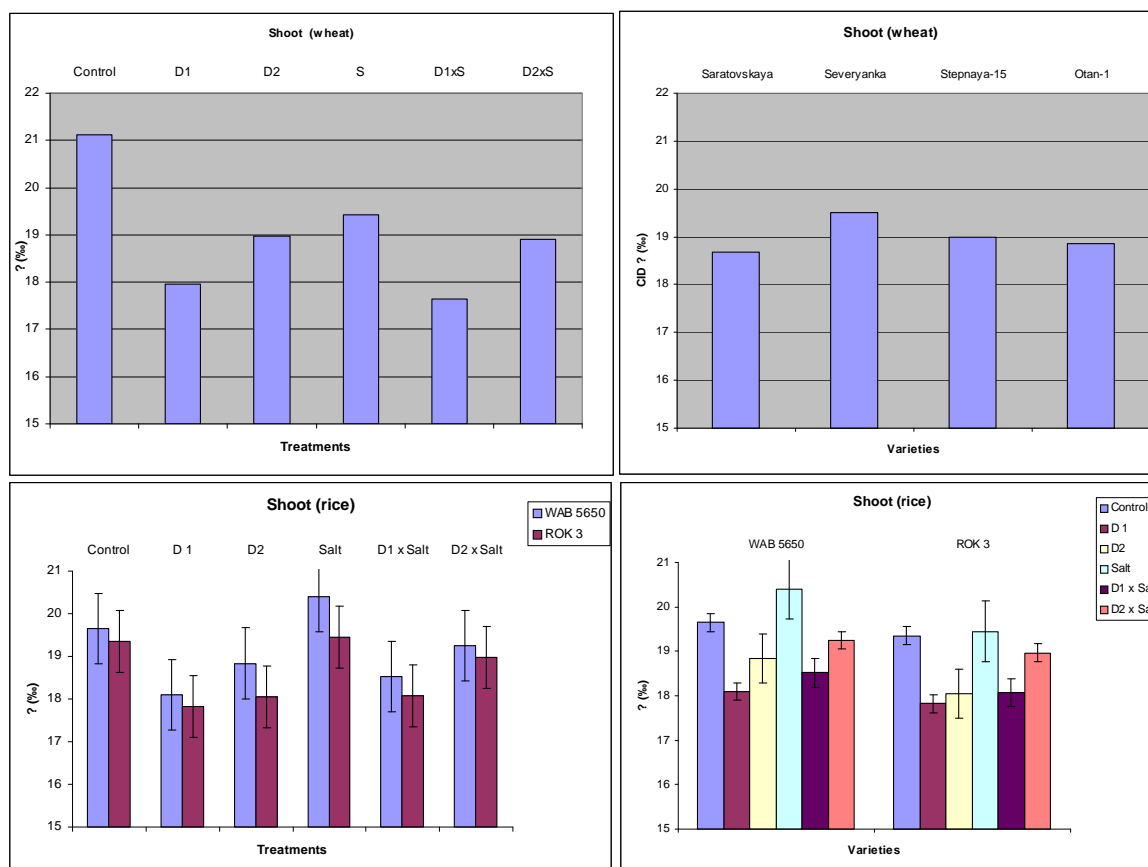


Figure 9. Mean carbon isotope discrimination (Δ ‰) in spikes and shoot of wheat varieties at varying phosphorus levels.

3.8. Variations in Phosphorus Acquisition from Sparingly Soluble Forms by Maize and Soybean in Low and Medium-Phosphorus Soils Using ^{32}P ⁸

J Adu-Gyamfi, M Aigner and D Gludovacz, Soil Science Unit

3.8.1. The Challenge

Soils characterized by poor phosphorus (P) availability are widespread globally and for these soils to be agriculturally productive, they require regular application of water-soluble superphosphate or ammonium phosphate fertilizers. These soluble phosphates applied to P deficient soils are retained by iron (Fe), aluminium (Al) and calcium (Ca) ions and are virtually unavailable to most plant species. Plants differ greatly in their ability to grow on low P soils because they have developed specific physico-chemical mechanisms/processes to utilize P compounds in these low P fertility soils. Evaluating and identifying crop plants for genotype variation in their ability to access and utilize sparingly soluble forms of soil P (Ca-P, Al-P and Fe-P) has been proposed as a possible means for overcoming P deficiency stress in soils and optimize P fertiliser use in cropping systems where P is poorly available.

Radio-isotopic P techniques using the principle of isotopic exchange allow measurement of the amount of orthophosphate that can be transferred from the soil solid to the solution in a given time and thus provide a powerful alternative means for characterizing soil P availability and sources of P pools to plants in soil-plant systems. The study aimed to evaluate the differential ability of maize and cowpea to access and utilize phosphorus from different soil P pools using a low-P (Hungarian) and a medium-P (Waldviertel) soil.

3.8.2. Experimental Design

Two experiments were simultaneously set up for non-labelled (without ^{32}P) and labelled (with ^{32}P) on 2 different soils using maize (cereal) and soybean (legume). The experiment was set up in factorial design with 2 crop species (maize and soybean), 2 soil (low- and medium available P) and 4 replications. In all there were 20 pots for the radioisotope (including 4 pots without plants as control) and 36 pots (including 4 pot without plants and 2 sampling periods) for the non-radioisotope (**Figure 10**).

A low-P soil from Hungary (total P 302, available P 21 Bray PII, 13.3 mg.kg⁻¹ Olsen P, pH 5.6 (KCl) classified as Dystric Eutrocrepts, and a medium-P soil (Waldviertel) from Austria (total P 513, available P 46 (Bray P2), 13.3 mg.kg⁻¹ Olsen P, pH 5.6 (KCl) was used (see Table 1 for detailed physical and chemical characteristics of the two soil). A maize variety (DK 315 from Austria) and a soybean variety (TGX 1910-4F from IITA, Nigeria) were grown in plastic pots (1 plant per pot) containing 1 kg of soil in a naturally lit glasshouse with a temperature regime of 34/21°C day/night and relative humidity of 40-70%. Each pot received basal fertilizer equivalent to 200 kg N ha⁻¹ as ammonium sulphate and 50 kg K ha⁻¹ as potassium chloride. Prior to planting, the weight and P concentration of soybean and maize seeds used for the experiment were determined. The amount of P in seed was 0.98 mg P.kg⁻¹ soil (0.35 g with 2.8 mg.kg⁻¹ P) for maize and 0.59 mg P.kg⁻¹ soil (0.59 g with 5.9 mg.kg⁻¹ P) for soybean. Phosphorus-32 labelled K₂H³²PO₄ was applied to the pots on 23 July 2008.

⁸ Project 2.1.1.1. Integrated soil-plant approaches to increasing crop productivity in harsh environments - Task 5.

To ensure uniform labelling of the soil 5 portions of dilute ^{32}P solution (50 ml for Waldviertel and 30 mL for Hungarian soils) were applied to a layer of 200 g soil) to achieve 70% of the water holding capacity of each soil. A total of 250 ml for the Waldviertel and 150 ml for the Hungarian containing 12.4 MBq (335 μCi) of a $\text{K}_2\text{H}^{32}\text{PO}_4$ solution was applied to each of the 20 pots containing 1 kg soil. Pre-germinated maize and soybean seeds were sown at one per pot immediately after the addition of ^{32}P . 20 mL of inoculum (*Bradyrhizobium japonicum*) mixture was added to all the pots. On 20 August (28 days after sowing), nitrogen was applied equivalent to 100 kg ha^{-1} as ammonium sulphate to ensure adequate N for the plants. The watering of plants was carried out on weight basis of the pots and were supplied everyday with an amount of water equal to the evapotranspiration loss, maintaining as much as possible constant soil water content in the pots.

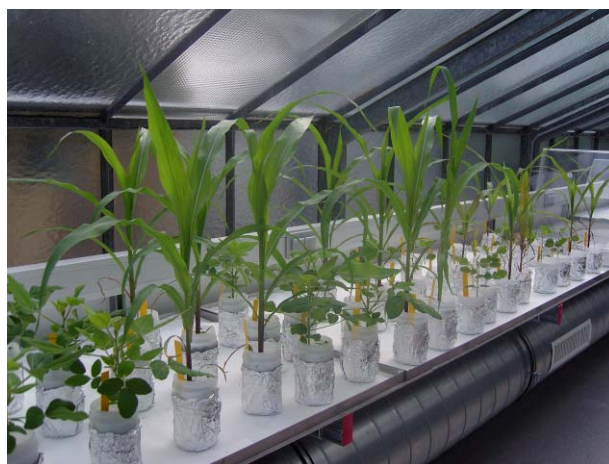


Figure 10. Characterizing soil phosphorus (P) availability and sources of P pools to plants in the soil-plant systems using radioisotope phosphorus.

3.8.3. Plant and Soil Sampling and Analyses

The first plant sampling for the labelled and the non-labelled treatments was done at 42 days after sowing (DAS) whereas the non-labelled treatments were allowed to grow till 60 DAS. Soil samples (10-12 g) was taken with a special soil auger (inner dia 8 mm, outside dia 10 mm and length 25 cm) at 0, 1, 5, 42 and 60 DAS, oven-dried at 70°C for 18 h, milled and a portion was used for analysis. Plants were harvested and separated into shoots (radioisotope-labelled) and shoot and roots (non-radioisotope), chopped into small pieces, oven dried, weighed, and grinded. The root dry weight of the radioactive plants was estimated using the root/shoot ratio of the non-radioisotope plants. This is to prevent the complications of root sampling and washing for the ^{32}P -labelled pots. Total P in soils was determined using the colorimetric method after acid digestion, and available P (Bray P II and Olsen) was determined by colorimetric method after extraction (**Figure 11**).

The inorganic soil P fractions were measured according to a fractionation scheme based on the



Figure 11. Soil and plant sampling of P-32 labelled plants at the glasshouse to elucidate mechanisms of tolerance of maize and soybean to low P soils.

Sekiya method. Briefly the fractionation involved a sequential extraction of Ca-P (300 mg of soil extracted with acetic acid), Al-P (extracted with ammonium fluoride after the extraction of Ca-P) and Fe-P (soil after extraction of Al-P was washed twice with saturated sodium chloride and discarded and then extracted with and sodium hydroxide) and the P in extracts were determined by colorimetric method. The ^{32}P radioactivity in all the fractions (total-P, available-P, Ca-P, Al-P and Fe-P) was measured by liquid scintillation spectrometry (Packward 2000) using a flour solution consisting of 1mL solution and 9 mL of Aquasol-2 (NEN research product). Similarly, phosphorus in the ground plant materials were wet digested in a 4 ml H_2SO_4 and 3 ml H_2O_2 for 2 min till digest was colourless, and aliquots of the samples were diluted and the total P measured by the method of Murphy and Riley (1962) and ^{32}P was determined by the Liquid Scintillation Counter. The P in seed of maize and soybean was determined after five seed samples each of 100 mg were grinded and acid digested. The total radioactivity in each pot at sowing of seeds was 744×10^6 dpm.

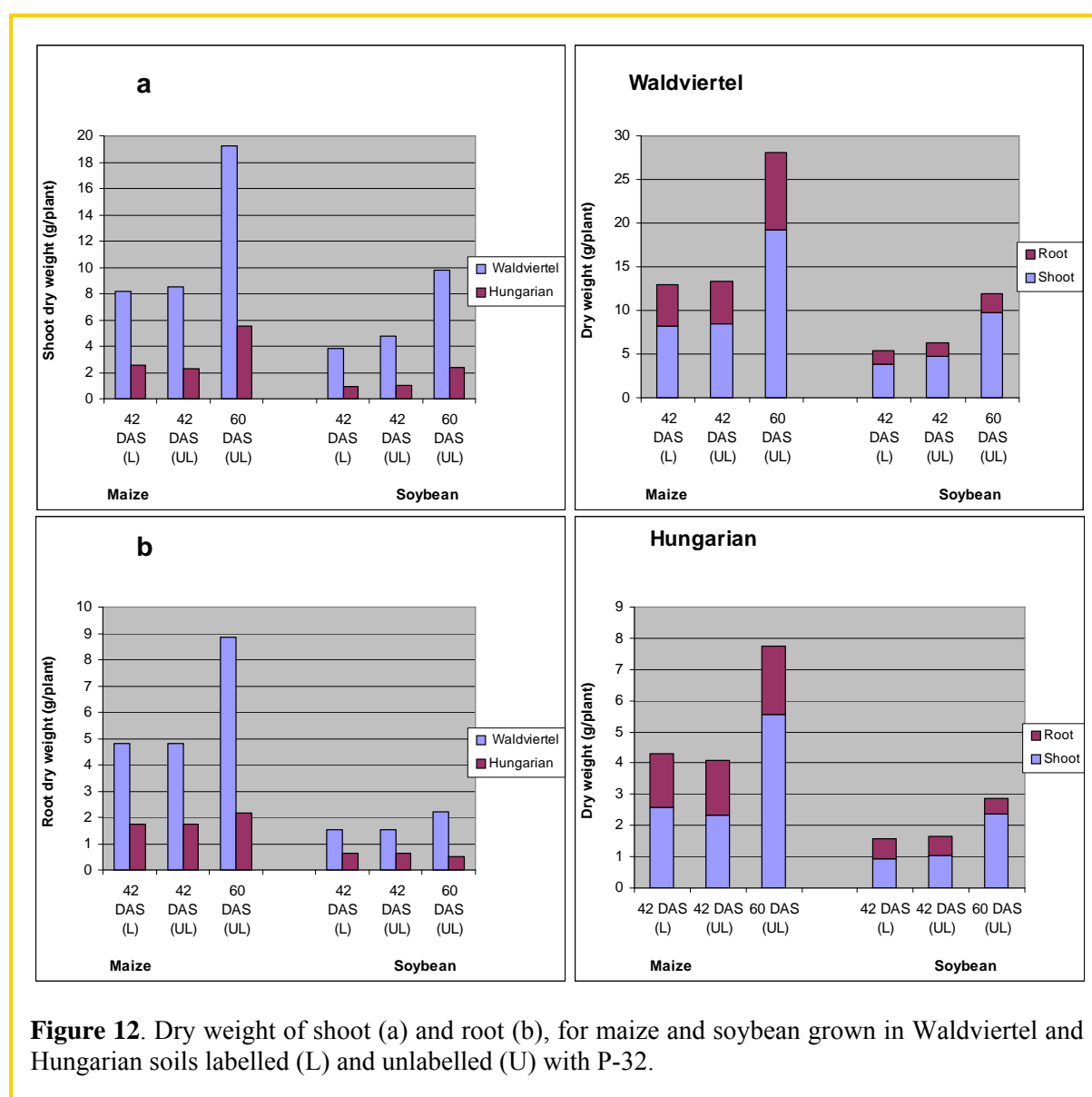


Figure 12. Dry weight of shoot (a) and root (b), for maize and soybean grown in Waldviertel and Hungarian soils labelled (L) and unlabelled (U) with P-32.

3.8.4. Results

The shoot and root biomass of both maize and soybean were significantly greater when grown on the Waldviertel soil than on the Hungarian soil, and there was a significant increase in shoot dry weight from 42 to 60 days after sowing (**Figure 12**). The root/shoot ratio was generally higher at 42 (0.6-0.7) than at 60 (0.2-0.45) DAS for maize and soybean and higher for Hungarian than for Waldviertel except at 60 DAS. There was a 20% (Waldviertel) and 70% (Hungarian) reduction in root/shoot ratio when plants were sampled at 42 compared to 60 DAS (**Figure 13**). The shoot P concentrations were higher for soybean (1.7-2.2 g kg⁻¹) than for maize (1.1-1.4 g kg⁻¹) and decreased with plant age for maize and not for soybean (**Figure 14**). **Figure 15** shows the P concentrations of the inorganic P pools and available P extracted from the two soils at 0, 1, 5, 42 and 60 DAS and the percentage distribution. There was a slight increase in total P (mg kg⁻¹) from at 0 DAS to 302 to 312 (Hungarian) and 502 to 537 (Waldviertel). Available P decreased significantly in Hungarian soil from 33 at 0 DAS to 27 at 60 DAS and for Waldviertel from 56 to 37.5 (mg kg⁻¹). Changes in the soil inorganic pools were evident. All the soil P fractions (except Al-P than increased slightly) decreased from 0 DAS to 60 DAS in the two soils used. The percentage of Al-P was the largest among the fractions measured.

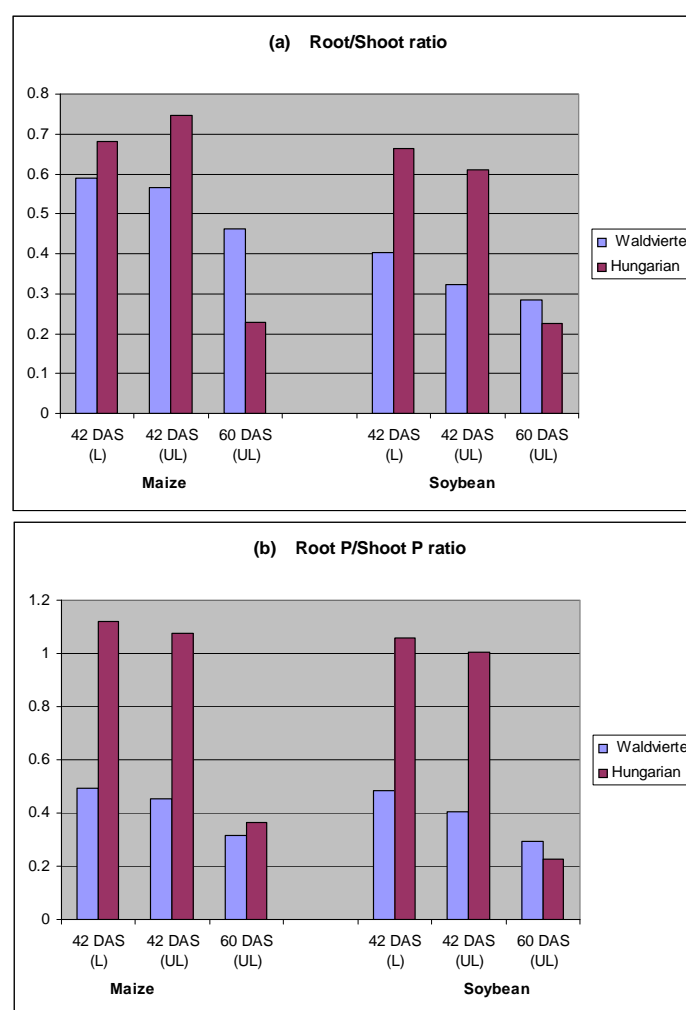


Figure 13. Root/shoot ratio in terms of dry weight (a) and P amount (b) of maize and soybean grown in the two soils.

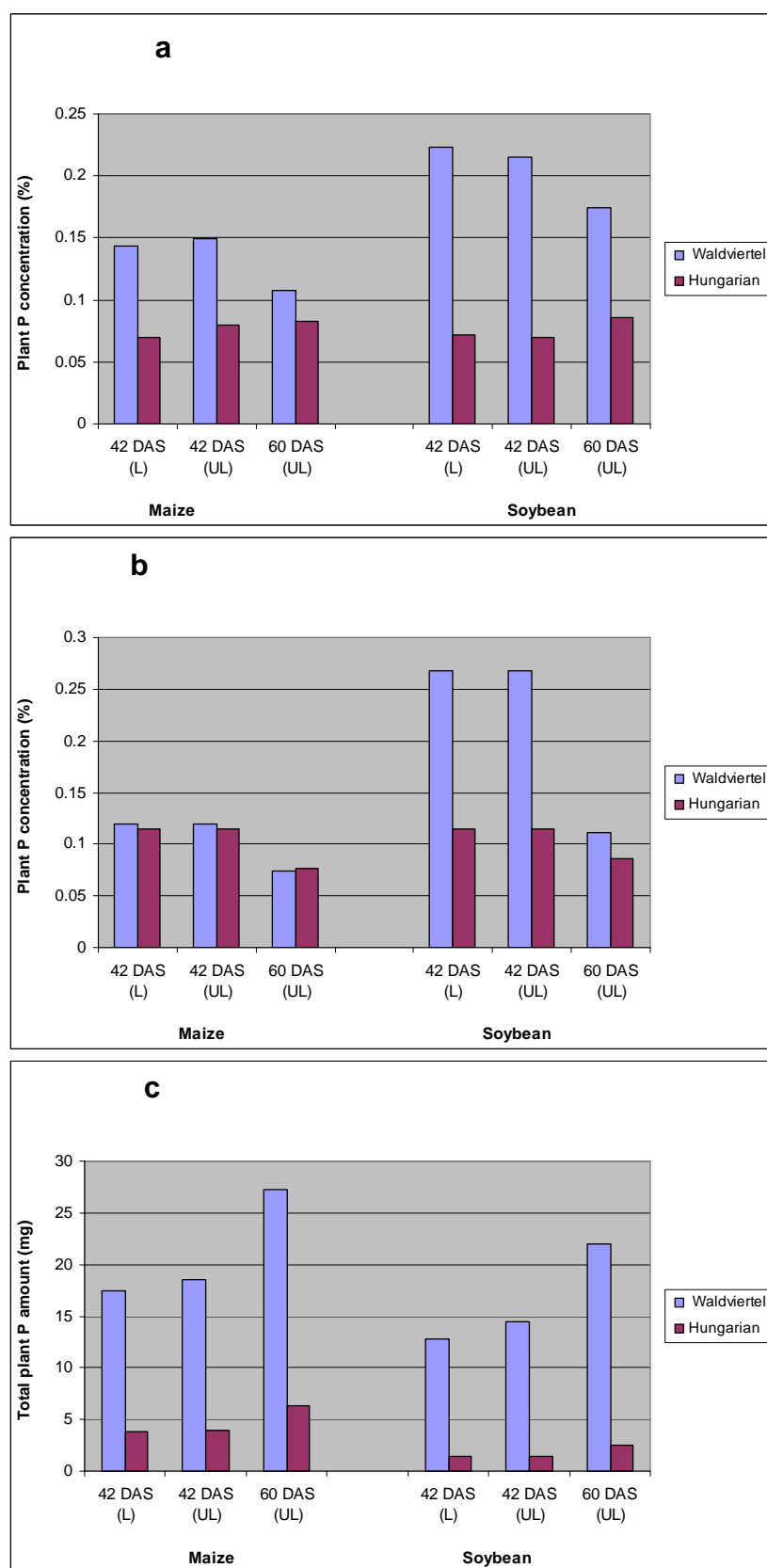


Figure 14. P concentration of shoot (a) and root (b) and plant P amount (c) for maize and soybean grown in 2 different soils. For legend see **Figure 12**.

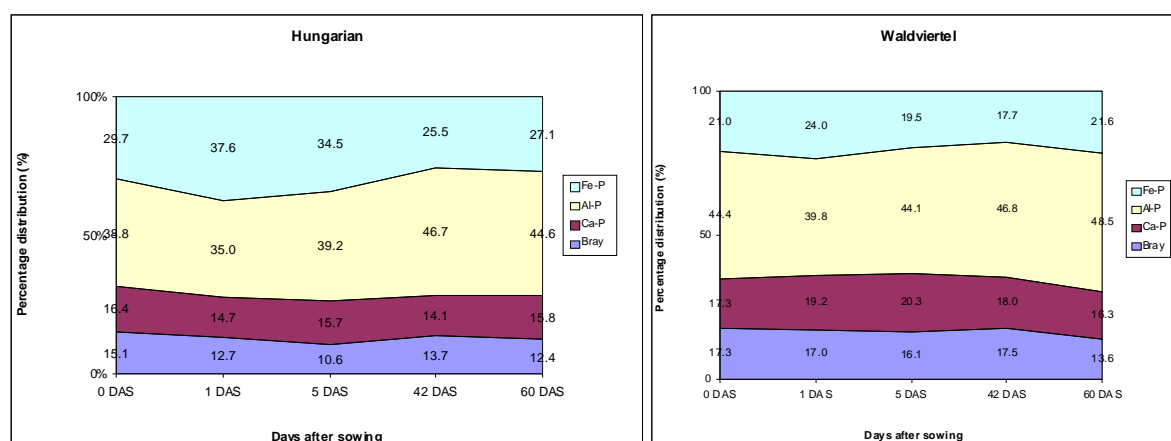


Figure 15. Percentage distribution of inorganic P pools (Ca-P, Al-P and Fe-P) in the Hungarian and Waldviertel soils at the different sampling dates.

The total radioactivity ($\text{dpm} \times 10^6$) was higher in plants grown in Waldviertel than in Hungarian soil and the values reflected on the plant P uptake and shoot biomass of soybean and maize. Maize and soybean showed severe deficiency when grown on the Hungarian soil and the P concentration in plant was below ($<1 \text{ mg g}^{-1}$) suggesting that Bray II overestimated the available/labile P fractions in the soil. The available P (Bray II) and the Ca-P were the fractions depleted most by plants followed by the Fe-P fractions in the two soils, and differences observed between the crops were not significant. Total radioactivity in maize was 1.4 times higher than in soybean grown on the Waldviertel soil but 4.3 times higher than soybean when grown on the low-P Hungarian soil (**Figure 16**).

To assess the amount of isotopically exchangeable P, the L-value (Larsen value) was estimated. The L values ($\mu\text{gP} \cdot \text{g soil}^{-1}$) in maize and soybean were higher in Waldviertel (>70.0) than in Hungarian were (<20.0). No significant differences in L values were observed for maize and soybean grown on the Waldviertel, but for the Hungarian soil, the L values were higher for maize (20.0) than in soybean (9.6) suggesting that in this soil, maize was efficient to take up more P than soybean (**Figure 17**). Maize and soybean grown in medium-P Waldviertel soil had lower specific radioactivity ($\text{KBq } 10^3 \cdot \text{mgP}^{-1}$) in shoot than those grown on the low-P Waldviertel soil indicate that plants were using otherwise unavailable P sources.

3.8.5. Main Findings

The main finding from this study is that maize was more efficient to take up P from otherwise sparingly soluble inorganic-P sources than soybean in the medium-P Waldviertel soil as indicated by the low specific radioactivity ($\text{dpm} \times 10^3 \text{ mgP}^{-1}$ or $\text{KBq } 10^3 \cdot \text{mgP}^{-1}$) in shoot. The L-values (with seed P uptake correction factor) of maize was two times higher than that of soybean in the low-P Hungarian soil suggesting the superiority of maize to access sparingly soluble P from soils compared with soybean. When P is not supplied, maize and soybean are able to access P mainly from the available P (Bray II), Fe- and Ca-P sparingly soluble fractions and not Al-P from the soil. Maize and soybean showed severe deficiency when grown on the Hungarian soil and the P concentration in plant was below ($<1 \text{ mg g}^{-1}$) suggesting that Bray II overestimated the available/labile P fractions in the soil.

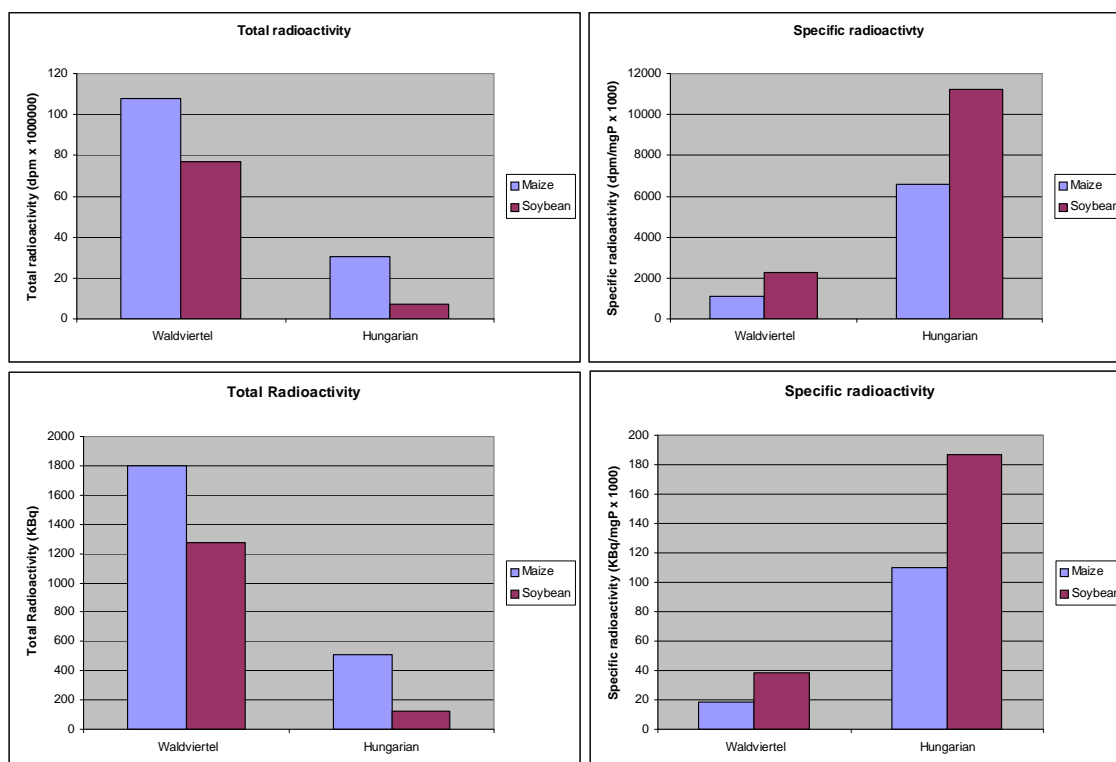


Figure 16. Total radioactivity and specific activities of maize and soybean grown on low-P (Hungarian) and medium-P (Waldviertel) soils.

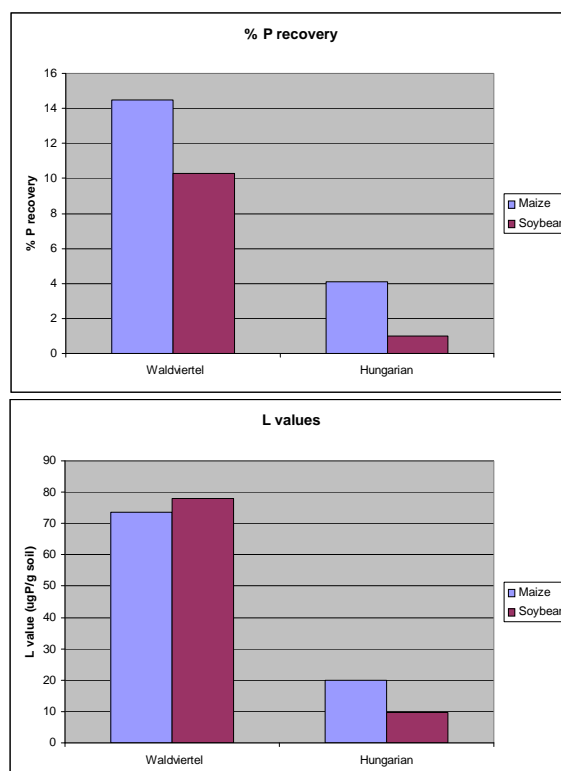


Figure 17. Percentage P recovery in plant shoot and the L-values calculated for maize and soybean grown on two soils.

3.9. Investigation of the Plant Response to Irrigation Water with Conventional Methods and ^{18}O

P Macaigne, JL Arrillaga, L Mayr

3.9.1. Introduction

Agriculture is one of the several competing user for water, therefore there is an actual great interest to use it more efficiently. However overuse of water in cropping area lowers water yield due to water losses by percolation or evaporation. It also induces leaching of nutrients and other pollutants out of the soil system into the environment. Downwards water percolation through soil will occur when soil water content is higher than field capacity. Thus, it is of high importance adjusting water to the right demand of the plant. Determining the optimum amount of required water for specific plant, soil, environment and climate can be difficult.

^{18}O and ^2H stable isotopes can be used to follow water of a known origin directly through soil and plant. It also allows an individual follow-up of evaporation (E) and transpiration (T). Previous studies have been done specifically on isotopic signature of soil water in bare soils to investigate the downwards flux: water percolation and the upwards flux: soil evaporation. Other studies have concentrated on investigating plant transpiration from plant tissue or the separation of E from T within the ET flux either based on direct isotopic measurement of the ET flux or on soil water using mass balance. More investigation has to be done on this topic for a better understanding of the soil-plant-water system in cropped areas.

3.9.2. Objective of the Study

The objective of the study is to investigate evaporation (E) and transpiration (T) at different stages of maize (*Zea mays* L, variety DK315) development under two irrigation water levels with both conventional measurement (mass balance and TDR) and isotopic techniques (^{18}O).

3.9.3. Material and Methods

The experiment was conducted in a glass-house located in Seibersdorf. Humidity and temperature of the glass-house were not controlled, but were recorded. The pot experiment is divided into 4 blocs. Each bloc included 9 pots of 50 L capacity. In the bottom of each pot, holes are made avoiding water accumulation (**Figure 18**). Soil was a homogeneous 1:1 mixture of 5 mm sieved Seibersdorf soil and quartz sand. In each pot, 46 kg of the soil mixture was poured in order to have a soil height of approximately 25 cm (**Figure 18**).

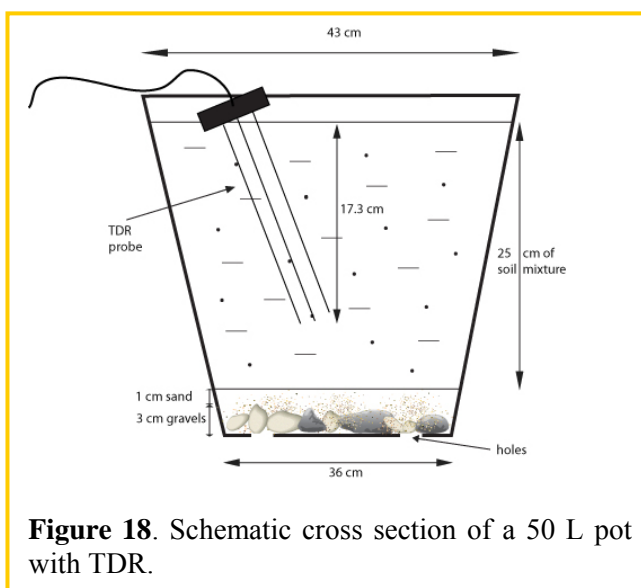


Figure 18. Schematic cross section of a 50 L pot with TDR.

A test was conducted to measure field capacity by pouring a predetermined amount of water in a pot, then covering the pot and following-up the decrease of soil humidity until it reaches stability. Therefore four 20 cm-TDR (Time Domain Reflectometry) probes were inserted vertically within the pot. Water was poured on soil before covering the pots to prevent soil evaporation. Water in excess percolated through the pot. After 8 hours, soil water content reached equilibrium until the end of the experiment 40 hours later. This equilibrium was considered to be soil field capacity.

3.9.4. Irrigation System and Soil Preparation

An automatic irrigation system was built with a pump connected to a water tank and a pre-programmed logger controlling the opening and closing of the valves. On each irrigation line, pressure compensated drippers were implemented to apply water near plant roots for each pot following the randomized design. Opening time of each irrigation line was fixed according to three treatments and it was adjusted to maintain soil humidity constant during the cropping season compensating plant needs for each treatment. The three treatments were: (i) soil at field capacity and pot cropped with maize (T1); (ii) soil at 20-60% of field capacity and pot cropped with maize (T2); (iii) soil at 60% of field capacity and bare pot (T3).

Automatic daily irrigation was adjusted every week to plant needs or demand (bare pots) based on soil water recorded the previous week, on equations (4 to 6) and on Matlab programs specifically designed for the experiment. In each bloc, one pre-germinated maize seed (*Zea Mays* L, variety DK375) was planted on the 30th of April 2008. The 9th pot of each bloc was bare. After planting, pots cropped with maize were covered with plastic sheets tight with elastics around the pot avoiding soil evaporation. Only a small area was opened to allow plant growth (**Figure 19**).

One day before each sampling event the automatic irrigation system was turned off and the scheduled irrigation water was replaced by the same amount of ^{18}O enriched water manually poured at the centre of the pot near plant roots.

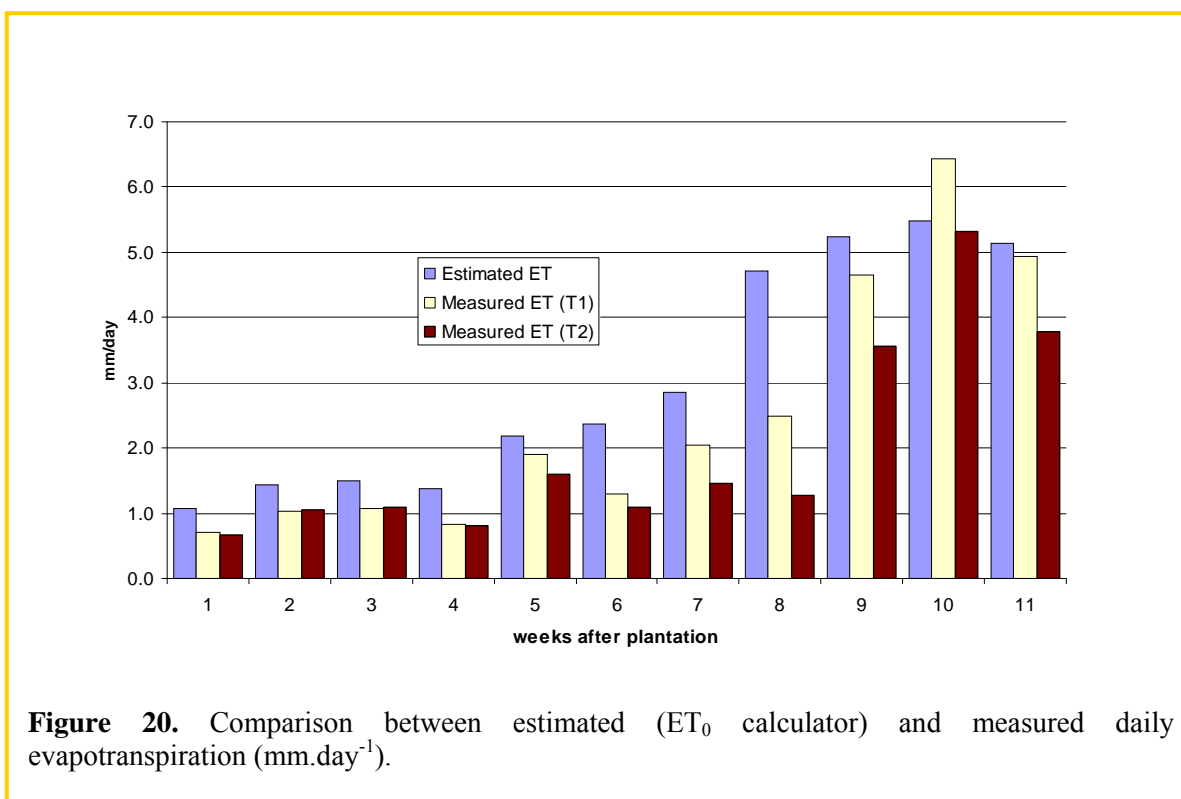
3.9.5. Preliminary Results

Since ^{18}O samples are still being analysed, only results related to soil water measurements with TDR will be presented here.

Before starting the field capacity test, volumetric soil water content was around 5%, and after pouring the water in the soil, it reached a maximum of 35.1%, then it lowers down to reach an average value of 30.1% $\pm 0.7\%$, considered to be field capacity.



Figure 19. The pot experiment at early stage: one week after plantation (7 May 2008).



3.9.6. Soil Characteristics

The soil texture (1:1 mixture between sand and Seibersdorf soil) is a sandy loam (USDA soil classification) with $70.9\% \pm 0.4$ of sand, $17.6\% \pm 1.5$ of silt and $11.4\% \pm 1.1$ of clay. Physical characteristics are as follow: permanent wilting point of $6.78\% \text{vol} \pm 0.24$; bulk density of $1.61 \text{ g}\cdot\text{cm}^{-3} \pm 0.01$; particle density of $2.62 \text{ g}\cdot\text{cm}^{-3} \pm 0.01$; pore volume of $38.7\% \text{vol} \pm 0.44$; water content at saturation of $47.7\% \text{vol} \pm 0.39$. Chemical characteristics of the soil are as follow: pH of 8.48 ± 0.04 , EC at 25°C of $128.3 \mu\text{S}\cdot\text{cm}^{-1} \pm 3.9$, C_{tot} of $1.77\% \pm 0.02$, C_{inorg} of $1.66\% \pm 0.02$, Organic carbon content of 0.1% , N_{tot} of 0.06% , CaCO_3 of $13.8\% \pm 0.2$ and CEC of $15.8 \text{ cMol}\cdot\text{kg}^{-1} \pm 1.2$.

Figure 20 compares ET calculated either from soil humidity weekly variations measured with TDR probes for treatment 1 (T1) and 2 (T2) or from FAO model (ET_0 calculator) with recorded relative humidity and temperature data shown in Table 5. It shows that ET estimated with ET_0 calculator model is usually overestimated compared to values obtained from measured data and are closer to values calculated from treatment 1 (Field capacity).

Figure 21 presents crop coefficient (K_c) either from recommended values (K_c for maize) or by calculation using the following equation: $K_{c(T1, T2)} = ET_{(T1, T2)} / ET_0$. Recommended K_c values are overestimated and rise slower compared to the ones obtained by TDR measurements and calculation. Calculated values also give a more accurate value of K_c , with a higher value for T1 than for T2.

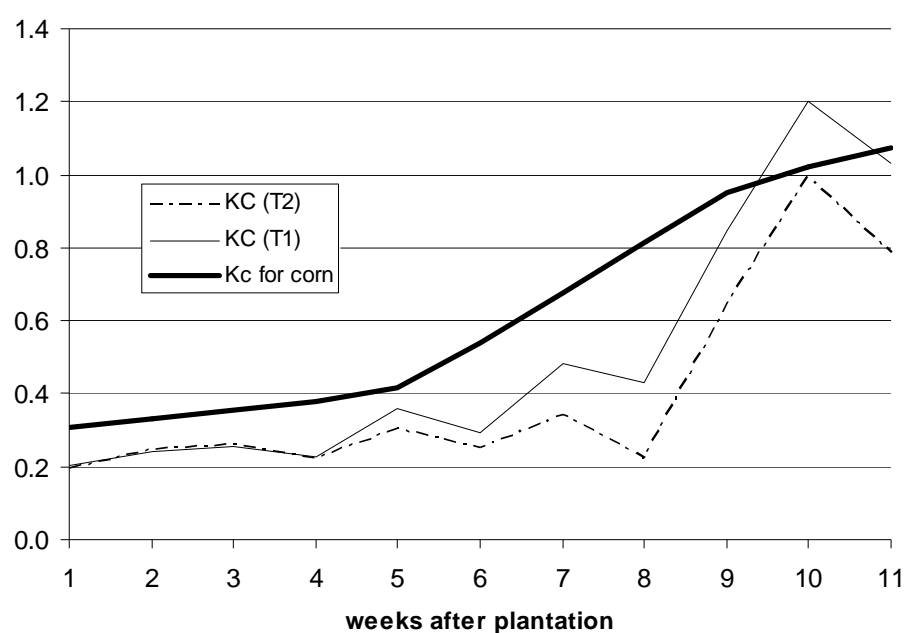


Figure 21. Comparison of crop coefficient either based on established data (K_c for maize) or on a comparison between ET_0 (calculated with climatic data and ET_0 calculator) and ET (from soil humidity measurements).

3.9.7. Conclusion

Ongoing soil water content measurements with TDR probes in cropped and bare pots provided us an accurate value for transpiration (T) and evaporation (E) rates, respectively. An estimation of ET related to each water treatment (field capacity: T1 and water stressed: T2). These values were then compared to ET calculated with climatic data and ET_0 calculator model, which slightly overestimates ET . This approach is the first step of the project, which will be completed by further ^{18}O data to estimate the ^{18}O isotopic signature of evaporation and transpiration.

3.10. Can Efficient Irrigation and Nitrogen Management Practices Contribute to Nitrate Reduction in Groundwater under Intensive Farmer-Managed Vegetable Fields in Slovenia Catchments? ⁹

Collaborative work between V Zupanc, M Pintar, P Korpar (Agronomy Department, Biotechnical Faculty, University of Ljubljana, Slovenia) and J Adu-Gyamfi (SSU)

3.10.1. The Challenge

Groundwater is a very important drinking water source in Slovenia. However, the intensification of agriculture through the use of nitrogen (N) fertilizers and organic manure from livestock (pig farms) to enhance crop yields may be one of the causes of groundwater contamination through leaching of nitrates. It is predicted that intensive vegetable production is the major cause of nitrate contamination in the Ljubljana aquifer, which is the major source of drinking water in Ljubljana, Slovenia.

3.10.2. The Project

Slovenia aims to meet the EU Water Framework Directive (2000/60/EC) and national standards for good quality groundwater status by 2013 while maintaining an intensive agriculture production. A Technical Cooperation Project (TCP) SLO 5002 was funded by IAEA to help improve the capabilities of the Slovenia Counterpart institutes to address nitrate and also pesticides in drinking water by establishing a monitoring system for soil water balance, and for pesticide and nitrate leaching from agricultural benchmark sites in Slovenia catchments. The objective of the study is to assess how different irrigation, nitrogen and cropping system management strategies could help reduce nitrate leaching while sustaining yields in a farmer-managed vegetable field using farmers' (one time fertilizer application before planting and irrigating shortly after planting) and improved practices (scheduled irrigation and fertilization) in a benchmark site in Sneberje, Slovenia. The project also aims to transfer knowledge to the stakeholders.

Nitrogen-15 fertilizer was used as a tracer to monitor the N acquisition by plants and nitrate movement in the soil. Soil water was monitored using 2 capacitance probes (EnviroScan and Time Domain Reflectometer). The IAEA provided experts, training, equipments, stable and radioactive tracers and consumables and the Governmental Authorities of Slovenia executed the Project. The annual precipitation during the experimental period is shown in **Figure 22**.

⁹ Project 2.1.1.5. Contributions to TC projects under achievements of TC Project SLO/5/002 - Task 13.

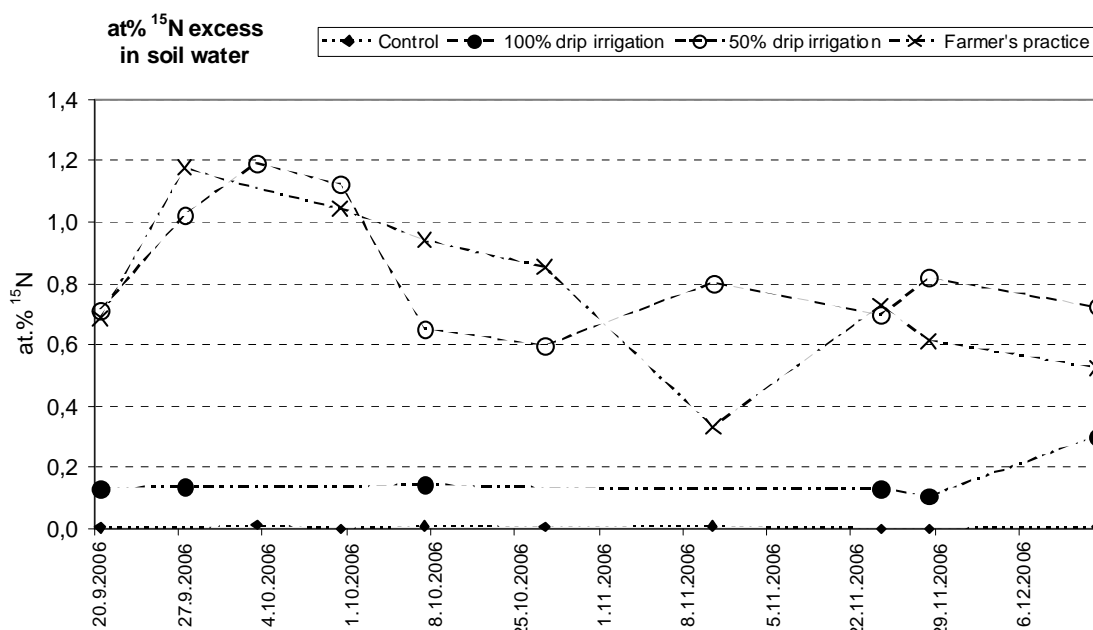


Figure 22. ^{15}N (at. % excess) in soil water collected with suction cups at 50 cm depth in 2006. Control (farmers' irrigation practices with no fertilization), Farmers' practice (farmers' irrigation practices with fertilization of 80 kg N, 50 kg P and 120 kg K ha⁻¹ all applied at planting), 100% drip irrigation (100% water requirements + 50 kg P and 120 kg K ha⁻¹ applied at planting but 80 kg N applied in 3 splits), 50% drip irrigation (50% water requirements + 80 kg N, 50 kg P and 120 kg K ha⁻¹ all applied at planting).

3.10.3. Main Findings

Preliminary results have shown that applying mineral fertilizers by fertigation and covering 100% of potential evapotranspiration with irrigation caused on the average the lowest nitrate concentration in soil water and thus presented the lowest risk of groundwater contamination. Nitrate concentrations in soil water monitored by suction cups were highest under farmer's practice in September – October 2006, following the crop rotation of iceberg lettuce in June and endive in August – September. Nitrate concentration under 50% irrigation plot was lower than that under farmer's plots but higher than under 100% irrigation and values ranged from 10 and 90 mg L⁻¹.

Both the EnviroScan and Time Domain Reflectometer were proved to be effective tools to monitor soil pollutants (nitrates) although soil moisture data obtained using the TDR was more strongly correlated with values from gravimetric measurements than that of the EnviroScan. A methodology for nitrate leaching modelling on a catchment scale was established, and minimum input data sets (i.e. soil, water, weather data) for modelling of nitrate leaching were produced.

3.10.4. A 2-day Round Table Discussion to Mark the Culmination of TC project SLO/5002¹⁰

J Adu-Gyamfi (SSU)

A Technical Cooperation Project (TCP) SLO 5002 was funded by IAEA for 3 years to help improve the capabilities of the Slovenia Counterpart institutes to address nitrate and pesticide in drinking water by establishing a monitoring system for soil water balance, and for pesticide and nitrate leaching from agricultural benchmark sites in Slovenia catchments.

The purpose of the two-day meeting (29-30 July 2008) which was held in the Vienna International Centre (VIC) was to highlight the main achievements of the project, to identify specific technical and project management issues to ensure a successful outcome of the TC project and to develop a roadmap for Slovenia to comply with the EU Water Framework Directive 2000/60/EC. The meeting was attended by the Counterparts from Slovenia, the two Technical Officers (TO) of the project, Mr J Adu-Gyamfi and Mr IG Ferris, the Project Management Officer (PMO) Ms Marta Ferrari and the Section Head TC Europe (SH-TCEU), Mr Oscar E Acuna.

During the meeting, the PMO and SH-TCEU acknowledged the good results achieved so far, and the need to organize the results to be used by End-users and Managers. A National Stakeholder workshop in Ljubljana, Slovenia to discuss a roadmap for scaling up the technology was scheduled for 4 December 2008.



Figure 23. Monitoring nitrate and other soil pollutants in farmer-managed (a) vegetable and (b) maize field with isotopes to ensuring compliance with EU Water framework in Sneberje and Moškanjci in Slovenia.

¹⁰ Project 2.1.1.5. Contributions to TC projects under achievements of TC Project SLO/5/002 - Task 13.

Highlights of some of the main achievements during the three-year period were:

- The establishment of a national network to monitor good agricultural practices at a catchment scale, focusing on nitrate and pesticide leaching to groundwater.
- Results from the three experimental pilot sites (vegetable, maize and hop growing areas) using soil water monitoring equipment and isotope tracers, indicated that applying mineral fertilizers by fertigation and covering 100% of potential evapotranspiration with irrigation caused the lowest nitrate concentration in soil water on average, thus presenting the lowest risk of groundwater contamination (**Figure 23**).
- Using soil, water and weather data, models were used to identify the dominant pathways and sources of pesticide contamination and a soil sensitivity map indicating vulnerable areas for pesticide leaching was produced (**Figure 24**).
- A continuous dialogue with the Ministry of Agriculture, the Ministry of Environment and the Chamber for Agriculture and Forestry to adjust legislation concerning nitrate and pesticide pollution was established.
- In order to enhance the educational component and to effectively exchange the project outputs with farmers and extension officers, project outputs are communicated in special issue supplements to a weekly newspaper (*Farmer's Voice*).
- 'Champion' farmers and other stakeholders who can assist in the future 'scaling up/out' of project outputs were identified and established, and the compilation of guidelines for good agricultural practices relating to fertilisation and irrigation in the local language, financed by the Ministry of Agriculture is in progress.

The capacity of project counterparts through training in the use of nuclear and related techniques in various fields related to the project objectives was enhanced.



Figure 24. Nitrate monitoring in maize and sunflower fields in Slovenia.

3.11. Selection and Evaluation of Food (Cereal and Legume) Crop Genotypes Tolerant to Low Nitrogen and Phosphorus Soils through the Use of Isotopic and Nuclear Related Techniques¹¹

3.11.1. A Mid-Term Review

Technical Officers: J Adu-Gyamfi and G Dercon

The mid term review of this CRP was completed during the third quarter of 2008 after a second RCM in Morelia, Mexico from 21 to 25 April 2008. The review critically assessed the progress achieved in line with the specific objectives of the CRP, identified gaps and made suggestions to improvement of work plans (**Figure 25**).

The overall assessment indicated that most of the participants made progress during the first two years of the CRP in the area of evaluating rice, maize, common beans, cowpeas and soybean genotypes in the laboratory, greenhouse and field to identify root traits conferring P and N acquisition. The CRP has promoted the exchange of germplasm amongst the project partners and Member States (MS) With participants from 17 countries (Australia, Benin, Burkina Faso, Brazil, Cameroon, China Peoples Republic, Cuba, France, Germany, Ghana, Kenya, Malaysia, Mexico, Mozambique, Nigeria, Sierra Leone and USA) covering a wide range of agro-ecological zones and farming systems where low and declining soil fertility constrains crop yields, the networked research and results obtained so far is of global relevance.

Technical adjustments to workplans to help achieve the overall objective of the project included:

- Examination of the nutrient acquisition by crop genotypes from the different soil N and P pools as a criterion for the adaptation of crops to low N and P soils. Protocols for determining soil P pools (Fe-P, Ca-P and Al-P) using non-labelled and labelled phosphorus (³²P) will be used by the project participants from China, Brazil, Cuba and Malaysia.
- Ensuring that all field studies should include soil sampling at the planting, anthesis and maturity to investigate the correlation between the agronomic (root characteristics and yield) component and soil nutrient status (total and available soil N and P) at the different crop growth stages.
- Establishing the need to standardize: (i) experimental protocols to determine soil N and P pools; (ii) terminologies (N and P efficiencies) used; (iii) measurements units and (iv) the collection of quantitative data.
- Publishing research results obtained in scientific journals, national bulletins.

The third RCM is proposed for the first quarter of 2010 and will be held in either Mozambique or Austria.

¹¹ Project 2.1.1.5. Contributions to Coordinated Research Project D1.50.10 – Task 7.



Figure 25. Opening Ceremony (from right, Dr N Bellino, FAO Representative, J Adu-Gyamfi, IAEA, Ms LG Rangel, Constitutional Governor, Dr SF Zamudio, President, Universidad Michoachan de San Nicholas de Hidalgo, and the host Dr J Bayuelo-Jimenez.

3.12. Roots for Crop Productivity

Collaboration work between the Pennsylvania State University (PSU), USA and IAEA

J Adu-Gyamfi, (SSU) and J Lynch (PSU)

The impacts of increased droughts, salinity and nutrient deficiencies are a serious threat to the production of the major world food crops (wheat, rice and maize). Degraded and marginal lands (harsh environments) are the results of nutrient mining, poor land and water management and the inappropriate matching of plants to their environment, particularly with increasing climate variability.

Roots-the hidden half of the plant -play an important role in improving soil and crop and productivity because of its central importance for capturing and utilizing soil water and nutrients for plant growth. However root research has received very little attention because of the high labour cost of assessing a large number of roots in the field, but plant life begins with roots. A joint successful collaboration between the IAEA and the Pennsylvania State University through a CRP has resulted in the development of a field root methodology that is capable of discerning variations for root traits important for efficient acquisition of nutrients and water with minimum cost. This methodology which is available at a website <http://roots.psu.edu> is user-friendly and available to our member states. This validated protocol has been used to effectively identify deep and shallow root genotypes which could be intercropped to maximize the utilization of water and nutrient resources in cropping system. Details are available on the SWMCN website <http://www-naweb.iaea.org/nafa/swmn/news-swmcn.html>.

3.13. Stable Isotope Analyses

The Soil Science Unit performed 12 024 stable isotope measurements during the year 2008 as shown in **Table 3**. Most of the analyses were for supportive research and training with some 3700 for CRPs and 100 for TCPs.

Table 3. Stable isotope measurements during 2008.

Sample measured:

	¹⁵ N enriched	¹⁵ N nat. ab.	¹³ C nat. ab.	¹⁸ O nat. ab.	Total
D1-2008	0	0	1566	0	1566
D1-5009	279	0	449	0	728
TC	66	0	0	0	66
Seibersdorf	686	783	1151	1402	4022
Total	1031	783	3166	1402	6382

Measurements carried out (including standards, blanks, test samples, replicates):

	¹⁵ N enriched	¹⁵ N nat. ab.	¹³ C nat. ab.	¹⁸ O nat. ab.	Total
D1-2008	0	0	2446	0	2446
D1-5009	471	0	763	0	1234
TC	112	0	0	0	112
Seibersdorf	1184	2098	2638	2312	8232
Total	1767	2098	5847	2312	12024

3.14. Radioisotope Analyses ¹²

The Soil Science Unit performed 855 radioisotopes measurements for supportive research in 2008. The SSU γ -detector includes a sampler changer system with a capacity of 12 samples and a HPGe coaxial detector (*p*-type). The performance specifications of the detector measured are as following: resolution (FWHM) at 1.33 MeV, ^{60}Co = 1.89 keV, Peak-to-Compton Ratio, ^{60}Co = 95.1; relative efficiency at 1.33 MeV, ^{60}Co = 115%; peak shape (FWTM/FWHM), ^{60}Co = 1.93; resolution (FWHM) at 122 keV, ^{57}Co = 0.82 keV. The dimensions are: 81.7 mm diameter, 104.2 mm length and 4 mm from end cap to detector. The lead shield is cylindrical with a wall thickness of 10 cm. The spectra are evaluated with Gamma Vision-32 software. The detector is calibrated using the sealed radioactive source FG 607 from Amersham. Counting times ranged between 10 000 and 50 000 seconds, depending on the isotopes activity.

Table 4 summarizes the analytical services provided by the SSU. Two FRN (^{137}Cs and ^7Be) and 5 other isotopes (^{40}K , ^{226}Ra , ^{232}Th , ^{238}U , ^{235}U) were analysed in two different type of matrix, e.g. soil and water. The rain water in Seibersdorf was investigated for its ^7Be daily content. Also, as in 2007, additional *in-situ* gamma measurements were performed under field conditions in Austria (Mistelbach) in collaboration with the Chemistry Unit. An example also of the Minimum Detectable Activity for ^{137}Cs , ^{40}K , ^{226}Ra , ^{232}Th , ^{235}U and ^{238}U during the gamma measurement of the Slovenian soil samples is provided in **Table 5**.

Table 4. Number of different FRN and geogenic radioisotopes analysis performed in 2008.

	^{137}Cs	^7Be	^7Be	^{40}K	^{226}Ra	^{232}Th	^{238}U	^{235}U	Total
<i>Matrix</i>	<i>soil</i>	<i>soil</i>	<i>water</i>	<i>soil</i>	<i>soil</i>	<i>soil</i>	<i>soil</i>	<i>soil</i>	
External Network	90	-	-	90	90	90	90	90	540
Seibersdorf	158	132	7	-	-	-	-	-	297
In situ gamma measurements	9	9							18
									855

¹² Project 2.1.1.1. Soil Management and conservation for sustainable agriculture and environment - Task 1: Providing services to Member States.

Table 5. Minimum Detectable Activity of ^{137}Cs , ^{40}K , ^{226}R , ^{232}Th , ^{235}U and ^{238}U and error measurement per soil increments (n=80) obtain with the SSU gamma detector

	^{137}Cs (Bq/kg)	^{40}K (Bq/kg)	^{226}R (Bq/kg)	^{232}Th (Bq/kg)	^{235}U (Bq/kg)	^{238}U (Bq/kg)
Soil increments						
0-10 cm	0.3 (2.6 ± 1.2)*	2.4 (2.3 ± 0.5)*	0.9 (4.8 ± 0.8)*	5.3 (4.5 ± 3.3)*	0.3 (8.8 ± 1.2)*	14.7 (33.2 ± 17)*
10-20 cm	0.2 (6.5 ± 3.3)*	1.9 (2.5 ± 0.4)*	0.7 (4.4 ± 0.5)*	3.8 (4.5 ± 3.1)*	0.2 (7.1 ± 0.9)*	11.4 (27.8 ± 12.8)*
20-30 cm	0.2 (26 ± 14)*	2.1 (2.5 ± 0.3)*	0.6 (4.1 ± 0.5)*	3.8 (4.2 ± 2.7)*	0.2 (7.0 ± 0.6)*	13.0 (37.6 ± 16)*
30-40 cm	0.2 (46 ± 24)*	1.9 (2.2 ± 0.6)*	0.6 (4.2 ± 0.5)*	3.8 (4.0 ± 2.3)*	0.2 (6.9 ± 0.3)*	11.4 (28.9 ± 15.4)*

3.15. External Quality Assurance

M Aigner

Since the year 1995 the FAO/IAEA Soil Science Unit has been organizing annual Proficiency Tests (PT) on the analysis of plant materials for (enriched) ^{15}N and since the year 2004 also for ^{13}C isotope abundance as well as for the element concentrations of nitrogen and carbon.

Due to the re-organization of the tasks implemented by the FAO/IAEA in the year 2008 the Soil Science Unit has established a new collaboration with the University of Wageningen, The Netherlands, already organizing regular PTs on ^{15}N and ^{13}C in plant materials at the natural abundance level since several years (see the International Plant-analytical Exchange Programme *IPE* on their homepage, http://www.wepal.nl/website/about_wepal/Scope.htm).

The Wageningen Evaluating Programs for Analytical Laboratories (WEPAL) is accredited for the organization of Interlaboratory Studies by the Dutch Accreditation Council RvA since April 26, 2000 (registration number R002). The accreditation is based on the ILAC-requirements (Guidelines for the requirements for the competence of providers of proficiency testing schemes, ILAC-G13:2000). The accreditation covers the quality system of the organisation as well as all the parameters mentioned in the scope.

It was agreed between the Soil Science Unit and the PT-organizer to include one ^{15}N -enriched plant material (range: 0.1 – 2.5 % ^{15}N atom excess) per year into the IPE test sample set. A bulk amount of uniformly ^{15}N -enriched plant material was produced by the FAO/IAEA Soil Science Unit and sent to WEPAL for milling, homogenization and bottling through the routine test sample production process for PTs. This ^{15}N -enriched material was sent out together with 3 other not enriched plant materials.

In February 2008 all participants in PTs previously organized by the Soil Science Unit were invited to participate in the WEPAL IPE programme. Participants were invited to perform analysis offered in the WEPAL IPE scheme including ^{15}N (enriched and/or natural abundance level), total N (N-elementary), Kjeldahl-N, ^{13}C and total C (C-elementary). The participation fee for one round of PT in 2008 (round IPE2008.2) was covered by the IAEA (**Figure 26 and 27**).

Twenty-four participants that were registered in the "SSU PT scheme" in previous years were provided with the WEPAL test sample set IPE 2008.2 consisting of the four test samples of 20 g plant material each. Eleven laboratories reported isotope abundance data within the deadline, one IAEA-participant reported only Kjeldahl-N-data. The Soil Science Unit also participated in this round of PT.

3.15.1. Evaluation Criteria for IAEA-participants

Calculation of Z-score

For all analytical data a Z-score is calculated according to the formula:

$$z = \frac{(X - X_{\text{mean}})}{sd}$$

in which:

X = the reported value

X_{mean} = the mean of all values after outlier elimination

sd = standard deviation of all values after outlier elimination

All participants received the quarterly evaluation report 2008.2 (April-June 2008) from WEPAL providing a description of the test sample preparation, statistical evaluation criteria, outlier calculation and results of all reported analytical results performed on all determinants. Participant's performance in ^{15}N - and ^{13}C atom abundance analysis was acceptable, if the z-scores of the ^{15}N -enriched test sample were within the accepted control limits:

$-2 \leq z \leq +2$ acceptable results

$-3 \leq z \leq +3$ warning (doubtful results)

$-3 > z > +3$ not acceptable (out of control limits)

Data could also be compared to the data reported to WEPAL by the IAEA-SSU.

A certificate for "successful participation" is provided to stable isotope laboratories supported by the IAEA that showed proficiency in both the isotope- *and* elementary analysis of Nitrogen (i.e. ^{15}N isotope abundance and total N analysis, i.e. N-elementary or Kjeldahl-N) and / or Carbon (i.e. ^{13}C isotope abundance and C elementary) of the ^{15}N enriched test sample.

3.15.2. Conclusions

The first Joint Proficiency Test for stable isotopes in plant materials by WEPAL and IAEA was successful and will be continued in this form. The new PT round *IPE2009.2* has already been started and test samples are being sent out in February 2009.

The big advantage of comparing analytical data to those of a large and increasing number of analytical laboratories worldwide will provide high confidence in the laboratory's analytical performance and is an invaluable tool for external quality control. It is hoped that in the future more stable isotope laboratories will make use of this opportunity to assess their analytical performance and provide evidence of the sustainable high quality of their analytical data.

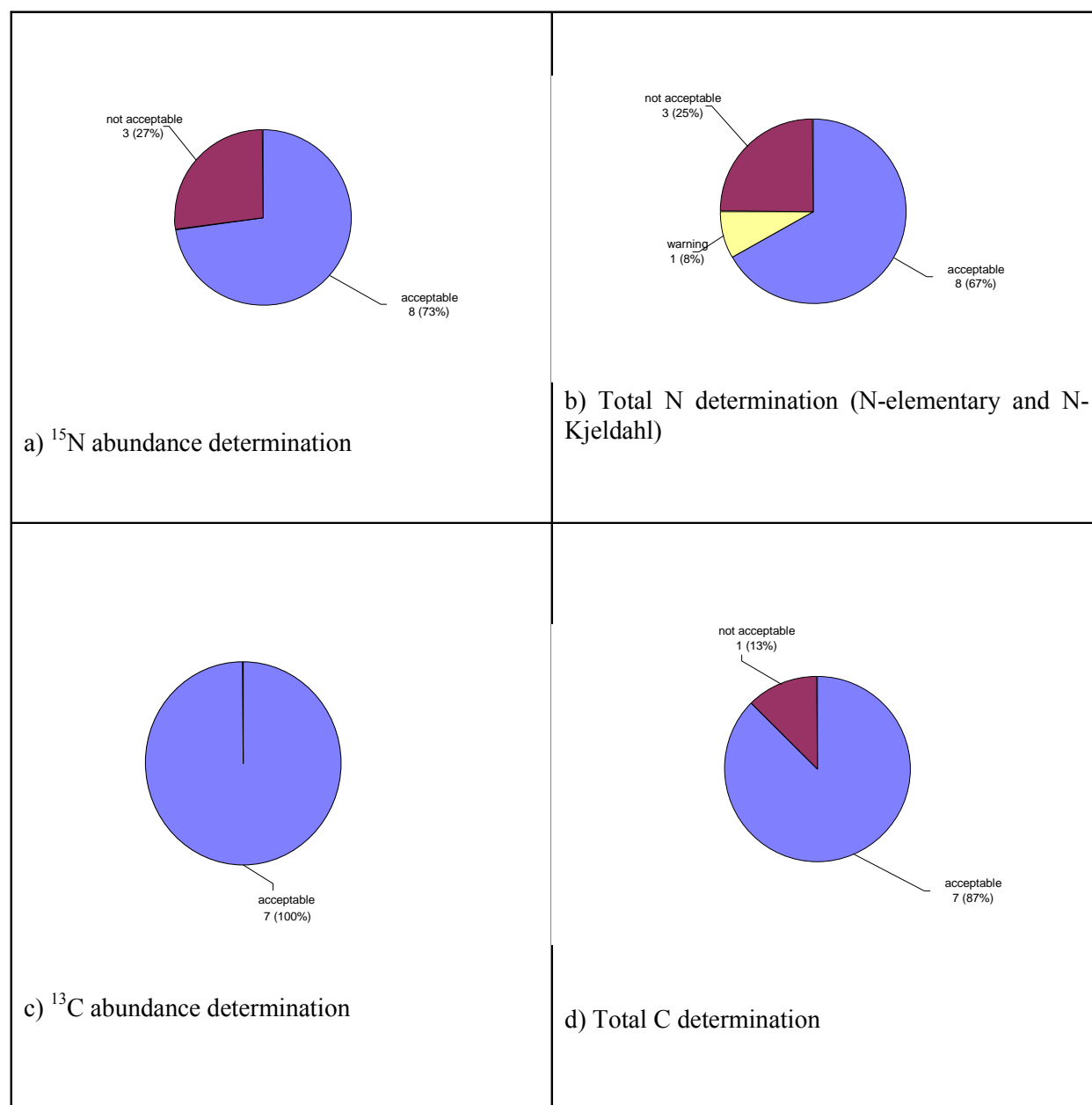


Figure 26. Performance of IAEA-participants.

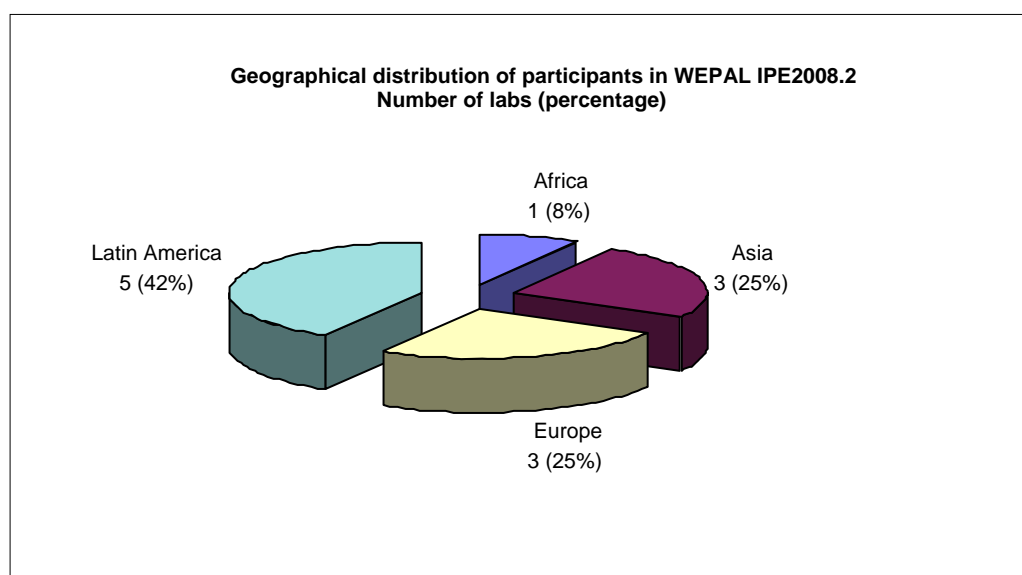


Figure 27. Geographical distribution of IAEA participants.

4. TRAINING ACTIVITIES

4.1. Individual Fellowship Training

J Adu-Gyamfi, L Mabit

Nine fellows received individual fellowship training in the use of stable and radioactive isotopes at the Soil Science Unit during 2008 (See **Section 6.4**).

Isotopes of carbon and nitrogen provide useful estimates of sources, movements and pathways of water and nutrients that help crops grow on drylands and saline soils. Four fellows from Bangladesh, Indonesia, Mauritius and Pakistan, who concluded their fellowship training in the Agency's Laboratories in Seibersdorf, analyzed and interpreted the data obtained on from the greenhouse experiments on carbon isotope discrimination and N-15 studies using wheat and *Brassica spp* from their countries and produced 4 posters during 2008:

- Rahman MA, Ram T, Bachiri H, Shirazi MU, Adu-Gyamfi JJ, Heiling M. Bringing hope to marginal environments: the potential of the carbon isotope discrimination technique to select wheat genotypes in drought-prone environments
- Ram T, Rahman MA, Shirazi MU, Bachiri H, Rasyid B, Adu-Gyamfi JJ, Heiling M. Carbon isotope discrimination as a rapid and effective screening tool to select wheat genotypes adapted to salt-stressed environments
- Shirazi MU, Ram T, Rasyid B, Adu-Gyamfi JJ, Heiling M. Carbon isotope signature in Brassica (*Brassica spp*) at varying salinity levels
- Ram T, Shirazi MU, Rasyid B, Rahman MA, Adu-Gyamfi JJ, Heiling M. N fertilizer use efficiency in Brassica under water-stressed and salinity conditions.



Figure 29. Mr Solonjara (MAG07007) performing rain water collection in Seibersdorf prior to ^7Be gamma analysis.

4.2. Scientific Visits

Eight scientific visitors received training by the Soil Science Unit during the year in the field of crop nutrition, water management and soil erosion and sedimentation (See **Section 6.4.**).



Figure 30. Training fellows on the use of carbon isotope discrimination for evaluating wheat genotypes for greater agronomic water use efficiency in glasshouse.



Figure 31. Integrated soil-plant approaches to increase productivity in harsh environments: A fellow from Eritrea (Plant Breeder) explore the potential of the C-13 technique to screen and evaluate mutants of sorghum and millet genotypes.

5. ACKNOWLEDGEMENTS

i) The update of the R&D activity 3.1: *'The use of Fallout radionuclides (^{137}Cs & ^{210}Pb) in Mistelbach-Austria'* was performed with the partnership of the Dr Andreas Klik from Boku University and the efficient teamwork of the staff and fellows of the SSU and CU.

ii) Regarding the implementation of the R&D activity 3.2: *'Preliminary test in Slovenia to assess erosion and sedimentation processes using radio-isotopic approach'* the SSU want to acknowledge the support provided by Dr Vesna Zupanc – previous fellow with the SSU – from the Centre for Agricultural Land Management and Agrohydrology of the University of Ljubljana (Slovenia) and by Dr Paul Martin the Section Head of the Physics, Chemistry and Instrumentation Laboratory, IAEA Laboratories Seibersdorf.

iii) The guideline materials presented through the R&D activities 3.3 and 3.4: *'How to select the most appropriate FRN (^{137}Cs , ^7Be , ^{210}Pb) for agroenvironmental investigation in Member States ?'* and 3.4: *'State of the art, research needs and analysis of recent and future trends in the use of FRN for documenting soil erosion and soil redistribution'* have been implemented with the collaboration of the Centre national de l'énergie, des sciences et des techniques nucléaires (CNESTEN), Rabat, Morocco and the University of Exeter, Department of Geography, UK. Also the information provided by the following persons is also acknowledged: Dr Gyula Kis-Benedek (IAEA, CU, Seibersdorf), Dr Philippe Bonté (CEA-CNRS, France) and Dr Andrew Tyler (School of Biological and Environmental Sciences, University of Stirling, UK).

iv) The R&D activity 3.5: *'First investigation in Seibersdorf of a promising short term soil tracer: ^7Be '* have been initiated during the training of Mr Solonjara, Asivelo Fanantenansoa and we would like to underline his valuable contribution. We also acknowledge the collaboration and support provided by Mr Anton Nirschl from the IAEA Mechanical Workshop during the conception of the SSU Fine soil increment collector and our rainfall collector.

v) The R&D activity 3.6: *'Application of nuclear techniques (FRN) to evaluate erosion processes in Nigeria (east Africa)'* was mostly conducted by the Dr Junge Birte, the manager of the project from the International Institute of Tropical Agriculture (IITA) in Ibadan-Nigeria. The SSU as well as the SWMCN section based on their expertise in the field of nuclear techniques were cordially associated to this project.

6. APPENDICES

6.1. Staff Publications

6.1.1. Journal Articles

Bernard, C, **L Mabit**, MR Laverdière (2008). Utilisation du ^{137}Cs pour estimer la production de sédiments d'origine agricole à l'échelle du bassin versant. In: AUF, EAC et IRD éditeurs. *Efficacité de la gestion de l'eau et de la fertilité des sols en milieux semi-arides*. ISBN: 978-2-914610-76-6. pp. 390-397.

Chaudhary, MI, **JJ Adu-Gyamfi**, H Saneoka, TN Nguyen, R Suwa, S Kanai, H El-Shemy, DA Lightfoot, K Fujita (2008). The effect of phosphorus deficiency during hydroponics on nutrient uptake, biological nitrogen fixation and photosynthetic rate among mashbean, mungbean and soybean *Acta Physiologiae Plantarum*, 30 (4):537-544

Høgh-Jensen, H, R Odgaard, D Kamalongo, FA Myaka, **JJ Adu-Gyamfi** (2008). Multiple nutrient balances in ear leaves of on-farm unfertilized maize in eastern and southern Africa. *African Journal of Agricultural Research* (in press)

IAEA, 2008 Guidelines on Nitrogen Management in Agricultural Systems, Training Course Series 29, Vienna. IAEA-TCS 29/CD

Kanai, S, **JJ Adu-Gyamfi**, K Lei, J Ito, K Ohkura, REA Moghaieb, H El-Shemy, R Mohapatra, PK Mohapatra, H Saneoka, K Fujita (2008). N-deficiency damps out circadian rhythmic changes of stem diameter dynamics in tomato plant. *Plant Science* 174, 183-191

Mabit, L, M Benmansour, DE Walling (2008). Comparative advantages and limitations of Fallout radionuclides (^{137}Cs , ^{210}Pb and ^7Be) to assess soil erosion and sedimentation. *Journal of Environmental Radioactivity*, 99(12), 1799-1807.

Mabit, L, C Bernard, M Makhoulf, MR Laverdière (2008). Spatial variability of erosion and soil organic matter content estimated from ^{137}Cs measurements and geostatistics. *Geoderma*, 145(3-4), 245-251.

Shakhashiro, A, **L Mabit** (2008). Results of an IAEA inter-comparison exercise to assess ^{137}Cs and total ^{210}Pb analytical performance in soil. *Applied Radiation and Isotopes* (In press).

6.1.2. Conference Proceedings/Abstracts /Reports

Adu-Gyamfi, JJ (2008). Report of the 2nd Research Coordination Meeting of the FAO/IAEA Coordinated Research Project D1.50.10 "Selection and evaluation of food crop genotypes tolerant to low nitrogen and phosphorus soils through the use of isotopic and nuclear-related techniques" IAEA Publication (Limited Distribution). IAEA 311-D1-RC-1031.2 page 26.

Adu-Gyamfi, JJ (2008). Coordinated Research Report Mid-year review of CRP "Selection and evaluation of food crop genotypes tolerant to low nitrogen and phosphorus soils through the use of isotopic and nuclear-related techniques" CPR No.1290 RCS

Bernard, C, **L Mabit**, MR Laverdiere (2008). Comparing soil erosion and sediment production in two contrasted catchments from ^{137}Cs measurements. In: WEH Blum, MH Gerzabek and M Vodrazka (Eds.). Book of Abstracts, EUROSIL 2008, Soil-Society-environment. ISBN: 978-3-902382-05-4. pp. 28.

Høgh-Jensen, H, R Odgaard, FA Myaka, WD Sakala, **JJ Adu-Gyamfi** and JM Vesterager (2008). Integrating pigeonpea in maize based farming systems may increase food production and alleviate poverty. Poster presented at Cultivating the Future Based on Science: 2nd Conference of the International Society for Organic Agriculture Research ISOFAR, 16th IFOAM Organic World Congress Modena, Italy, June 18-20, 2008. <http://orgprints.org/11420>

Mabit, L (2008). Laboratory support activities to the Coordinated Research Project D1.50.08. In: F Zapata, Y Li. Report of the Fourth and Final Research Coordination Meeting of the FAO/IAEA Coordinated Research Project D1.50.08 'Assess the Effectiveness of Soil Conservation Techniques for Sustainable Watershed Management Using Fallout Radionuclides'. IAEA Publication (Limited Distribution). IAEA 311-D1-RC-888.4: page 26.

Mabit, L, A Klik (2008). Erosion and sedimentation evaluation in a small agricultural Austrian watershed using Caesium-137, Lead-210 and traditional approaches. In: Geophysical Research Abstracts (CD-Rom), Volume 10, European Geosciences Union - General Assembly 2008. Abstract EGU2008-A-01651. pdf, 2 pages.

Mabit, L, A Klik (2008). Quantification of erosion process through plot measurements and radioisotopic methods (^{137}Cs , ^{210}Pb). In: WEH Blum, MH Gerzabek and M Vodrazka (Eds.). Book of Abstracts, EUROSIL 2008, Soil-Society-environment. ISBN: 978-3-902382-05-4. pp. 257-258.

Mabit, L, A Klik (2008). Test of ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$ to assess erosion and sedimentation process: A case study in Austria. In: P Zdruli and E Costantini. (Eds.). "*Moving ahead from assessments to action: Could we win the struggle with land degradation ?*" 5th International conference on land degradation Valenzano Bari, Italy 18-22 September 2008. Book of abstracts. ISBN 2-85352-399-2. Vol I, pp. 61-65.

6.2. Staff Travels

Staff Member	Destination	Period	Purpose of Travel
Mabit, Lionel	Vienna, Austria	13-18 April	A presentation entitled ' <i>Erosion and sedimentation evaluation in a small agricultural Austrian watershed using Caesium-137, Lead-210 and traditional approaches</i> ' on the potential use of ^{137}Cs & ^{210}Pb as soil tracer under Austrian field conditions was made at the European Geosciences Union General Assembly.
	Vienna, Austria	25-29 August	Two contributions were presented at The 3 rd International EUROSOIL congress, soil-society-environment: i) on the measurement of soil erosion/sedimentation under conventional and conservation cropping practices using runoff plots and FRN entitled ' <i>Quantification of erosion process through plot measurements and radioisotopic methods (^{137}Cs, ^{210}Pb)</i> ' ii) on the use of ^{137}Cs at the watershed scale entitled ' <i>Comparing soil erosion and sediment production in two contrasted catchments from ^{137}Cs measurements</i> '.
	Valenzano-Bari, Italy	18-22 September	A paper highlighting the research activities of the soils subprogramme on the use of FRN ' <i>Test of ^{137}Cs and $^{210}\text{Pb}_{ex}$ to assess erosion and sedimentation process: A case study in Austria</i> ' was presented at The 5 th International conference on land degradation, ' <i>Moving ahead from assessments to action: Could we win the struggle with land degradation?</i> '.

Staff Member	Destination	Period	Purpose of Travel
Adu-Gyamfi, Joseph	Asmara, Eritrea (See Figure 32)	8-15 March	To review the progress on an expert report, and to make technical adjustments to the work plans. To organize a training course on the use of the carbon isotope discrimination technique to select crops for greater water use efficiency in water limited environments (TC project ERI5004 on 'Improving crop productivity and combating desertification').
	Morelia, Mexico (See Figure 33)	21-25 April	To act as Scientific Secretary for the second RCM of the CRP D1.50.10.
	Dhaka, Bangladesh (See Figure 34)	8-17 August	To assess progress in the soil water management component of the project and to discuss and make technical adjustments to the workplan for this TC project on 'Increasing agricultural production in the coastal area through improved crop, water and soil management'. To organize a training course on the use of the carbon isotope discrimination technique and other nuclear techniques to select crops for greater water use efficiency in water limited and saline environments (TC project BGD5026).
	Khartoum, Sudan (See Figure 35)	22-29 November	To review the technical progress and to assist in preparing a supplementary workplan, including the Agency's inputs for 2008–2009. To make a presentation on the use of N-15 and C-13 to select crops for greater water and nitrogen use efficiency in water and nitrogen limited environments (TC project SUD5030).
Hardarson, Gudni	Ulaanbaatar and Darkhan, Mongolia	4-8 August	To review the progress made in the project and assist in the planning of future research work in the country (TC project MON5014).



Figure 32. Field work at the National Agricultural Research Institute, Halehale, near Asmara, Eritrea.



Figure 33. Participants at the second RCM at Moleria, Mexico.



Figure 34. Soil and water management for increased rice production in lowland coastal areas Bangladesh.



a)



b)

Figure 35. (a) Main gate of the Gezira Irrigation Scheme, the breadbasket of Sudan (b) Good yield from irrigation— a farmer demonstrates that he is food secured.

6.3. External Collaborations and Partnerships

Collaborations and partnerships are essential for enhancing research activities. The SSU established collaborations with external partners from Member States on the following projects:

Institution	Topic
Universität für Bodenkultur Wien , Department für Wasser-Atmosphäre-Umwelt, Institut für Hydraulik und landeskulturelle Wasserwirtschaft, Vienna, Austria.	Assessment of environmental impact and magnitude of soil redistribution in Mistelbach watershed (Austria) using FRN and conventional approaches ¹³
Centre national de l'énergie, des sciences et des techniques nucléaires (CNESTEN) , Rabat, Morocco.	
GSF Forschungszentr.f.Umwelt und Gesundheit GMBH , Oberschleissheim, Germany.	
Laboratoire des sciences du climat et de l'environnement, (LSCE), Commissariat à l'énergie atomique (CEA), Centre national de la recherche scientifique (CNRS) , Gif-sur-Yvette, France.	
International Institute of Tropical Agriculture (IITA) , Ibadan, Nigeria.	First application of nuclear techniques (FRN) in the derived savanna of Nigeria for estimating medium-term soil redistribution rates ¹³
Bundesanstalt fuer Geowissenschaften und Rohstoffe (BGR) , Hannover, Germany.	
Institute of Soil Science and Land Evaluation & Institute of Plant Production in the Tropics and Subtropics, University of Hohenheim , Stuttgart, Germany.	
University of Exeter, Department of Geography , Exeter, UK.	
Centre national de l'énergie, des sciences et des techniques nucléaires (CNESTEN) , Rabat, Morocco.	Supportive materials to select the most appropriate FRN (¹³⁷ Cs, ⁷ Be, ²¹⁰ Pb) for agroenvironmental investigation in Member States ¹³
University of Exeter, Department of Geography , Exeter, UK.	

¹³ Project 2.1.1.1. Soil Management and conservation for sustainable agriculture and environment - Task 2: Improve FRN methodologies to measure soil redistribution rates at a range of scales in agricultural landscapes with the use of geostatistic approach.

Institution	Topic
Center for Agricultural Land Management and Agrohydrology Department for Agronomy, Biotechnical Faculty , Ljubljana, Slovenia.	Measurements of erosion and sedimentation magnitude using radio-isotopic approaches in Šalamenci watershed (Slovenia) ¹³
Atomic Energy Commission of Syria , Damascus, Syria.	Spatial variability of erosion and soil organic matter content estimated from ¹³⁷ Cs measurements and geostatistics ¹³
Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec , Québec, Canada.	
Institut de recherche et de développement en agroenvironnement , Sainte-Foy, Québec, Canada.	
Département des sols et de génie agroalimentaire, Université Laval , Sainte-Foy, Québec, Canada.	

6.4. Trainees, Fellows and Scientific Visitors

Name	Country	Duration	Topic of Training
Fellows			
Ram, Mr T (MAR/07005)	Mauritius	5 months	Field estimation of soil water content, and water balance using different soil water monitoring equipment under two irrigation regimes.
Rasyid, Mr B (INS/07006)	Indonesia	4 months	Comparing soil water moisture equipment (installation, measurements, data collection, analysis and data interpretation).
Shirazi, Mr MU (PAK/05047)	Pakistan	5 months	Use of combined isotopes of carbon and oxygen to evaluate wheat and <i>Brassica</i> genotypes for their tolerance to drought and salinity
Bachiri, Mr H (ALG/07029)	Algeria	3 months	The use of carbon isotope discrimination to evaluate wheat lines tolerant to drought and salinity.
Rahman, Mr MA (BGD/07017)	Bangladesh	4 months	Field estimation of crop-water balance under irrigated and non-irrigated conditions.
Zupanc, Ms V (SLO/07019)	Slovenia	2 months	Water balance calculations and simulation of water flow related leaching, and data analyses and interpretation of soil water measurements from Snerberje experimental plot in Slovenia (part of the TC project SLO/5/002). She was also trained for 2 weeks on the use of environmental radionuclides to assess erosion and sedimentation processes. Soil samples from Slovenia were analysed, the data treatment was almost completed and the redaction of a scientific contribution was initiated.
Russom, Mr NA (ERI/08007)	Eritrea	4 months	Use of carbon isotope discrimination techniques to evaluate putative mutants of sorghum and millet at vary soil moisture and phosphorus availability. The training is jointly hosted by the Soil Science and the Plant Breeding Units (ERI/5/002)

Name	Country	Duration	Topic of Training
Solonjara, Mr AF (MAG/07007)	Madagascar	3 months	The training was related to the IAEA's TC project MAG5014 entitled: ' <i>Use of Environmental Radioisotopes for the Assessment of Soil Erosion and Sedimentation and for Supporting Land Management in the Province of Antananarivo, Madagascar</i> '. To support the local team and to fulfill this TC project, the topics included in the training were: i) introduction to erosion/sedimentation process, ii) use of ^{137}Cs and ^7Be to estimate erosion/sedimentation magnitude, iii) soil sample preparation for gamma analysis, iv) radio-analytical techniques, v) introduction to geostatistical analysis, vi) mapping, analysis and interpretation of data and vii) use and adaptation of conversion models to Madagascar environmental condition. A field practical training including sampling strategy elaboration and soil/rain water samples collection using different devices in Seibersdorf (^7Be) and also in Mistelbach watershed (^{137}Cs) was also part of the training received by the fellow.
Mert, Mr Y (TUR/08007)	Turkey	1 months	Training on stable isotope analyses and sample preparation by the use of mass spectrometry.

Scientific Visitors

Ramma, Ms I (MAR/07004)	Mauritius	5 days	
Traore, Mr B (MLI/08001)	Mali	5 days	
Fofana, Mr A (MLI/08004)	Mali	5 days	
Severin, Mr A (HAI/08001V)	Haiti	5 days	
Shilulu, Ms I (NAM/09001V)	Namibia	5 days	
Pierre, Mr KJJ (HAI/08003V)	Haiti	5 days	

Name	Country	Duration	Topic of Training
Donald, Mr J (HAI/08004V)	Haiti	5 days	
Hassan, Mr AA (BGD/07019)	Bangladesh	5 days	

6.5. Co-ordinated Research Projects (CRP) and Technical Cooperation Projects (TCP)

CRP Title	Scientific Secretary
Selection and Evaluation of Food (Cereal and Legume) Crop Genotypes Tolerant to Low Nitrogen and Phosphorus Soils through the Use of Isotopic and Nuclear related Techniques (2006-2011)	Adu-Gyamfi, Joseph
TCP Title	Technical Officer
Effect of Biofertilizer and Inorganic Fertilizer Uses on the Growth and Yield of Maize and Bean in Ferralitic Soils of Huambo (ANG5005)	Hardarson, Gudni
Increasing Agricultural Production in the Coastal Area through Improved Crop, Water and Soil Management (BGD5026)	Shu, Qingyao Adu-Gyamfi, Joseph
Integrated Watershed Management for the Sustainability of Agricultural Lands (CHI5048)	Ferris, Ian Mabit, Lionel
Improving Crop Productivity and Combating Desertification (ERI5004)	Adu-Gyamfi, Joseph Lokko, Yvonne Rosaline
Improvement of Yield in Plantain and Cassava through the Use of Legume Cover Crops (IVC5029)	Hardarson, Gudni
Isotope Techniques for Assessment of Water and Nitrogen Use Efficiency in Cow-Pea/Maize Intercropping Systems (KEN5026)	Adu-Gyamfi, Joseph
Use of Environmental Radioisotopes for the Assessment of Soil Erosion and Sedimentation in the Province of Antananarivo, Madagascar (MAG5014)	Mabit, Lionel
Assessment of Soil Erosion and Sedimentation in the Niger Watershed with the Use of Radioisotopes, Phase I (MLI5022)	Mabit, Lionel
Application of Isotopes in Soil and Plant Studies (MON5014)	Hardarson, Gudni
Contribution of Nitrogen Fixing Legumes to Soil Fertility in Rice-based Cropping Systems (SIL5008)	Hardarson, Gudni
Protecting Groundwater and Soil against Pollutants Using Nuclear Techniques (SLO5002)	Adu-Gyamfi, Joseph Ferris, Ian
Increasing Productivity of Selected Crops Using Nuclear Related Techniques (SUD5030)	Shu, Qingyao Adu-Gyamfi, Joseph
Drip Irrigation and Fertigation for Improved Agricultural Productivity (YEM5002)	Adu-Gyamfi, Joseph

6.6. Abbreviations

CNESTEN	Centre national de l'énergie, des sciences et des techniques nucléaires (Morocco)
CP	Counterpart
CRP	Coordinated Research Project
CU	Chemistry Unit
CV	Coefficient of Variation
FRN	Fallout radionuclides
FSIC	Fine Soil Increment Collector
IITA	International Institute of Tropical Agriculture
MBM 2	Mass Balance Model 2
MDA	Minimum Detectable Activity
PMO	Programme Management Officer
PT	Proficiency Test
RCM	Research Coordination Meeting
SD	Standard Deviation
SSU	Soil Science Unit
SWMCN	Soil Water Management and Crop Nutrition section
TCP	Technical Cooperation Project
TO	Technical Officer



International Atomic Energy Agency
Wagramerstrasse 5
P.O. Box 100
A-1400 Vienna, Austria

**Food and Agriculture Organization
of the United Nations**
Vial delle Terme di Caracalla
I-00100 Rome, Italy

Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

<http://www-naweb.iaea.org/nafa/index.html>