Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Soil Science Unit

Activities Report

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IAEA Laboratories Seibersdorf

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The Soil Science Unit (SSU) develops and tests nuclear techniques in the field of crop nutrition and water management. During the past years the research and development activities of the Unit have had major impact in Member States through the transfer of nuclear techniques to measure fertilizer use efficiency, soil erosion and sedimentation, biological nitrogen fixation and water use efficiency for improving crop nutrition and water management.

Very good progress has been achieved during 2007 on the soil erosion and sedimentation research using Fallout Radionuclides. ^{137}Cs *and* ^{210}Pb *methodologies to estimate soil redistribution rates at several spatial and temporal scales were tested and validated in eastern Austria under conventional and conservation cropping practices. A Fine Soil Increment Collector (FSIC) to resolve the main limitation of the use of* ^{7}Be *as a soil tracer under field conditions was also developed. The results of the proficiency test (*^{137}Cs*/total* ^{210}Pb*) organized by the SSU in support of the CRP D1.50.08 were analysed and recommendations to improve FRN gamma spectrometry measurements were provided to Member States. New external collaborations and partnerships were established with institutes in Austria, Canada, France, Germany, Morocco, Slovenia and Turkey to support the R&D activities of the Unit, 9 papers were published and staff participated in three international conferences.*

Major progress was also made on the research on abiotic stress on crop production. Climate change threatens many important food crops, across the world and there is an urgent need to focus research on how to make crops more resilient to environmental stress. In response to a need to "bring hope to the marginal and harsh environments", the SSU tested and refined the carbon isotope discrimination methodology (using the ratios of different carbon isotopes in plants) to effectively evaluate and select rice, wheat and maize genotypes tolerant to the interactive effects of drought, salinity and nutrient stress. Water stress and its interactive effect with salt resulted in less negative $^{12}C/^{13}C$ *(*$\delta^{13}C$*) values as compared to the other treatments. The method was successfully used to evaluate and select wheat and rice genotypes from Kazakhstan and Vietnam tolerant to drought and salinity conditions. The carbon isotope technique was found to be influenced by soil phosphorus and nitrogen availability, indicating that the use of this technique to evaluate drought and salt tolerant genotypes in nutrient-stressed environments requires further investigations.*

Training activities at the SSU included a 4-week inter-regional training course on "Use of nuclear and related techniques to measure storage, flows and balance of water in cropping systems" with 22 participants from 21 developing countries. Nine TC fellows and four scientific visitors were trained on a range of isotopic and nuclear techniques related to land and water management for crop productivity and environmental sustainability. An existing greenhouse and a laboratory were refurbished to the Type B security standard, with training and research activities commencing in 2008.

A total of 10 567 stable isotope measurements were performed during 2007. Most analyses were for supportive research as well as training, with some 3400 for CRPs and 800 for TCPs. Furthermore fallout radionuclide analytical services for CRP participants and external quality assurance for national and regional laboratories were provided with 230 samples analysed.

The SSU coordinated 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 (D1.50.10) with ten Research Contractors, five Agreement Holders and two Technical Contracts and evaluated requests for contract renewals. The second research coordinated meeting is now being planned and will be held in Mexico during 2008. The SSU provided scientific and technical support during the Research Coordination Meeting for CRP D1.50.08 on the Assessment of the Effectiveness of Soil Conservation Measures for Sustainable Watershed Management Using Fallout Radionuclides and to the Consultants Meeting to assess land use activities on soil/loss sediment transport and related environmental problems. In addition, the SSU coordinated 15 TC projects (in Angola, Bangladesh, Chile, Eritrea, Kenya, Libya, Madagascar, Mali, Mongolia, Ivory Coast, Sierra Leone, Slovenia, Sudan and Yemen).

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1. PROGRAMMATIC AND UNIT OBJECTIVES

Management practices and technological packages that 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 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 groundwaters 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 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 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 provides details on current and planned programmes.

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3. RESEARCH AND DEVELOPMENT ACTIVITIES

3.1. Evaluation of Erosion and Sedimentation Rates Using ^{137}Cs, ^{210}Pb and Conventional Erosion Measurements within an Austrian Watershed [1]

Quantitative and qualitative studies on arable soil degradation have been carried out all over the world and water erosion has been identified as one of the major cause of soil degradation. Erosion decreases soil productivity (on-farm impacts) and increases environmental pollution problems (off-farm impacts). Traditional monitoring techniques for soil erosion require many years of measurements to integrate climatic inter-annual variability.

Fallout of ^{137}Cs (an artificial radionuclide coming from thermonuclear weapon tests with a half-life of 30.2 years) and ^{210}Pb (a natural geogenic radioisotope with a half-life of 22.2 years) can be used to assess medium-term soil erosion rates and patterns under varied agro-environmental conditions while direct measurements are related to single rainfall events or rather short periods of time.

The magnitude of sedimentation processes was evaluated using Fallout RadioNuclides (FRN) (^{137}Cs and ^{210}Pb) and the mid-term (13 years) magnitude of erosion rates was quantified, using conventional runoff plot measurements in a small agricultural watershed under conventional and conservation cropping practices at Mistelbach watershed (18 ha) located 60 km north of Vienna in Austria. Our objectives were to measure magnitude of soil erosion in eastern Austria under conventional and conservation cropping practices using runoff plots; to test and validate the potential use of FRN (^{137}Cs and ^{210}Pb) as soil tracer under Austrian field conditions; to evaluate the initial fallout; to establish the physico-chemical characterization of the reference site selected and to assess the sedimentation rates using FRN approach.

3.1.1. Study area and setup of runoff and erosion measurements using conventional erosion plots

In 1994 a field experiment was initiated by Dr A Klik (BOKU) to investigate the impacts of three tillage practices. The experiments were carried out on plots of agricultural schools in Mistelbach in Austria **(Figures 1 and 2)** to measure surface runoff and erosion processes.

Mistelbach is located 60 km north of Vienna in the so-called Wine Quarter. This region is one of the warmest and also driest parts of Austria. The landscape is characterized by gentle to fairly steep slopes. Long-term average precipitation is 643 mm yr^{-1} and air temperatures 9.6°C yr^{-1}. Soil textures range from silt loam to loam. Crop rotation consists mainly of corn-small grains.

Figure 1. Location of the study area.

[1] Project E1.02, Activity 2

The study design consists of one 3-metre-wide and 15-metre-long runoff plot for each management variation. Runoff and soil loss were measured using an automated erosion wheel. Three different tillage treatments were compared: conventional tillage system (CT); conservational tillage (CS) with cover crops during winter; and direct seeding (DS) with cover crops during winter.

Figure 2. Aerial photography of Mistelbach watershed.

3.1.2. Soil sampling design and laboratory analysis

One of the most important steps in using the ^{137}Cs and ^{210}Pb method is to select and determine a suitable reference inventory, against which other values spatially distributed in the watershed will be compared. Because of the restricted number of permanent pastures, and after compilation of background information and consultation of available documents coupled with field study, the choice fell onto an undisturbed forest within the watershed. Basic enquiries and aerial photography consultation confirmed that this small forest was present more than 30 years ago. This small area that was identified as a potential valid reference site is about 2500 m^2 (50 x 50m) with a low gradient slope and low canopy density **(Figure 2)**. A homogenous 400 m² surface (20 x 20 m) inside the forest was selected. A systematic multi-grid design including three different scale levels (20 x 20 m, 5 x 5 m and 1 x 1 m) was tested for samples collection **(Figure 3)**. A total of 174 sample increments representing 76 soils samples were collected. Each sample corresponds to a composite of two mixed increments (0-10 cm and 10-20 cm) in order to, later on, simplify and reduce the number of gamma analyses in the laboratory.

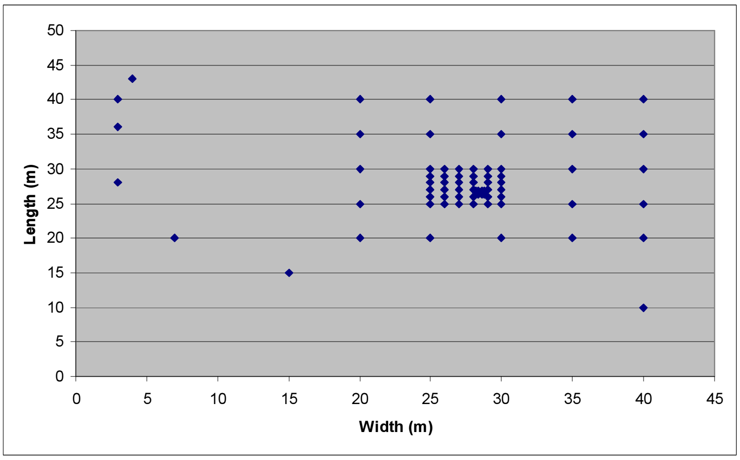

Figure 3. Sampling design in the reference site.

Ten additional samples were taken to characterize the physical and chemical soil proprieties of the reference site. The measured parameters were: bulk density, particle size distribution, water content, organic carbon/organic matter, total nitrogen, C/N ratio, pH in $CaCl_2$, cation exchange capacity, calcium carbonate content and total phosphorus.

In the sedimentation area of the watershed **(Figure 2)**, three different cores were collected in a radius of 2 m with a soil column cylinder auger with a gasoline-powered hammer (**Figure 4**).

Figure 4. SSU and CU (staffs and fellows) during sampling collection of full soil profil and soil sub-sample increment in Mistelbach watersheld.

Soil profiles were collected to 1 m depth and divided into 5 cm increments. The samples from similar increment were combined to obtain a composite profile (Profile 1). Another single profile (Profile 2) was collected and divided into 10 cm increments in the talweg runoff convergence. It is expected that the sedimentation rates would be more important than for profile 1 as this profile will be representative of more effective sedimentation processes linked to the basin geomorphology **(Figure 2)**.

All soil samples were oven-dried for 48 hours at 70°C, ground to 2 mm and homogenized. The material < 2 mm was used in order to analyze ^{137}Cs, total ^{210}Pb and ^{226}Ra (from ^{214}Bi) gamma activity. For the samples collected in the reference site and in the agricultural fields, the ^{137}Cs activity measurements were carried out with the gamma detector of the Soil Science Unit. The spectra were evaluated with Gamma Vision-32 software. The detector was calibrated using the sealed radioactive source FG 607 from Amersham. Counting times ranged between 30 000 and 50 000 seconds, depending on the ^{137}Cs activity. This was sufficient to obtain an average counting error of 6.2% ±1.8% at 2 sigma precision. Additional control on the ^{137}Cs measurements was implemented through the organization of an inter-comparison exercise with the Institute of Radiation Protection of the GSF-National Research Center for Environment and Health in Germany, demonstrating an overall difference of 5% on the samples tested.

Among the 76 samples collected, 11 samples from the forest were selected randomly to be analyzed later on in the laboratory for determination of the $^{210}Pb_{ex}$ reference level. 11 homogenized sub-samples of 100 g for total ^{210}Pb, ^{226}Ra (from ^{214}Bi) and $^{210}Pb_{ex}$ determination were analyzed by the CNESTEN in Morocco and controlled by the CEA/ CNRS in Gif-sur-Yvette in France. $^{210}Pb_{ex}$ activities were calculated by measuring both total ^{210}Pb and ^{226}Ra and subtracting the supported ^{210}Pb in equilibrium with ^{226}Ra from the ^{210}Pb total activity. The analytical results will be presented below in the result part. Also for each increment of the samples collected in the sedimentation area, the ^{137}Cs, the total ^{210}Pb, the ^{226}Ra and the $^{210}Pb_{ex}$ activity were measured. After gamma measurement the areal activities of ^{137}Cs were converted into soil movement (t ha^{-1} yr^{-1}) using the Mass Balance Model 2 (MBM 2) and linked with the net erosion rates provided by the 13 years plot erosion measurements.

3.1.3. Results obtained from the experimental plots

During the 13 years of investigation by Dr Klik (1994-2006), the average surface runoff from the different treatments was 13.5 mm for the CT, 8.4 mm for the CS and 10.5 mm for the DS **(Table 1).** A large variability was observed due to precipitation during the growing season and type of crop cover. In 1994, surface runoff was around 72-80 mm from the different treatments. In six of the 13 years, no runoff could be determined throughout the growing season. On average, no statistically significant difference ($p < 0.05$) between the tillage treatments was found. However, in the last five years since 2002, a numerical decrease can be derived from the measured data.

Table 1. Crop rotation and yearly amounts of runoff and soil loss in Mistelbach

Year	crop	Soil loss (t ha^{-1})			Runoff (mm)		
		CT	CS	DS	CT	CS	DS
1994	corn	317.20	43.8	26.00	80.6	72.2	79.9
1995	w-wheat	0.12	0.06	0.04	0.2	0	0
1996	sugar beet	3.25	0.60	0.41	10.1	1.5	5.6
1997	s-barley	0.00	0.00	0.00	2.7	0.4	1.8
1998	sunflower	19.75	5.92	5.43	41.1	20.8	31.8
1999	w-wheat	0.00	0.00	0.00	0	0	0
2000	corn	0.00	0.00	0.00	0	0	0
2001	w-wheat	0.00	0.00	0.00	0	0	0
2002	corn	11.98	0.16	0.38	22.0	2.0	3.2
2003	w-wheat	0.03	0.04	0.02	1.3	1.3	1.3
2004	sunflower	0.05	0.03	0.04	2.2	1.6	1.9
2005	w-wheat	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.
2006	corn	0.34	0.08	0.07	1.7	1.4	0
Average erosion rate (t ha^{-1})		**29.38**	**4.22**	**2.70**	**13.5**	**8.4**	**10.5**

CT = conventional tillage system; CS = conservational tillage with cover crops during winter; DS = direct seeding with cover crops during winter; n.m = not measured

Thirty-two runoff events were registered in Mistelbach from CT, but only 27 from DS and 23 from CS. Between 62% (CT) and 70% (DS) of these events produced less than 1 mm runoff, between 80% and 94% were smaller than 50 mm. During the investigated period, only one event was registered with more than 5 mm runoff amount, and it occurred on the CT as well as on the DS plot.

For soil erosion similar results were obtained. From CS and DS 80% of the erosive events yielded a soil loss less than 1 t ha^{-1}. From CT plots only 72% of the events led to this low erosion amount, whereas about 4% of all events exceeded a soil loss of 50 t ha^{-1}. In the DS treatment no soil loss > 50 t ha^{-1} was measured during the whole investigation period; for CS only 1.5% exceeded this threshold.

Long-term average soil erosion could be reduced significantly from 28.4 t ha^{-1} yr^{-1} in CT to 4.2 and 2.7 t ha^{-1} yr^{-1} for CS and DS, respectively **(Table 1).** The 13-year average value was dominated by three rainfall events (total of 257 mm) in 1994, which led up to a soil loss of 319 t ha^{-1} in the CT treatment. At least one of these events (P = 115 mm) had a reoccurrence of 50 years.

3.1.4. Physicochemical characterization of the reference site and evaluation of the ^{137}Cs base level

The reference site in the forest area was characterized through its texture and through different chemical parameters (n = 10). Using the United States Department of Agriculture (USDA) soil classification system based on grain size, the soil can be described as a silt loam. The other chemical properties are summarized in **Table 2**.

Table 2. Descriptive statistics of the chemical parameters of the reference site (n = 10)

A)	*pH*	*Conductivity (µS/cm)*	*N-total (% N)*	*P-total (mgP/100g soil)*	*C-total (%C)*	*C-org. (%C)*	*C-inorg. (%C)*	*CEC (cMol/kg)*	*C/N*	*SOM (%)*
Mean	8.09	212.9	0.16	62.08	3.86	1.72	2.14	19.33	10.84	2.96
Standard Error	0.02	5.7	0.01	1.26	0.08	0.09	0.07	0.64	0.40	0.16
Median	8.04	221.5	0.16	63.00	3.90	1.68	2.19	19.71	10.67	2.88
Standard Deviation	0.08	18.0	0.03	3.99	0.24	0.29	0.23	1.57	1.26	0.50
Sample Variance	0.01	324.8	0.001	15.92	0.06	0.08	0.05	2.47	1.58	0.25
Kurtosis	-1.95	-1.38	-0.18	-0.03	0.32	1.94	-0.89	-0.64	0.47	1.94
Skewness	0.53	-0.55	-0.46	-0.84	-0.42	0.74	-0.24	-0.57	0.83	0.74
Range	0.18	49	0.09	12.83	0.81	1.09	0.70	4.27	4.10	1.87
Minimum	8.01	187	0.11	54.33	3.40	1.25	1.77	16.93	9.26	2.16
Maximum	8.19	236	0.20	67.16	4.21	2.34	2.47	21.20	13.36	4.02
Confidence Level (95 %)	0.06	12.89	0.02	2.85	0.17	0.21	0.17	1.65	0.90	0.35

A) Result for 0-10cm soil increments

B)	*pH*	*Conductivity (µS/cm)*	*N-total (% N)*	*P-total (mgP/100g soil)*	*C-total (%C)*	*C-org. (%C)*	*C-inorg. (%C)*	*CEC (cMol/kg)*	*C/N*	*SOM (%)*
Mean	8.25	175.80	0.09	58.14	3.18	0.999	2.18	19.72	10.90	1.72
Standard Error	0.04	18.83	0.01	1.29	0.10	0.12	0.08	0.68	0.73	0.20
Median	8.28	155.00	0.09	58.34	3.14	0.92	2.21	20.47	10.41	1.57
Standard Deviation	0.13	59.56	0.02	4.08	0.30	0.37	0.25	1.80	2.31	0.63
Sample Variance	0.02	3547	0.0004	16.66	0.09	0.14	0.06	3.25	5.33	0.40
Kurtosis	5.74	8.35	0.05	-0.66	3.41	4.51	0.52	0.00	6.46	4.51
Skewness	-2.08	2.82	0.69	-0.15	1.64	1.97	-0.34	-0.54	2.27	1.97
Range	0.47	199	0.07	12.52	1.02	1.25	0.88	5.44	8.74	2.15
Minimum	7.93	141	0.06	51.18	2.89	0.67	1.71	16.70	8.21	1.15
Maximum	8.40	340	0.13	63.70	3.91	1.92	2.59	22.14	16.95	3.30
Confidence Level (95 %)	0.09	42.60	0.01	2.92	0.22	0.26	0.18	1.67	1.65	0.45

B) Result for 10-20 cm soil increments

This alkaline soil with a C/N ratio ~ 10-11 presents a high degree of humification. Regarding the standard deviation to the mean, the different chemical parameters do not present a big variability in the different soil increment (0-10 and 10-20 cm). The organic carbon content can be classified as medium and the electric conductivity as low.

A composite sample was used to determinate the profile distribution of ^{137}Cs and its maximum depth presence. A classical exponential depth distribution activity was found with 90% of the ^{137}Cs in the first 15 cm. A mass activity of 12.1 Bq kg^{-1} was found in the first 5 cm with an exponential decrease till 3.4 Bq kg^{-1} in the 15-20 cm increment. No cesium was detected under the 20 cm layer. **Figure 5** shows the vertical distribution of the ^{137}Cs areal activity in the reference site. The maximum depth of ^{137}Cs presence in this soil was also confirmed by the texture differentiation. Below 20 cm depth, the soil is composed of more than 80% stones and large gravels.

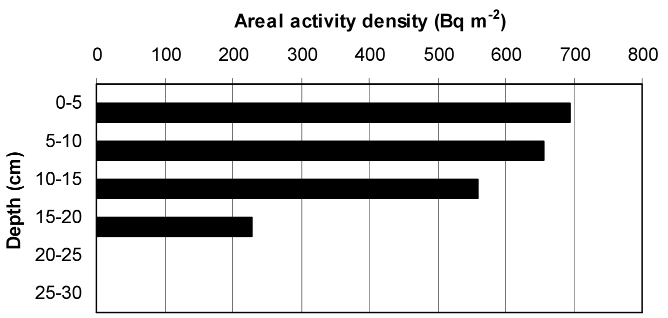

Figure 5.Depth distribution of ^{137}Cs in the reference site (0-30 cm).

Based on the seventy six (76) samples collected on integrated grids the ^{137}Cs initial fallout was evaluated at 1954 Bq m^{-1} with a coefficient of variation of 20.4%. This value is in full agreement with the literature review on reference sites. The activity of the reference site < 2 kBqm^{-2} of ^{137}Cs demonstrates clearly a negligible amount of Chernobyl contribution. It could be therefore concluded that the Chernobyl fallouts in the study area were small and would not significantly influence the relationship between soil and ^{137}Cs losses.

3.1.5. Test and validation of the ^{210}Pb methodology

The average measurement error for the reference site and the sedimentation area samples at 2 sigma for total ^{210}Pb, ^{226}Ra, $^{210}Pb_{ex}$ (n = 40) were 11.3 ± 1.6%, 5.5 ± 1.1% and 377 ± 210%, respectively at the 95% confidence level. In most cases the values of total ^{210}Pb and ^{226}Ra were similar **(Tables 3 and 4)**. The measurement error of total ^{210}Pb and ^{226}Ra was acceptable; however the bias concerning the value of $^{210}Pb_{ex}$ can be as high as the measured values itself.

Table 3. Results and error measurements of $^{210}Pb_{tot}$, ^{226}Ra and $^{210}Pb_{ex}$ (reference site)

^{210}Pb-total Bq kg^{-1}	Error $^{(1)}$ Bq kg^{-1}	^{226}Ra Bq kg^{-1}	Error $^{(1)}$ Bq kg^{-1}	$^{210}Pb_{ex}$ Bq kg^{-1}	Error $^{(1)}$ Bq kg^{-1}	Error $^{(1)}$ (in %)
40.14	6.76	35.36	2.96	4.78	7.38	154
34.69	6.08	33.38	2.42	1.31	6.54	499
34.45	5.18	35.63	3.18	0	n.a	n.a
35.52	6.22	34.30	3.18	1.22	6.98	572
42.60	6.84	35.42	3.36	7.18	7.62	106
42.25	6.60	33.10	2.90	9.15	7.22	79
39.69	1.89	36.68	0.41	3.01	1.93	64
40.06	1.91	39.50	0.41	0.56	1.95	348
43.00	1.68	40.45	0.37	2.55	1.72	67
34.02	1.85	35.84	0.40	0	n.a	n.a
30.53	1.91	39.10	0.44	0	n.a	n.a

n.a = non applicable; $^{(1)}$ measurement error at 2 sigma

Due to ''overlapping of values'' (^{226}Ra activity ≥ total ^{210}Pb activity) and the measurement uncertainty for total ^{210}Pb and ^{226}Ra, the value of $^{210}Pb_{ex}$ can sometimes even be negative. In that case the value of $^{210}Pb_{ex}$ was reported as zero **(Tables 3 and 4).**

In the reference site (n = 11) the total ^{210}Pb activity ranged from 30.5 to 43 Bq kg^{-1} for a mean value of 37.9 Bq kg^{-1} ± 11% (mean ± CV), the ^{226}Ra ranged from 33.1 to 40.4 Bq kg^{-1} for a mean value of 36.3 Bq kg^{-1} ± 7% (mean ± CV) and the $^{210}Pb_{ex}$ ranged from 0 to 9.15 Bq kg^{-1} for a mean value of 2.7 Bq kg^{-1} ± 115% (mean ± CV) (**Table 3**). Including the uncertainty of the different sample measurement and using a mixture model probability density function the reference value is 2.6 Bq kg^{-1} ± 4.9 Bq kg^{-1} at 2 sigma.

It is clear that the use of the ^{210}Pb method did not provide the expected output. Due to a similar activity of total ^{210}Pb and ^{226}Ra reflected by a very low level of 'unsupported' ^{210}Pb coupled with a high variability of the initial fallout inventory (2.7 Bq kg^{-1} ± 115% (mean ± CV); n = 11) and a high measurement error (377 ± 210% at the 95% confidence level; n = 40), it was not possible to validate the ^{210}Pb method in the Mistelbach watershed. The limitation of the use of ^{210}Pb has also be recently demonstrated in France and Chile. It is therefore clear that the precipitation which affected the area was not enriched with 'unsupported' ^{210}Pb.

Table 4. Results and error measurements of $^{210}Pb_{tot}$, ^{226}Ra and $^{210}Pb_{ex}$ (sedimentation area)

Echantillon	$^{210}Pb_{tot}$ Bq kg^{-1}	Error [(1)] Bq kg^{-1}	^{226}Ra Bq kg^{-1}	Error [(1)] Bq kg^{-1}	$^{210}Pb_{ex}$ Bq kg^{-1}	Error [(1)] Bq kg^{-1}	Error [(1)] (in %)
P1 (0-5 cm)	44.16	6.62	35.92	3.08	8.24	7.3	88
P1 (5-10 cm)	41.45	5.84	38.71	3.00	2.74	6.58	240
P1 (10-15 cm)	36.79	4.96	36.54	3.14	0.25	5.86	2344
P1 (15-20 cm)	39.04	5.70	36.99	3.10	2.05	6.5	317
P1 (20-25 cm)	37.42	4.88	37.03	2.70	0.39	5.56	1425
P1 (25-30 cm)	37.41	6.08	35.74	2.96	1.66	6.78	408
P1 (30-35 cm)	32.19	5.46	32.65	2.88	0	n.a	n.a
P1 (35-40 cm)	40.14	6.62	36.83	2.96	3.31	7.24	218
P1 (40-45 cm)	40.02	5.54	37.58	3.18	2.45	6.4	261
P1 (45-50 cm)	37.91	6.42	34.14	3.12	3.77	7.14	189
P1 (50-55 cm)	40.53	6.30	37.17	3.30	3.36	7.1	211
P1 (55-60 cm)	40.24	6.04	35.99	3.02	4.25	6.74	158
P1 (60-65 cm)	35.31	4.58	35.32	2.46	0	n.a	n.a
P1 (65-70 cm)	45.27	6.72	37.76	3.08	7.51	7.38	98
P1 (70-75 cm)	37.17	5.34	36.88	2.78	0.29	6.02	2075
P1 (75-80 cm)	37.74	5.08	36.10	2.96	1.64	5.88	358
P1 (80-85 cm)	40.38	5.84	36.02	2.96	4.36	6.54	150
P1 (85-90 cm)	37.98	4.90	36.60	2.74	1.38	5.6	405
P1 (90-95 cm)	35.63	5.84	36.92	2.94	0	n.a	n.a
P2 (0-10 cm)	40.25	1.94	43.81	0.44	0	n.a	n.a
P2 (10-20 cm)	42.06	1.66	38.37	0.29	3.69	1.69	46
P2 (20-30 cm)	39.36	2.18	38.03	0.38	1.33	2.21	166
P2 (30-40 cm)	41.49	2.12	39.15	0.37	2.34	2.15	92
P2 (40-50 cm)	38.00	2.19	38.86	0.39	0	n.a	n.a
P2 (50-60 cm)	40.14	2.05	40.43	0.37	0	n.a	n.a
P2 (60-70 cm)	38.59	2.09	38.94	0.37	0	n.a	n.a
P2 (70-80 cm)	41.64	1.33	38.02	0.23	3.62	1.35	37
P2 (80-90 cm)	39.38	1.78	34.90	0.30	4.48	1.81	40
P2 (90-100 cm)	37.56	1.98	35.84	0.33	1.72	2.01	117

P1=profile 1, P2 = profile 2; n.a = non applicable; [(1)] measurement error at 2 sigma

3.1.6. *Evaluation of soil deposition magnitude using ^{137}Cs data*

The total areal activity of the first soil profile (Profile 1) was 2836 Bq m^{-2} with a maximum activity of 7.5 Bq kg^{-1} in the 20-25 cm increment. Taking into account the bulk density of each increment, the maximum areal activity was found at 5-10 and 15-20 cm depth with respective values of 563 and 547 Bq m^{-2}. ^{137}Cs was present until 40 cm depth. The ^{137}Cs areal activity of the first profile is presented in **(Figure 6)**.

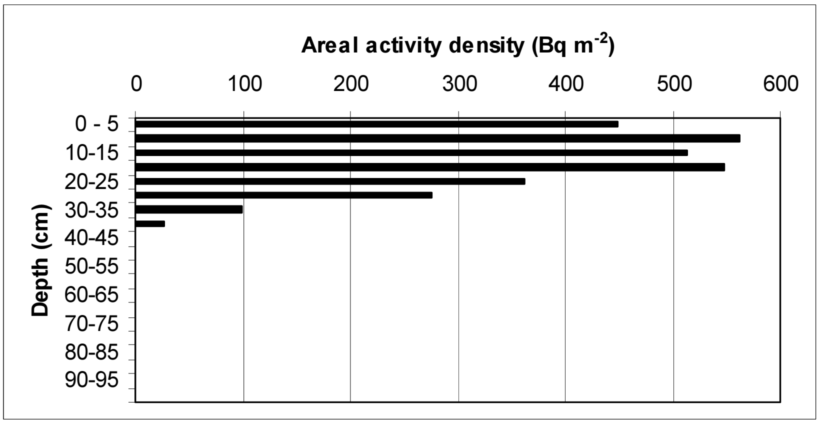

Figure 6. ^{137}Cs distribution in the sedimentation area – Profile 1.

The ^{137}Cs areal activity of the second profile is presented in **(Figure 7)**. The total areal activity was 4776 Bq m^{-2} with a maximum activity at 10 - 20 cm depth of 11.2 Bq kg^{-1} equivalent of 1344 Bq m^{-2} taking into account the bulk density of this soil layer.

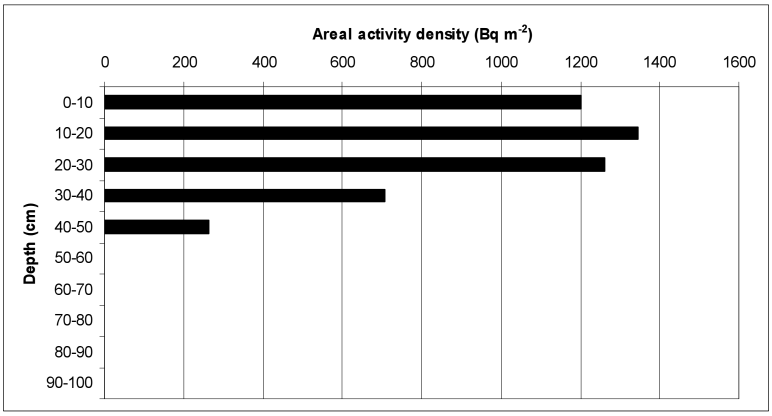

Figure 7. ^{137}Cs distribution in the sedimentation area – Profile 2.

The ^{137}Cs measurement illustrate quite well the sedimentation process in the deposition area with an activity significantly higher than the reference site. For the two profiles, the sedimentation magnitude was assessed using the MBM 2 in order to convert the ^{137}Cs activity of the samples into soil movement. For particle size factor, relaxation depth and proportional factor, default values were used. In this agricultural watershed the tillage depth is around 30 cm. The parameters used in the conversion model are listed below:

- Bulk density: 1380 kg m^{-3} (mean bulk density of the 30 samples increments collected)
- Particle size factor: 1
- Sampling year: 2007
- Reference inventory: 1954 Bq m^{-2}
- Proportional factor: 1
- Relaxation depth: 4 kg m^{-2}
- Tillage depth: 414 kg m^{-2} (0.3 m x 1380 kg m^{-3})
- Year of initial tillage: 1954

As the MBM 2 need data on a transect basis, the model was run according to the net erosion rates produced by the CT, CS and DS erosion plots. The ^{137}Cs activity data provided by the plots (685 Bq m^{-2} for CT; 1680 Bq m^{-2} for CS and 1775 Bq m^{-2} for DS) were integrated into MBM 2 and used as point values to assess the sedimentation magnitude (t ha^{-1} yr^{-1}) linked to the different treatments. Using this approach, the profile 1 revealed a sedimentation rate of 20.3 t^{-1} ha^{-1} yr^{-1}, 13.5 t^{-1} ha^{-1} yr^{-1} and 13.2 t^{-1} ha^{-1} yr^{-1} respectively for CT, CS and DS. The second profile revealed a sedimentation rate of 65 t^{-1} ha^{-1} yr^{-1}, 43.3 t^{-1} ha^{-1} yr^{-1} and 42.2 t^{-1} ha^{-1} yr^{-1}, respectively for CT, CS and DS.

Taking into account the average bulk density in the different soil layers in the sedimentation area, and that these annual average values cover a 54-year period (1954-2007), it is possible to evaluate the layer of soil deposited; the layer varies from 0.9 mm yr^{-1} (13.2 t^{-1} ha^{-1} yr^{-1}) to 4.7 mm yr^{-1} (65 t^{-1} ha^{-1} yr^{-1}) corresponding to a total material accumulation of 4.8 cm and 20.3 cm. This clearly shows the magnitude of deposition that occurred in the selected watershed in relation to the topography and tillage treatment.

This study demonstrates the complementarities of both approaches in order to assess erosion and sedimentation processes under different conservation cropping practices. In order to better understand and quantify sediment mobilization, transfer and storage fluxes in this watershed, our future investigations will focus on the comparison of the magnitude and spatial distribution of soil erosion/deposition using FRN, particularly ^{137}Cs (laboratory and *in-situ* measurements) and conventional measurements. Also interpolation tools will be used to evaluate the spatial structure of the initial ^{137}Cs fallout in the undisturbed forest.

3.2. Tests of ^{7}Be as Soil Tracer and Development of a Fine Soil Increment Collector (FSIC) to Solve the Main Limitation of its Use in Field Condition [2]

^{7}Be (Beryllium-7) is a natural cosmogenic radionuclide produced in the upper atmosphere by cosmic ray spallation of nitrogen and oxygen. This radionuclide has a very short half life ($t_{1/2}$ = 53.3 days) relative to ^{137}Cs and ^{210}Pb. The potential evaluation of erosion rates for individual events or conservation practices represents the major advantage of the use of ^{7}Be which can not be investigated by ^{137}Cs or ^{210}Pb. However, the main limitation is the need to restrict soil sample collection to shallow depths due to its superficial deposition on the topsoil. 2 mm to 5 mm increment sample collection is needed to establish the initial ^{7}Be vertical distribution in soil. This information will be integrated later in a model to convert the variation of ^{7}Be activity into soil redistribution. To address this limitation, the SSU in collaboration with the IAEA mechanical workshop developed a new tool – the FSIC (Fine Soil Increment Collector; **Figures 8 and 9**).

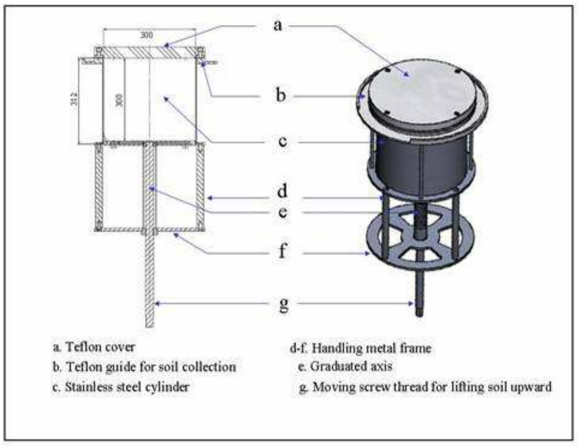

Figure 8. Technical description of the Fine Soil Increment Collector.

[2] Project E1.02, Activity 2

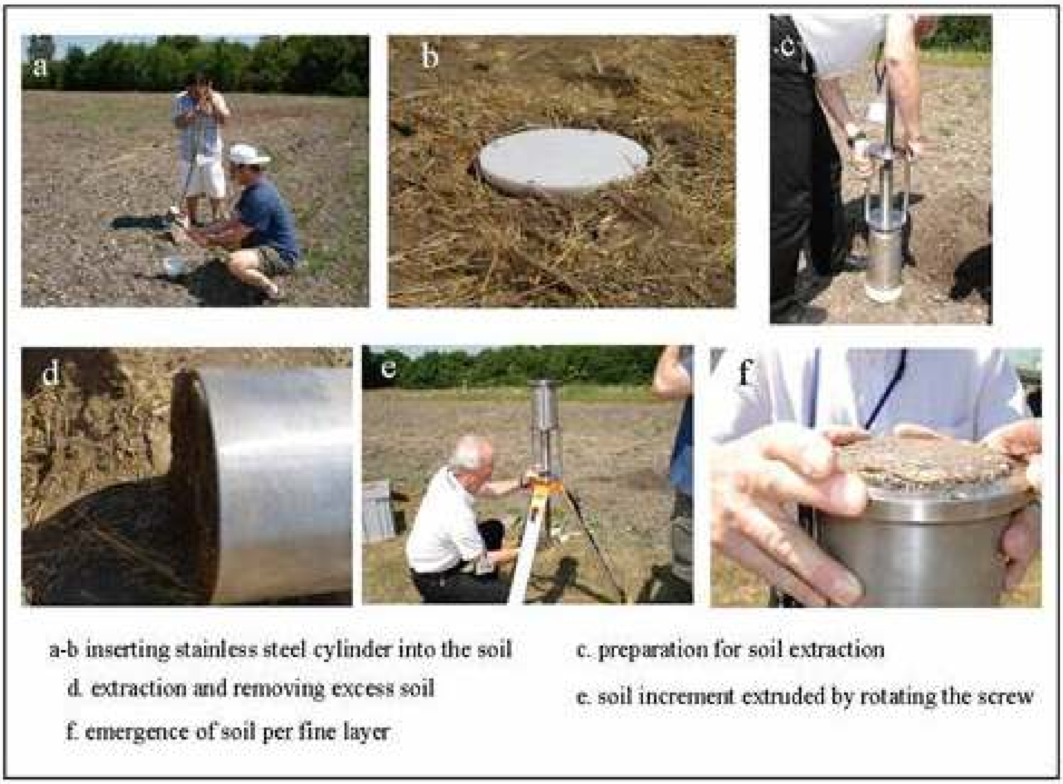

Figure 9. Tests of the FSIC under field conditions in Seibersdorf.

Based on our last two field experiments in Mistelbach (Austria), the *in-situ* measurement represents an effective approach to analyze the amount of ^{7}Be without time consuming survey and laboratory measurements. However, the counting time in the field needs to be at least double as compared to the measurement of ^{137}Cs. Production of ^{7}Be is relatively constant but fallout is dependant on rain occurrence. In March and August 2007, when two sampling surveys were done in Mistelbach, nonsignificant level of ^{7}Be was revealed due to a drought period of 6 months with only 5 mm precipitation that is correlated with the 340-700 Bq m^{-2} of ^{7}Be in the agricultural field (assuming exponential distribution and 1 cm relaxation depth). Sampling should be done in relation to the objective of the study (assessment of one event, comparison of tillage practice, comparison of crops erosivity) and should be planned in function of the precipitation effectively received in the area under investigation. Much more than for ^{137}Cs investigation, skill and flexibility is necessary for such investigation.

3.3. 2007 Proficiency Test (^{137}Cs/total ^{210}Pb) [3] – Progress Report

FRN measurements for soil redistribution involve gamma analysis in soil matrix. The measurement of the radionuclides by HPGe gamma spectrometry is therefore an essential component of the application of FRN techniques in soil erosion and sedimentation studies. Consequently it is important that the analytical data is correct to assure that the conclusions of such studies are based on reliable and validated analytical results and to ensure the comparability of results from different countries and regions.

[3] Project E1.02, Activity 1

Following a recommendation of the first Research Coordination Meeting of the CRP on "Assessment of the effectiveness of soil conservation measures for sustainable watershed management using fallout radionuclides", held in Vienna (19-23 May 2003), the SSU initiated a collaboration between the Chemistry Unit and the Soil Science Unit of the IAEA laboratories to organize an intercomparison exercise with and distribution of reference materials to assess the validity and reliability of ^{137}Cs and total ^{210}Pb analytical results in the various laboratories participating in the above mentioned IAEA Coordinated Research Project. Only the summary of the analysed results 2007 and the main recommendations of the PT will be presented in this contribution.

3.3.1. Results and discussions

Ninety spiked soil samples (PT materials) were distributed in 2006 to the participating laboratories for the determination of ^{137}Cs and total ^{210}Pb,. The laboratories were requested to analyse the samples employing the methods used in their daily routine gamma measurements. Fourteen laboratories from the 18 initially registered reported their results. The analytical results of the laboratories were compared with the reference values assigned to the PT materials, and a rating system was applied.

The results from the overall performance evaluation showed that the ^{137}Cs measurements had a higher number of acceptable scores than those of ^{210}Pb determination. **Figure 10** illustrates the summary results of this proficiency test.

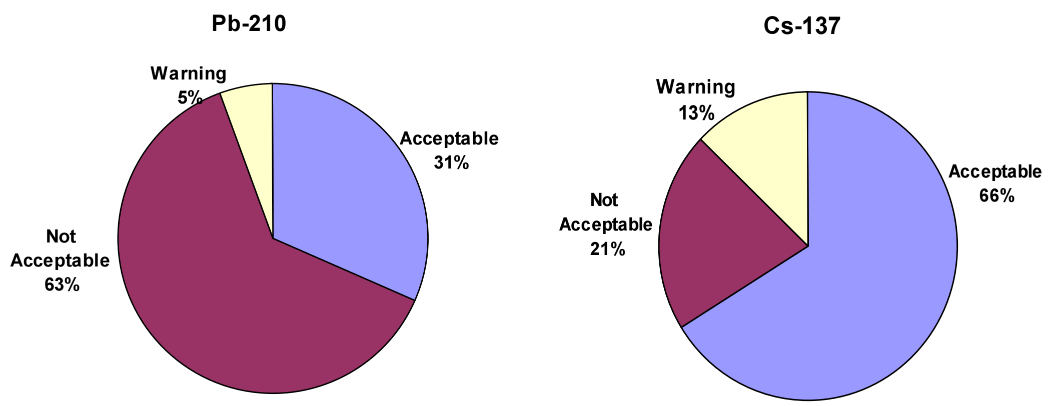

Figure 10. Summary evaluation of the analytical data (Total ^{210}Pb and ^{137}Cs measurements) of the proficiency test completed by the 14 laboratories.

In the case of ^{137}Cs, the analytical results were satisfactory with 66% of the participating institutes producing acceptable results (only the sample with low ^{137}Cs activity 2.6 ± 0.2 Bq kg^{-1} gave less accurate result with more than 40% of unacceptable results) while the ^{210}Pb analysis indicated a clear need for corrective actions in the analysis process **(Figure 10).** Only 37% of the laboratories involve in the proficiency test were able to accurately access total ^{210}Pb using ≤ 10% error – whereas 79% were able to analyse ^{137}Cs. Therefore, in the case of ^{210}Pb analysis corrective actions in the analysis procedures are needed to improve the quality of the results.

It is well known that the determination of ^{210}Pb by gamma spectrometry is more complicated than ^{137}Cs determination. This is mainly related to the relatively low emission probability and low energy (46.5 keV) of the gamma ray used in the ^{210}Pb measurement. Hence, particular care is needed when performing efficiency calibrations and sample self-attenuation corrections.

Although such a bias in ^{210}Pb measurements could arise in a number of ways, there are three major sources of error which may be investigated:

- Firstly, the laboratory may have used a biased calibration source. There may be a problem with the calibration of the detector's efficiency. For example, the use of an extrapolated ^{210}Pb efficiency calibration can lead to large discrepancies.
- Secondly, many laboratories do not report the use of proper matrix reference materials to check the validity of the detector's efficiency calibration.
- Thirdly, the underestimation of the correction coefficient for self-attenuation of the gamma ray in the sample could be a source of negative bias.

3.3.2. Recommendation on, further issues for, FRN's measurements by gamma spectrometry

The analysis of FRN's by gamma spectrometry using High Purity Germanium (HPGe) detectors in soil/sediment samples is a complex task that demand specific and expensive equipment and staff with high skills and experience to achieve accurate results with good precision.

Different factors can influence the precision of gamma measurement of soil samples: detector and associated equipment (performance of the detector –relative efficiency–, detector type, size, configuration, calibration, internal background interference, geometry and lead-shield thickness), collection, preparation, pre-treatment and configuration of the sample (sample mass and sample activity), laboratory radiation exposition (external background interference, constancy of the background) and software for data acquisition and evaluation.

As a result from the above mentioned proficiency test some recommendations were provided to optimize FRN's measurements with appropriate analytical facilities:

- The sample size (quantity) should be as large as possible. This means that the sampling strategy should be adapted in order to collect sufficient amount of soil for accurate analysis and adapted to the geometry calibration employed in the laboratory.
- Different sample geometry for measurement should be prepared in the laboratory.
- The gamma detector should be installed in a low and constant background environment (to reduce environmental radiation) and the lead shield should have a minimum thickness of 100 mm to protect the measurement from external background.
- For calibration old standard or certified solutions with expired validity should not be used.
- Standards with an appropriate matrix should be used for calibration and an appropriate correction factor should be applied depending on the density of the material.
- Gamma spectra information should be collected and evaluated using appropriate modern software.
- The calibration of the detector should be controlled regularly with reference

material and blank sample. In order to assess the precision of gamma analysis, a quality control and quality assurance protocol should be produced and used by all laboratories to obtain accurate and valid measurement on mid term and long term.

- The IAEA recommends to the national laboratories to organize and run their own inter-comparison exercises at the regional level, thus the data obtained by national laboratories can be compared on a regular basis.
- The IAEA recommends also the participating laboratories of the inter-comparison exercise to develop and improve their analytical quality assurance system including diagnosis and standard operating procedures (quality control based on standards radioactive materials with known activity level) to assess the accuracy and precision of their analytical data.

3.4 Identification and Development of Crop Germplasm with Superior Resource Use Efficiency and Nutritional Value and Adapted to Harsh Environments [4]

Climate change threatens the most important food crops, including wheat, rice and maize, across the world. With the successive report warnings of the International Panel on Climate Change, that increased droughts, salinity and nutrient deficiencies will have serious consequences on world food crop supply, there is an urgent need to refocus our research on how to make crops more resilience to environmental stress. In the quest to "bring hope to the marginal and harsh environments", the SSU tested and refined the carbon isotope discrimination methodology (using the ratios of different carbon isotopes in plants) to effectively evaluate and select rice, wheat and maize genotypes tolerant to drought, salinity and nutrient stress.

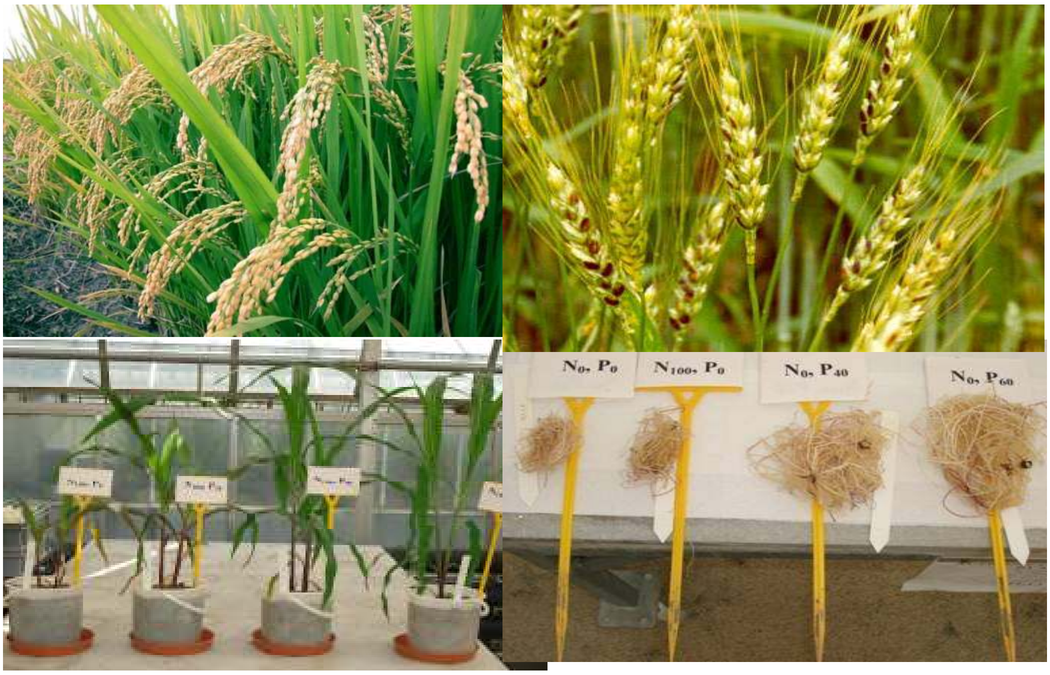

Figure11. New opportunities for improvement of crop plants for water, nutrient and salt stressed environments.

[4] Project E.1.05

3.5. Interactive Effects of Water Stress and Salinity on Carbon-13 Isotope Discrimination[5] by Rice, Wheat and Maize Varieties [5]

The carbon isotope discrimination (CID) has been proposed as a possible selection criterion for greater water use efficiency in breeding programmes for water limited and salt stress environments because it provides an integrative assessment of genotypic variation in leaf transpiration efficiency. Although the relationship between carbon isotope discrimination and water and/or salt stress have been well studied and documented for C_3 and C_4 plants, few studies have looked at the interactive effects of salt and water stress in C_3 and C_4 plants. Experiments focusing on methodology were conducted in the greenhouse to assess the potential of the ^{13}C isotope discrimination observation as a tool for evaluating and selecting rice and wheat (C_3) and maize (C_3) varieties under the interactive effects of water and salt stresses.

Carbon, the major building block of carbohydrate and proteins in plant tissues contains both light and heavy carbon stable isotopes (^{12}C and ^{13}C). The measurement of natural variations in the abundance of ^{13}C and ^{12}C in plant materials is increasingly being used to select and evaluate plant cultivars that can withstand drought and salt stress. Under drought, less carbon (in the form of carbon dioxide), particularly ^{13}C from the atmosphere is taken up by plants for growth because of plant stress, thus creating a major variation in the natural isotopic ratios of ^{13}C and ^{12}C in plant materials. A plant cultivar, which is resistant to water scarcity should display less depletion in ^{13}C compared with a susceptible cultivar. Such discrimination against ^{13}C (i.e. difference between ^{13}C and ^{13}C , expressed as delta $\delta^{13}C$) in plant tissues (leaves and grains) has been successfully used in the selection of drought-resistant species. Under salinity conditions it has been hypothesized that high delta values (maximum discrimination) are positively correlated with increased salt tolerance in rice varieties In addition a reduction in $\Delta^{13}C$ as salinity increases suggested that salinity induces a greater degree of stomata resistance that provides less opportunity for discrimination against the heavier ^{13}C isotope, indicating that $\delta^{13}C$ ($^{13}C/^{12}C$ isotopic ratio) could be use as a selection criterion in breeding efforts to develop salt tolerant crops. Scientists have shown that $\delta^{13}C$ in plant leaves and grain is negatively related to WUE. Besides acting as a surrogate for WUE, carbon isotope discrimination (CID) measured in different plant parts at harvest can be used as an historical account on how water availability varied during the cropping season.

Pot experiments were conducted using wheat, rice and maize varieties at IAEA Laboratories Seibersdorf. The soil used (Seibersdorf) was a sandy clay having the following composition: total N (2.27 $g.kg^{-1}$), C (32 $g.kg^{-1}$), total P (1115 $mg.kg^{-1}$), available P (382 $mg.kg^{-1}$ Bray P2), pH KCl (7.5) and $\delta^{13}C$ (−25.7‰). Each pots had 4 kg soil: sand mixture (1:1). Six treatments including: (i) control, (ii) salt (50 mM or 10 dSm^{-1}), (iii) drought 1 (30% field capacity [FC] 8d after planting), (iv) drought 2 (30% FC at 50% booting), (v) drought 1 x salt and (vi) drought 2 x salt. The soil moisture was monitored with time domain reflectometers (TDR).

Four spring wheat varieties from Kazakhstan (Saratovskaya, Severyanka, Stepnaya-15 and Otan-1), two upland rice varieties (WAB 5650 and ROK 3) from Sierra Leone, and two maize varieties from Austria (ES Beatle, and DK 315) were arranged in a randomized

[5] Project E.1.05, Activity 3

complete block design with the six treatments and 3 replications In all there were 72 pots for the wheat, 36 each for the rice and maize varieties. Each pot contained 3 plants and received fertilizers equivalent to 100 kg N (N-15 ammonium sulphate at 2% atom excess) in two split applications, 40 kg P (as triple superphosphate) and 50 kg K (muriate of potash) per ha. All the plants were harvested at physiological maturity, separated into spikes (if any), shoot and roots, oven dried to constant temperature at 70°C, weighed, ground and a portion of the grounded samples were used for analysis of $\delta^{13}C$, carbon, nitrogen and ^{15}N using the Europa Scientific ANCA 20-20/GSL stable isotope mass spectrometers. The overall precision in $\delta^{13}C$ was around 0.15‰. The $\delta^{13}C$ content was expressed in $\delta^{13}C$‰ units using the Vienna Pee Dee Belemnite standard as

$$\delta^{13}C = \{(R_{sample} / R_{standard}) - 1\} \times 1000$$

Where $R = {}^{13}C/{}^{12}C$

The $\delta^{13}C$ content of the plant material is related to ^{13}C isotope discrimination (Δ) by the following equation:

$$\Delta = (\delta^{13}C_{air} - \delta^{13}C_{plant}) / (1 + \{\delta^{13}C_{plant} /1000\}$$

where $\delta^{13}C_{air}$ is the $\delta^{13}C$ value of air (–8‰) and the $\delta^{13}C_{plant}$ is the measured value of the plant material

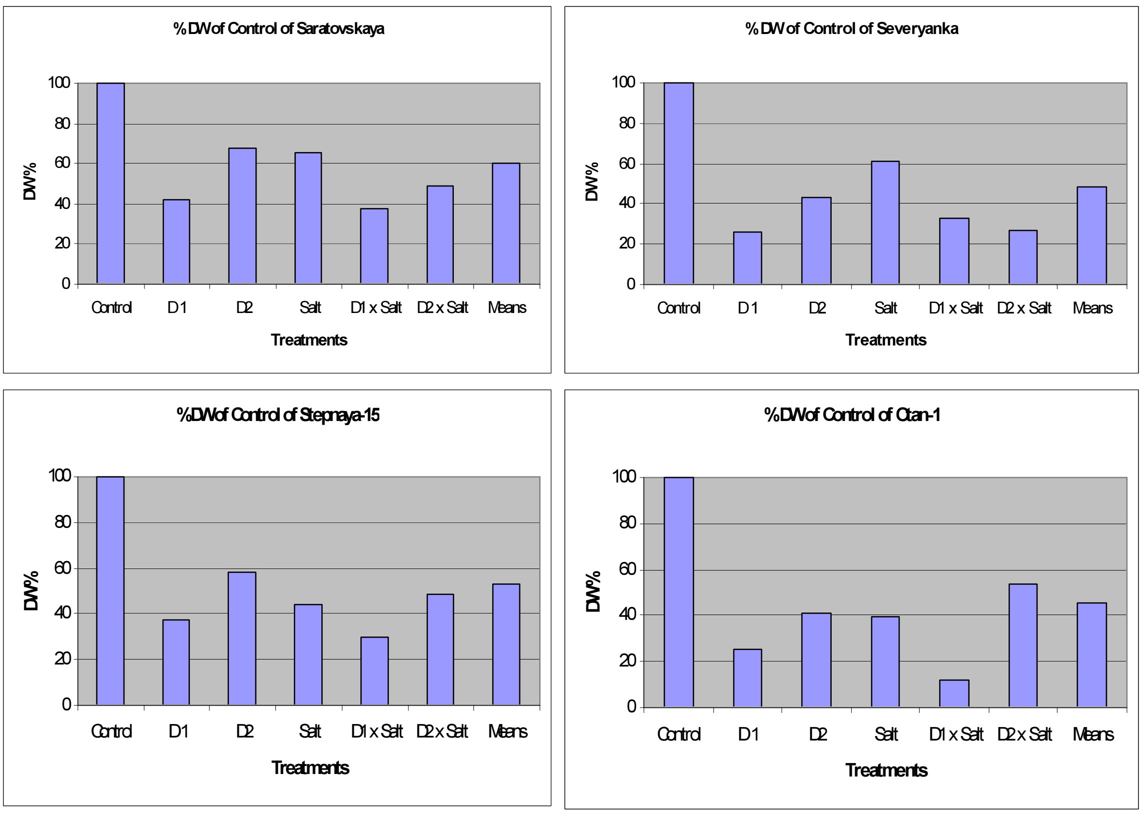

Figure 12. Interactive effect of salinity and water stress on % DM of 4 wheat varieties compared to control.

Drought and salt treatments and their interactive effects caused a decrease DM of spikes, shoot and roots in wheat, rice and maize. For wheat, the water stress treatment (D1) and its combination with salt stress (D1 x salt) resulted a more drastic reduction in DM of spikes than all to all the treatments (**Figure 12**). The % reduction in DM compared to control was lower in the salt x drought 2 compared to the individual salt and drought 2 treatments. The % reduction in DM of spikes by the treatments compared to the control was most severe in Otan-1 and less severe in Saratovskaya. **Figure 12** indicates that Saratovskaya was more tolerant to water and salt stress than the other varieties. The rice varieties were more susceptible to salt than water stress and a combination of water and salt stress had a more severe effect on the shoot The mean % reduction on shoot compared to the control were 56% (D1), 60% (D2), 40% (salt), 20% (D1 x salt) and 28% (D2 x salt). The DM yields were slightly higher in WAB 5650 than ROK 3 despite the severe reduction in root DM in WAB 5650 compared to that of ROK 3.

For the wheat varieties used the mean $\delta^{13}C$ value was more negative in the control (–28.7‰) compared to the other treatments (from –25.2‰ in the D1 to –26.8‰ in the D2 and salt treatments). The treatments resulted in a more negative $\delta^{13}C$ values compared to the control in spikes (from –25.2‰ to –26.8‰ than in the shoot (from –27.3‰ to –27.9‰) and in roots (from –27.0‰ to –27.5‰)(**Figure 13**). **Figure 14** shows that all the treatments resulted in a LESS negative values of $\delta^{13}C$ in spikes of Saratovskaya than the other 3 varieties (Severyanka, Stepnaya-15 and Otan-1) compared to the control.

The N amount (mg N/plant) followed a similar trend to that of the DM. Nitrogen amount was lowest in the D1, the D1 x salt and the D2 x salt (4.4-5.2 mg N) and highest in the control (8.4 mg). Among the varieties the N amount in spikes was highest in Stepnaya-15 and Saratovskaya and lowest in Otan-1, however Otan-1 accumulated more N in shoot and roots than the other varieties. A similar trend was observed for C accumulation in plants.

The combined effects of water stress and salinity resulted in less negative $^{12}C/^{13}C$ ($\delta^{13}C$) values as compared to the other treatments. The method was successfully used to evaluate and select wheat and rice genotypes from Kazakhstan and Vietnam tolerant to drought and salinity conditions.

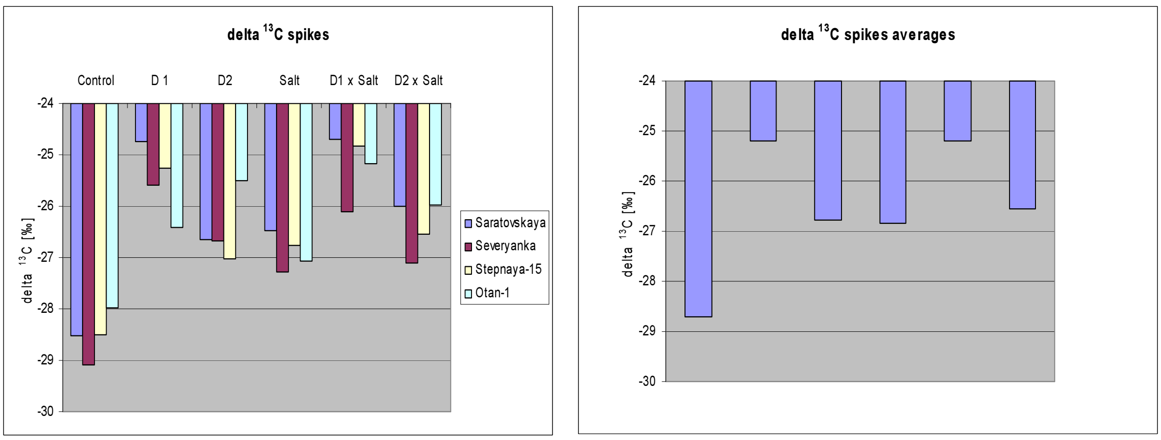

Figure 13. Interactive effects of salinity and water stress on $\delta^{13}C$ values of 4 wheat varieties.

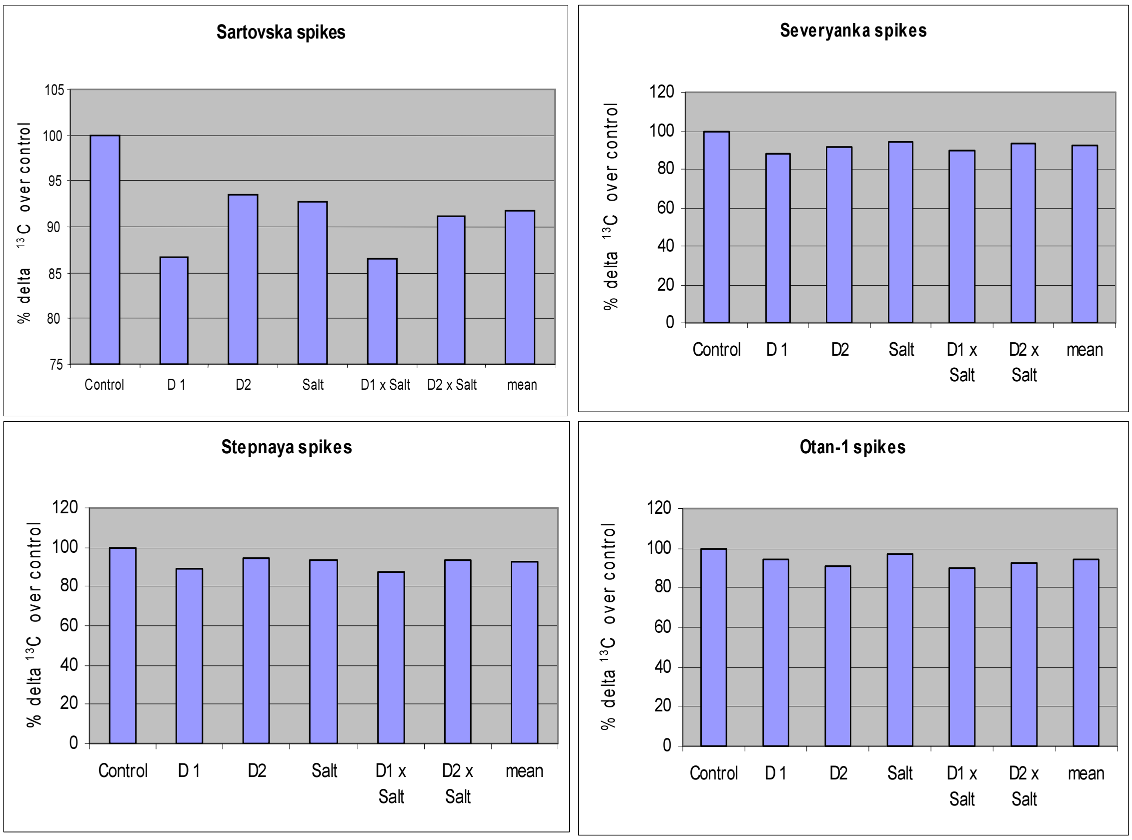

Figure 14. Interactive effects of salinity and water stress on $\delta^{13}C$ values compared to control of 4 wheat varieties.

3.6. Evaluating Rice, Wheat and Maize to Nitrogen and Phosphorus Supply Using the C-13 Isotope Discrimination under Drought and Salinity Conditions [6]

The sustained productivity of agricultural ecosystems in developing countries in which rice, maize and wheat are produced is constrained by low soil P availability. If $\Delta^{13}C$ can be shown to reliably predict salinity tolerance in upland rice under low bioavailability of nutrient (N and P) conditions, it would provide a useful tool for rapid evaluation of upland rice germplasm for salt tolerance. For C_3 plants the Δ is related to diffusional fraction (a = 4.4‰) and discrimination against $^{13}CO_2$ by ribolose diphosphate carbolylase or RubisCo (b =30‰), and pi/pa, the ratio of intercellular to ambient partial pressure of CO_2 can be expressed as

$$\Delta\ C_3 = a = (b-a)\ p_i/p_a,$$

Similarly for C_4 plants the photosynthesis induced Δ is described by the equation

$$\Delta\ C_4 = a + [b_4 + \varphi\ (b_3 - s) - a]\ p_i/p_a,$$

Where **a** is the ^{13}C discrimination due to CO_2 diffusion in air (4.4), $\mathbf{b_4}$ is the fraction of the dissolution of CO_2 to HCO_3- and fixation by phosphoenolpyruvate or PEP (-5.7‰ at 30°C) and $\mathbf{b_3}$ is the ^{13}C discrimination due to RuBisCo (30‰), and $\boldsymbol{\varphi}$ is the fraction of CO_2 fixed by PEP carboxylase.

[6] Project E1.05, Activity 4

The two equations above suggest that factors other than water such as phosphorus (P) and nitrogen (N) that play a major role in photosynthesis could hamper the use of the CID as an effective tool to select crops with improved WUE.

Water use efficiency (WUE) has been shown to be negatively correlated with Δ so WUE increase with nitrogen supply and increasing water stress $\delta^{13}C$ values decrease with increasing water stressed but increased with increasing nitrogen availability and that higher N supply favored CID because diffusion from the air outside to the air inside the leaf is not sufficiently fast to keep up with the CO_2 demand generated by increased N availability. Thus under N stress conditions when water is non-limiting, the stomates remain open and no or little restrictions to atmospheric CO_2 occurs therefore the increase in $\delta^{13}C$ with N stress reside in the differential fixation of CO_2 by PEPcase and Rubisco which reside in different physical proximities within the bundle sheet/mesophyll area.

Although the CID has been proposed as a possible selection criterion for greater water use efficiency in breeding programmes for water limited environments because it provides an integrative assessment of genotypic variation in leaf transpiration efficiency, it is not known whether it could be use as an effective selection tool for rice, wheat and maize in P limiting environments. The carbon costs associated with N and P acquisition by crops and its effects on crop biomass and yield suggest that $\Delta^{13}C$ may be affected by a combination of N and P stress. The present study was therefore implemented to assess the interactive effect of N and P supply on CID under water limiting and salinity stress conditions.

Three pot experiments were conducted in a glasshouse at IAEA Laboratories Seibersdorf, Austria to assess the interactive effect of N and P supply on the $\delta^{13}C$ discrimination in wheat, maize and rice under water and salt stress regimes. The soil used (Weinvertel) was a sandy loam having the following composition: total N (0.83 $g.kg^{-1}$), C (7.91 $g.kg^{-1}$), total P (233 $mg.kg^{-1}$), available P (6.5 $mg.kg^{-1}$ Bray P2), pH KCl (5.4) and $\delta^{13}C$ (−25.7‰). In experiment 1, four wheat varieties (Saratovskaya, Severyanka, Stepnaya-15 and Otan-1) from Kazakstan were grown with 4 P levels (0, 20, 40 and 60 kg ha^{-1} P). Each 4 kg pots received basal fertilizer application equivalent to 100 kg N/ha (N-15 ammonium sulphate at 2% ae) and 50 kg K/ha. A second experiment included a rice (*Oryza savita* L.,TDS 5) cultivar from Vietnam, which was grown with four P levels (0, 20, 40 and 60 kg ha^{-1} P), three N levels (0, 50 and 100 kg ha^{-1} N) and two salt treatments (1 and 10 dSm^{-1}). In the third experiment maize was grown at two water regimes (W0 at field capacity) and W1 (50% field capacity), two N (0 and 100 kg ha^{-1} N) and four P (0, 20, 40 and 60 kg ha^{-1} P) supply. Soil water moisture monitoring device, the time domain reflectometer (TDR), was installed in all the pots and water was supplied to the pots based on the TDR readings. Plants were harvested at physiological maturity, separated into spikes shoot and roots, oven dried at 70°C to a constant weight, weighed and ground. A portion of the ground samples were used for $\delta^{13}C$ analysis, carbon, nitrogen and N-15 using either the mass

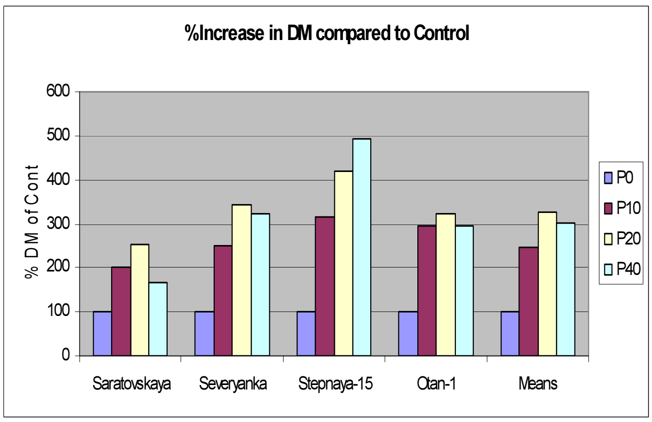

Figure 15. Phosphorus supply on % increase in spike weight of wheat compared to control

spectrometer (Europa Scientific ANCA 20-20/GSL) or Isoprime IRMS (G V Instrument GB) stable isotope mass spectrometer. The overall precision in $\delta^{13}C$ was around 0.15‰. The $\delta^{13}C$ content was expressed in $\delta^{13}C$‰ units using the Vienna Pee Dee Belemnite standard as described above.

Dry matter yield of the spike and shoot increased with P supply in all the wheat varieties with the maximum yield recorded at P 40 although the increase in aboveground DM did not differ much at P20 and P40 (**Figure 15**). The mean % increase over the control (P0) in DM of spikes was 247% for P10, 325% for P20 and 302% for P40. P supply resulted in an increase in root DM from 0.09 g at P0 to 0.230 g at P40. Among the varieties, Saratovskaya and Stepnaya-15 were more tolerant to low P and also showed a response to increasing P supply compared to Otan-1 and Severyanka, that recorded higher root dry weight.

$\delta^{13}C$ values decreased with increasing P supply. The $\delta^{13}C$ values (‰) in spikes decreased from –28.11 (P0) to –26.98 (P40). Similar trend was observed for the shoots (ranging from –29.08 to –28.29) and roots (–28.22 to –27.71), although there was no clear differences in $\delta^{13}C$ values among the varieties (**Figure 16**).

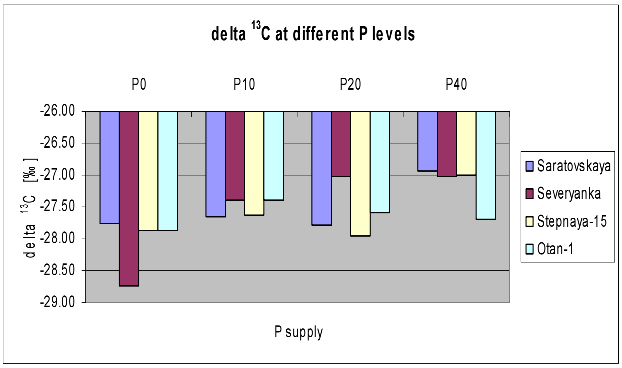

Figure 16. Phosphorus supply on $\delta^{13}C$ values (‰) of wheat spikes.

Phosphorus supply increased N accumulation in plants with the average ranging from 10.8 mg at P0 to 26.7 mg/pl at P40 in whole plant. The two varieties Saratovskaya and Stepnaya-15 recorded a high N in plants compared to the other 2 varieties. Otan-1 had the highest N accumulation in shoots and roots. The carbon accumulation in plants followed the same trend as the N accumulation.

Rice biomass increased sharply with P supply from P0 to P20 after which the increase of P supply (P40 and P60) did not result in an increase in shoot biomass. However biomass increased with increasing N supply even up to N100. (**Figure 17**). Applying NaCl at 10 dSm $^{-1}$ caused a decrease in shoot and root biomass. The interactive effect of P deficiency and salinity was more sever than that of N x salinity interaction. Root biomass was severely affected by the salt treatment compared to the shoot.

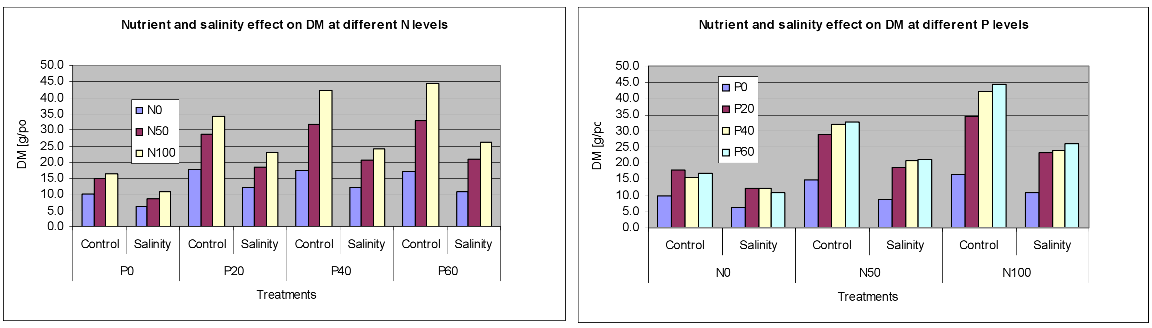

Figure 17. Dry matter of rice as affected by salinity at varying N and P supply.

N and P supply did not affect the $\delta^{13}C$ values in rice, but salinity resulted in a less negative $\delta^{13}C$ values in shoot (ranging from –29.27 at control and –28.40‰ at salinity conditions) and in roots (ranging from –28.68 for the control and –28.20 at salinity conditions) (**Figure18**).

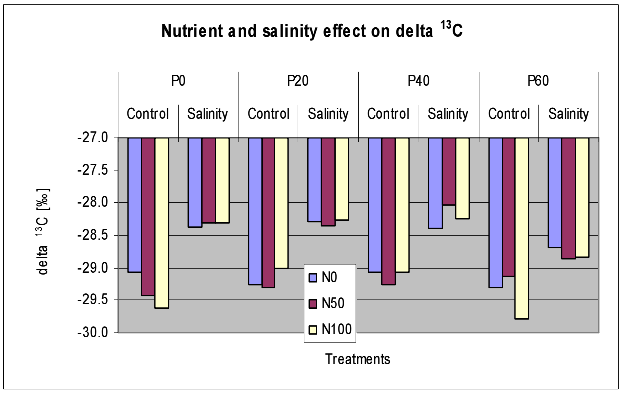

Figure 18. Salinity effect on $\delta^{13}C$ values in rice at varying N and P supply.

Nitrogen and carbon accumulation in shoot and root increased with N and P supply. Salinity treatment resulted in a decrease in N and C amount in plants. The interaction of N stress and salinity resulted in a more severe reduction in nitrogen as compared to the P stress x salinity interaction.

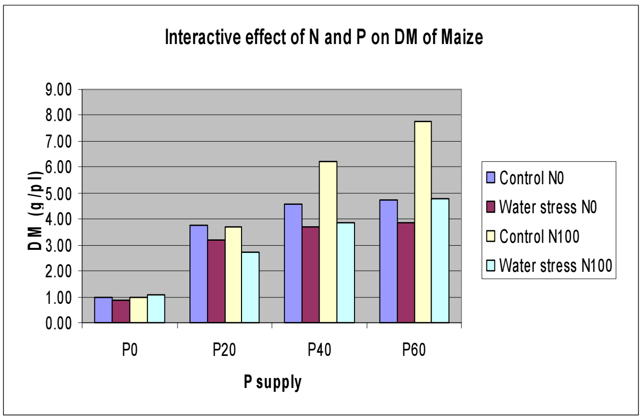

Figure 19. Interactive effects of water stress in maize at varying N and P supply.

Maize DM increased with P supply up to P20 and thereby no effect of P on DM when no N was applied. However, high N application at P40 and P60 resulted in an increased shoot DM (**Figure19**). Water stressed treatment resulted in a decreased DM of maize especially at the high N and P application. The effect of water stress on DM was not realized at P0 and N0.

Nitrogen treatment did not affect the $\delta^{13}C$ values although increasing P supply resulted in a less negative values (**Figure20**) whereas water stress resulted in a more negative $\delta^{13}C$ values (–12.5‰ for control and –12.7‰ for water stress treatments).

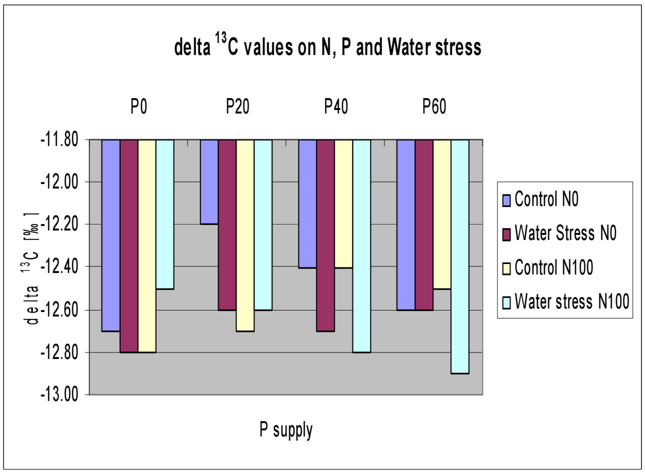

Figure 20. $\delta^{13}C$ values and varying phosphorus and nitrogen under water stress conditions.

Nitrogen and carbon accumulation in shoot and root increased with N and P supply. At control conditions there was a sharp increase in N amount in shoot of maize when P supply increased from P0 to P20 and thereafter only slight increases were observed with increasing P supply Water stress resulted in a lower N and C amount than the control treatment.

We summarize the main conclusions as follows:

Increasing P supply resulted in less negative values of δ in wheat but not in rice indicating that low P availability favours high negative $\delta^{13}C$ values. This indicates that the carbon isotope technique is influenced by soil phosphorus and nitrogen availability suggesting that the use of this technique to evaluate drought and salt tolerant genotypes in nutrient-stressed environments requires further investigations.

3.7. Fine-Tuning Methodologies to Determine Phosphorus Fractions in Plant- and Soil Samples Labelled with Radioisotope ^{32}P and/or ^{33}P [7]

In preparation for the ^{32}P/^{33}P work in the laboratory and greenhouse, selected methods for the determination of P fractions in plant and soil were tested and fine-tuned with non-labelled materials. Selected materials were validated against certified reference materials (NIST1547, NIST 1646, NIST 2709) and were compared to analytical results provided by national soil-testing laboratories on an internal standard soil and/or tested soil samples. The tested methods were applied to fractionate the low –P soil, which has been selected for future ^{32}P experiments in the newly refurbished greenhouse experiments. The following methods have been identified and validated:

- Total P in plant samples by wet digestion with concentrated sulphuric acid,
- Total P in soil samples by perchloric acid digestion,
- Available P in soil samples by the Bray-P2 extraction method,
- Fractionated extraction of Ca-P, Fe-P and Al-P in low P soils (pH 5.9) by acetic acid, ammonia fluoride and sodium hydroxide extractants, respectively.

The next step will be to use ^{32}P labelled plant and soil samples for the tests.

3.8. A Rehabilitated Greenhouse for ^{32}P Radioisotope Studies and Training in Seibersdorf

Two major activities of the Soil Science Unit in Seibersdorf are to develop and test isotope methodologies and guidelines to support CRPs and TCPs, and to conduct training to strengthen the analytical and professional capabilities of Member States. This is achieved through regional, interregional and laboratory training. Whereas development of methodologies and guidelines for stable isotopes such as (^{13}C, ^{15}N, ^{18}O) in the Unit has advanced in the area of soil-water-nutrient plant continuum, the use of isotopes of phosphorus (^{32}P, ^{33}P) has received little attention in the Unit during the last ten years. The main reason for this has been the lack of a greenhouse and laboratories that conform to the required safety standards for conducting experiments because of the radioactive nature of the phosphorus isotopes. In most of the developing countries where P bio-availability in the soil is low, the use of ^{32}P and ^{33}P is crucial to understanding P dynamics in soil, and to quantify P pools that can be mobilized by crop genotypes with superior nutrient resource recovery.

In response to a demand from Member States to train fellows in the use of P isotopes, and the need to conduct research to support the on-going CRP on the "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" (D1.50.10), the Soil Science Unit has refurbished an old glasshouse (new ventilation and cooling systems, floor renovation etc) and a laboratory to a Type B radiation standard. Fellowship training in the

[7] Project E1.05, Activity 3

use of ^{32}P and ^{33}P radio-isotopes for soil P dynamics and P nutrition experiments, safety precautions, sample preparation, measurements using a liquid scintillation counter and calculations, can now be conducted at the Soil Science Unit in Seibersdorf.

3.9. Analytical Services

3.9.1. Stable isotope analyses

The Soil Science Unit performed 10 567 stable isotope measurements during the year 2007 as shown in the following Table. Most of the analyses were for supportive research as well as training with some 3400 for CRPs and 800 for TCPs.

		CRP	TC	Seib	**Total**
Measurements carried out	^{15}N enriched	634	292	2685	**3611**
	^{15}N nat. ab.	53	542	530	**1125**
	^{13}C nat. ab.	2678	0	2889	**5567**
	^{18}O nat. ab.	0	0	264	**264**
	Total	**3365**	**834**	**6368**	**10567**

3.9.2. Radio isotope analyses [8]

In 2007, the Soil Science Unit provided fallout radionuclides analyses for CRPs and for the other FAO/IAEA regular activities. The following table summarizes the analytical services provided by the SSU during 2007. In section 3.1.3. the main result of the external quality assurance evaluation through the proficiency test of the CRP D1.50.08 participants organized by the CCU/SSU has been already presented. Two hundred-thirty different samples were analyzed for ^{137}Cs by the SSU in 2007. The average counting time peer samples was 50 000 s to obtain a measurements error <10% at 2 sigma precision that represent a total counting time of 3195 hours in 2007.

Table 5. Number of FRN analysis performed in 2007

	CRP	**Seibersdorf**	**External network**	**Inter-comparison exercise**	**In-situ gamma measurements**
^{137}Cs	**197**	**33**	**-**	**101**	**15**
^{210}Pb	**-**	**-**	**37**	**-**	**-**
^{7}Be	**-**	**24**	**-**	**-**	**15**

[8] Project E1.02, Activity 1

The SSU gamma detector was used to analyze ^{137}Cs and ^{7}Be. As this detector can not perform ^{210}Pb analysis, cost free agreement was made with the CNESTEN (Morocco) and the CEA/CNRS in Gif-sur-Yvette (France) for ^{210}Pb measurements. An inter-comparison exercise was done in collaboration with the GSF Forschungszentr.f.Umwelt und Gesundheit GMBH (Germany) in order to verify the accuracy of the SSU measurement due to technical problem with the crystal of the detector in the beginning of 2007. *In-situ* gamma measurements were furthermore performed under field conditions in collaboration with the CU in the summer 2007.

3.9.3. External quality assurance activities in 2007

Since 1995 ten rounds of Proficiency Tests (PT) on ^{15}N isotopic abundance determination and total N content analysis in plant materials have been organized by the Soil Science Unit. Since 2004 additionally ^{13}C and total C content of the same test materials can optionally be analyzed by the participants in the frame of each PT exercise. More than 30 laboratories from Member States have participated in one or several of these annual PTs, with a steady core of about 15 of them on a regular basis.

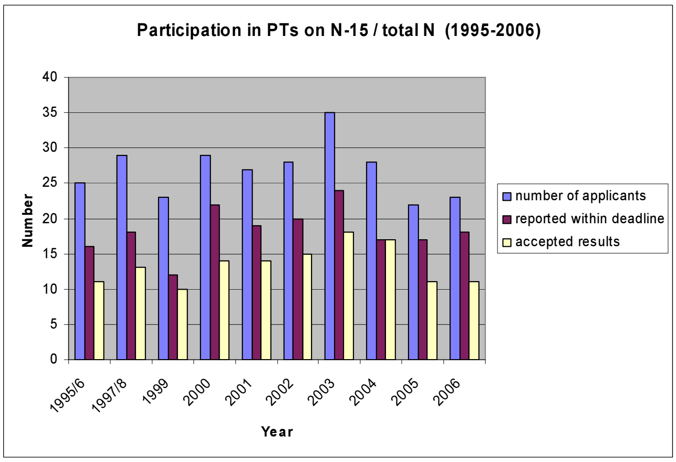

Figure 21. Number of laboratories participating in the PT on ^{15}N and total N determination from the year 1995 to 2006.

The objective of these Proficiency Tests was to evaluate the analytical performance of the participants in analyzing the isotopic abundance of ^{15}N and the total N content of three different plant samples and optionally the isotopic abundance of ^{13}C and total carbon content of the same materials. The test samples were enriched in ^{15}N in the range of 0.5 and 0.8 % atom abundance, which is an enrichment level, often applied in isotope aided agricultural studies. ^{13}C isotopic abundance was at the natural abundance level. Total nitrogen and total carbon had to be analyzed additionally to the corresponding isotope ratio.

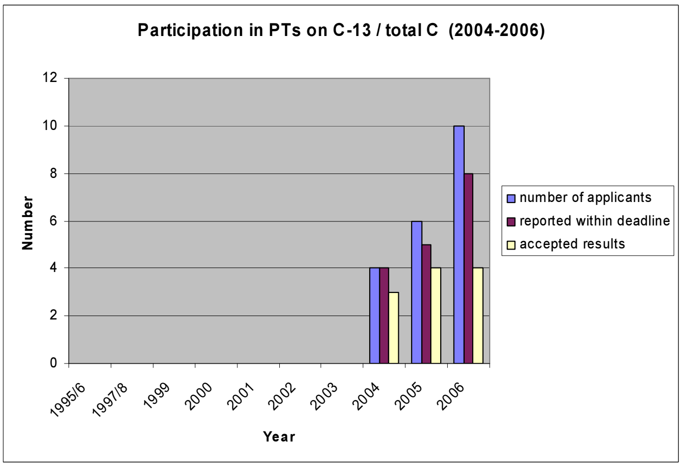

Figure 22. Number of laboratories participating in the PT on ^{13}C and total C determination from the year 2004 to 2006.

In 2007 the SSU received 24 applications for the new round of PT. A new Internal Reference Material (IRM) was introduced in the mass spec laboratory and traceability to SI units was established. The assigned reference- and uncertainty values of this IRM were derived from a calibration against four different certified reference materials (NIST1547, IAEA-CH6, IAEA-305B, IAEA 310B) and two pure chemical products (D(+) sucrose from Fluka and Sigma) had been established according to ISO13528.

In a new collaboration with the University of Wageningen, the Netherlands, the new mature EQA technology is currently being transferred to WEPAL. Proficiency Tests on ^{15}N and ^{13}C in plant materials at the natural abundance level (WEPAL-project *IPE*) has been initiated and it is planned to run PTs through WEPAL in the future, thus enabling the SSU to continue focusing on new emerging technologies such as ^{18}O, deuterium and ^{137}Cs. The SSU will regularly produce N-15 enriched plant materials which will be used as test samples by WEPAL.

4. TRAINING ACTIVITIES

4.1. Interregional Training Course on Use of Nuclear and Related Techniques to Measure Storage, Flows and Balance of Water in Cropping Systems, 1 to 25 October 2007

Although agriculture is the predominant user (75-80%) of fresh water resources, the competition among different sectors for water is increasing because of: climate change resulting from global warming and increased demand for water from urban and industrial sectors. This water scarcity has a serious implication on the food security in developing countries. In order to increase food production in developing countries there is an urgent need to: (i) increase on-farm water use efficiency, (ii) produce more food with less water (i.e., to achieve more crops per drop) and (iii) improve crop water productivity.

It is against this background that the Soil and Water Management and Crop Nutrition Section of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and the Soil Science Unit of the Joint FAO/IAEA Agriculture & Biotechnology Laboratory organized an Interregional Training Course on the "**Use of nuclear and related techniques to measure storage, flows and balance of water in cropping systems"** from 1 to 25 October 2007 at the IAEA Laboratories Seibersdorf.

The training course was announced in March 2007 and the prospectus for the course, including the purpose, justification and description, was published in the Soils Newsletter Vol. 30, July 2007. A total of 60 applications from 39 developing countries in five regions were received by 15 July 2007 **(Table 6).**

Table 6. Number of applications received for the interregional training course

Region	Countries	No of Applicants
Africa	17	29
Middle East	5	7
Asia and Pacific	7	12
Latin America and the Caribbean	6	8
Europe	4	4

Twenty-two candidates from 21 countries **(Section 6.4.)** were selected based on their qualifications, general experience, experience with water management, knowledge in the use of nuclear and related techniques, age and the benefits the respective countries might derive from their participation. Qualified candidates not selected were retained in the database of the SWMCN Section so that they may be informed of other training courses. In addition to the 22 candidates who received funding from FAO, four candidates were nominated and sponsored by the IAEA Department of Technical Cooperation (TC). The staff of the SWMCN subprogramme and four invited instructors (selected on the basis of their technical/ research skills, technology dissemination capability and future networking) from USA, Israel and Austria, gave lectures and conducted practical work during the training course.

The training course was opened on 1 October 2007 in Seibersdorf with welcoming addresses by the Acting Director of the IAEA Laboratories, the Acting Director of NAFA/AGE, the Acting Head of the FAO/IAEA Agriculture & Biotechnology Laboratory, and the Head of the SSU. The keynote address was delivered by Mr Werner Burkart, Deputy Director General (DDG), Department of Nuclear Sciences and Applications of the IAEA. Mr Burkart stressed that although agriculture is the predominant user (75-80%) of fresh water resources, the competition among different sectors for water is increasing because of climate change resulting from global warming, increased demand for water from urban and industrial sectors and the increased awareness of water quality for recreational purposes and

Figure 23. Participants and Instructors at the Interregional Training Course.

Figure 24. DDG-NA addressing Participants.

tourism. Mr Burkart outlined the challenges and stressed that there is a need to increase on-farm water use efficiency, to produce more food with less water (i.e., to achieve more crops per drop) and to enhance water use efficiency and crop water productivity. He wished all the participants and instructors a very successful training course and an enjoyable stay in Vienna. During a keynote lecture on Integrated Land and Water Management for Food and Environmental Security, Mr Winfried Blum, President, European Confederation of Soil Science Societies, acknowledged the goods and services provided by land and soil and the need to strike a balance between productivity and efficiency of land use. Large scale production of crops for bio-fuel, and its consequences on the land productivity was highlighted.

Figure 25. Sampling soils for soil moisture determination.

In the first week of the Course, participants learned about new developments in soil water monitoring devices and took part in computer laboratory exercises aimed at estimating crop water use. The participants were taught the principles behind the electromagnetic (capacitance) probes and why they do not work effectively. During practical sessions they learned how to use the hydroprobes in the field and also learned how to build their own time domain reflectometry (TDRs). It was emphasized that the soil moisture readings from the neutron probe are currently

Figure 26. Dr Steve Evett demonstrates the use of neutron probe to training participants.

the best, but the need for better capacitance sensors was advocated.

Lectures and practicals during the second week focused on plant water relationships, evapotranspiration and crop water use and requirements. Participants learned about the theory and construction of thermocouples and TDR sap flow sensors and constructed their own thermocouples and TDR sap flow sensors to measure and analyze sap flow in citrus. The use of porometers to measure transpiration and leaf conductance and portable infra red (IR) thermometers for measuring the crop water stress index was also demonstrated.

Figure 27. Participants testing equipments they built in the laboratory to estimate crop water use by plants.

The third week lectures and practical sessions focused on the use of stable isotopes to trace plant source water, leaf water isotope enrichment and transpiration and combining ^{13}C and ^{18}O to understand plant response to a water deficit. Participants had field practicals on isotopic procedures for determining sources and fluxes of water in plants and soil, and isotopic methods for integrating inputs and losses to receiving water bodies. There was also a computer laboratory exercise on interpreting, understanding and presenting data generated from the Mass Spectrometer.

The last week of the course was devoted to practical field training both in Seibersdorf and at the BOKU University in Großenzersdorf. Participants also prepared individual proposals for presentation outlining the applicability of the proposed project to their individual developing countries.

Figure 28. Air and vapor sampling to determine of Oxygen-18 and Deuterium for separating transpiration component from evapotranspiration.

Besides the technical sessions, there was a presentation by the Research Contract and Administration Section where the participants were exposed to the pathways for involvements in CRPs. The new development in the CRP that was of interest to the group was the newly introduced “Doctoral CRPs”. The session closed with the presentation of Certificates by the Director of the Joint FAO/IAEA Division, to the participants having all fulfilled the criteria for the successful completion of the training course.

Feedback from the participants included: (i) the need for more training course at least once very 2 years (preferably at the regional level because of language barriers), (ii) the time allotted for the training course (4 weeks) was too short and should be at least 6 weeks for such a course subject to the availability of funds, (iii) the training has provided a network and contacts with renowned scientists in the field of soil-crop-water monitoring and (iv) the training also provided the participants with new estimates for refining input parameters and validating/testing of the FAO crop water productivity model (AquaCrop Model) in the development of better irrigation strategies.

One of the external lecturers commented that "*what was accomplished through these trainings goes far beyond the simple technological and theoretical training aspects. You are developing the next generation of agricultural science leaders in many countries and establishing the networks that they will use during their careers* ".

The workshop was deemed successful because the objectives and outputs were met. Thanks to the invited lecturers: Mr Steve Evett (USA), Mr Sheptai Cohen (Israel), Mr David Williams (USA), Mr Peter Harker (ARC, Austria), Mr Peter Cepuder (BOKU University), Mr WEH Blum (Austria), and all the IAEA staff that contributed to make the workshop a success.

4.2. Individual Fellowship Training

Ms Saule KENZHEBAYEVA (Kazakhstan)

Ms Kenzhebayeva was trained for three months on the interactive effects of drought and salinity on ^{13}C isotope discrimination at varying soil phosphorus availability in wheat varieties from Kazakhstan. The training includes weekly lectures on the use of stable and radio isotopes, and other nuclear-related techniques in soil-water-plant relations. The fellowship was related to a regional TC project on “Evaluation of South Eastern Europe’s Natural and Mutant Genetics (RER/5/013).

Mr Zandraagombo DOVCHIN (Mongolia)

Mr Dovchin was trained for three months on the use of stable isotopes to evaluate cereals and legumes for their tolerance to water and nutrient stress. The training includes the development of a rapid screening technique for root traits (adventitious, basal and primary) of cereals and legumes contributing to enhanced P acquisition from low P soils. Mr Dovchin received weekly lectures on isotopes and the use of stable and radioisotopes to quantify nutrient efficiencies by cereals and legumes in cropping systems.

Ms Martina STURM (Slovenia)

Ms Sturm received training for four months on crop production practices on soil water balance and nitrate movement within and beyond the crop root zone. The training included the use of soil water monitoring equipments (neutron and other capacitance probes) and the use of suction cups to monitor nitrate movement. Ms Sturm also attended the Interregional Training Course on "Use of nuclear and related techniques to measure storage, flows and balance of water in cropping systems” held in Seibersdorf during 1-25 October 2007.

Figure 29. Sampling water by suction for nitrate and O-18 determination.

Figure 30. Field practical training—A fellow from Slovenia conducts experiment to monitor the effect of crop production practices on nitrate movement in soil.

Mr Peter KORPAR (Slovenia)

Mr Korpar received field practical training for two months on the application of soil water monitoring equipments (neutron and other capacitance probes) and the application of stable isotopes in water management. Mr Korpar also attended the Interregional Training Course on "Use of nuclear and related techniques to measure storage, flows and balance of water in cropping systems" held in Seibersdorf during 1-25 October 2007

Mr John H KIHUMBA (Kenya)

Mr Kihumba attended the Interregional Training Course on "Use of nuclear and related techniques to measure storage, flows and balance of water in cropping systems" held in Seibersdorf during 1-25 October 2007, followed up by one week of practical training on the application of soil moisture neutron probe for monitoring periodic soil water content.

Mr Leonard BUCKLE (Kenya)

Mr Buckle attended the Interregional Training Course on "Use of nuclear and related techniques to measure storage, flows and balance of water in cropping systems" held in Seibersdorf during 1-25 October 2007, followed by two weeks of practical training on water management.

Mr David A KAMARA (Sierra Leone), **Ms M. S. MURWIRA** (Zimbabwe) and **Ms N.D.T. YAO** (Ivory Coast) were trained for six, three or one months, respectively, in the use of ^{15}N isotope dilution methodology in the measurement of biological nitrogen fixation in leguminous crops. They performed greenhouse and field experiments using tracer technology and were trained in various aspects of legume production, including experimental design, implementation, and data evaluation.

4.3. IAEA General Conference Display by the SWMCN Subprogramme

During the 51st General Conference of the IAEA, held from 17 to 23 September 2007, the SSU mounted a display to demonstrate the interactive effects of fertilizer nitrogen (N) and phosphorus (P) on the root development and growth of cereals and legumes in soil and solution culture media. Maize (cereal) and common beans (legume) were grown in transparent glass tubes in either soil or nutrient solution, and clearly displaying the root system.

Figure 31. Live display of soil-nutrient-plant interaction at the General Conference.

Four treatment regimes were displayed: 1) No N and P applied, 2) N applied at 200 kg ha^{-1} but no P applied, 3) P applied at 60 kg ha^{-1} but no N applied and 4) N applied at 200 kg ha^{-1} and P at 60 kg ha^{-1}. Similar treatments were used for the solution culture display, except that the N treatment was 20 mg L^{-1} and the P 5 L^{-1} in the same combinations as the soil culture.

Figure 32. DG of FAO and Director of the Joint FAO/ IAEA Division at the poster display.

The display gave an excellent visual perception and clearly demonstrated that the application of P fertilizer enhanced root development and crop growth through enhanced N uptake by crops. Crop growth and root development were more impaired when no P was applied (despite the application of N) than in the treatments where P was applied but no N, while the effect of no added P on plant growth was more severe in the cereal than in the legume.

The display received much attention and positive feedback from the many delegates and was clearly an “eye opener”.

Figure 33. Director of NAAL visits the live display.

5. ACKNOWLEDGEMENTS

The SSU is grateful to the people who were involved during the sampling collection in the soil erosion and sedimentation project: Ms Maitane Melero-Urzainqui, Ms Sonia Rubio-Martinez, Ms Johanna Hofmann from Vienna Agriculture University; Ms Bai, Ms Li, Ms Marvalee Walker, Mr Daniel Asare and Ms Jawahir Al-Meslemani, all previous IAEA Fellows; Mr Josef Seufzenecker (previous Staff); and in particular to Dr Andreas Klik for his constant support and contribution to this project. We also thank Dr Moncef Bemansour (CNESTEN, Morocco) and Dr Philippe Bonté (CEA/CNRS Gif-sur-Yvette, France) for the ^{210}Pb measurements. We are grateful to Prof DE Walling from Exeter University (England) for discussions on the data treatment from the sedimentation area and how to link these with the experimental erosion plots.

The SSU wants to acknowledge the support provided by Mr Anton Nirschl (Seibersdorf mechanical workshop) for his help in the conception of the Fine Soil Increment Collector (FSIC), and Mr Umberto Sansone (Head of the CU) and Abdulghani Shakhashiro (CU) in the organization of the proficiency test and the data treatment.

6. APPENDICES

6.1. Staff Publications

6.1.1. Journal articles

Adu-Gyamfi, JJ, FA Myaka, WD Sakala, R Odgaard, JM Vesterager and HH Jensen (2007). Biological nitrogen fixation and nitrogen and phosphorus budgets in farmer-managed intercrops of maize-pigeonpea in the semi-arid southern and eastern Africa. *Plant and Soil,* 295,127-136.

Hogh-Jensen, H, FA Myaka, WD Sakala, D Kamalongo, RNA Odgaard, NE Nielsen and **JJ Adu-Gyamfi**, (2007). Yields and qualities of pigeonpea varieties grown under smallholder farmers' conditions in Eastern and Southern Africa. *African J Agric. Res,* 2(6), 269-278

Kanai, S, K Ohkura, JJ **Adu-Gyamfi**, PK Mohapatra, NT Nguyen, H Saneoka and K Fujita, (2007). Depression of sink activity precedes the inhibition of biomass production in tomato plants subjected to potassium deficiency. *J Experimental Botany*. 58, 2917-2928

Mabit, L, C Bernard (2007). Assessment of spatial distribution of Fallout RadioNuclides through geostatistics concept. *Journal of Environmental Radioactivity,* 97(2-3), 206-219.

Mabit, L, C Bernard, MR Laverdière (2007). Assessment of erosion in the Boyer River watershed (Canada) using a GIS oriented sampling strategy and ^{137}Cs measurements. *Catena*, 71(2), 242-249.

Mabit, L, C Bernard, MR Laverdière (2007). Étude de la dégradation des sols par l'érosion hydrique à l'échelle des bassins versants en utilisant la méthode du Cs^{137}. *Agrosolution*, 18 (1), 12-16.

6.1.2. Conference proceedings / abstracts

Mabit, L, L Li, **A Toloza,** C Bernard (2007). Soil erosion processes and soil quality variability evaluated using fallout radionuclides. In: Geophysical Research Abstracts (CD-Rom), Volume 9, European Geosciences Union – General Assembly 2007. Abstract EGU2007-A-01090. pdf, 2 pages.

Mabit, L, E Fulajtar (2007). The use of ^{137}Cs to assess soil erosion and sedimentation processes: advantages and limitations. In: Extended Synopses of the International Conference on Environmental Radioactivity: From Measurements and Assessments to Regulation. 23-27 April 2007, IAEA, Vienna, Austria. IAEA Publication. Iaea-cn-145. Pages 338-339.

Mabit, L. (2007). Use of Geostatistics to Establish Soil Movement Map and Sediment Budget Using Fallout Radionuclides (FRN) pp.247-254. In: Proceedings of the tenth International symposium on river sedimentation. Effects of river sediments and channel processes on social, economic and environmental safety. 10th International Symposium on River Sedimentation, 1-4 August 2007, Moscow, Russia. Publication of the Moscow University, Russia. Vol I.

6.2. Staff Travel

Staff Member	Destination/Meeting	Period	Purpose of travel
Adu-Gyamfi, Joseph	TC travel to Slovenia	10-15 September	Duty travel to Slovenia (SLO5002) to monitor and evaluate project progress, to assist in drafting a proposal for possible extension of the project.
Mabit, Lionel	General Assembly of the European Geosciences Union. Vienna, Austria.	15-20 April	A paper from the Soils subprogramme was presented entitled: *Soil erosion processes and soil quality variability evaluated using fallout radionuclides.*
	International Conference on Environmental Radioactivity: From Measurements and Assessments to Regulation. IAEA headquarters, Vienna, Austria.	23-27 April	A contribution was presented entitled: *The use of ^{137}Cs to assess soil erosion and sedimentation processes: advantages and limitations*. This review of the advantages and limitations of the use of ^{137}Cs as soil tracer also provided an overview of the activities of the Joint FAO/ IAEA Programme to improve this method and to transfer it to IAEA Member States.
	The 10th International Symposium on River Sedimentation, Moscow, Russia.	1-4 August	Presentation entitled ''*Use of Geostatistics to Establish Soil Movement Map and Sediment Budget Using Fallout Radionuclides (FRN)*'' was made.
Toloza, Arsenio	International Measurement Session on "*In-Situ* Intercomparison Scenario" (ISIS). Wiener Neustadt, Austria.	16-20 April	The staff of the Soil Science Unit and the Chemistry Unit participated and performed the "*In-Situ* Intercomparison Scenario" (ISIS).
	European Training Course for Gamma Vision Software, Meerbusch, Germany.	24-28 September	Participation in The European Training Course for Gamma Vision that was held in Meerbusch, Germany for evaluating and analyzing spectrum, reviewing report and display result graphically.

6.3. External Collaborations and Partnerships

Effective collaborations and partnerships are essential for enhancing the research activities of the SSU. The Unit established collaborations with external partners on the following projects:

<table>
<tr><th>Institution</th><th>Topic</th></tr>
<tr><td>Universität für Bodenkultur Wien, Department für Wasser-Atmosphäre-Umwelt, Institut für Hydraulik und landeskulturelle Wasserwirtschaft, Vienna, Austria. (IAEA Technical Contract 13401 – Investigation of soil erosion and soil redistribution in a small agricultural watershed in Austria using traditional and radionuclide methodology)</td><td rowspan="3">Collaborations on research activities linked directly to the CRP D1.50.08 on “Assess the effectiveness of soil conservation measures for sustainable watershed management using fallout radionuclides”</td></tr>
<tr><td>Istanbul Technical University, Institute of Energy, Istanbul Turkey</td></tr>
<tr><td>Istanbul University, Department of Geography, Istanbul, Turkey</td></tr>
<tr><td>Universität für Bodenkultur Wien, Department für Wasser-Atmosphäre-Umwelt, Institut für Hydraulik und landeskulturelle Wasserwirtschaft, Vienna, Austria.</td><td rowspan="10">Collaborations to test and validate FRN methodology at different scales</td></tr>
<tr><td>Centre national de l'énergie, des sciences et des techniques nucléaires (CNESTEN), Rabat, Morocco.</td></tr>
<tr><td>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</td></tr>
<tr><td>Atomic Energy Commission of Syria, Damascus, Syria.</td></tr>
<tr><td>GSF Forschungszentrum für Umwelt und Gesundheit GMBH, Oberschleissheim, Germany.</td></tr>
<tr><td>Ministère de l’Agriculture, des Pêcheries et de l’Alimentation du Québec, Québec, Canada.</td></tr>
<tr><td>Institut de recherche et de développement en agroenvironnement, Sainte-Foy, Québec, Canada.</td></tr>
<tr><td>Département des sols et de génie agroalimentaire, Université Laval, Sainte-Foy, Québec, Canada.</td></tr>
<tr><td>Department of Geography and Resource Management, The Chinese University of Hong Kong, Hong Kong.</td></tr>
<tr><td>Center for Agricultural Land Management and Agrohydrology Department for Agronomy, Biotechnical Faculty, Ljubljana, Slovenia</td></tr>
</table>

6.4. Trainees, Fellows and Scientific Visitors

Name	Country/Project	Months/Days	From	To
Trainees (Participants at the Interregional Training Course on Use of Nuclear and Related Techniques to Measure Storage, Flows and Balance of Water in Cropping Systems, 1-25 October 2007)				
HAMENNI, Ms N	ALGERIA	4 weeks	2007-10-01	2007-10-25
KOUMANOV, Mr K	BULGARIA	4 weeks	2007-10-01	2007-10-25
SENG, Mr V	CAMBODIA	4 weeks	2007-10-01	2007-10-25
SEGUEL, Mr O	CHILE	4 weeks	2007-10-01	2007-10-25
BIART MOLINA, Ms M	CUBA	4 weeks	2007-10-01	2007-10-25
MOHAMED, Ms K	EGYPT	4 weeks	2007-10-01	2007-10-25
ABENNEY-MICKSON, Mr S	GHANA	4 weeks	2007-10-01	2007-10-25
WALUYO, Mr SH	INDONESIA	4 weeks	2007-10-01	2007-10-25
KIHUMBA, Mr JN	KENYA	4 weeks	2007-10-01	2007-10-25
ESTEPHAN, Mr C	LEBANON	4 weeks	2007-10-01	2007-10-25
TAPARAUSKIENE, Ms L	LITHUANIA	4 weeks	2007-10-01	2007-10-25
BACORISEN, Ms G	MAURITIUS	4 weeks	2007-10-01	2007-10-25
AMENZOU, Mr N	MOROCCO	4 weeks	2007-10-01	2007-10-25
IDRISSA, Mr B	NIGER	4 weeks	2007-10-01	2007-10-25
SHAH, Mr A	PAKISTAN	4 weeks	2007-10-01	2007-10-25
COLLADO, Mr M	PHILIPPINES	4 weeks	2007-10-01	2007-10-25
BUCKLE, Mr LB	SIERRA LEONE	4 weeks	2007-10-01	2007-10-25
STURM, Ms M	SLOVENIA	4 weeks	2007-10-01	2007-10-25
KORPAR, Mr P	SLOVENIA	4 weeks	2007-10-01	2007-10-25
ALCHAMMAA, Mr M	SYRIAN ARAB REPUBLIC	4 weeks	2007-10-01	2007-10-25
TANASKOVIK, Mr V	REP. OF MACEDONIA	4 weeks	2007-10-01	2007-10-25
NGATOLUWA, Mr R	UNITED REPUBLIC OF TANZANIA	4 weeks	2007-10-01	2007-10-25

Name	Country/Project	Months/Days	From	To
Fellows				
KAMARA, Mr DA	SIL/05007	6 months	2007-04-16	2007-10-15
STURM, Ms M	SLO/07004	6 months	2007-04-16	2007-10-15
KORPAR, Mr P	SLO/07005	3 months	2007-09-15	2007-12-14
KIHUMBA, Mr JH	KEN/06005	1 month	2007-10-01	2007-10-30
BUCKLE, Mr L	SIL/07002	1 month	2007-10-07	2007-11-06
KENZHEBAYEVA, Ms	KAZ/05024	3 months	2007-04-16	2007-07-15
DOVCHIN, Mr Z	MON/05010	3 months	2007-04-16	2007-07-15
YAO, Ms NDT	IVC/05001	1 month	2007-05-02	2007-06-01
MURWIRA, Ms MS	ZIM/06012	3 months	2007-04-16	2007-07-15
Scientific Visitors				
DHLIWAYO, Mr D	ZIM/06011V	1 week	2007-01-22	2007-01-26
ESILABA, Mr AO	KEN/06019V	1 week	2007-01-22	2007-01-26
KILUSINGA, Mr DK	ANG/06007V	1 week	2007-01-22	2007-01-26
NANCY, Mr KS	SEY/07001V	1 week	2007-11-12	2007-11-16
Other visitors				
GIBBS, Mr M	NEW ZEALAND	1 day	2007-11-08	
BONTE, Mr P	FRANCE	1 day	2007-11-08	
ZAWADZKI, Ms A	AUSTRALIA	1 day	2007-11-20	

6.5. Coordinated Research Projects and Technical Cooperation Projects

CRP Title	Scientific Officer
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)	Joseph Adu-Gyamfi
TCP Title	**Technical Officer**
Integrated Watershed Management for the Sustainability of Agricultural Lands (2005-2009)	Lionel Mabit and Ian Ferris
Use of Environmental Radioisotopes for the Assessment of Soil Erosion and Sedimentation and for Supporting Land Management in the Province of Antananarivo, Madagascar (2007-2010)	Lionel Mabit
Assessment of Erosion and Sedimentation in the Niger Watershed with the Use of Radioisotopes Phase-1 (2007-2010)	Lionel Mabit and Ian Ferris
Protecting Groundwater and Soil against pollutants Using Nuclear Techniques (2005-2008)	Joseph Adu-Gyamfi and Ian Ferris
Improved Water Management Technologies in the Inland Valley Agro-Ecology Project (2001-2008)	Joseph Adu-Gyamfi
Establishing a Drip irrigation-Fertigation Systems Using Nuclear Techniques (2003-2008)	Joseph Adu-Gyamfi
Drip Irrigation and Fertigation for improved Agricultural Productivity in Yemen (2001-2008)	Joseph Adu-Gyamfi
Isotope techniques for Assessing of Water and Nitrogen Use Efficiency in Cowpea and Maize Intercropping Systems (2005-2008)	Joseph Adu-Gyamfi
Increasing Productivity of Selected Crops Using Nuclear and Related Techniques (2007-2011)	Joseph Adu-Gyamfi and Qingyao Shu
Improving Crop productivity and Combating Desertification (2007-2012)	Joseph Adu-Gyamfi and Pierre Lagoda
Increasing agricultural production in the coastal area through improved crop, water and soil management (2007-2009)	Joseph Adu-Gyamfi and Qingyao Shu
Application of Isotopes in Soil and Plant Studies (2005-2009)	Gudni Hardarson
Effect of Biofertilizer and Inorganic Fertilizer Uses on the Growth and Yield of Maize and Bean in Ferralitic Soils of Huambo (2007-2009)	Gudni Hardarson
Contribution of Nitrogen Fixing Legumes to Soil Fertility in Rice-based Cropping Systems (2005-2009)	Gudni Hardarson
Increasing agricultural production in the coastal area through improved crop, water and soil management (2005-2009)	Gudni Hardarson

6.6. Abbreviations

BOKU	Universität für Bodenkultur Wien
CNESTEN	Centre National de L'énergie, des Sciences et des Techniques Nucléaires (Morocco)
CRP	Coordinated Research Project
CU	Chemistry Unit, IAEA Laboratories Seibersdorf
FRN	Fallout Radionuclides
MBM 2	Mass Balance Model 2
PMO	Programme Management Officer
PT	Proficiency Test
RCM	Research Coordination Meeting
SSU	Soil Science Unit
SWMCN	Soil Water Management and Crop Nutrition Section
TCP	Technical Cooperation Project
TO	Technical Officer

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