Assess the Effectiveness of Soil Conservation Techniques for Sustainable Watershed Management and Crop Production Using Fallout Radionuclides (D1-50.08)

Report of the First Research Co-ordination Meeting of the FAO/IAEA Co-ordinated Research Project held in Vienna, Austria on 19 – 23 May 2003

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(Scientific Secretary)

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1. INTRODUCTION

Accelerated soil erosion and associated land degradation worldwide represent a major threat to sustainable intensification of agricultural production, conservation of natural resources and protection of the environment. There is an urgent need to obtain reliable quantitative data on the extent and rates of soil erosion and sedimentation to provide a comprehensive assessment of the magnitude of these problems and underpin the selection of effective soil conservation measures. The quest for alternative techniques for assessing water soil erosion to complement classical methods has directed attention to the use of radionuclides, in particular \(^{137}\)Cs, as tracers to obtain quantitative estimates of water soil erosion and deposition on agricultural landscapes.

The implementation of two closely linked IAEA research networks (Co-ordinated Research Projects or CRPs), during the period (1996-2001) involving some 25 research groups worldwide has made a major contribution to coordinating efforts to refine and standardize the \(^{137}\)Cs technique. These methodological developments are documented in a Handbook for the Assessment of Soil Erosion and Sedimentation using Environmental Radionuclides published by Kluwer (2002). The efficacy and value of the approach has been demonstrated by investigations carried out in a range of environments. These findings are reported in two special issues of the journals Acta Geologica Hispanica (2000) and Soil and Tillage Research (2003). They have paved the way to both extending the approach to other environmental radionuclides and expanding applications exploiting the essentially unique advantages provided by the technique. To date about 3000 publications on the topic are recorded at URL http://hydrolab.asusda.gov/cesium.

Some 40 research groups equally distributed across developed / developing countries now have the capacity to conduct such investigations, which are expected to contribute to controlling/mitigating soil erosion. The FAO/IAEA Program through research networks and other mechanisms is promoting further development and applications of environmental radionuclides in soil erosion/sedimentation investigations.

As follow-up activities, two expert consultations were held in October 2000 (F3) and May 2001 (D1) to discuss ways and means to exploit recent developments in the use of fallout radionuclides in soil erosion/sedimentation within an agriculture /watershed context, and in particular to asses the impacts of major land use types on soil erosion and sedimentation and the effectiveness of specific soil conservation technologies. The consultations recommended the initiation of two CRPs on “Isotope techniques for sediment sources characterization” and “Assess the effectiveness of soil conservation measures for sustainable watershed management using fallout radionuclides”.

The First Research Co-ordination Meeting of the CRPs was held from 19 - 23 May 2003, in Vienna, Austria. The activities carried out during the meeting are described in a summarized way in this report. The program of the meeting, list of participants, abstracts of the presentations and the revised project document are included as Annexes.
2. THE CO-ORDINATED RESEARCH PROJECTS (CRPs)

The CRP on “Assess the effectiveness of soil conservation measures for sustainable watershed management using fallout radionuclides” from the Joint FAO/IAEA Division and the CRP on “Isotope techniques for sediment source characterization” from the Physical and Chemistry Division will be merged into one CRP and implemented together over a period of 5 years (2003-2007). The project document (revised) is included in Annex A.

The overall aim of these projects is to develop diagnostic tools for assessing soil erosion and sedimentation processes and effective soil conservation measures for sustainable watershed management. The specific research objectives are: i) to further develop fallout radionuclide (FRN) methodologies, with particular emphasis on the combined use of $^{137}$Cs, $^{210}$Pb and $^{7}$Be for measuring soil erosion over several spatial and time scales, ii) to establish standardized protocols for the combined application of the above techniques, and iii) to utilise these techniques to assess the impact of short-term changes in land use practices and the effectiveness of specific soil conservation measures.

Thirteen research contract holders: A. Bujan (Argentina), O. Bacchi (Brazil), M.E. Trumper / P. Schuller (Chile), Yong Li (China PR), Xinbao Zhang (China PR), K. Manjaiah (India), M. Benmansour (Morocco), M. Rafiq Sheikh (Pakistan), W. Froehlich (Poland), Nelu Popa (Romania), V. Golosov (Russia), S. Haciyyakupoglu (Turkey), and Hai Son Phan (Vietnam); one technical contractor: D.E. Walling (UK) and eight agreement holders: P. Wallbrink (Australia), A. Klik (Austria), C. Bernard (Canada), D. Lobb (Canada), J. Onda (Japan), H. Liniger (WOCAT-Switzerland), J. Ritchie (USA), Ted Yang (USA) are currently participating in the project. The participants are representing multi-disciplinary and inter-institutional teams involved in soil erosion /sedimentation research in their countries.

3. THE FIRST CO-ORDINATED RESEARCH MEETING

The First Research Co-ordination Meeting of the CRPs was held from 19 - 23 May 2003, in Vienna, Austria. Twenty scientists from the research network, namely twelve contract holders from institutes in Argentina, Brazil, China (2), Chile, Morocco, Pakistan, Poland, Romania, Russia, Turkey, and Vietnam; one technical contractor from UK, seven agreement holders from advanced research organizations in Australia, Austria, Canada (2), Japan, Switzerland (WOCAT) and USA participated. In addition, one FAO representative and seven observers attended the meeting (See Annex B, List of participants).

The objective of this meeting was to review the experimental plans of the participants in the context of the work plan and objectives of the project and to establish experimental plans for the next 18 months (see Annex C, Program of the meeting).

During the presentations and group discussions, research objectives, approaches, and methodologies were thoroughly examined. Abstracts of the presentations are included in Annex D. A technical workshop to review generic topics on both the application of fallout radionuclides in soil erosion research and the use of databases and methodologies on soil and
water conservation of the World Overview of Conservation Technologies and Approaches (WOCAT) consortium was held at the IAEA Laboratories in Seibersdorf, near Vienna.

In continuation the summary reports of the discussants on the presentations are included for convenience:

SESSION I: REGIONAL APPLICATIONS – ‘SOUTH AMERICA’
Discussant: D. Lobb

Alfonso Bujan (Argentina)
Utilization of $^{137}\text{Cs}$, $^{210}\text{Pb}$ and $^{7}\text{Be}$ to investigate soil erosion and sedimentation in the Pampa Ondulada region

Soil conservation strategies:
- land use change?
- land management: conservation tillage, terracing?
- use of USLE model

Study:
- standardize and assess methodologies
- evaluate soil conservation practices (direct seeding, terracing)
- transects within watersheds
- $^{137}\text{Cs}$ reference profiles, and $^{210}\text{Pb}$ and $^{7}\text{Be}$ reference profiles
- assessment of soil erosion risk

Status:
- establishing baseline

Concerns:
- regarding the use of $^{210}\text{Pb}$
- definition of soil conservation strategies

Osny Bacchi (Brazil)
Use of $^{137}\text{Cs}$ fallout redistribution analysis for determination of optimal width of riparian forest for erosion control

Soil conservation strategy:
- riparian forests for sediment trapping/filtering
- use of WEPP model

Study:
- $^{137}\text{Cs}$ profiles in riparian zones to assess sedimentation
- require reference profiles/inventories from equivalent cropped/forest sites

Status:
- preliminary results

Concerns
- Regarding radionuclide methodology (more discrimination)
Paulina Schuller (Chile)
Use of $^{137}$Cs measurements to estimate changes in soil erosion rates associated with changes in cultivation practices on agricultural land

Soil conservation strategy:
- conservation tillage
Study:
- use of hillslope transects
- use of $^{137}$Cs profiles to discriminate management “periods”
- use of mass balance methods
- development and use of simplified methods
Status:
- simplified method validated
Concern
- regarding sample throughput on research capability

SESSION II: REGIONAL APPLICATIONS – ‘ASIA’
Discussant: P. Wallbrink

Yong Li (China)
“Profile variation of $^{137}$Cs, $^{210}$Pb$_{ex}$ and soil organic matter (SOM) as affected by intensive tillage on slope land”

Objectives:
- Assess short term erosion rates and redistribution by tillage
- hypothesis: “if $^{137}$Cs, $^{210}$Pb$_{ex}$ and SOM move by the same physical mechanisms” then can link soil redistribution pattern on slopes to soil quality patterns
- Assess the profile development associated with tillage.

Study:
- Chinese Loess Plateau
- selection of reference sites
- Background data on land use history, topography, soil types etc.
- Representative hillslope study sites selected
- 50 plowing operations over a 5-day period on 27° using standard ‘donkey drawn’ moldboard plow.
- sampling for measurement of $^{137}$Cs, $^{210}$Pb$_{ex}$ and SOM at different slope positions.
Status:
- 180 samples collected
- After plowing, lower slopes had increase in SOM and $^{137}$Cs at >30 cm depth,
- upper and mid slopes showed decreases in $^{137}$Cs, $^{210}$Pb$_{ex}$ and SOM
$^{137}$Cs, $^{210}$Pb$_{ex}$ and SOM changes were able to be quantified
- SOM correlated to $^{137}$Cs activity $r^2 = .81$
- SOM correlated to $^{210}$Pb$_{ex}$ $r^2 = 0.88$
- Conclusion $^{137}$Cs, and $^{210}$Pb$_{ex}$ can be used to quantify
Concerns/issues:
- Measurement methodology
- sampling methodology, (sampling depths at base of slope)
- standardisation of methodologies

Muhammad Sheik (Pakistan)
“Status of soil erosion and sedimentation in Pakistan and role of nuclear techniques in soil conservation” (note: sedimentation CRP)

Objectives:
- estimate erosion rates in different catchments of a watershed
- identify tracers to be used for fingerprinting
- identify source areas
- evaluate remediation practices

Study:
- catchment has large variability in rainfall 375-1700 mm
- four large dams, two of which have high accumulation rates (big numbers), % loss of storage up to 43%.
- Surface runoff is high due to impermeable clay layers. Soil erosion from cultivated lands on loess is significant primarily of sheet/rill erosion at foothills of mountain slopes.
- Sediment loads are high and composed of silt and clay.
- Watershed management has reduced sediment loads by about 40%.
- Storage of sediment within river systems is significant (reservoirs and channels).
- Sedimentation model – schematic diagram – could be tested by $^{137}$Cs profiles.

Status:
$^{137}$Cs inventories at some reference sites established
$^{137}$Cs depth profiles established at two locations
- 1961 and 1963 peaks used to calculate accumulation rates.
- Five areas selected for preliminary study, literature survey of climate data completed.
- Two sites sampled to establish initial inventories of radionuclides

Concerns/issues:
- fingerprinting – discrimination of sources
- reference inventories too high? What does it mean given rainfall variability across catchment
- interpretation of $^{137}$Cs depth profiles, complexities arising from grain size issues.
- Watershed management, soil conservation measures??

Phan Son Hai (Viet Nam)
“Assessment of soil erosion on some industrial and annual crops in the central highland of Vietnam using $^{137}$Cs, $^{210}$Pb$_{ex}$ and $^7$Be”

Objectives:
- investigate soil erosion and sedimentation on sloping lands
- promotion of technique
- understand distribution of fallout nuclides in soil profiles
$^7$Be sorption to soils, leaching using lysimeters, laboratory extraction experiments
$^{210}$Pb$_{ex}$ and $^7$Be deposition fluxes
-develop and test conversion models for determining soil loss in plots

**Study:**
Central Highlands occupy 17% of total, 1600-2000 mm annual rainfall susceptible to erosion
Traditional methods, run-off plots, erosion pins
pilot study commenced, $^{137}$Cs measured on two transects
Runoff plots, 255 m², short day (annual?) crops
Four soil conservation models (plots?)
Nested plot within area type experimental design.

**Status:**
depth distribution of $^{137}$Cs at reference sites, inventory 320 Bq/m²
variability has been examined: found to be 340 Bq/m², variance 52 Bq/m², thus number of samples to calculate mean has been estimated.
Estimates of soil loss using an empirical relationship from transect data, 31 t/ha? ($^{137}$Cs proportional model) vs 42 t/ha (runoff plots)

**Concerns/issues:**
high concentrations of supported Pb-210, thus low concentrations of $^{210}$Pb$_{ex}$
calculation of erosion loss estimates from runoff plot data, derivation of empirical equation, discrepancy of time scales?
Use of alternative conversion models
Technique development, Be-7 adsorption experiments.

**Moncef Benmansour (Morocco)**
“Use of radionuclides to investigate soil erosion on agricultural fields in Morocco and to evaluate the effectiveness of soil conservation measures”

**Objectives:**
-To confirm the potential of Cs-137 technique, identify local constraints
-To investigate erosion under different conditions land use practices
-Better understand transect approach
-Use fallout nuclides to test effectiveness of ‘no till” and ‘direct drilling’ soil conservation -- methods at Merchouch site

**Studies:**
-total soil erosion loss in Morocco is $100 \times 10^6$ t/yr
-Reservoir capacity decrease about 1% of capacity annually
-Sampling strategy involved fields on different slopes
-Sampling along transects, reference site 10 cores
-Proportional model, Mass balance model, mean and gross erosion rates
-Merchouch site: 1074 ha, cultivation 84%, 405mm, ‘no till’ and ‘direct drill’ conservation methods

**Status:**
-Cs-137 profiles measured in various scenarios
-Soil redistribution rate determined for two slopes. Similar results from both models except for high erosion rate
-El Hoceima 5-16 t/ha/yr; Casablanca, 30-60 t/ha/yr; Ifrane, 17-44 t/ha/yr
-Identified constraints: reference sites, complexity of geomorphology, heterogeneity and stoniness of soil
-Merchouch site: 18 plots installed by INRA; reference profiles measured for $^{137}\text{Cs}$ and $^7\text{Be}$.
-Differences between both nuclides for reference and cultivated sites (thus can be used to determine loss rates).
-More work required to develop calibration models for $^7\text{Be}$ and $^{210}\text{Pb}$

Concerns/issues:
- determination of various parameters for mass balance conversion model
- effects of wind erosion

SESSION III: METHODOLOGICAL DEVELOPMENTS – ‘RADIONUCLIDES’
Discussant: V. Golosov

Presentations of Walling, Lobb, Wallbrink, Ritchie

BASIC RESEARCH

Progress
1. Validation of calibration models using comparison of plot observations and $^{137}\text{Cs}$ concentration relationship concentration of $^{137}\text{Cs}$ in soil and in sediments
2. Validation of calibration models using comparison of direct measurement of soil losses at catchment scale and soil losses estimated from $^{137}\text{Cs}$ losses demonstrate that improved diffusion model fits better to direct observations
3. Rainfall experiments: soil loss and $^{134}\text{Cs}$ losses
4. Combined use of $^{137}\text{Cs}$ Cs-137 technique, erosion models and GIS for assessment of sediment redistribution within cascade system cultivated slope – river basin
5. Combined use of geochemistry, fallout radionuclide and theoretical models for identification of sediment sources

Concerns/Issues
Very small plots – soil aggregates do not destroy. Need for similar experiments with larger plots.
Absent of long-term direct (plot, catchment) observations of soil losses,
Number of sampling points for fingerprinting study in river basin (s) scale

Perspectives
Improvement of grain size coefficient in calibration models
Validation of calibration models for slope and catchment scales
Combined use fingerprinting approach with GIS

APPLIED RESEARCH

Progress
- Calculation of tillage erosion input in soil losses. Tillage translocation experiments
- Monitoring of soil losses using repeated survey with measurements of $^{137}\text{Cs}$ concentration
- Study of soil losses for different rotation system and different conservation methods
- Study influence of residues on nutrient losses in runoff boxes
- Using $^{137}$Cs for assessment of influence of different factors on soil losses
- Application of radionuclides for determining sources of sediments in a system cultivated area
- Drain system - river basins – Sea bay.
- Use $^{137}$Cs for assessment of carbon movement patterns under different conservation tillage practices.

Concerns/Issues:
- Different cultivation slope morphology – different influence of tillage erosion
- Scale effect influence: Experiment on runoff plot – cultivated field
- Selection positions for reference samples for large watersheds
- Choice of sampling strategy for different landscape situations and different morphological units within the each field or watershed

Perspectives:
- More detailed study of nutrient migration with sediment
- Study of tillage erosion in different agricultural landscapes around the world using fallout radionuclides
- More monitoring studies using $^{137}$Cs
- Assess the effectiveness of different conservation methods using $^{210}$Pb, $^{7}$Be at the runoff plots and field scale (compare traditional cultivation and conservation methods) using $^{7}$Be
- Assess the effectiveness of different rotation systems and fertilization using $^{7}$Be
- Improvement of sampling strategy
- Combine application fallout radionuclides with different methods for assessing/predicting soil and nutrient losses
- Model development for evaluation of soil carbon pattern using $^{137}$Cs

SESSION IV: REGIONAL APPLICATIONS - ‘EUROPE AND OTHER REGIONS’
Discussant: C. Bernard

Valentin Golosov (Russia)
Application of radionuclides for assessment of soil conservation works in forest-steppe zone of Central Russia: approaches and perspectives

Problems addressed
- Surface and gully erosion from intensive cultivation, overgrazing
- River sedimentation and sediment transportation
- Migration of Chernobyl fallout
- Eroded cropland up to 40%

Progress
- New project
- Erosion max: c.a. 1900
- Conservation practices at experimental station: Mulching, Deep tillage, Minimum till, Contour ridging, Windbreaks, etc.
- 1-3 and 3-5 t/ha/yr dominant erosion classes

Problems/ concerns
- Sites suitable for reference inventory
- Sites representative of actual practices
Perspectives
- Random variability nuclides
- Sediment redistribution: $^7$Be; $^{137}$Cs from Chernobyl; bomb $^{137}$Cs; $^{210}$Pb
- Effectiveness conservation practices
- Redistribution $^{137}$Cs from Chernobyl

Wojciech Froehlich (Poland)
The use of fallout radionuclides and classical methods in soil erosion investigations, including assessment of the impact of short-term land use change and the effectiveness of soil conservation techniques, in the Polish Carpathians (preliminary results)

Problems addressed
- Quick land use change since 1989 (political, economic): impacts on soil erosion, sediment production
- Efficiency of terraces for extreme events?

Progress
- Homerka catchment
- Conservation practices in place: rotations, terraces
- Mountain slopes: $^{137}$Cs redistribution
- Transects: classical methods and radioisotopes ($^{137}$Cs, $^{210}$Pb, $^7$Be)
- Rainfall characterization: duration, intensity, depth
- Runoff mechanisms, impact on erosion
- Cs in SS in river
- Magnetic properties
- Tracing age of sediments in reservoir with $^{137}$Cs
  $^{137}$Cs content for different phases or types of runoff

Problems, concerns
- Influence of extreme events
- Scale effect: from plot to large watershed
- Representativity of soil samples for $^7$Be
- Interpretation of $^{137}$Cs content of sediments
- Skeletal soils: grain size distribution of samples measured

Perspectives
- Thresholds values for different erosive processes
- Crop rotations and soil erosion ($^7$Be + conventional)
- Calibration procedure from isotope to erosion
- Sampling plots
- SS in flood events

Dumitru Nistor (Romania)
Preliminary studies regarding the use of fallout radionuclides in estimating the effectiveness of soil conservation measures on sloping cropland in Romania

Problem addressed
- Erosion on 6 Mha, 43% agric. Land; surface and gully types.
- Rates up to 30 t/ha/yr
Progress
-3 watersheds, plots
-Climatic data, soil data,
-Conservation practices (structural) and tillage: good results
-Soil sampling according to implemented practices

Problems, concerns
-Sites represent conservation measures, soil types, land use of Romania
-Easily accessible
-Drought -> Erosion?
-Support of state?

Perspectives
\(^{137}\text{Cs}, \ ^{210}\text{Pb}, \ ^{7}\text{Be}\) for erosion on different spatial (100 m\(^2\) – 300 ha) and time (short – \(^{7}\text{Be}\); long – \(^{210}\text{Pb}\)) scales
-Standardized protocols
-Impact of short term land use change and conservation practices
-Reliable soil erosion data
-Comparison soil erosion models - isotopes

Sevilay Haciyakupoglu (Turkey)
The use of \(^{137}\text{Cs}\) and \(^{210}\text{Pb}\) and \(^{7}\text{Be}\) measurements for the assessment of soil erosion and sedimentation in the Riva Basin (Istanbul, NW Turkey)

Problems addressed
-Important problem; severe to very severe on 63% cropland
-Need for reliable data
-Bank erosion, landslides
-Siltation or reservoir
-Source of drinking water for Istanbul

Progress
-Riva Creek watershed, characterization
-Tree planting in protection areas
-Reference site searched and characterized, soil sampling for Cs-137; Variability

Problems, concerns
-Many sites needed in watershed, representing different land uses
-Long counting times

Perspectives
-Evaluate erosion/sediment rates from radio-isotopes
-Implement conservation practices

Xinbao Zhang (China)
Investigation of soil erosion and sedimentation by using nuclide tracers of \(^{137}\text{Cs}\), \(^{210}\text{Pb}_{\text{ex}}\) and \(^{7}\text{Be}\) on the Loess Plateau as well as in the Upper Yangtze River Basin, China

Problem addressed
-Severity of erosion / sedimentation in study area
Progress
137Cs and 210Pb profiles in uncultivated sites, reference inventories
-Parameters for interpretation models
-Project in Zhaojia Catchment: origin of sediments, relative contributions
-Characterization study area, eroded sediments
-Depth distribution of 137Cs in reservoir sediments
-Contribution gully / inter-gully areas assessed from 137Cs content
-Erosion-sediment yields before / after cultivation was stopped
7Be depth distribution in other project

Problems, concerns
137Cs, 210Pb, behave differently in reference sites, use of same models?
-Impacts of parameters values on soil loss estimates
-Uncertainty around 7Be reference inventories in SW China

Perspectives
-Combined use of 137Cs and 210Pb,
-More work with 7Be ??

SESSION V: METHODOLOGICAL DEVELOPMENTS - ‘SOIL CONSERVATION MEASURES AND MODELING’
Discussant: J. Ritchie

Y. Onda (Japan)
Erosion and sediment transport analysis by 137Cs and 210Pb in forested environments in Japan

Problems:
-High conservation of suspended sediments in reservoirs
-Cultivated area low (Paddy)
-Sediment production from forested area (Managed vs non-managed)
-Landslides are problem

Study:
-Determine sediment sources flowing to reservoir using fingerprinting techniques
-Used 137Cs and 210Pb

Status:
-Defined watershed vegetation cover and history
137Cs low in most tributaries
-High 137Cs and 210Pb, in tributaries from unmanaged forest
-High 210Pb from sub-watershed with recent landslides
137Cs and 210Pb differed with Landslide area

Plans:
-Collect suspended sediment during storm
-Model system

Concerns/issues:
-What is particle size of sediments?
-More variables for fingerprinting are needed
Andreas Klik (Austria)
Soil conservation in Austria

Problems:
- Soil erosion (Water) is a problem

Study:
- Sites North and West of Vienna
- Plot studies CC, CT, NT
- No difference in runoff
- Sediment, N, P, pesticides with practice
- Slope differences

Status:
- Long-term research, ongoing since 1994

Plans:
- Continue plots
- Study impact conservation on soil/water quality
- Validated models
- Available for other studies

Concern/Issues:
- Not many events
- Potential use of radionuclides

H.P. Liniger (Switzerland)
World overview of conservation approaches and technologies – WOCAT

Study:
- Background of WOCAT (Possible links CRP)
- Defined Scope
- Purpose (Save valuable knowledge)
- Technology and approaches for soil and water conservation

Status:
- Questionnaires to Databases to Output
- Great need to document experiences
- Mapping to compliment local studies

Plans:
- Help CRP get information out and standard terms

Concern: (Needs)
- Getting all the experiences into database
- Systematic method to map
- Funding
- How CRP can work with WOCAT
Hassan Nabhan (FAO)
Land degradation assessment in drylands – LADA

Study:
- Overview of LADA
- Definitions to give context
- Objectives of LADA
- History

Status:
- New project
- Methods
- Identification of Indicators for LADA Assessment
- Economic – Alert policy and decision makers
- Shift Management to participatory approach

Concern: (Needs)
- Quantitative assessment of soil degradation on productivity
- Possible link between CRP and LADA (Agencies)

4. REPORTS OF THE WORKING GROUPS

The participants divided in two working groups developed guidelines and approaches for utilising fallout radionuclides to assess the effectiveness of soil conservation measures and fingerprint techniques to discriminate sources in sedimentation studies and for utilising standardised protocols to describe the soil conservation technologies to be studied by the network (sections 4.1 and 4.2 below).

The SWC technologies will be described in a standardized manner using the WOCAT questionnaires for further approval and inputting into the databases. Dr. Hanspeter Liniger, Centre for Development and Environment, University of Bern representing the WOCAT consortium took active part in the meeting to ensure appropriate linkages between WOCAT and the CRP. Final plenary sessions were devoted to discuss and adopt the reports of the working groups and draw conclusions and recommendations of the meeting.

Detailed recommendations were also given for consideration by the IAEA to facilitate and further support research and training in the use of fallout radionuclides in soil erosion and sedimentation research and related activities (section 4.3 below).

4.1 REPORT OF GROUP ONE: GENERAL DISCUSSIONS ON METHODOLOGICAL (RADIONUCLIDE) ISSUES

In developing a framework for the discussion, the Group decided to focus on three key issues relating to the future development of the CRP and more particularly the methods to be employed viz.

- Approaches
- Challenges
- Protocols for upcoming work plans
Approaches:

A key focus of the CRP is to develop novel applications of environmental or fallout radionuclides (FRNs) for assessing the impact of soil conservation measures on soil erosion and sedimentation. $^{137}$Cs and excess $^{210}$Pb and $^7$Be have already been identified as the primary radionuclides for inclusion. The following potential approaches involving these radionuclides were identified, although it was emphasized that this list should not been seen as exhaustive. Furthermore, it is to be hoped that additional approaches might be developed within the framework of the CRP.

1) Use of detailed measurements of $^{137}$Cs depth distributions and inventories to establish changes in soil redistribution rates over the period covered by bomb fallout in response to a major change in land management. The report presented by Schuller et al. usefully exemplified the potential of this approach. It should be noted however, that the change in land use/management has to date back to many years to apply successfully this approach.

2) Combined use of Chernobyl and bomb $^{137}$Cs to investigate changes in soil redistribution rates associated with the post Chernobyl period. The utilization of this approach was likely to be limited primarily to those areas of Europe where bomb and Chernobyl fallout inventories were of similar magnitude.

3) Time series measurements of $^{137}$Cs inventories aimed at quantifying changes in soil redistribution rates during specific periods, as proposed by Lobb. It was clear that the application of this approach would be constrained by the need for periods of sufficient duration between measurement campaigns to ensure that the change in inventory was greater than the uncertainty associated with the sampling and laboratory measurement procedures. Its application was therefore, likely to be restricted to areas with relatively high erosion rates. This need to undertake an initial measurement campaign to provide a baseline against which to compare future measurements meant that in general it was unlikely to be possible to obtain results from this approach during the duration of the CRP. However, there are a few detailed data sets in existence, which could be used to provide an existing baseline.

4) Use of $^7$Be appears a promising approach for short-term comparisons and measurements. The successful use of $^7$Be measurements to quantify erosion rates during individual events or short periods had been reported by Wallbrink et al. and Walling. The approach clearly involved a number of complexities and would require careful application. In addition an appropriate experimental design would be required to ensure that meaningful results were obtained. For example, in determining the effectiveness of soil conservation measures it will be necessary to have a control area for comparison purposes.

5) Use of $^{210}$Pb measurements. There was still a need to explore more fully the potential for using $^{210}$Pb measurements to estimate soil redistribution rates but potential was felt to exist for such work. The concerns raised for $^{137}$Cs in point 3 above also apply for $^{210}$Pb.
6) Conjunctive use of $^{137}$Cs, $^{210}$Pb and $^7$Be. The studies reported by Wallbrink et al. and Walling had demonstrated the potential for using two or three of these radionuclides in combination to derive information on change in soil redistribution rates through time.

7) Source fingerprinting procedures. The studies reported by Wallbrink and Onda had clearly demonstrated the potential for using fingerprinting techniques for discriminating and identifying suspended sediment sources. Coupled with an appropriate experimental design this approach could afford a powerful tool for assessing changes in sediment sources resulting from the introduction of soil conservation measures. This would be valid in cases where the sites with conservation measures and the control area exhibit contrasting fingerprint characteristics.

8) Explore the potential to use FRNs to assess or predict losses of carbon, nutrients, pesticides, etc. from the watershed.

**Challenges:**

A number of technical challenges in applying and developing the approaches outlined above were identified. These are outlined below.

i) Global Location and Environmental Conditions

The environmental conditions under which fallout radionuclides (FRNs) are currently being applied vary considerably – a variety of climates, soils, topographies and land uses. One of the most significant consequences is the variety of FRN deposition histories and current inventory levels (can be quite low or highly variable). Uncertainties still exist as to the inventories to be expected in some areas of the world (e.g. $^{137}$Cs inventories in tropical areas, excess $^{210}$Pb inventories in coastal areas with prevailing onshore winds, and high levels of supported $^{210}$Pb relative to excess $^{210}$Pb in areas such as Vietnam). In some circumstances low FRN levels can be dealt with by analysing samples for greater durations (requiring more detectors, longer studies, or alternate sampling strategies--bulking) or using more efficient detectors (requiring more capital investment), but practical limits may exist.

ii) Reference Sites

Reliable reference sites can be difficult to establish due to the high degree of variability in local precipitation and the difficulty of identifying undisturbed stable sites. In this respect, it is essential that utmost care be taken by the researchers to establish the reference inventory of FRN in their study area. Finding suitable reference sites was a particular problem in mountain areas and areas with intensive cultivation. In studies covering large areas, the use of a single value for reference inventory may be inappropriate.

iii) Fate of FRNs

There are still some uncertainties associated with the behaviour of fallout FRNs in the soil and related environments e.g. plant interception, preferential adsorption/desorption mechanisms within the soil, and plant uptake. These uncertainties require further elucidation.
There is scope for exchange of information with other groups concerned with radioecology etc (role for IAEA).

v) Use of $^7$Be

Many projects proposed to use $^7$Be. The use of $^7$Be involves considerably more complexity than the traditional $^{137}$Cs method (e.g. the need to monitor fallout inputs). Further work and testing of this approach was required before it could be widely adopted with confidence.

iv) Quality Assurance / Quality Control / Technical support

Several issues were identified under this broad topic: (a) need for training to establish a minimum skill set in field procedures, analytical procedures and data interpretation; (b) access to standards for calibration; (c) sample exchange programmes (d) analytical support for some CRP members. The IAEA’s role has been developed as Recommendations for IAEA (in a separate section).

v) New Technologies

Gamma spectrometry undergoes regular “advances” (new hardware such as in-situ detectors and software), which may or may not afford new opportunities for the use of FRN in soil erosion studies. These advances need to be rigorously tested to assess their value in our studies (possible role for IAEA). Clearly defined testing strategies are required.

vi) Appropriate Technologies

This issue was raised with regard to the analysis of $^{210}$Pb e.g. appropriate Ge detectors and the use of alpha spectrometry as an alternative method. This could be an issue for (iv).

vii) Conversion Models

Further development and validation of existing (and development of new) conversion models is required. Uncertainties associated with these models need to be better understood (e.g. grain size effects). There is a need for standardization of methods, although with the development of new approaches the potential for standardisation was bound to reduce. Circulation of models and guidelines for their application within the CRP members was proposed.

viii) Source fingerprinting

Although basic procedures were now well established, there was a need to explore the application of new fingerprint properties capable of providing improved discrimination between potential sources and to develop rigorous statistical/numerical procedures for establishing the relative importance of the sources considered. Again, an appropriate and rigorous experimental design was essential to ensure the generation of meaningful results.

ix) Climatic changes (extreme events or storms)
It was important that any attempt to quantify changes in soil redistribution rates resulting from changes in land management should be able to distinguish from those changes arising from climate change alone (frequency and intensity of extreme events or storms). Such considerations should be incorporated in the experimental design for a study.

x) Closer linking of the two components of the CRP

Although there were close links between the two components of the CRP, it was important that these links should be further strengthened to ensure that the results obtained from the CRP were applicable at both the field and watershed scales. This would also promote the integration of studies focusing on either on-site or off-site effects.

Protocols for upcoming work:

The potential for developing a set of protocols or a framework for upcoming work within the CRP was discussed. Although the need for such protocols/frameworks was accepted it was felt that the nature of the CRP precluded the establishment of prescriptive guidelines.

Specifically to consider that:

a) The CRP was effectively promoting research aimed at exploring the development of novel approaches to the use of FRNs for assessing soil erosion and more particularly the effectiveness of soil conservation strategies. It was emphasised that there can be no single method used in applying FRNs in erosion studies. Methods will be specific to the FRN being used, the research question(s) being asked, the environmental conditions under which the study is being carried out and the local land management conditions.

b) The CRP aimed to explore and develop novel approaches and should not be unduly constrained. The general guidelines developed for the use of $^{137}$Cs and documented in the Kluwer’s Handbook would provide good guidance for establishing project methodologies.

c) It was emphasised that all studies should be underpinned by a carefully conceived experimental design. Measurements themselves cannot provide the information or answers required. They can be used as a tool within the experimental design. To ensure the use of appropriate experimental designs, it was suggested that an internal review process should be established immediately (role for IAEA). It was noted that it is much better to conduct this review at an early stage than to identify problems with the experimental design after the work had been undertaken and results were being presented.

d) It is envisaged that some guidelines for the application of some of the approaches mentioned above may be established at the second RCM when the participants have defined the specific soil conservation technologies to be studied, and have gathered basic information on the FRNs inventories in the study areas.
4.2 REPORT OF GROUP TWO: GENERAL DISCUSSIONS ON DOCUMENTATION OF SOIL CONSERVATION TECHNOLOGIES (ASSESSED WITH FRNs METHODS)

In this regard the Group considered the following main points:

Soil and Water Conservation (SWC) technologies should be described in a **standard and comprehensive** way (talking the same language and allowing comparison) in order to fully document the technologies and promote exchange of information.

For this purpose use WOCAT standard terminology (e.g. SWC categorization) and procedures. Issues to be described (according to WOCAT) are the following:

**FROM THE WOCAT QUESTIONNAIRE ON SWC TECHNOLOGIES**

1 GENERAL INFORMATION
1.1 Contributing SWC specialist
1.2 Brief identification of SWC Technology
1.3 Area information
1.4 Land degradation

2 SPECIFICATION OF SWC TECHNOLOGY
2.1 Description
2.2 Purpose and Classification
2.3 Status
2.4 Design, technical and management specifications
2.5 Natural environment
2.6 Human environment and land use
2.7 Costs
2.8 Supportive technologies

3 ANALYSIS OF THE SWC TECHNOLOGY
3.1 Benefits, advantages and disadvantages
3.2 Economic analysis
3.3 Adaptation
3.4 Acceptance or adoption
3.5 Concluding statements

**Expected results:**
- Compilation of the existing knowledge about these technologies in a comprehensive way
- Identification of the knowledge gaps
- Clarify pros and cons: environmental and socio-economic efficiency, inputs/outputs, etc.

Be aware: if you use an existing methodology like WOCAT there will always be some disadvantages because it has not been developed specifically for your purpose alone. However, the advantages are that you can share with others. Try to use as much as possible...
the existing methodology and provide feedback to WOCAT to improve. As necessary, make additions/modifications.

**Aspects not covered by WOCAT:**

Specific information about FRN experiments:

1. Experimental layout (using a standard methodology for the Inventory of erosion plots e.g. European Society of Soil Conservation, see website in the references)
   - specific site information: e.g. additional soil information, geographic location, history of site, duration of experiment …
   - treatments
   - design (layout, size, number, …)
   - parameters measured
   - data collection (conventional and FRN - techniques)
   - analytical techniques and references

2. Results: Environmental (e.g. from erosive events: rainfall, runoff, soil, nutrient, pesticide losses / depositions) and agronomic data
   Need to develop a standard database???

3. Data analysis (including documentation of conversion models) and interpretation

4. Disseminate guidelines/ recommendations
   - share the knowledge and make it available
   - make others (researchers and practitioners) involved (seek feed-back)
   - presentation according to different target/user groups
   - use of WOCAT or other networks? (create a link between WOCAT and CRP FRN-database).

5. Budget implications and sources
6. Analysis of advantages/limitations in the use of FRNs
7. Feedback to CRP
   - Progress made in implementing the work plan and contributing to achieve the objectives of the CRP.
   - if not, recommendation for future work

**Additional points for the CRP:**

- Define what is internal information to be shared and what should go public (internet), role of IAEA.
- Present the results in scientific meetings and publish papers in scientific journals
- Establish a database for linkage to WOCAT
4.3 RECOMMENDATIONS FOR CONSIDERATION BY IAEA

The following recommendations were developed by the participants of the CRPs D1-50-08 and F3.10.03 who attended the first RCM in Vienna in May 2003. Action on these recommendations is considered necessary for the IAEA to establish the technical and scientific capacity to support the CRP and related activities. Such support is considered critical to achieve major advances in the use of fallout radionuclides in soil erosion and sedimentation research.

The International Atomic Energy Agency (IAEA), through its co-ordination of the current CRP and the preceding CRP, has had a significant impact in expanding and enhancing the use of fallout radionuclides in soil erosion and sedimentation research worldwide.

The IAEA's commitment to this role is critical to the success of the current CRP and to related current and future activities of the IAEA Programmes. Although the IAEA's role as a coordinator is greatly valued, the CRP participants feel that the IAEA should embrace a broader vision of their role; this means that the IAEA must be more directly involved in the facilitation of this research and development work.

The group of participants formulated the following recommendations (listed in descending priority order):

1) Establish and sustain technical analytical capacity

The measurement of the radionuclides by HP gamma spectrometry is an essential component of the application of these techniques in soil erosion and sedimentation research. In view of the varying levels of expertise and experience of the CRP participants and their associated laboratories, technical support is also needed to varying degrees. Two main areas of support provision were identified. Firstly, some participants require technical support in the use of gamma spectrometry (hardware, software and operation). Although manufacturers and suppliers of gamma spectrometers do provide technical support, there is a need for specialised support from an independent body, with specific expertise in the measurement of fallout radionuclides (\(^{137}\text{Cs}, {210}\text{Pb}, {7}\text{Be}\)) in soil erosion and sedimentation research, to which participants can have easy access. IAEA is clearly the organization to satisfy this need. Secondly, the laboratory facilities available to some participants are very limited in terms of both capacity and analytical capability (e.g. low-energy photon detectors for measuring \(^{210}\text{Pb}\)). There is a need to provide analytical support to such participants in order to increase the number of necessary analyses and to extend their capabilities to make use of radionuclides other than \(^{137}\text{Cs}\) in their research.

It is therefore recommended that IAEA should commit resources to establish and sustain a laboratory capable of providing both technical expertise and analytical capacity to support CRP participants. As a minimum this laboratory facility should include:

a) Two low background HPGe detectors capable of covering the energy range required for the determination of \(^{210}\text{Pb}, {137}\text{Cs} \text{and} {7}\text{Be}\).

b) Sample preparation equipment for analysis of soil and sediment samples by gamma-ray
c) A laboratory technician to run/support the gamma spectrometry systems.
d) A professional technical officer capable of providing technical advice and assistance to CRP participants.

These laboratory resources would provide valuable on-site and remote training capacity.

2) Establish and sustain research capacity

To effectively support the research of the CRP, the IAEA must be actively and directly involved in such research. It is recommended that IAEA commit resources to establish and sustain scientific/technical capabilities in the use of fallout radionuclides in soil erosion and sedimentation. These resources should consist of:

a) One scientist to conduct research in soil erosion and sedimentation using fallout radionuclides.
b) One technician to support the research activities of the scientist. A technician is essential for carrying out an effective field research programme, calculation and assembly of data, running of conversion models, etc.

The activities of this research team could include:

- Research on soil erosion and sedimentation using fallout radionuclides. This research would not only include soil erosion and sedimentation processes but also soil redistribution related environmental studies, i.e. carbon sequestration, pesticide contamination, etc..
- Provision of technical support in the selection of the study area, identification of reference sites, field sampling design, sampling methods and samples processing (Essential for beginners).
- Provision of scientific/technical advice on data collection, processing and interpretation (experimental designs, conversion models, etc.)
- Research on the fate of fallout radionuclides in main agro-ecological zones and soil types (adsorption, desorption, plant interception, plant uptake, etc.).
- Research on sampling equipment, techniques and strategies for utilising/presenting spatially distributed data (e.g. application of geostatistics, GIS, DEM, etc.).
- Development and use of conversion models. Developing and testing independent validation methods for the soil erosion/sedimentation rates obtained with the use of fallout radionuclides.

3) Provide “spiked” standards of $^{137}$Cs and $^{210}$Pb and $^{7}$Be

This recommendation could fall under recommendation 1, but it was separated to emphasize the importance of spiked standards and to encourage more immediate action.

The IAEA has an important role to play in ensuring quality assurance and quality control in the laboratories of the CRP participants. To this end, it was recommended that the IAEA provide each CRP participants with a 1 kg soil sample with a density of 1 g cm$^{-3}$
and activities of 10 Bq kg\(^{-1}\) \(^{137}\)Cs and 50 Bq kg\(^{-1}\) \(^{210}\)Pb.

It is also envisaged to utilize \(^{7}\)Be in short-term mechanistic studies at several stages during the implementation of the work plan of the project. As there are no reference materials for \(^{7}\)Be available in the market it is recommended to prepare a spiked matrix (soil/sediment) with known activity of \(^{7}\)Be for use at appropriate stages of the CRP. In view of its short half-life and different rates of progress and application by individual groups, these \(^{7}\)Be standards would need to be produced and circulated as required by the participants during the CRP. In addition, the IAEA should organize an inter-comparison exercise for the \(^{137}\)Cs and \(^{210}\)Pb measurements among the participating laboratories.

4) Acquisition and testing a modern “in-situ” detector for soil erosion studies

This recommendation could be subsumed under recommendation 1, but was separated to signify a lower priority in terms of the CRP implementation. Discussions amongst participants in the CRP identified differences of opinion as to the potential for use of in-situ detectors in soil erosion and sedimentation research. Their use had already been trialled by participants in the previous CRPs with equivocal results. Furthermore, the use of such detectors was likely to be limited in areas of the world with low \(^{137}\)Cs inventories and in more remote areas, due to the need for ready access to a supply of liquid nitrogen. Important uncertainties existed regarding calibration and the effects of soil moisture content on the measurements obtained. However, technical advances in both hardware and software were being made and, in view of the potential advantages of in-situ measurements, it was important that a watching brief should be maintained on such advances and that further field trials should be undertaken as appropriate. Rigorous protocols should be established for comparison of the performance of this equipment against conventional laboratory measurements. IAEA was an appropriate body to assume this role in testing new nuclear technologies such as “in-situ” detectors.

5. CONCLUSIONS AND RECOMMENDATIONS OF THE MEETING

During the final session of the first RCM the participants made the following conclusions and recommendations:

1) The research network was established with the twelve research contractors and eight agreement holders participating at the first RCM held in Vienna, 19-23 May 2003.

2) The participants recognised the inter-relationship between soil erosion (and sedimentation) processes and also between soil erosion and other land degradation processes.

3) A key focus of the CRP is to develop novel applications of environmental or fallout radionuclides (FRNs) for assessing the impact of soil conservation measures on soil erosion and sedimentation. \(^{137}\)Cs, excess \(^{210}\)Pb and \(^{7}\)Be have already been identified as the primary radionuclides for inclusion.
4) Potential approaches involving these radionuclides were identified, although it was emphasized that this list should not been seen as exhaustive. Furthermore, it is to be hoped that additional approaches might be developed within the framework of the CRP.

5) A number of technical issues considered as challenges in applying and developing the approaches involving radionuclides were outlined.

6) The potential for developing a set of protocols or a framework for upcoming work within the CRP was discussed. Although the need for such protocols/frameworks was accepted it was felt that the nature of the CRP precluded the establishment of clear guidelines.

7) An integrated approach should be applied and developed in studying specific soil conservation technologies together with other land use/management practices at the watershed level.

8) Soil and Water Conservation (SWC) technologies should be described in a standard and comprehensive way (talking the same language and allowing comparison) in order to fully document the technologies and promote exchange of information. For this purpose WOCAT standard terminology (e.g. SWC categorization) and procedures should be utilised.

9) Guidelines were also developed for aspects not covered by WOCAT.

10) It was recommended to collect relevant references to the new FRN methodologies for distribution to the participants.

11) Detailed and prioritised requirements in terms of back-up research, laboratory and other support for the CRP were discussed and agreed to. The document “Recommendations for IAEA consideration” was prepared and submitted.

12) The second RCM will be held in October 2004. Two venues were proposed and Istanbul, Turkey was selected to host the meeting. The other venue (Beijing, China) will be considered for the third RCM.

6. SELECTED REFERENCES (AND WEBSITES)


Organization for Economic Co-operation and Development (OECD). Environmental Indicators for Agriculture. 3 volumes (pdf files) from the OECD website at: http://www1.oecd.org/agr/env/biodiversity/index.htm then look under “Links and related information” where you will find the pdf files.


Annexes
ANNEX A

PROJECT DOCUMENT
1. **Title of the CRP:**

   Assess the effectiveness of soil conservation techniques for sustainable watershed management and crop production using fallout radionuclides (D1.50.08)

2. **Proposed duration:** 5 years (2002-2007).

   To be jointly implemented by the Soil and Water Management & Crop Nutrition Sub-programme (E1) and the Isotope Hydrology Sub-programme (G1).

3. **Justification:**

   In response to the Agenda 21, produced by the Earth Summit in Rio de Janeiro in 1992, the UN System launched EARTHWATCH, a worldwide environmental programme. The IAEA joined this initiative through a series of activities on environmental monitoring, impact assessment and environmental protection. In this context, recognizing that soil erosion and associated sedimentation are a serious threat to sustainable agricultural production and environmental protection, two IAEA Divisions, the Joint FAO/IAEA Division of Nuclear Techniques and the Division of Physical and Chemical Sciences joined forces to plan, organize and implement activities to exploit the use of fallout radionuclides and develop methodologies for the assessment of soil redistribution and hence, soil erosion and sedimentation. The two closely linked CRPs: Soil Erosion (D1-50.05) and Sedimentation (F3-10.01) have been successfully completed and resulted in a number of achievements. A significant number of research groups equally distributed across developed and developing countries now have the capacity to conduct such investigations. Some highlights of the results obtained are presented below:

   - Standardised methods and protocols for application of the $^{137}$Cs technique have now been successfully developed. These have been documented through the production of a “Handbook for the Assessment of Soil Erosion and Sedimentation using Environmental Radionuclides”.

   - The data assembled by the contributors to the CRP using standardized protocols for the $^{137}$Cs technique have provided directly comparable and reliable information on soil erosion rates in a wide range of environments worldwide. Countries represented include Argentina, Australia, Brazil, Canada, Chile, China, Greece, Morocco, Romania, Russia, Slovakia, UK, USA and Zimbabwe. Values range from (0 - $>$100 t ha$^{-1}$ year$^{-1}$ and demonstrate that in general local land use exerts a more important influence on the range of values encountered than climate or lithology and soil type. However, the influence of the latter can be readily distinguished.

   - The $^{137}$Cs technique is now a well-established nuclear technology that should be broadly disseminated. To date over 2500 publications are recorded in the Internet URL [http://hydrolab.arsusda.gov/cesium137bib.htm](http://hydrolab.arsusda.gov/cesium137bib.htm). This nuclear technology is mature and ready for transfer through IAEA Technical Cooperation Projects. Currently a regional IAEA/RCA Technical Co-operation Project RAS/5/039 “Restoration of Soil Fertility and Sustenance of Agricultural Productivity”, Part II: Measuring soil erosion/sedimentation and associated pesticide contamination is implemented through the period 2002-2004 with seven
participating countries (CPR, INS, MAL, PAK, PHI, SRL, VIE). In addition national projects on land degradation / dam reservoirs siltation have a soil erosion component.

- The $^{137}$Cs technique has the potential to provide an improved understanding of the relationship between rates of soil loss and soil quality, soil carbon and nutrient redistribution and the fate of agrochemicals and related contaminants at the landscape scale. This should be further investigated.

- There has been a marked increase in the skill levels of the CRP participants and their laboratories, as well as in their capacity to undertake routine applications of the method. They have gained a better understanding of soil erosion processes as well as providing a set of the guidelines for selecting soil conservation technologies. These outputs include the publication of over hundred individual papers, one special issue in Acta Geologica Hispanica and another special issue of Soil and Tillage Research.

Estimates from a Global Assessment of Soil Degradation (GLASOD) made by UNEP in 1992 revealed that one third of the agricultural soils or 2 billion ha. is affected by several types of soil degradation, of which 84% are affected by wind and water erosion. Measuring soil erosion and productivity loss is essential to indicate priorities for action in land rehabilitation for sustainable productivity.

In developing countries, few national soil conservation programmes are operational and many have been terminated due to economic measures. Soil erosion research requires substantial commitment in terms of skilled staffing, equipment and operational budgets.

As there is an urgent need to control soil erosion and associated sedimentation worldwide and here there is still considerable scope for the wider application of $^{137}$Cs and other fallout radionuclides in these studies, the Joint FAO/IAEA Division in close collaboration with the Land and Water Development Division (AGL) of FAO and UNEP, plans to develop further initiatives in this field.

Two expert consultations were held in October 2000 (G1) and May 2001 (E1) to discuss ways and means of exploiting recent developments in the use of fallout radionuclides in soil erosion/sedimentation within an agricultural/watershed context, and in particular to assess the impact of major land use types on erosion and sedimentation rates and the effectiveness of specific soil conservation technologies. The consultations recommended the initiation of two CRPs on “Isotope Techniques for Sediment Source Characterization” and “Using fallout radionuclides to evaluate the effectiveness of soil conservation measures for sustainable crop production”. Subsequently, the first CRP was approved by the PCC in Feb. 2001 but has not yet been implemented. Due to similar overall objectives, it is now recommended to implement a single CRP jointly under E1 and G1.

The following main conclusions were produced from the consultations:

1. Results from the past CRPs on soil erosion and sedimentation have shown that the fallout $^{137}$Cs technique is cost-effective, providing reliable, spatially distributed and time-integrated data, not only on soil erosion rates, but also on soil redistribution at the landscape level. This technique, however, has been mainly developed for documenting long-term (about 40 years) average erosion rates. Further refinement and the combined use of $^{137}$Cs, $^{210}$Pb and $^{7}$Be for measuring short- (single rainfall event), medium- (~40 years) and long- (~100 years)
term soil erosion rates and patterns of soil redistribution rates are needed in the context of soil conservation studies.

2. The World Overview of Conservation Approaches and Technologies (WOCAT), co-sponsored by FAO and UNEP, among others, through standardized approaches and methodologies provides a valuable framework for the evaluation of soil and water conservation (SWC) technologies. WOCAT is a network of soil and water specialists from all over the world, organized as a consortium of national and international institutions operating in a de-centralized manner. A wealth of soil conservation knowledge and information exists and it is stored in a database with easy access through several ways media, i.e. books, CDs, maps, Internet, etc. to improve decision making. WOCAT promotes sustainable land management, thus contributing to the implementation of the United Nations Conventions, such as the Convention to Combat Desertification (CCD), the Framework Convention on Climate Change (FCCC), and the Convention for Biodiversity (CBD).

3. The IAEA should support the efforts of other UN organizations, such as FAO and UNEP in combating land degradation and soil erosion in particular. Collaboration with CGIAR centres (ICARDA, ICRAF) and other Advanced Research Institutes should be also established.

The proposed CRP will be conducted through the establishment of a network of National Agricultural Research Systems (NARS) and International Agricultural Research Centres (IARCs) and Advanced Research Organizations. Appropriate co-ordination will be established with the IAEA Technical Co-operation Programme. Synergies will be enhanced through appropriate linkage to existing networks on soil conservation. In this regard close collaboration will be established with FAO, Land and Water Development Division, UNEP and other institutions through WOCAT. In implementing the project, selected agro-ecological zones will be targeted and specific benchmark areas or flagship sites will be identified and selected as focal points for strategic research and development activities.

The Agency’s involvement is justified in that:

* A suite of fallout radionuclides is essential to obtain spatially distributed and time integrated estimates of soil erosion rates. In addition to the well-established $^{137}$Cs technique, these include the combined use of $^{137}$Cs, $^{210}$Pb and $^7$Be to obtain more complete information on the soil erosion rates over several spatial and time scales for evaluating the effectiveness of soil conservation measures. In addition, other nuclear techniques, such as the soil moisture neutron probe and several isotope techniques can be utilised to study water storage and nutrient cycling processes respectively.

* The objectives of the proposed CRP are in line with the objectives of projects E1.02 and G.1.02 (IAEA PWB 2002-2003) and consistent with the Agency’s Medium Term Plan, and with the strategic objectives of the FAO’s Department of Agriculture.

* The research approaches envisaged are highly relevant to sustainable use and conservation of natural resource base of all Member States worldwide, in particular those severely affected by wind and water erosion, following the recommendations of Agenda 21 of the Earth Summit in Rio de Janeiro, 1992 (Chapters 10 and 12).

* The proposed CRP will entail the formation of a network of international and national research institutes utilising fallout radionuclides and working on soil erosion research
and soil conservation. Experimental protocols will be established to develop further the combined use of fallout radionuclides to address soil conservation priority issues in an integrated manner.

* The nuclear technologies developed under this project should be transferred to Member States through the IAEA Technical Co-operation Programme to underpin the selection of effective soil conservation measures for controlling soil erosion. To ensure direct transfer of the results and to maximise the impact of the outputs, several activities will be promoted to disseminate the information generated through the project, i.e. the results should be presented at scientific meetings and published in international journals. Whenever possible, the experiments should be undertaken in farmers’ fields and close links should be established with existing extension services. Also, database formation and validation of models should be considered for extrapolation of the results.

4. **Overall Objective**

To develop diagnostic tools for assessing soil erosion and sedimentation processes and effective soil conservation measures for sustainable watershed management and crop production.

5. **Specific Research Objective**

- To further develop fallout radionuclide methodologies, with particular emphasis on the combined use of $^{137}$Cs, $^{210}$Pb and $^7$Be for measuring soil erosion and sedimentation over several spatial and time scales.
- To establish standardized protocols for the combined application of the above techniques to develop watershed management decision making models and tools for the remediation of erosion and sedimentation problems.
- To utilize these techniques to assess the impact of short-term changes in land use practices and the effectiveness of specific soil conservation measures.

6. **Expected Outputs**

Expected outputs from the CRP should include:

a) A package of methodologies and management tools based on nuclear techniques and validated by sediment transport models focused towards planning and design of erosion and sedimentation remediation strategies

b) A better understanding of the effectiveness of specific soil conservation measures in controlling soil erosion and sedimentation for sustainable watershed management and crop production.

c) Strengthening the capacity of national and regional institutions on erosion and sedimentation remediation technologies through training, workshops and direct involvement of national institutions in identified flagship sites.

d) Publication of the methodologies, guidelines and research results.
These outputs together with the goal and purpose statements are presented in a logical framework matrix below.

### 7. Project Log Frame

<table>
<thead>
<tr>
<th>Narrative summary</th>
<th>Verifiable indicators</th>
<th>Means of verification</th>
<th>Important assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goal</strong> (overall objective):</td>
<td>Farmers adopt better land use type and management technologies for controlling soil erosion</td>
<td>Changes in land use patterns and management practices, crop yield data</td>
<td>Policy and decision makers commitment to support the implementation of the strategies/technologies developed</td>
</tr>
<tr>
<td>To develop improved land management strategies for sustainable crop production through effective soil erosion control practices.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Purpose (specific objectives) | Participating institutes are using fallout radionuclides to select effective measures to control soil erosion | Reports of participating institutes containing: | |
| a)To further develop fallout radionuclide methodologies, with particular emphasis on the combined use of $^{137}$Cs, $^{210}$Pb and $^{7}$Be for measuring short-term soil erosion and redistribution rates. | | Data on soil erosion rates | |
| b)To establish standardized protocols for the combined application of the above techniques. | | Data on soil and water quality indicators (soil organic matter, nutrient contents) | |
| c)To utilize these techniques to assess the impact of short-term changes in land use types and management on soil erosion rates and the effectiveness of specific soil conservation measures. | | Crop yield data | |

| Outputs: | Standardised methodologies and | Publications and project reports. | Partners institutions have the |
| 1. Standardized methodologies and | | | |

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*Please note that the table above is a logical framework matrix that outlines the goal, purpose, and outputs of a project related to developing improved land management strategies for sustainable crop production through effective soil erosion control practices.*
<table>
<thead>
<tr>
<th>Narrative summary</th>
<th>Verifiable indicators</th>
<th>Means of verification</th>
<th>Important assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>guide of fallout radionuclides for the assessment of the impact of short-term changes in land use types and management and the effectiveness of specific soil conservation measures.</td>
<td>guidelines for their application available</td>
<td></td>
<td>facilities and capacities, with IAEA support to undertake isotopic studies</td>
</tr>
<tr>
<td>2. Reliable data on short-term soil erosion rates and soil redistribution patterns under different land use types and management in a range of agro-ecological zones.</td>
<td>Reliable data on short-term erosion rates and soil redistribution patterns available, in the context of soil conservation measures.</td>
<td>Publications and Project reports</td>
<td>Partner institutions utilise standardised protocols to evaluate land use and soil conservation measures</td>
</tr>
<tr>
<td>3. Better understanding of the effectiveness of specific soil conservation measures in controlling soil erosion for sustainable crop production.</td>
<td>Effective soil erosion control practices identified and guidelines available</td>
<td>Guidelines Publications Project reports</td>
<td>Partner institutions have skilled staff to evaluate the effectiveness of soil conservation measures.</td>
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<tr>
<td>4. Strengthening the capacity of national institutions to assess soil erosion rates through training, workshops and other activities.</td>
<td>NARS personnel skills and physical capacities enhanced</td>
<td>Quality publications and presentations</td>
<td>Committed staff participate. Additional training. Functional network of contractors and agreement holders.</td>
</tr>
<tr>
<td>6. Results communicated</td>
<td>Reports by contract holders. Methodologies, guidelines and scientific papers published. Presentations in relevant scientific meetings</td>
<td>Evaluation of reports Publications available</td>
<td>Significant results obtained and manuscripts submitted. Timely submission of reports by participants</td>
</tr>
</tbody>
</table>
### Activities:

<table>
<thead>
<tr>
<th>Activities</th>
<th>Verifiable indicators</th>
<th>Means of verification</th>
<th>Important assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Final RCM to present all results</td>
<td>5. Hold Final RCM (2007)</td>
<td>5. Collection of final reports and manuscripts.</td>
<td>5. Preparation and timely submission of final reports by all participants</td>
</tr>
</tbody>
</table>

### 8. Work Plan

Under past CRPs significant developments in the refinement and standardisation of the $^{137}$Cs technique have been achieved. It is intended to continue further this development work on the use of fallout radionuclides, and particularly the combined use of use of $^{137}$Cs, $^{210}$Pb and $^7$Be for establishing rates and patterns of soil redistribution over several spatial and time scales. Although it is known that several factors influence soil redistribution within the landscape, land use was found to be a major factor influencing soil erosion.

The focus of the proposed project will, therefore, be to further develop the use of fallout radionuclides to assess the impact of major land use types and their changes on rates and patterns of soil redistribution, and to evaluate the effectiveness of specific soil conservation measures in controlling soil erosion.
8.1 Target topics

The target topics include:

- Selection of representative farms/watersheds in terms of the land use and management and specific soil conservation measures to be assessed.

- Further development of fallout radionuclide methodologies for measuring soil erosion and redistribution over several spatial and time scales. Particular emphasis should be given to the combined use of $^{137}\text{Cs}$, $^{210}\text{Pb}$ and $^{7}\text{Be}$.

- Establishment of standardized procedures and guidelines for the application of the developed methodologies.

- Utilization of the developed methodologies to assess the impact of short-term changes in land use/management practices and the effectiveness of specific soil conservation measures.

8.2 Sites and partner selection

The following criteria should be considered in the selection of sites and partners.

Sites should be:

- Well distributed among the main categories of soil conservation measures. (Agronomic, vegetative, management or combined, according to WOCAT)

- Representative of a range of agro-ecological zones and land use types (FAO, UNEP).

At locations where soil erosion has been identified as a serious problem (according to WOCAT) and conservation measures are being implemented.

- Well characterised in terms of landscape, soil type, and available climate data according to WOCAT.

- Due consideration should be given, in the selection of sites, to other on-going projects of the IAEA Technical Co-operation and Research Contract Programmes.

Partners should represent:

Institutions working on soil conservation programmes and nuclear applications in soil erosion/sedimentation research. They should form multidisciplinary teams, with expertise on:

- nuclear techniques, with experience in measuring fallout radionuclides,
- soil erosion and conservation and
- other relevant disciplines, including socio-economics.

Collaboration with other UN organizations (UNEP, FAO), CGIAR centres (ICARDA, ICRAF) and other Advanced Research Institutes will be established.
8.3. Isotope techniques for use in the target topics:

Fallout radionuclides, with particular emphasis on the combined use of $^{137}$Cs, $^{210}$Pb and $^7$Be for measuring soil erosion rates and establishing patterns of soil redistribution at several spatial and time scales.

8.4. Other Resources required.

Laboratory support from the Agency’s Laboratories at Seibersdorf, as well as from the Agreement Holders in terms of training, quality assurance, analytical services and strategic research will be essential to implement the activities of this CRP.

8.5. Timeframe

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<td>Activity 2</td>
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<td>Activity 4</td>
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<td>Activity 5</td>
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<td>Activity 6</td>
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</table>

Activity 1.

Activity 2.
Submission of proposal for joint CRP (E1 and G1) to PCC (Feb. 25, 2002) for approval. Advertise the CRP (March 2002) - Receipt of research contract and agreement proposals (deadlines by the end of August 202). Selection of collaborators based on criteria given in point 8.2 above. Establish a network of national and international agricultural research institutes. The proposed CRP will involve approximately ten Research Contract Holders from NARS in developing countries and 4-5 Research Agreement Holders from CGIAR and Advanced Institutes. Strategically award individual research or technical contracts.

Activity 3.
Organise 1st RCM to present the overall work plan of the project and discuss and agree on the experimental design, work plans and protocols for the next 18 months. For this purpose, the attendance of all contract and agreement holders will be essential. Introductory
Workshop on the use of fallout radionuclides in soil erosion research and WOCAT methodologies for evaluating soil conservation measures. Preparation of the progress report of the First RCM.

**Activity 4.**
Organise 2nd RCM to evaluate results from the experimental work plans identified at the 1st RCM, with emphasis on the use of fallout radionuclides and the application of standardised protocols. Testing of conversion models.

A critical examination of the first two years implementation will be made based on the progress reports of the participants and modifications/adjustments of the work plan of the project will be introduced, if necessary, to ensure the achievement of the objectives. Discussion and agreement on the follow-up experimental work plans for the next 18 months. Preparation of the progress report of the Second RCM.

**Activity 5.**
Organise 3rd RCM to evaluate the preliminary results obtained on the impact of major land use systems and land use change on soil erosion rates and the effectiveness of soil conservation measures in controlling soil erosion rates. Mini-training workshop on database creation and modelling. Preparation of guidelines for selecting effective soil conservation measures. Provision of guidelines for preparation of final reports and summaries, and final publication of results (IAEA TECDOC or external publication). Preparation of the progress report of the Third RCM.

**Activity 6.**
Organise 4th RCM to present the final reports of the CRP. In the light of the objectives of the CRP, participants will critically examine the outputs/achievements and draw conclusions from the project. Also formulate recommendations for further research. Preparation of the final report of the CRP.

Development of a CRP database to complement the WOCAT integrated database. Develop guidelines for selecting effective soil conservation measures for sustainable agricultural production and disseminate them through WOCAT. Synthesise and disseminate information collected through scientific publications and IAEA technical documents (TECDOCs).

8.6. **Inputs**

**8.6.1 Financial resources required (In US $ )**

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<tr>
<td>Technical contracts</td>
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<tr>
<td>Co-ordination Meetings</td>
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<td>40,000</td>
<td>45,000</td>
<td>Vienna</td>
<td>Vienna</td>
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</table>
8.6.2 Other financial resources required
Some strategic research issues identified during the project implementation may require specific financial support through technical contracts. High precision and quality-assured measurements of fallout radionuclides, in particular $^{210}$Pb and $^7$Be should be made in major established analytical laboratories. Financial support may be granted for providing such services to those contractors, who do not have adequate analytical facilities but conducting high quality work.

9. Assumptions

- National Institutes have adequate (inter-disciplinary teams) staffing and field/laboratory facilities to implement integrated activities on the use of fallout radionuclides in soil erosion studies, with emphasis on soil and water conservation.
- Study sites will be selected in diverse agro-ecological zones, identifying specific flagship sites as focal points for strategic research and development activities.
- The research contract obligations are fulfilled.
- Additional training of junior staff, as required.
- Contractors will publish their research results and utilise proper mechanisms for dissemination of the results.
- Agreement holders will provide strategic support to implement the main elements of the project.
- Continuity of the CRP management (administration and technical coordination) provided by the IAEA.

10. Brief Description for the IAEA Bulletin

This CRP will be launched in 2003 to further develop and standardise fallout radionuclide methodologies, with particular emphasis on the combined use of $^{137}$Cs, $^{210}$Pb and $^7$Be for (i) measuring soil erosion rates and establishing soil redistribution patterns at several spatial and time scales, and ii) to utilize these techniques to assess the impact of short-term changes in land use types and the effectiveness of soil conservation measures tailored to local conditions and resources. These new and refined methods will allow systems of land use and management, and the effectiveness of specific soil conservation technologies, to be rapidly evaluated in a cost-effective manner. The new techniques will also provide an improved understanding of the relationships between rates of soil loss and soil quality, soil carbon and nutrient redistribution and the fate of agrochemicals and other environmental contaminants at the landscape level.

11. Selected References


IAEA, 1998. Use of $^{137}\text{Cs}$ in the study of soil erosion and sedimentation. IAEA TECDOC-1028, IAEA, Vienna, Austria.


ANNEX B

LIST OF PARTICIPANTS
LIST OF PARTICIPANTS

First Research Co-ordination Meeting (311-RC-888)
of the Co-ordinated Research Project “Assess the effectiveness of soil
conservation techniques for sustainable watershed management and crop
production using fallout radionuclides” (D1-50-08)

19 – 23 May 2003
Vienna International Centre, Vienna
Room VI C07 (Ext. 21361)

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First RCM (311-RC-888)
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(F3.10.03)

Vienna, Austria
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ANNEX C

PROGRAMME OF THE MEETING
First RCM of the CRP “Assess the effectiveness of soil conservation techniques for sustainable watershed management using fallout radionuclides”
Conference Room VI C07

Monday, 19 May

08:00-09:00 Registration
09:00-09:25 Official Opening and presentation of the subprogramme
P.M. Chalk (IAEA)
09:25-10:00 Remarks by Scientific Secretary
F. Zapata (IAEA)

SESSION I  Chairperson: P. M. Chalk (IAEA)
Regional Applications, South America
10:00-10:30 Alfonso Bujan (Argentina)
Utilization of $^{137}$Cs, $^{210}$Pb and $^7$Be to investigate soil erosion and sedimentation in Pampa Ondulada region, Argentine
10:30-11:00 Coffee break
11:00-11:30 Osny Bacchi (Brazil)
Use of $^{137}$Cs fallout redistribution analysis for the determination of optimal width of riparian forest for erosion control
11:30-12:00 Paulina Schuller (Chile)
Use of $^{137}$Cs measurements to estimate changes in soil erosion rates associated with changes in cultivation practices on agricultural land
12:00-12:30 General discussion on papers of Session I
Discussant: D. Lobb
12:30-14:30 Lunch break

SESSION II  Chairperson: D. E. Walling (U.K.)
Regional Applications, Asia
14:30-15:00 Yong Li (P.R. China)
Profile variation of $^{137}$Cs, $^{210}$Pb$_{ex}$ and soil carbon as affected by intensive tillage on slope land
15:00-15:30    Coffee break

15:30-16:00    M. Sheikh (Pakistan)
Status of soil erosion and sedimentation in Pakistan and role of
nuclear techniques in soil conservation techniques

16:00-16:30    Son Hai Phan (Vietnam)
Assessment of soil erosion on some industrial and annual crops
in the Central Highland of Viet Nam using $^{137}$Cs, $^{210}$Pb and $^7$Be

16:30-17:00    Moncef Benmansour (Morocco)
Use of radionuclides to investigate soil erosion on agricultural
fields in Morocco and to evaluate the effectiveness of soil
conservation measures

17:00-17:30    General discussion on papers presented in Session II
Discussant: P. Wallbrink

Tuesday, 20 May

SESSION III  Chairperson: Wojciech Froehlich (Poland)
Methodological Developments (Radionuclides)

09:00-09:30    D.E. Walling (UK)
Testing and validating conversion models for use with $^{137}$Cs
measurements in soil erosion investigations

09:30-10:00    D. Lobb (Canada)
Canadian research on soil erosion and soil conservation using
radioisotopes

10:00-10:30    Coffee break

10:30-11:00    C. Bernard (Canada)
Assessment of soil redistribution under conventional and
conservation tillage practices in cool temperature regions from
radiotracer measurements

11:00-11:30    P. Wallbrink (Australia)
Determining sources of sediment to the Westernport Bay,
Victoria, Australia, using modelling, geochemistry and fallout
nuclides

11:30-12:00    J. Ritchie (USA)
Assessing soil and soil carbon movement patterns under long
term conservation tillage practices

12:00-12:30    General discussion on papers presented in Session III
Discussant: V. Golosov
12:30-14:00  Lunch break

SESSION IV  
**Chairperson: J. Ritchie (USA)**  
Regional Applications, Europe and other regions

14:00-14:30  V. Golosov (Russia)  
Application of radionuclide for assessment of soil conservation works in forest-steppe zone of Central Russia: approaches and perspectives

14:30-15:00  Wojciech Froehlich (Poland)  
The use of fallout radionuclides and classical methods in soil erosion investigations, including assessment of the impact of short-term land use change and the effectiveness of soil conservation techniques, in the Polish Carpathians (preliminary results)

15:00-15:30  Coffee break

15:30-16:00  Dumitru Nistor (Romania)  
Preliminary studies regarding the use of fallout radionuclides in estimating the effectiveness of soil conservation measures on sloping cropland in Romania

16:00-16:30  Sevila Haciyakupoglu (Turkey)  
The use of $^{137}$Cs and $^{210}$Pb and $^{7}$Be measurements for the assessment of soil erosion and sedimentation in the Riva Basin (Istanbul, NW Turkey)

16:30-17:00  Xinbao Zhang (P.R. China)  
Investigation of soil erosion and sedimentation by using nuclide tracers of $^{137}$Cs, $^{210}$Pb, and $^{7}$Be on the Loess Plateau as well as in the Upper Yangtze River Basin, China

17:00-17:30  General discussion on papers presented in Session IV  
Discussant: C. Bernard

18:00  Cocktail  
IAEA, Tower A, 22 floor - Room A-2210

**Wednesday, 21 May**

SESSION V  
**Chairperson: D. Lobb (Canada)**  
Methodological developments (Soil Conservation Measures and Modelling)
09:00-09:30 Y. Onda (Japan)  
Erosion and sediment transport analysis by $^{137}$Cs and $^{210}$Pb in forested environments in Japan

09:30-10:00 Andreas Klik (Austria)  
Soil Conservation in Austria

10:00-10:30 Coffee break

10:30-11:00 H.P. Liniger (Switzerland) World overview of conservation approaches and technologies - WOCAT

11:00-11:30 Hassan Nabhan (FAO)  
Land degradation assessment in drylands - LADA

11:30-12:00 General discussion on papers presented in Session V  
Discussant: J. Ritchie

12:00-14:00 Lunch break

SESSION VI  
Group development Session

14:00-14:30 D.E. Walling/ D. Lobb (Facilitators GROUP I)  
General discussion on Methodological (radionuclides) issues

14:30-15:00 C. Bernard/ H. P. Liniger (Facilitators GROUP II)  
General discussion on Soil Conservation Measures

15:00-15:30 Coffee break

15:30-17:30 Individual Group Sessions

GROUP I: Walling, Lobb, Benmansour, Froehlich, Golosov, Onda, Sevilay, Shafiq, Schuller, Wallbrink, and Zhang (Conference room VI C07)

GROUP II: Bernard, Liniger, Bacchi, Bujan, Klik, Manjiah, Nistor, Ritchie, Son Hai Phan, Yong Lai and Yong Li (Meeting room A-2210)

Thursday, 22 May
Technical Workshop on the use of fallout radionuclides in soil erosion research and WOCAT methodologies, IAEA Laboratories, Seibersdorf

09:00-09:30 Session 1. Introduction The Agency’s Laboratories and the use of Nuclear Techniques for peaceful applications (G. Voigt)
09:30-10:00 Session 2. Use of $^7$Be in soil erosion research (P.J. Wallbrink)
10:00-10:30 Session 3. The use of conversion models (D.E. Walling)
10:30-11:00 Coffee break
POSTER: Applications of radiometric estimation of soil erosion rates in Austria (F.J.Maringer, M. Hrachowitz)
11:00-12:30 Session 4. HP Gamma spectrometry for environmental radionuclides (M. Moslinger, Canberra/ M. Makarewicz. IAEA)
12:30-14:00 Lunch break
14:00-15:30 Visit to the laboratories of the Soil Science Unit (G. Hardarson)
15:30-16:00 Session 5. WOCAT tools/demonstration (H. Liniger)
16:00-16:30 Session 6. Interactions between soil erosion processes and between soil erosion and other biophysical processes (D.A. Lobb)
16:30-16:45 Laboratory support to the project (R. Hood)
16:45-17:00 An introduction to the Gumpoldskirchen erosion study site (F.J.Maringer and M. Hrachowitz)
17:00 Departure for Gumpoldskirchen
18:00 Dinner
20:00 Return to Vienna, VIC

**Friday, 23 May**

**SESSION VII**

Chairperson: P. M. Chalk (IAEA)
Conclusion and Recommendations

08:30-10:30 Finalization of reports by working groups
10:30-11:00 Coffee break
11:00-13:00 Presentation of reports by working groups and discussion of conclusions and recommendations
13:00 Closing
P.M. Chalk
15:00 Finalisation of Documents
Summaries, contracts, literature, other issues
ANNEX D

ABSTRACTS OF PRESENTATIONS
Determination of the optimal width of riparian forests to control soil erosion using $^{137}$Cs fallout redistribution analysis

Osny Bacchi

Riparian ecosystems are recognized for having many valuable functions such as sediment trapping, protection of stream environments and ground water recharge, flood reduction, filtering and decomposition of nutrients and pollutants, carbon storage and they are also being considered as key areas for the maintenance of global biodiversity. In Brazil, since 1965, the need of riparian forest (RF) preservation or rehabilitation is regulated by federal law, which establishes countrywide RF widths according to the correspondent waterway widths. Therefore, RF width recommendations are made without a scientific basis and do not take into account the main physical and biological variables involved, which would ensure the expected ecological benefits.

The purpose of this project is to evaluate quantitatively the efficiency and suitability of RF as part of the erosion control measures at the watershed scale. The assessment will be made through the combination of a GIS supported soil erosion prediction model using WEPP (USDA-Water Erosion Prediction Project), which allows expeditious large scale surveys, validated and calibrated by the $^{137}$Cs technique. The use of $^{137}$Cs will be made in order to quantify the rates of sediment deposition in selected riparian forests that will be compared with estimates made by the proposed prediction model. The results would allow the prediction of optimal width of riparian forests considering only their soil conservation function in the watershed.

Up to now, three large sugarcane farms of different regions of southeastern Brazil were selected for the study based on the availability of the necessary basic historical land use information, maps and aero photographs and some other field work support. At the same time, a multidisciplinary and inter-institutional new team of co-workers and collaborators (soil physicists, soil conservationist, pedologist, ecologist, forestry specialist and technicians and managers from sugarcane farms) was engaged in the project. It is now linked to another important project of the University of São Paulo, which deals with reforestation and riparian forest rehabilitation in sugarcane farms. The three selected farms involved in the present project are responsible for the rehabilitation of more than 5,000ha of riparian forests. It is expected that the results of the project can give a good support for this important and great task.

The preliminary results of $^{137}$Cs activity in soil profiles, taken from the upland watershed (sugarcane and pasture areas) and from riparian forests, are in accordance to what was expected and indicate the viability of the technique in achieving the proposed objective of the quantification of the rates of sediment deposition. Two ways for this quantification are being considered that will require different sampling strategies: a) by the difference of $^{137}$Cs total activity at deposition site profiles and reference profiles taken from the same forest and b) by the determination of the labeled sediment deposition depth.
Use of Radionuclides to control soil erosion agricultural lands of Morocco

Ben Mansour

Soil erosion has serious impacts on agricultural lands of Morocco. Obtaining reliable data on soil erosion rates and redistribution patterns is very important in order to evaluate the severity of the problem and to assess the effectiveness of the mitigating/controlling management practices. Using radionuclides ($^{137}$Cs, $^{210}$Pb and $^7$Be) as tracers allows obtaining data on soil erosion rates and redistribution patterns over spatial and time scales.

The aim of the research undertaken in Morocco is to use and develop fallout radionuclide methodologies to quantify soil erosion rates in agricultural fields of Morocco and to evaluate the effectiveness of selected soil conservation measures.

In this context, a pilot site (~ 1 ha extension), located in the "Bouregrag" basin, about 60 Km south of Rabat was chosen in collaboration with the "Institut National de la Recherche Agronomique" (INRA) to perform the study. Experimental plots are installed by INRA to test the soil conservation method called "no-til or direct drilling". Crops such as wheat or lentil are planted on the surface (~ 5 cm) without tillage.

Some results from a preliminary investigation of the soil erosion in this site using the $^{137}$Cs technique will be presented. Another study using $^{210}$Pb is going on. It is envisaged that future studies will focus on the combined use of $^{137}$Cs, $^{210}$Pb and $^7$Be.

Assessment of soil redistribution under conventional and conservation tillage practices in cool temperate regions from radiotracer measurements

Claude Bernard$^1$, Marc R. Laverdière$^2$, Marc Duchemin$^1$ and Jacques Gallichand$^2$

1 Research and Development Institute for the Agri-Environment inc. (IRDA)
2 Laval University, Department of Soil Science and Agri-food engineering

Context

Soil erosion is now considered as a major agri-environmental problem in Québec. The productivity of eroding soils is impaired. The problem is of particular importance in the province, since the land area presenting no major limitation for agricultural production is limited to 2 million ha. Eroded sediments contribute to the pollution of receiving water bodies by inducing turbidity and sedimentation problems and by carrying pollutants (nutrients, pesticides) from cultivated fields to waterways. The situation is such that soil erosion control is now considered as a key factor in any water rehabilitation program. However, despite the importance of erosion in the soil and water quality degradation processes, there is a lack of information in terms of where, when and how it occurs. Although the efficiency of some conservation practices has been demonstrated and estimated on experimental plots, their actual efficiency at the field scale remains largely un-documented. In this context, the use of fallout radionuclides offers an opportunity to develop this knowledge and to efficiently complement the plot-scale data by allowing the establishment of soil redistribution patterns and rates for whole fields presenting varied conditions of surface texture, slope, and land use.

Research program
The proposed research program includes measurements at three different spatial scales. In the summer of 2002, 15 small erosion plots (15m x 3m) were installed on a 3.5% slope. The treatments include conventional, chisel and zero tillage, combined or not with grassed buffer strips. The plots are equipped with runoff collectors and sub-samplers to collect a portion of water and sediment loadings, so the efficiency of the treatments can be measured. Soil samples will be collected in early 2003 and late 2006 from the plots, for $^{137}$Cs and $^{210}$Pb measurements. $^{7}$Be will also be measured after important rain events scattered throughout the growing season. The set-up will make possible the comparison of the results obtained by the radiotracers with the actual erosion measurements. From the plot measurements, the impact of soil loss on nutrient and organic matter export will be assessed.

Similar measurements will be done on nine larger plots (0.25 ha) that are part of IRDA’s soil quality monitoring program. Different tillage and rotation strategies are tested on these plots that have been operated for some 15 years. All plots are equipped with measuring devices for runoff, sediment and nutrient fluxes. Correlations between soil redistribution rates estimated from isotope measurements and actual soil loss data will be established. The efficiency of the different rotations and tillage systems under investigation to control soil losses will be estimated.

Finally, several pairs of full-scale (several ha) fields will be sampled for $^{7}$Be, on a rainfall event basis. For each pair, one of field will be under conservation tillage and the other under conventional tillage. The two fields will be located close to each other, to present similar conditions of climate, soil texture, slope, etc. The redistribution pattern of $^{7}$Be in the two fields of each pair will reveal the efficiency of the implemented conservation tillage practices.

Expected results

The research program will offer a good opportunity to compare actual soil losses data to those estimated from radioisotope budgets. These data will help improve the existing models relating isotope measurements to soil losses. They will also reveal how these models are sensitive to different factors (soil texture and slope, land use, etc.).

Correlations will also be developed between soil losses estimated from radioisotope measurements and exports of organic matter and nutrients. This way, the research program will also contribute to increase the capacity of models based on isotope redistribution to assess these exports. These models will then become interesting tools for environmental assessments.

Utilization of $^{137}$Cs, $^{210}$Pb and $^{7}$Be to investigate soil erosion and sedimentation in two watersheds with contrasting land use/management located in the “Pampa Ondulada” region, Argentina.

*Alfonso Bujan, **Santanatoglia Oscar J., **Chagas Celio, **Massobrio Marcelo, **Castiglioni Mario, *Leiva Carlos, *Miranda Gabriel, ***Ciallella Hugo, ***Fernandez Jorge.
* CNEA, **Facultad de Agronomía. Univ. de Buenos Aires., ***Autoridad Regulatoria Nuclear.
The overall objective of the study is the combined utilization of $^{137}\text{Cs}$, $^{210}\text{Pb}$ and $^7\text{Be}$ to investigate soil erosion and sedimentation in two areas with contrasting geomorphologic and land use/management conditions. Specific objectives are: a) Standardizing methodologies for using $^{137}\text{Cs}$, $^{210}\text{Pb}$ and $^7\text{Be}$ to study soil erosion and sedimentation, b) Developing and testing conversion models to estimate soil losses/deposition from the excess $^{210}\text{Pb}$ and $^7\text{Be}$ measurements, c) Testing and validation of models to predict soil losses in cultivated land and to predict sediment yields from small watersheds, and d) Evaluating the effectiveness of soil conservation measures on reducing soil loss and sediment yields in the basin.

Two small watersheds located in the medium basin of the Tala river (Arroyo del Tala) within the "Partido of San Pedro" in the province of Buenos Aires, Argentina, approximately 200 km NW of Buenos Aires City were selected for this study. Both of them have an extension of approximately 300 ha. The main soil type is classified as Argiudolls. One of them is part of the experimental farm “Los Patricios” belonging to the Agronomy Faculty of the University of Buenos Aires, where the Cs-137 technique was previously used. The general topography is undulated with slope gradients between 0 and 2.5 %. The other one belongs to “La Esperanza” farm with similar topographic characteristics and soil conditions but with slopes gradients over 3%. Annual cropping is the predominant land use. Soybean is the most important crop grown in rotation with cereals such as maize and wheat. Sometimes, annual crops are alternated with pastures (in the medium and lower positions) for livestock production.

To apply the fallout radionuclides technique, the first step was to conduct a reconnaissance survey of the study areas to select potential reference sites. Potentially long-term undisturbed (uneroded or undeposited) sites with slope inclination of less than 0.5 % were searched in both watersheds. Four depth increment profiles samples, in each study area were taken for the determination of the depth distribution of the Cs-137, Pb-210 and Be-7 activities in the soil profile. Subsamples were taken at 0- 2 cm, 2-5 cm, 5-10 cm, 10-20 cm and 20-30 cm depth. The radiocaesium analyses are carried out using a HP Germanium detector Canberra Model GC2518 in plastic containers of 7 cm diameter and 4 cm height at the Laboratory of the Nuclear Regulatory Authority, Ezeiza Atomic Center, National Atomic Energy Commission. Each sample is counted for 90000 seconds.

The use fallout radionuclides and classical methods in investigations of the impact of short-term land use changes and effectiveness of soil conservation techniques in the Polish Carpathians (Preliminary results)

W. Froehlich and D.E. Walling

The Polish Carpathians are characterized by highly active erosion, sediment transport and fluvial sedimentation processes, which in turn reflect the climate, the high relief energy, the erodible nature of the soils and parent rock, and the effects of land management. In the lower parts much of the land is utilised for arable cultivation. This land is divided into plots bounded by terraces and characterized by a dense network of unmetalled roads. The wetter areas at the base of the slopes and on the valley floors are occupied by meadows and pasture. In this area land use changes are an important aspect of the soil conservation and watershed management. The present-day land use changes are the result of political and social changes that occurred in 1989 and the impact of "free market" policies. In general, arable fields are currently decreasing in steep slopes and being converted into permanent cover as grassland or forest. Farm management decisions should consider the potential for erosion under different practices, especially on land that is marginal for annual crop production. To date, no attention
has been paid to the influence of changing land use patterns and farming activities in crop rotations on soil erosion. The high energy of events and their large spatial variability pose important technical difficulties in the application of classical techniques in investigating the impact of short-term land use changes and the effectiveness of soil conservation techniques. Data obtained with these methods are primarily limited to small areas such as experimental plots or slopes and representative for "normal events" and short time periods of record. Measurements obtained from runoff plots located on cultivated slopes within the area point to high rates of soil erosion under certain crops. Values for potatoes are as high as 22 t ha\(^{-1}\) yr\(^{-1}\), whilst typical values for winter crops, meadows and forest are 2.4 t ha\(^{-1}\) yr\(^{-1}\), 0.1 t ha\(^{-1}\) yr\(^{-1}\) and 0.03 t ha\(^{-1}\) yr\(^{-1}\) respectively. The use of fallout radionuclides (\(^{137}\)Cs, \(^{210}\)Pb and \(^{7}\)Be) is a valuable and effective alternative to classical monitoring techniques. The application of this method to investigations of soil erosion and sediment delivery has been largely restricted to areas of limited relief in lowland areas. Relatively little work has been undertaken in mountain areas, where altitudinal variations in precipitation, the importance of snow cover and the high energy environment necessitate some modifications to the approach. In mountain environments it is usually recommended to develop a soil and water conservation program at the scale of the small drainage basin. Mechanical protection techniques are necessary, in order to prevent overland flow from achieving threshold entrainment velocities. In the study area such techniques range from contour tillage, which produces water-retaining furrows along the slope, to bench terraces that are effective by reducing the length and angle of the cultivated slope. Deciding on a suitable spacing for the terraces therefore requires being able to estimate the critical slope length at which overland flow becomes erosive. It is likely that during major runoff events some of the sediment eroded cascades over the terrace into the adjacent downslope plot, but the radiocaesium inventories suggest that this is not a major process. The partial-area model has provided a valuable indication of where soil conservation works need to be located for maximum effect. The investigations are concentrated in the small (19.6 km\(^2\)) instrumented Homerka drainage basin where soil erosion and sediment transport monitoring techniques have been applied over the past 30 years and the larger (4692 km\(^2\)) basin of the Dunajec river, which is main river in Polish Carpathians. A better knowledge and understanding of the soil erosion and sediment delivery dynamics of the area is required to provide a basis for improved land management and soil conservation techniques to reduce rates of reservoir siltation.

**Application of radionuclides for assessment of soil conservation works in forest-steppe zone of Central Russia: approaches and perspectives**

V.N. Golosov, V.R. Belyaev, N.N. Ivanova, M.V. Markelov

The Forest-steppe zone of the Russian Plain is the main agricultural region of the country due to its high soil quality and favorable climate for agriculture. Since the XVIII century this area has been intensively cultivated and the extension of arable lands reached already 70-80% in the second half of XIX century. Very steep sloping lands of the valleys were ploughed and the development of very intensive gully erosion was promoted. Changes in crop rotation from different types of grain (rye, barley, wheat, oats etc.) to crops requiring tillage and cultivation between rows (maize, sugar beet, potato, etc.) took place in the beginning of XX century. Increased rill and sheet erosion rates became the consequences of these changes. At present agricultural lands of the forest-steppe zone are the most eroded lands of the Russian Plain, especially the Srednerusskaya upland, which is characterized by a dense valley network and relatively steep cultivated slopes.
Since 1923 Soil Conservation Works (SCW) were developed for the Srednerusskaya upland, where Professor A.S. Kozmenko established the Novosil experimental gully station. During first stage various types of vegetative measures were used for prevention of gully erosion in the valley banks. Later on, tree strips were planted along the contour of cultivated slopes to decrease their length. Since 1959 different agronomic measures and soil surface treatments were tested in erosion plots and structural measures were applied since 1924. The effectiveness of different SCW depends on the type of erosion (sheet, rill, gully, bank etc.) and off-site degradation effects. After World War II, other experimental soil conservation stations were organized within forest-steppe zone.

Soil erosion within the Srednerusskaya upland occurs during two periods: snow-melting (March-April) and summer rainstorms (May – September). Unfortunately most direct measurements of water and sediment discharges were done during the snow-melting period in erosion plots with different conservation measures. Thus, there is a strong need to assess the effectiveness of different SCW during the rainstorm period as well as over the entire small catchment area including uncultivated valley bottoms. It is also necessary to compare effect of different SCW on sediment redistribution. Different radionuclides (\(^{7}\text{Be},^{137}\text{Cs},^{210}\text{Pb}\)) will be used as markers for determination of erosion and sedimentation rates within small catchments with complex SCW and without any SCW. This study will allow evaluating the effectiveness of SCW at different time scales for sustainable watershed management.

**Land degradation assessment in drylands– LADA**

Hassan Nabhan

The Conference of the Parties of the United Nations Convention to Combat Desertification (UNCCD) has recognized that not enough is known of the root causes, nature, extent, severity and impacts of the diverse types of land degradation in drylands.

The Global Environment Facility (GEF) – created to provide funding to developing countries and countries in transition for measures that provide global environmental benefits- has designated land degradation and sustainable land management as focal areas of its global programme in order to enhance support for the successful implementation of the UNCCD.

The GEF in partnership with Food and Agriculture Organization of the United Nations (FAO), United Nations Environment Programme (UNEP), Global Mechanism of the UNCCD and other partners, has provided resources to catalyse an international undertaking in supporting a Land Degradation Assessment in Drylands (LADA) project to develop and test an effective assessment methodology for land degradation in drylands.

By marshalling the extensive knowledge and varied expertise already available worldwide, by creating a new, more interactive and comprehensive framework of assessment methods, and by capacity building and testing this framework in real-world situation, LADA is putting together the pieces of a global challenge. Once the tools and the data required in order to understand the root causes, driving forces and functioning of the degradation puzzle are in place, it will be possible to assess land degradation at global, national and subnational levels and to identify:

- the status and trends of land degradation in drylands in all its components including biodiversity;
- the hotspots: the areas with the most severe land constraints, the actual degradation of such areas and areas at risk of degradation, drought or flooding,
- the bright spots: the areas where conductive policies and actions have slowed or reversed the degradation and the priority areas where the conservation and rehabilitation of fragile lands could be most cost-effective. Such information will assist communities and governments in the design of effective remedial measures and supportive policies.

Assessment of soil erosion in the Central Highlands of Vietnam using $^{137}$Cs, $^{210}$Pb and $^7$Be.

Son Hai Phan$^1$, Duy Hien Pham$^1$, Thanh Binh Nguyen$^1$, Hong Lich Le$^2$, Cong Tu Trinh$^2$

$^1$Viet Nam Atomic Energy Commission, $^2$National Institute for soil and Fertilizer

The Central Highlands located at 11$^0$ – 16$^0$N, 107$^0$ – 108$^0$E; and 150 – 1500m asl cover 17% of the 330,000 km$^2$ Vietnam’s land. Agricultural products such as coffee, rubber latex, tea and pepper account for 65% of the country output. This region is susceptible to soil erosion due to heavy monsoon rainfalls, sloping lands and reclamation works. Conventional methods have been applied to estimate soil erosion rates and the impact of soil conservation measures in some areas of this region.

This study aims at utilizing excess $^{210}$Pb and $^7$Be with $^{137}$Cs to measure soil erosion and sedimentation in the sloping lands of the Central Highlands under different land use and management. The outline of the research work plan is as follows:

- Determination of $^{210}$Pb and $^7$Be fluxes and their distribution in soil profiles.
- Study of $^7$Be sorption capacity by soil using lysimeters and laboratory experiments.
- Field experiments using five plots (two plots for coffee, two for annual (short growing season) crops and one for rubber trees) and near-by control areas to: (i) Refine methodologies of using excess $^{210}$Pb and $^7$Be with $^{137}$Cs in soil erosion studies; (ii) Develop and test conversion models to assess soil loss and gain from excess $^{210}$Pb, $^7$Be and $^{137}$Cs data; (iii) Assess the impact of different land use on soil losses.
- Application of fallout radionuclide techniques to estimate soil erosion and redistribution in four soil conservation models with different hedgerows (405 m$^2$ for each model), and then assessing the impact of soil conservation measures on soil losses.

Soil Conservation in Austria

A. Klik

The protection of our environment is receiving increased attention by the society. Especially the conservation of our surface and groundwater bodies for drinking water purposes has been identified as a major issue. Soil erosion by wind and water is therefore a major threat to our environment and to agricultural productivity in general, but especially to the protection of our soil and water resources.

In Europe, soil degradation by soil erosion is probably the most important environmental problem caused by conventional agriculture, seriously affecting nearly 157 million hectares, which accounts for 16% of Europe. Most EU countries are affected by this problem to some extent. Water quality is greatly impaired by erosion processes. Soil sediment from eroded agricultural land is by far the most important contaminant of surface water. Soil erosion
transports also chemical fertilizers and pesticides into surface and ground water causing a serious problem concerning public health. Beside the ecological effects, the erosion problem has a strong economic impact on the affected agricultural land, and off-site on the surrounding civil public infrastructure. Estimates indicate that the erosion increases agricultural production costs by about 25% each year (53 EUR per hectare). Further, if on-site and off-site costs are combined, the total annual cost of erosion from agriculture in USA can be estimated at about 85.5 EUR per hectare (Pimentel et al., 1995). Therefore, appropriate soil conservation measures are needed to reduce environmental impacts.

In 1994 a long-term soil erosion study was started at three different locations in the eastern part of Austria, where most of the agricultural land is situated. The overall objective of this field project is the comparison of different tillage systems in terms of runoff, soil loss, nutrient and pesticide transport. Three tillage systems were compared: 1) conventional tillage (CV), 2) conservation tillage with cover crop (CS), and 3) no-till with cover crop (NT). Crop rotation was corn-small grains at two sites and corn-small grains-sugar beet at the third site. The study design consists of 4 m wide and 15 m long runoff plots for each management variation. Inclination of hillslopes varies between 6 and 16%. Long-term annual precipitation ranges from 530 to 730 mm. Runoff and sediment are collected and measured after each erosive storm event. Water and sediment samples are analyzed on N, P, and pesticide contents.

No significant differences in total runoff during growing season were measured between the three tillage practices. Average annual soil loss ranged from 2.7 to 8.4 t ha\(^{-1}\) with highest amount for CV and lowest for NT. Nutrient losses from April to October were 13.7 kg ha\(^{-1}\) a\(^{-1}\) for CV, 9.1 kg ha\(^{-1}\) a\(^{-1}\) for CS, and 7.7 kg ha\(^{-1}\) a\(^{-1}\) for NT. Corresponding values for phosphorus were 6.5, 3.1, and 2.0 kg ha\(^{-1}\) a\(^{-1}\). CS and NT management were able to reduce pesticide losses between 23 and 99%.

Besides conservation and no-till, other soil erosion protection measures like contouring, strip tillage and terraces are utilized in Austria. The Austrian system of incentives given for soil protection will be shown as well.

**World Overview of Conservation Approaches and Technologies (WOCAT) and the identified need to assess the effectiveness of soil conservation**

Hans Peter Liniger

Every day land users and soil and water conservation (SWC) specialists evaluate experience and generate know-how related to land management, improvement of soil fertility, and protection of soil resources. Most of this valuable knowledge, however, is not well documented or easily accessible, and comparison of different types of experience is difficult. This SWC knowledge therefore remains a local, individual resource, unavailable to others working in the same areas and seeking to accomplish similar tasks. This may be one of the reasons why soil and water degradation persists, despite many years of effort throughout the world and high investments in SWC.

WOCAT is a network of soil and water conservation specialists from all over the world. WOCAT's mission is to provide tools that allow SWC specialists to share their valuable knowledge in soil and water management, that assist them in their search for appropriate SWC technologies and approaches, and that support them in making decisions in the field and at the planning level. It facilitates more efficient use of existing know-how and, consequently, of development funds. It thus helps to optimise the implementation of appropriate SWC and to avoid duplication of effort. WOCAT also contributes to the implementation of United
Nations Conventions, such as the Convention to Combat Desertification (CCD), the Framework Convention on Climate Change (FCCC), and the Convention on Biodiversity (CBD).

WOCAT is organised as a consortium of national and international institutions and operates in a decentralised manner. This means that it is carried out through initiatives at regional and national levels, with backstopping from experienced members of the consortium. At the global level, WOCAT is co-ordinated by a management group, assisted by the global secretariat. Task forces are set up to further develop initiatives and tools, and to support national and regional institutions. Annual international workshops and steering meetings provide a basis for exchange on progress with different initiatives and for directing future activities. The WOCAT network is open to all individuals and organisations with a mandate or an interest in SWC. Anyone can be associated with WOCAT and join the WOCAT network. The core of the network consists of specialists, programmes, projects, NGOs and the like that present their local experience with SWC at national or regional workshops and share their knowledge with others who use WOCAT questionnaires. Regional and national institutions organise training workshops, compile and administer the database, and produce and disseminate the outputs. Thus anyone can become a consortium member and represent a node in the global network. So far over 40 international workshops and meetings have taken place in order to launch WOCAT activities and knowledge has been collected in over 35 countries worldwide.

The compilation of available knowledge has revealed a number of knowledge gaps and contradictions, which need to be presented and addressed by research. A key issue identified so far by the WOCAT is to clarify the impacts of land degradation or good land management practices on the natural resources (related to water, soils and vegetation) and on human welfare (related to social and economical aspects). The WOCAT data base reveals that there is hardly any quantitative assessment of the effectiveness of soil and water conservation available. Thus, very few hard facts concerning this issue are available. Therefore, WOCAT seeks collaboration with research projects to identify and quantify the impact of soil and water conservation. Several studies have been initiated which still need methodological support and collaboration with ongoing projects using the method of fallout radionuclides. This would allow the testing and further development of the methodology in a wide range of different environmental conditions. Thus, it provides a good opportunity to spread the use of this method and the combination with additional methods in order to assess the effectiveness of SWC.

**Canadian Research on soil erosion and soil conservation using radioisotopes**

David Lobb

The use of radioisotopes is a key element of the research being conducted by Lobb and his colleagues in Canada on soil erosion and soil conservation. This presentation provides a summary of current research activities to improve the use of radioisotopes and apply them to studies of soil erosion and its impacts.

1) **BEGe Detectors for Combined Analyses of $^{137}$Cs and $^{210}$Pb.** The Canadian prairie region provides an excellent opportunity to use both $^{137}$Cs and $^{210}$Pb to assess soil redistribution in cultivated landscapes. The majority of the land was first broke circa 1900, about 100 years BP, coincident with the optimum time scale for $^{210}$Pb. The time-zero date for $^{137}$Cs, 1960, is coincident with the major intensification in cropping and tillage practices within the region.
(shift to much larger tractors and implements, enlargement of fields, use of fertilizers and pesticides). As well, given the climate and geology, very little soil/sediment leaves prairie landscapes resulting in high degree of variability of $^{137}$Cs and $^{210}$Pb within these landscapes. One of the challenges of using both $^{137}$Cs and $^{210}$Pb is their combined analyses on large soil samples (500-2000 g, 50 to 200 cm$^2$ surface area). Large samples are considered necessary to gain an acceptable level of accuracy for erosion estimates. The Broad Energy Germanium (BEGe) detector is capable of measuring both $^{137}$Cs and $^{210}$Pb simultaneously on a single, large sample. Preliminary studies using the BEGe detector for combined analyses of $^{137}$Cs and $^{210}$Pb show considerable promise – high peak resolution and high sample throughput – however, sample preparation and reproducibility of $^{210}$Pb results are still problematic and are subject of continued study. This research is funded by the Canadian Foundation for Innovation, the National Science and Engineering Research Council and Canberra.

2) Time Series Analysis Using $^{137}$Cs. A major weakness in the use of $^{137}$Cs in the assessment of soil redistribution within landscapes is the reliance on a time-zero reference level (1960 fallout peak). The use of this reference level requires many assumptions. An alternative approach can be used which is much more accurate and more useful in the study of soil conservation options. This alternative method uses multiple measures of $^{137}$Cs over time. This method and its benefits are demonstrated in this presentation.

3) Impact of Tillage Translocation and Tillage Erosion on the Use of $^{137}$Cs and $^{210}$Pb. Tillage translocation and tillage erosion can significantly affect the accuracy of soil erosion estimates using any soil constituent. This problem and the approach to deal with it are demonstrated using $^{137}$Cs data first presented by Lobb in 1994.

4) Discrimination of Erosion Processes. The observed redistribution of soil in cultivated landscapes is the result of more than one erosion process – tillage erosion, and wind and water erosion. To accurately assess the benefits of soil conservation practices, it is necessary to discriminate soil erosion processes. This discrimination is being carried out in Lobb's studies using radioisotopes and erosion model optimization techniques that have been developed by others.

5) Applications of $^{137}$Cs and $^{210}$Pb to Studies of Soil Erosion and Its Impacts. Soil erosion is largely responsible for variability of soil properties observed within topographically complex cultivated landscapes of the Canadian prairie region. This variability impacts biophysical processes such as greenhouse gas production and emission and the sorption and biodegradation of pesticides. Lobb and his colleagues are using vertical profiles of $^{137}$Cs and $^{210}$Pb to assess the degree of soil loss and accumulation within cultivated landscapes, and these profiles are being coupled with profiles of biophysical properties and processes to assess the impacts of soil erosion. This research is funded by the National Science and Engineering Research Council and the Canadian Agricultural Research Council. The goal of these studies is to develop tillage practices and systems that are both agronomically and environmentally sustainable.
Soil conservation vis a vis soil erosion and future prospects using fallout radionuclides measurements

K.M. Manjaiah
Nuclear Research Laboratory, Indian Agricultural Research Institute, New Delhi

India has a geographical area of 328.7 million hectares, of which roughly 264 million hectares of land is available for agriculture, forestry, and related activities. The estimates by Sehgal and Abrol (1994) put the total degraded land in India at 187.8 million hectares. Amongst the different causes of soil degradation, erosion by water and wind is the most common cause of soil degradation in India. It accounts for about 87% of the area affected by soil degradation, and the share continues to increase over the time. Increasing pressure on land resources caused by the rapidly increasing population is further accelerating the processes of soil degradation. As regards the extent/rate of erosion, in dense forests, snow-clad cold deserts, and arid regions of western Rajasthan, on an average 5 tonnes of soil is eroded from every hectare of land every year, the figure is as high as 80 tonnes in the Shivalik hills. About 64% of the eroded soil come from a few severely eroded sites and soil types: the Shivaliks, the Western Ghats, and the North-Eastern states, and the ravines and the black and red soils. Of the eroded soil, nearly 30% is washed down to the sea and 10% ends up in reservoirs (TERI, 1998). The estimated economic loss caused by lower crop yields and reduced reservoir capacity, both of which are manifestations of soil degradation are enormous. The importance of land degradation in India has been increasingly recognized over the past 4 to 5 decades. India has over the years, developed research and education institutions to service agricultural development including rehabilitation of degraded lands. Different agencies/organizations, which have a major mandate to evolve soil and water conservation technologies for checking soil degradation and for rehabilitating degraded soils, the opportunities/challenges in using environmental radionuclide measurements as a potential tool for measuring the rate and extent of soil erosion in our conditions is being discussed.

Erosion and sediment transport analysis by $^{137}$Cs and $^{210}$Pb in forested environments in Japan

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To study the erosion and sediment transportation processes in a forested environment, soil and sediment sampling and $^{137}$Cs and $^{210}$Pb analyses were carried out in the Nagasawa dam reservoir watershed (70 km²), Shikoku island, Japan.

Soil sampling was conducted along hillslopes with various erosion processes such as landslide scar, surface erosion in unmanaged Hinoki ($Chamaecyparis obtusa$) plantation, and sediment collection in several tributaries located in the watershed of the Nagasawa reservoir. Detailed
sampling in the channel deposit was made in the Tebako river, one of the tributary upstream of the Nagasawa reservoir.

The land use of the Nagasawa reservoir watershed was analyzed using the aerial photos taken in 1968, 1975, 1978, 1989 and 1998. Forest logging and landslide areas were identified using the data obtained by the photo interpretation.

The $^{137}$Cs concentration in the tributary deposit varies from place to place and indicates that the $^{137}$Cs concentration in the tributary deposit decreases where the landslide area increases. The $^{210}$Pb$_{ex}$ concentration generally decreases with the landslide area, but in the Tebako river deposit shows high $^{210}$Pb$_{ex}$ concentration, although the landslide area ratio is the largest. These data suggest that the $^{137}$Cs and $^{210}$Pb$_{ex}$ in the channel deposit is basically generated from erosion of the forest floor but only in Tebako river basin, sediment delivery from landslide scar was judged to be the dominant source of the fine sediment.

**Preliminary studies on the use of fallout radionuclides for estimating the effectiveness of soil conservation measures on sloping cropland in Romania.**


Selection of the study areas has been made in relation to the land use type and specific soil conservation practices to be assessed. In this respect, three representative small watersheds have been considered in order to cover a whole range of natural conditions and categories of soil conservation measures. The Upper Tarina basin, within the Tutova Rolling Hills, is characterized by uniform gently to rolling slope, soil moderately deep with medium fertility and moderately eroded. The system of conservation measures comprises various land treatments such as: strip cropping, buffer strips, shelterbelts and an adequate agricultural exploitation road network. Several plots cultivated with different crops and fully instrumented are used to measuring runoff and soil loss. The Gheltag watershed, located in the same geographical area, with gently to hilly slopes, coarse to medium textured soil, affected by moderate to high erosion by water. The main types of conservation practices applied according to the slope gradient are strip cropping and bench terraces. The Crang watershed, with mean slopes of 20-25% was initially fragmented by successive discontinuous gullies. The local soils are mostly represented by regosoils and erodisoils (coarse to medium textured) on former forest soils. The conservation practices include strip cropping, buffer strips, bench terraces, a grassed waterway and a drainage network.

The land use types of the watersheds described above are annual and perennial cropping. Field sampling strategies for each basin was established with a view to define a sample network. The interest area is divided in transects with an increment of 100 –1000 m depending on watershed length and 6 – 12 points on each transects depending on its length as well. The sampling depth was given by the sample point characteristics considering that the specific point could be placed with a net export or a net import of eroded material.

The measurement technologies to determine fallout radionuclides ($^{137}$Cs, $^{210}$Pb$_{ex}$ and $^7$Be) in soil samples and water from precipitation samples were also established. Further precautions were taken because the peak of $^7$Be fallout occurs mainly in spring and it is associated with the rains. Besides, it has to be measured immediately after sampling due to its relatively short half-life.

With regard to the temporal scale studies it may be mentioned that it will be somewhat difficult to conduct a short-term assessment of effectiveness of soil conservation measures due to the insignificant changes induced by erosion in soil properties over a period of two or three years. For this reason longer and larger spatial scales seem more appropriate.
Assessing Soil And Soil Carbon Movement Patterns Under Different Management Using 137Cesium

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Soil carbon is the largest component of the terrestrial carbon cycle. Soil carbon varies with climate, topography, biological activity, soil movement, and land management leading to large uncertainties in the soil carbon budget especially in agricultural areas. This study is designed to determine soil carbon redistribution under different agricultural management system as related to soil movement. Soil movement (erosion/deposition) was measured using radioactive fallout 137Cesium. Agricultural fields have been sampled in Maryland, Ohio, and Iowa. These fields have a variety of different management practices. In the Iowa fields, organic carbon had an order of magnitude difference in concentration (0.5 to 5%) and was significantly correlated to soil 137Cs concentration and soil erosion/deposition rates. Sites of soil erosion have lower concentrations of organic carbon (2.4 %) while sites of soil deposition within the field have higher concentrations of soil carbon (3.4 %). This study shows the importance of being able to measure soil redistribution patterns within a field to understand soil carbon patterns and the potential of developing or implementing better management systems to increase carbon sequestration in agricultural areas. Combining information from different locations and management treatments will allow a better understanding of soil carbon movement.

Use of 137Cs measurements to estimate changes in soil erosion rates associated with changes in cultivation practices on agricultural land

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In south-central Chile, conventional tillage practices involve burning of crop residues after harvest and mechanized ploughing of the soil, even under high slope conditions. This soil management has resulted in 11.5x10^6 ha of agricultural land being affected by erosion, which has been classified as ranging from serious to very serious (CONAMA, 1994). Under these conditions, the introduction of no-till practices has been viewed as an important requirement for the development of sustainable agricultural production. No-till practices are seen as reducing soil loss and the discharge of nutrients to watercourses and improving soil quality (Acevedo, 2003). The magnitude of the reduction in soil loss associated with the introduction of no-till practices is, however, uncertain and there is currently a need to establish the extent of this reduction. One of the objectives of the present research project is to develop procedures for using 137Cs measurements to quantify the changes in rates of soil loss associated with changes in soil management, from conventional tillage to no-till.
The study area is located in the Coastal Mountain range of the 9th Region of Chile (38°37′S 73°04′W) and is characterised by Ultisols (Typic Hapludult), a temperate climate and a mean annual precipitation of 1100 mm. The field selected for this work at the Buenos Aires Farm near Carahue was under conventional tillage management until May 1986, when there was a change to no-till management. In addition, a site subject to continuing conventional tillage during the last decades, exhibiting similar soil characteristics and situated close to the study field was selected for determining the historical plough depth.

The procedure developed for using $^{137}$Cs measurements to estimate the change in erosion rates associated with the change from conventional tillage to no-till management comprised the following elements. Using the $^{137}$Cs vertical distributions observed at the sampling points, the following parameters were determined:

- $H =$ historical plough depth (the depth to which $^{137}$Cs was found to be homogeneously mixed at the site under conventional tillage, corrected for compaction to make it comparable to the longer-term no-till conditions),
- $h =$ the depth to which $^{137}$Cs was found to be homogeneously mixed at different points along a slope at the site under no-till management.

The mean erosion rate, $R$, for a specific sampling point, during the no-till period was estimated as

$$R = \frac{(H - h)d}{T}$$

where:

- $d =$ the bulk density of the upper soil layer at the sampling point under no-till management,
- $T =$ the time elapsed between the beginning of no-till management and the sampling date.

The $^{137}$Cs vertical distribution in the soil at the end of the period of conventional tillage (i.e. 1986) was reconstructed by means of parameters $h$ and $H$, and the measurements of $^{137}$Cs concentration in the upper part of the soil profile. Using the total $^{137}$Cs inventory of the soil in 1986 estimated by this approach; the erosion rate during the period of conventional tillage was calculated using the models proposed by Walling and He (1999).

The results concerning changes in erosion rate at eight points along a slope transect, resulting from the shift from conventional tillage to no-till management, will be discussed.

The procedure described above for estimating erosion rates associated with the periods of conventional tillage and no-till management requires appreciable effort, both in terms of the need to collect depth incremental samples and the relatively large number of samples requiring analysis for $^{137}$Cs activity. The latter limitation is of particular significance in Chile, where $^{137}$Cs activities are low and extended count times are required. A simpler approach that can be applied to additional sampling points in a study field has also been developed. This requires information on the total inventory (bulk cores), and the bulk density and $^{137}$Cs activity concentration in the plough layer (obtained by short cores of about 8 cm depth). When used in association with information available for depth incremental profiles in a study field and employing the same assumptions, this information enables the erosion rates associated with the two periods to be estimated for additional sampling points. This simplified method has the important advantage of only requiring two $^{137}$Cs measurements per sampling point and of avoiding the need to collect depth incremental samples. It is now being applied in the study field to provide additional and more spatially representative information on the magnitude of the change in rates of soil loss associated with the shift from conventional tillage to no-till management.
The Use of $^{137}\text{Cs}$, $^{210}\text{Pb}$ and $^{7}\text{Be}$ Measurements for Assessing Soil Erosion and Sedimentation in the Riva Basin (Istanbul, NW Turkey).

S. Haciyakupoglu, T.A. Ertek and D.E. Walling

Soil erosion is the most important process of land degradation in Turkey. Approximately 85% of the total area of Turkey is affected by water and wind erosion. The aim of the reported study is to evaluate erosion and sedimentation rates by using the environmental radionuclides $^{137}\text{Cs}$, $^{210}\text{Pb}$ and $^{7}\text{Be}$ at different representative areas in the Riva Basin in Istanbul, NW Turkey, taking account of the application of soil conservation techniques for sustainable watershed management.

The Riva Creek basin is located in the Kocaeli Peninsula, in the Marmara Region. The Omerli Reservoir located in the middle part of the Riva Creek basin constitutes one of the most important drinking water sources of Istanbul. There are serious problems along the margins of the reservoir, including erosion, sedimentation and active land mass movements, which are promoted by the local lithology, tectonic activity, the climate, poor vegetation cover, steep slopes and human activities. Reliable estimates of soil erosion/sedimentation rates are needed to assess these problems. To assemble representative data, four different representative areas of the basin comprising the Pasakoy, Kurtdogmus, Ballica and Esenceli villages have been chosen in the catchment of the Riva Creek.

Preliminary sampling has been undertaken to establish the $^{137}\text{Cs}$ depth distribution. Samples were collected from an undisturbed area (reference site), in order to determine the depth incremental $^{137}\text{Cs}$ profile, down to 18 cm depth. It is planned to measure the inventories of $^{137}\text{Cs}$, $^{210}\text{Pb}$ and $^{7}\text{Be}$ in the soils of the four selected areas of the basin to estimate the erosion and sedimentation rates and to compare forested sites to cultivated and pasture (non-forested) sites.

Status of soil erosion and sedimentation in Pakistan and role of nuclear techniques in soil conservation techniques

Muhammad Rafik Sheikh

Pakistan is an agricultural country that lies in a transitional zone between the East Asian Monsoon climate and the Mediterranean climate. Out of country’s total area of 79.6 million ha. only 23.6% is cultivated. Approximately 25% of the cultivated area are rain-fed semi-arid and face the most severe problems of soil erosion. Slight to moderate sheet and rill erosion is most common and annual soil loss of 3.0 to 4.5 t/ha has been estimated. Soil erosion of soil creates twin problems: on one hand productivity is reduced while on the other hand it increases the sediment load in the channels and storage dams.

Conventional methods for estimating soil erosion and sedimentation are limited in their capacity to provide complete and timely data. Recent advances in the use of environmental radionuclides to quantify the erosion and sediment accumulation rates have shown remarkable success in the assessment of soil erosion and sediment mobilization.

PINSTECH has established analytical facilities for commonly used radionuclides in soil erosion and sedimentation studies. High $^{137}\text{Cs}$ inventories (4380 and 5671 Bq/m$^2$) have already been recorded from different areas. End-user departments and policy sector management authorities are already convinced to apply nuclear techniques and strong collaboration exists with them.
The environmental radionuclides $^{137}$Cs and unsupported $^{210}$Pb will be used to quantify the medium and long-term erosion rates and sediment accumulation whereas the short lived $^{7}$Be will be used as tracer in studying sediment mobilization, transport and storage over shorter time scales. An active and more susceptible area to soil erosion with contrasting geology, soils and land-use has been selected for the study. Reliable information on rates of soil loss and sediment transfer and storage can provide a basis for formulating and implementing improved erosion and sediment control strategies. It is expected that the established data will help to evaluate the effectiveness of soil conservation techniques in a short-term period.

**Determining sources of sediment to the Westernport Bay, Victoria, Australia, using modelling, geochemistry and fallout nuclides**

P. Wallbrink

This presentation summarizes the findings of a three-year study to determine the contributions of sediment to Western Port, Victoria. The delivery of sediment to Western Port has changed since European arrival. Large-scale clearing, draining of the Koo Wee Rup swamp, and construction of channels across the swamp has led to an increase in catchment erosion and an increase in the efficiency of sediment delivery to the marine environment.

A combination of geochemistry and radionuclide tracing shows that the dominant catchment source of the fine sediment is subsoil from channel and gully erosion of the Bunyip and Lang Lang river systems. Erosion from the clay banks to the north west of the Lang Lang jetty also appears to be an important local source of fine sediment. The contribution of the Bass River is relatively minor, contributing less than 10% to the fine sediments in the southern (Rhyll) segment of Western Port.

Sediments from catchment erosion will continue to be a problem to Western Port if rehabilitation and stabilization programs are not undertaken. The time frame for recovery is probably in the order of decades and is a function of i) the effectiveness of rehabilitation efforts to reduce sediment influxes from the tributary catchments and the clay banks, ii) the residence times of sediment in the tributary channels and iii) flushing rates of sediments from the bay.

**Testing and validating conversion models for use with $^{137}$Cs measurements in soil erosion investigations**

D.E. Walling

The work reported focuses on two studies exploring different aspects of the validation of conversion models for use with $^{137}$Cs measurements to estimate erosion rates.

The first study makes use of measurements of the $^{137}$Cs content of soil eroded from a suite of erosion plots located in Calabria, Southern Italy, to explore the relationship between $^{137}$Cs loss and soil loss. The results indicate a well-defined relationship between these two variables, with little evidence of shifts in the relationship according to event magnitude. This provides a clear validation of the basic assumptions of the $^{137}$Cs technique. Consideration of the relationship between the $^{137}$Cs content of eroded soil and that of the parent soil provides evidence of considerable complexity, which cannot be accounted for using simple grain size
correction procedures. Further work is required to improve existing grain size correction procedures.

The second study aims to provide direct empirical validation of erosion rate estimates derived for uncultivated soils using an exponential profile distribution model and two diffusion and migration models. This is achieved by comparing estimates of the net erosion rates from two small catchments in Calabria, Southern Italy, with sediment delivery ratios close to 100%, derived using $^{137}$Cs measurements, with the long-term measured sediment yields from the catchments. The results provide clear evidence of the general validity of the erosion rate estimates provided by the $^{137}$Cs measurements and also indicate that a modified diffusion and migration model generates results providing the closest agreement between the estimates of net soil loss derived from $^{137}$Cs measurements and the measured sediment yields.

Both studies provide valuable confirmation of the validity of erosion rate estimates derived from $^{137}$Cs measurements.

**Investigations of soil erosion and sedimentation by using nuclide tracers of $^{137}$Cs, $^{210}$Pb$_{ex}$ and $^{7}$Be in the upper Yangtze River Basin of China**

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Investigations of soil erosion and sedimentation were carried out in the Zhaojia Gully, Loess Plateau, during 2001, and at the Yanting Purple Soil Agro-ecological Experimental Station of Chengdu Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, the Upper Yangtze River Basin and in the Yuntaishan Gully, Loess Plateau, during 2002. About 560 soil and sediment samples were collected for analyses. One paper entitled “$^{210}$Pb$_{ex}$ Depth Distribution in Soil and Calibration Models for Assessment of Soil Erosion Rates from $^{210}$Pb$_{ex}$ measurements” was published in Chinese Science Bulletin in both Chinese and English. Two manuscripts entitled “A study on sediment delivery changes response to closing cultivation by using reservoir deposits and $^{137}$Cs measurements in a small catchment of the Loess Plateau, China” and “$^{7}$Be distribution in purple soil and its reference inventory in the Central Hilly Area, China” were submitted to journals for peer review.

The main results of these studies can be summarized as follows:

$^{210}$Pb$_{ex}$ Depth Distribution in Soil and Calibration Models for Assessment of Soil Erosion Rates from $^{210}$Pb$_{ex}$ measurements.

1. Unlike $^{137}$Cs, fallout $^{210}$Pb$_{ex}$ is naturally derived and continuously falls down on the earth surface. $^{210}$Pb$_{ex}$ distribution in soil is in a steady state on both uncultivated and cultivated land where land environment, land use and erosion processes are constant for a long term e.g., >100 years. Under a steady state condition, the amount and the depth distribution of fallout $^{210}$Pb$_{ex}$ in soil are constant.

2. Maximum concentration of $^{210}$Pb$_{ex}$ concentration occurs at the surface on uncultivated land then decreases exponentially with depth. Soil losses at an eroded site on uncultivated land can be estimated by using the $^{210}$Pb$_{ex}$ depth distribution equation from the difference of the $^{210}$Pb$_{ex}$ inventory at the eroded site to the reference inventory.

3. $^{210}$Pb$_{ex}$ concentrations are almost uniform throughout the plough layer as a result of the mixing associated with cultivation. $^{210}$Pb$_{ex}$ surface enrichment has a considerable effect on estimating soil erosion rates on cultivated land. The proportion of the freshly deposited $^{210}$Pb$_{ex}$ fallout on cultivated land removed by erosion can be calculated from the $^{210}$Pb$_{ex}$ depth
distribution at uneroded permanent grass land, which can be considered as a long term natural experiment of $^{210}\text{Pb}_{\text{ex}}$ mass balance on uncultivated land.

A study on sediment delivery changes response to closing cultivation by using reservoir deposits and $^{137}\text{Cs}$ measurements in a small catchment of the Loess Plateau, China

1. Changes in the extension of sloping cultivated land in the inter-gully area slopes has not resulted in reduction of sediment yields in the Zhaojia Gully, a small catchment in the rolling plateau, since early 1990s. The mean annual sediment yield of 29,650 t km$^{-2}$ year$^{-1}$ during the period of 1994-1996 was 2.2 times of the average annual sediment yield, although the mean annual precipitations of the three years are close to the average annual value.

2. Average annual $^{137}\text{Cs}$ concentration of the sediment deposits sharply declined from 0.75 mBq g$^{-1}$ in 1994 to 0.49 mBq g$^{-1}$ in 1995 and 0.18 mBq g$^{-1}$ in 1996. The relative contribution of the sediment derived from the inter-gully area to the total sediment yield in the catchment decreased from the 23 per cent in 1994 to 15 per cent in 1995 and 6 percent in 1996, while that from the gully area increased from 77 per cent in 1994 to 85 per cent in 1995 and 94 per cent in 1996. The average sediment yield in the inter-gully area decreased from 14,335 t km$^{-2}$ year$^{-1}$ in 1994 to 7,034 t km$^{-2}$ year$^{-1}$ in 1995 and 3,517 t km$^{-2}$ year$^{-1}$ in 1996, while that in the gully area had a tendency to increase and varied between 44,944 t km$^{-2}$ year$^{-1}$ and 62,136 t km$^{-2}$ year$^{-1}$ during the period.

3. The mechanism of sediment yield causing decreases in the inter-gully area and increases in the gully area during the period of 1994-1996 is probably the compaction of the ploughed soil resulting in a soil erosion reduction and runoff increase in the inter-gully area. In turn, the increased runoff delivered from the inter-gully area may have had induced severe gully erosion and mass-movements in the gully area.

4. Closing cultivation may be beneficial to soil erosion control in the rolling loess plateau over a long term but not in a short term. Although landforms of the loess plateau are sensitive to hydrological regime changes, there is a long way to go for the complete adjustment of the landforms to these changes after closing cultivation in the Loess Plateau.

$^{7}\text{Be}$ distribution in soil and its reference inventory in the Central Sichuan Hilly Basin, China

1. $^{7}\text{Be}$ is mainly distributed within the first 20 mm of soil in depth and the peak concentration occurs at 2 mm in depth, then the concentration declines exponentially with depth.

2. There are certain differences in $^{7}\text{Be}$ depth distribution between cultivated and uncultivated soil. $^{7}\text{Be}$ concentration is higher in the surface horizon and declines with depth more rapidly in grassland (uncultivated) soil than in cultivated soil. This effect may be due to the better porosity of the cultivated soil that promotes infiltration of rainwater.

3. $^{7}\text{Be}$ reference inventories of spring and autumn seasons in Yanting, Central Sichuan Hilly Basin, are 117.4 Bq m$^{-2}$ and 169.9 Bq m$^{-2}$, respectively. These values are lower than most of reported $^{7}\text{Be}$ reference inventories in the world. The possible reasons may be the following: a) The Southwest air currents from the Indian Ocean near the equator that contain low $^{7}\text{Be}$ are the predominant air moisture sources to the precipitation in the Basin; b) The thick cloud horizons and great number of cloudy days due to the basin topography may preclude cosmic ray penetration.
Profile variations of $^{137}$Cs, $^{210}$Pb$_{ex}$ and SOM as affected by intensive tillage on sloping land in China.

Yong Li and Lingyu Bai

Accelerated soil erosion by intensive tillage on steep slopes is the major threat for sustainable agricultural production in western China and it has serious environmental impacts as well. This erosion results in progressive removal of the surface soils and it has adverse on-site effects on the soil quality. Soil Organic Matter (SOM), mainly concentrated in soil surface horizon, is an important determinant of the soil quality. SOM is preferentially removed by overland flow and tillage erosion. Few direct measurements, however, have been conducted to investigate these dynamic processes occurring at the landscape and resulting from intensive tillage. The key problem is how to link the soil redistribution patterns on the slope to the soil organic matter patterns. Ritchie and McCarty suggested that $^{137}$Cs and soil carbon are moving along similar physical pathways. The objective of this study is to test if $^{137}$Cs, $^{210}$Pb$_{ex}$ and SOM move on sloping land by similar physical mechanisms during tillage operations. To confirm this hypothesis, the profile variations of $^{137}$Cs, $^{210}$Pb$_{ex}$ and SOM contents along hillslope were measured before and after a suite of tillage operations. Intensive tillage was simulated by 50 plowing operations over a 5-days period using a donkey-drawn mould board-plow on a steep back slope at the Chinese Loess Plateau. Profile variations of $^{137}$Cs, $^{210}$Pb$_{ex}$ and SOM contents were measured at the upper, mid, and lower positions of the sloping land after the 50 plowing operations. Intensive tillage effects on $^{137}$Cs, $^{210}$Pb$_{ex}$ and SOM contents were determined from a control slope adjacent to the experimental slope. $^{137}$Cs concentration was uniformly mixed in the upper 15-30 cm of soil whereas $^{210}$Pb$_{ex}$ showed a linear decrease at upper and mid portion, and an exponential decrease with depth on the lower portion of the control slope. SOM contents of the topsoil (0-30 cm) were much higher than the subsoil (layers below 30 cm) on the control slope, and showed a similar decrease pattern to profile pattern of $^{210}$Pb$_{ex}$ on the mid and lower portion of the control slope. Concentrations of $^{137}$Cs, $^{210}$Pb$_{ex}$ and SOM spatially increased in the following order: lower > mid > upper for both the experimental slope after 50 plowing operations and the control slope. Fifty 50-plowing operations resulted in a decrease of SOM content (g kg$^{-1}$) by 37% and by 45% for the topsoil layers (0-45 cm) at upper portion and mid portion, respectively. However, the lower position showed an increase of SOM content by 34% in the soil layers of 0-100 cm after 50 plowing operations. Weighed mean values of $^{137}$Cs concentrations decreased from 2.20 to 0.32 Bq kg$^{-1}$ at the upper position and from 3.79 to 0.33 Bq kg$^{-1}$ at the mid position, whereas they increased from 1.48 to 2.63 Bq kg$^{-1}$ at the lower position. Weighed mean values of $^{210}$Pb$_{ex}$ concentrations decreased from 27.71 to 6.45 Bq kg$^{-1}$ at upper position, from 35.46 to 1.57 Bq kg$^{-1}$ at mid position, and from 25.53 to 19.40 Bq kg$^{-1}$ at lower position. Profile concentrations of $^{137}$Cs and $^{210}$Pb$_{ex}$ are significantly correlated with SOM contents with $R^2$ values of 0.82-0.86 for control slope, and 0.86-0.90 for experimental slope. Our results above suggested that fallout $^{137}$Cs and $^{210}$Pb$_{ex}$ could be used directly for establishing soil organic matter-soil redistribution relationships as affected by tillage operations in a hill slope.

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