Assessing Soil Erosion Using Nuclear Techniques

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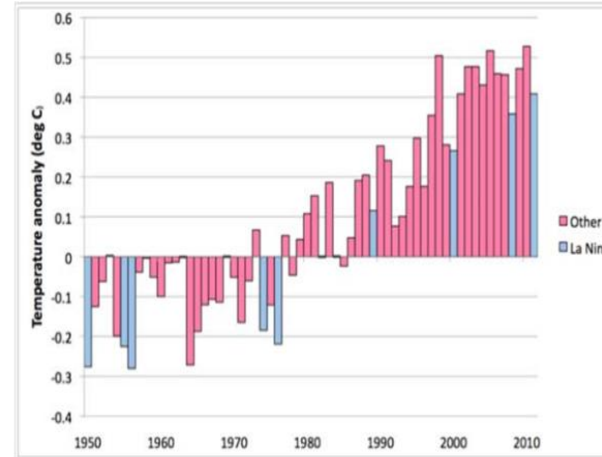
Major Challenges

1. Achieve Food Security

- Every day, 1 billion go to sleep hungry.
- Rising human population (current 7.3 billion, will reach 9 billion by 2050).
- Majority of population increase occur in under-developed and developing countries of Asia and Africa that already face food shortage.
- Current food production needs to be increased by 70% to meet the increasing demand of food.

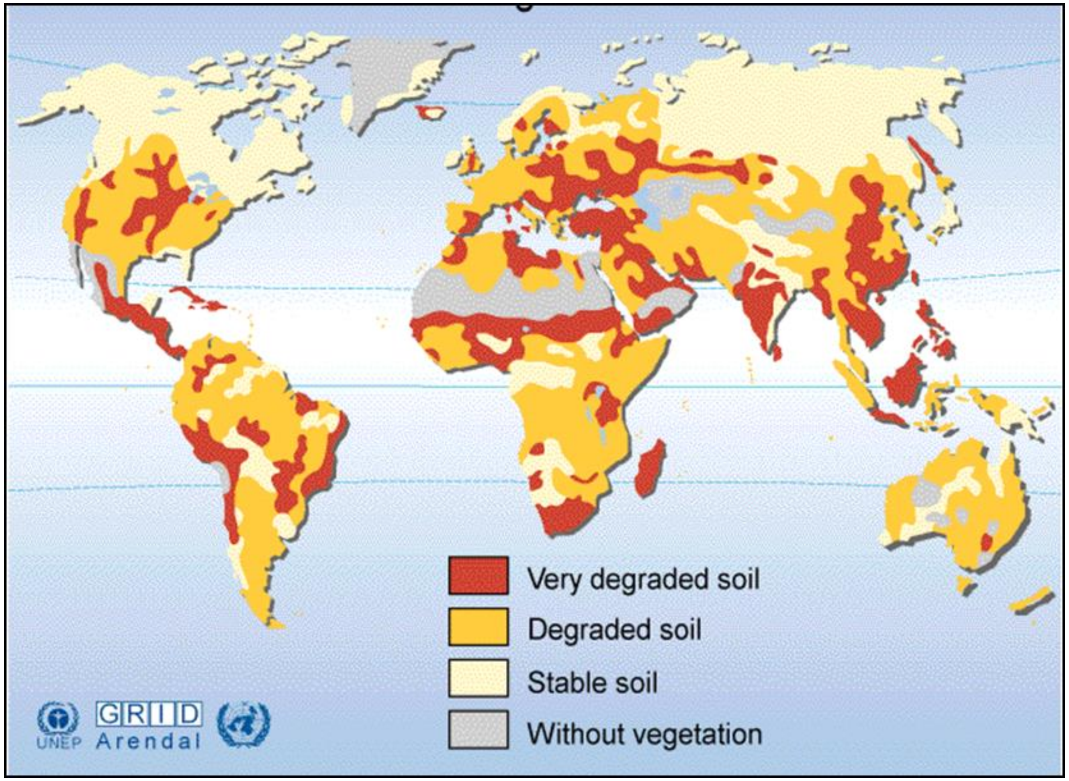


2. Minimize the Impact of Climate Change

- Increased greenhouse gas (GHG) emissions leading to rising temperature and extreme weather (drought and flooding).
- Agriculture and land use changes contribute 30% of GHG emissions therefore need to be reduced.

3. Conservation of Soil & Water Resources

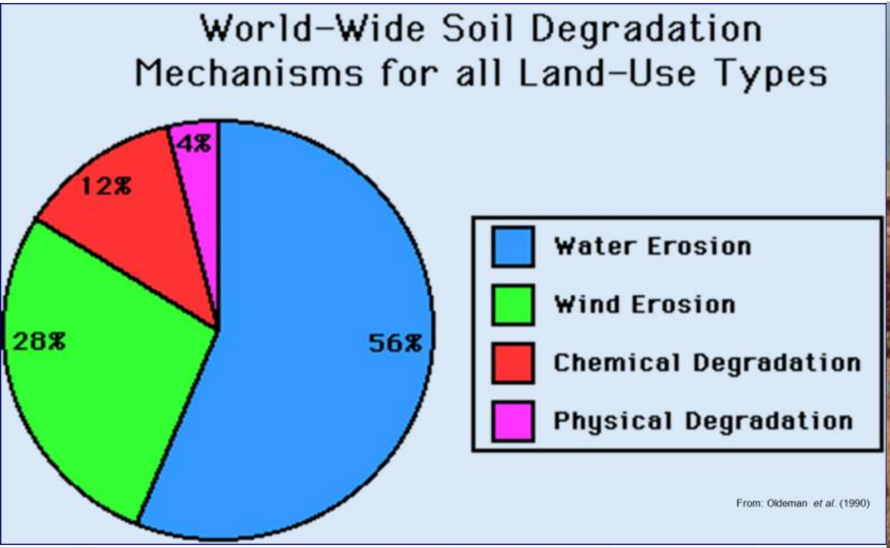
Soil Degradation

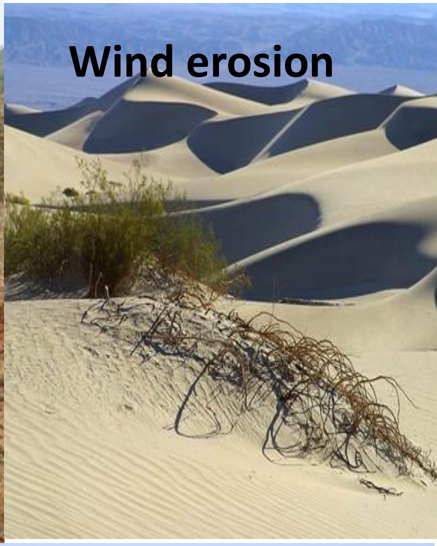


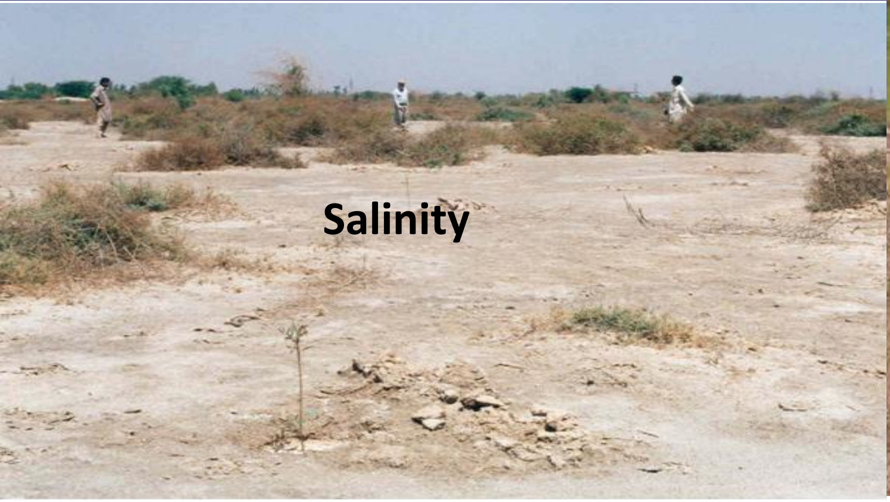
- ✓ 65% of the global soil resources is degraded (1.9 billion ha)
- ✓ Since 1960, 30% of arable land have been lost
- ✓ 80% of degraded land is located in developing countries
- ✓ On-farm + off-farm costs of soil erosion =

US $400 billion per year

Land Degradation

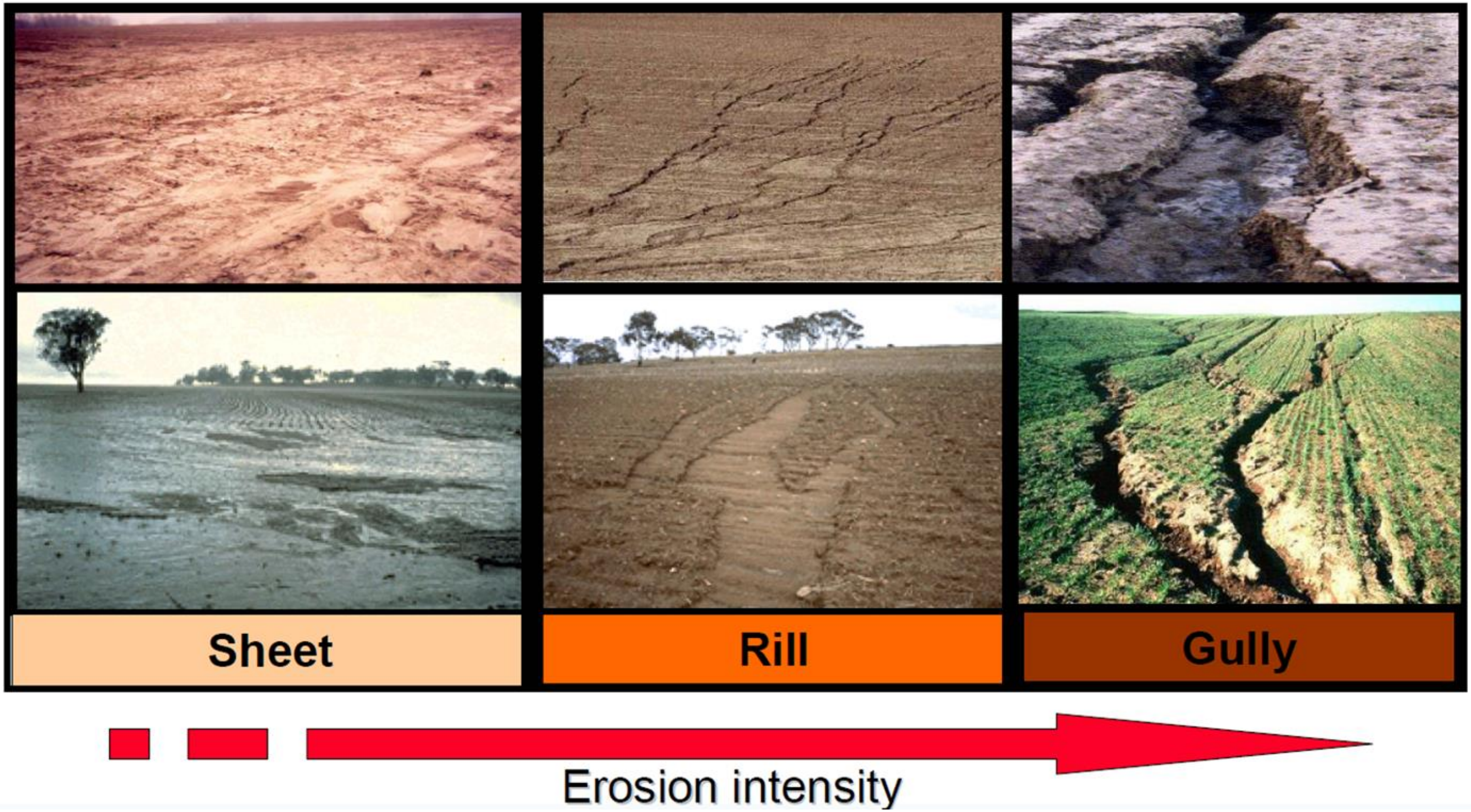






If rainfall > infiltration = runoff

Forms of water erosion



Methods for soil erosion measurement

" If you can't measure it, you can't manage it ! "

- Modeling (e.g. USLE)
- Erosion pins

- Erosion plots

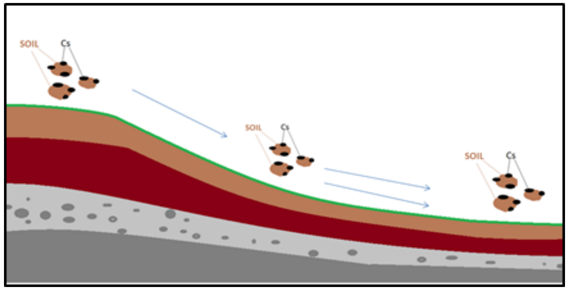
- Indirect methods (sediment deposits)

- Nuclear techniques (Fallout Radionuclides)

Basic concepts of the use of FRNs to investigate soil erosion

Reasons for using Fallout Radionuclides

- ❑ Fallout of radionuclides is universal

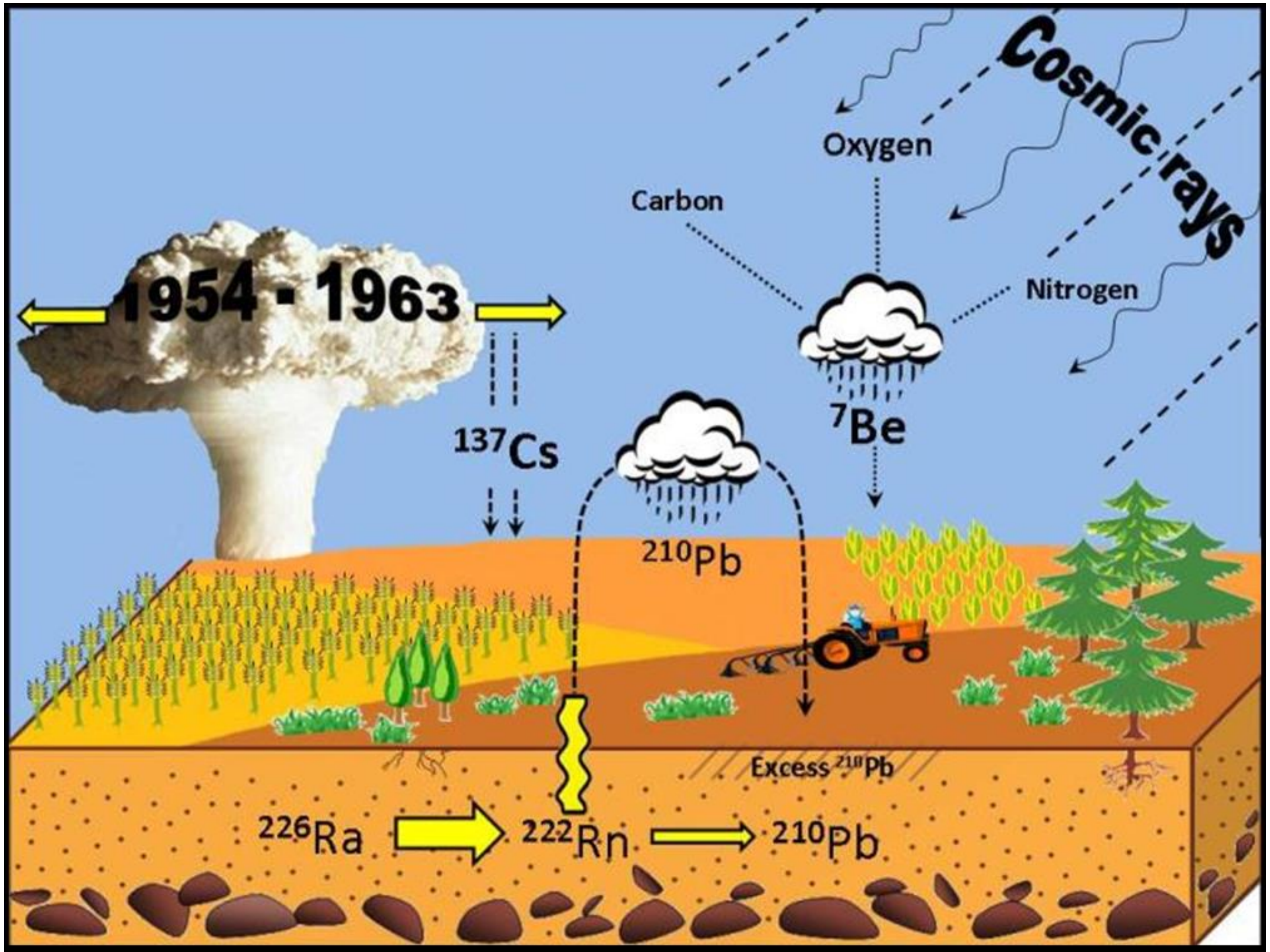


- ❑ Strongly fixed on fine soil particles

[therefore these isotopes can be used as reliable soil tracers for estimating soil erosion and sedimentation rates]

- ❑ Only one sampling campaign is required to estimate erosion processes

Fallout Radionuclides (FRNs) for erosion studies

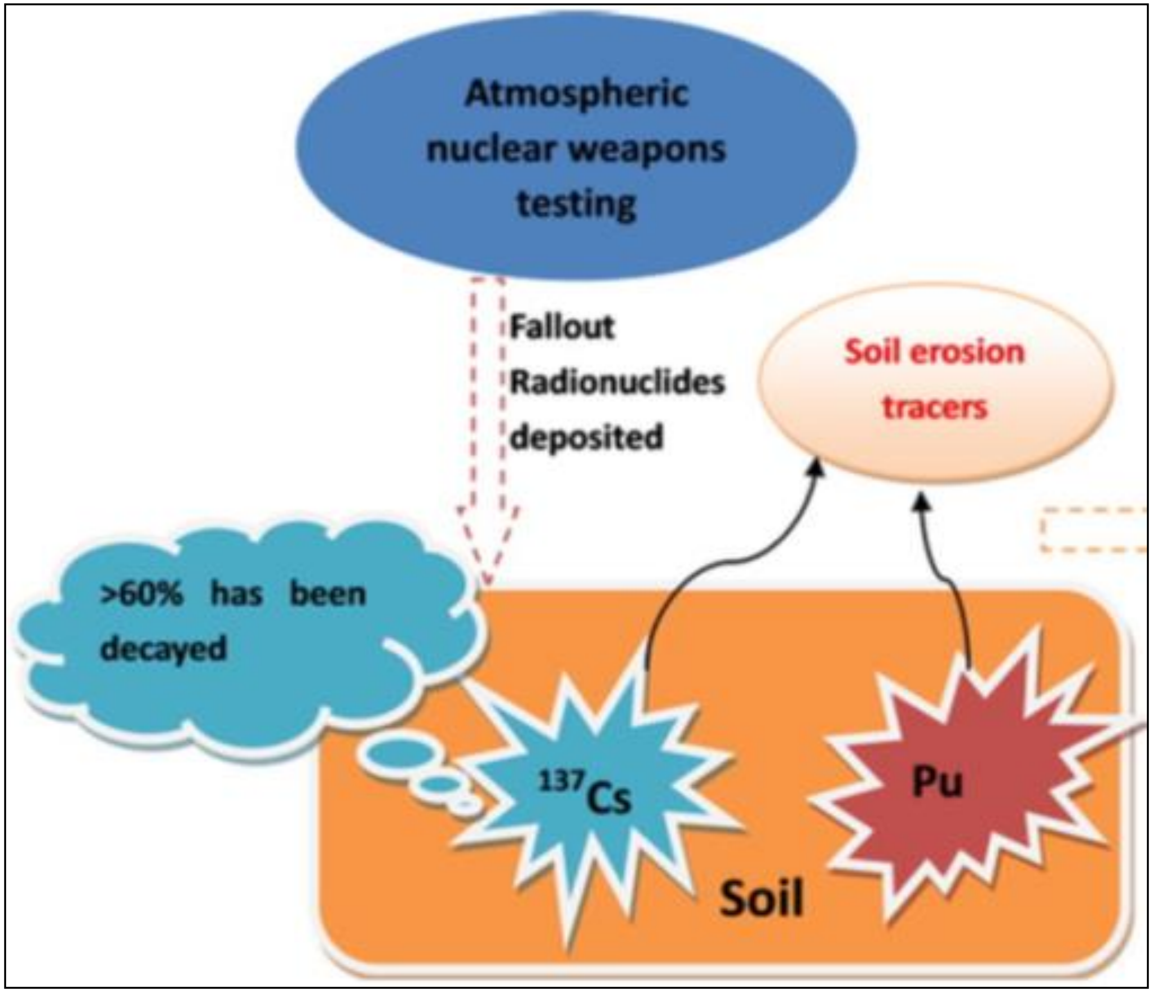


Adapted from : Zupanc, V., Mabit, L. (2010). Nuclear techniques support to assess erosion and sedimentation processes: preliminary results of the use of ^{137}Cs as soil tracer in Slovenia. *Dela,* 33, 21-36.

Main Radionuclides for erosion studies

Nuclide	Origin	Half-life	γ-Energy
^{137}Cs	**Artificial**	**30 y**	**661 keV**
^{7}Be	**Natural**	**53 d**	**477 keV**
^{210}Pb	**Natural**	**22 y**	**46 keV**

New FRN soil tracers: $^{239+240}Pu$



After assessing soil erosion, the Question: Where did all that sediment come from?

- What conservation measure (s) I need to put in place and where?

- ✓ To answer, these questions require an understanding of the catchment:

- ✓ What are the land uses in the catchment?

- ✓ How is the land managed?

- ✓ Then select the Right Technique?

Compound Specific Stable Isotope (CSSI) techniques

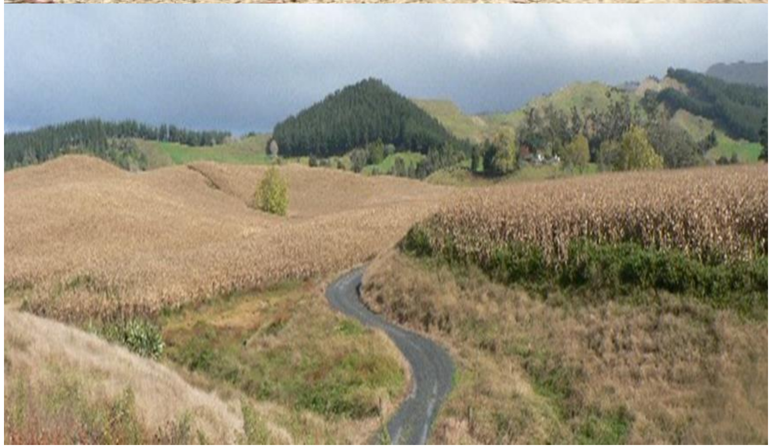
- **The CSSI techniques, a forensic tool, identify the "Source" of soil erosion in a landscape with different land uses**

- **Land use** is typically described by the associated **plant community** on it e.g. pasture, crops, forest & horticulture

- The plant community (C3 and C4) produce a range of organic compounds which "leak" into the soil from their roots and bind to the soil particles becoming "labels" for that land use

- The CSSI technique uses the straight-chain fatty acids (Oleic acid) C14 to C24 as biomarkers

- Mixing models are used to determine how much each soil sources contributing to the sediment



CSSI concept

The key to discriminating between soils from different land uses is that different plants produce these fatty acids in slightly different ways.

This changes the isotopic fractionation of the ^{13}C in each fatty acid giving it a different $\delta^{13}C$ isotopic signature, depending on the plant community …

Land-use / Sources	Bulk carbon $\delta^{13}C$ (‰)	CSSI (Fatty acids) Myristic (C14:0) (‰)	Palmitic (C16:0) (‰)	Oleic (C18:1) (‰)
Pasture	-22.2	-27.0	-24.0	-21.6
Native Forest (Nikau)	-27.7	-34.9	-30.4	-28.2
Native Forest (Kauri)	-25.1	-28.9	-25.6	-27.8
Pine forest (Mature)	-26.2	-40.7	-32.4	-29.5
Pine forest (Clear-felled)	-26.5	-32.7	-28.7	-28.2
Seagrass (estuary)	-8.0	-11.7	-10.9	-16.9

In this landscape, there are four land use types:

The expectation would be for soil source contributions to be proportional to the area of each land use.

Interpretation of the CSSI data told a different story …

Source	**% contribution from**	**% of catchment**
Pine forest	50-54 %	12%
Pasture	32-44 %	72%
Native forest	6-14 %	16%

These results indicated that there was a "major source" of erosion associated with production pine forestry


The cause was poor management practice

Application of FRNs and CSSI techniques

The above techniques were applied in a regional project in Asia-Pacific RAS 5055 on Improving Soil Fertility, Land Productivity and Land Degradation Mitigation involving 14 countries:

- **Australia**
- **Bangladesh**
- **China**
- **Indonesia**
- **Malaysia**
- **Mongolia**
- **Myanmar**
- **Nepal**
- **Pakistan**
- **Philippines**
- **South Korea**
- **Sri Lanka**
- **Thailand**
- **Vietnam**

Success Stories

- **Developed database of FRNs in 14 Asian Countries**

- **Reduced land degradation by 50% saving millions $ in retaining plant essential nutrients on farm, enhanced productivity and improvement of water quality**

China	Indonesia	Pakistan	Philippines	Viet Nam
- 48%	- 50%	- 53%	- 63%	- 45%

FRNs for investigating soil erosion disseminated to 65 countries

- **Latin America [18]:** Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Jamaica, Nicaragua, Paraguay, Peru, Uruguay, Venezuela.
- **Europe [14]:** Austria, Belgium, France, Germany, Italy, Poland, Romania, Russia, Slovakia, Slovenia, Spain, Switzerland, Tajikistan, UK.
- **North America [3]:** Canada, Mexico, USA.
- **Africa [10]:** Algeria, Benin, Ivory Coast, Madagascar, Mali, Morocco, Senegal, Tunisia, Uganda, Zimbabwe.
- **Asia Pacific [20]:** Australia, Bangladesh, China, Indonesia, Iraq, Japan, Malaysia, Mongolia, Myanmar, Nepal, New-Zealand, Pakistan, Philippines, Republic of Korea, Sri Lanka, Syria, Thailand, Turkey, Viet Nam, Yemen.

Train-The-Trainers: training activities on erosion at the SWMCN Laboratory Seibersdorf









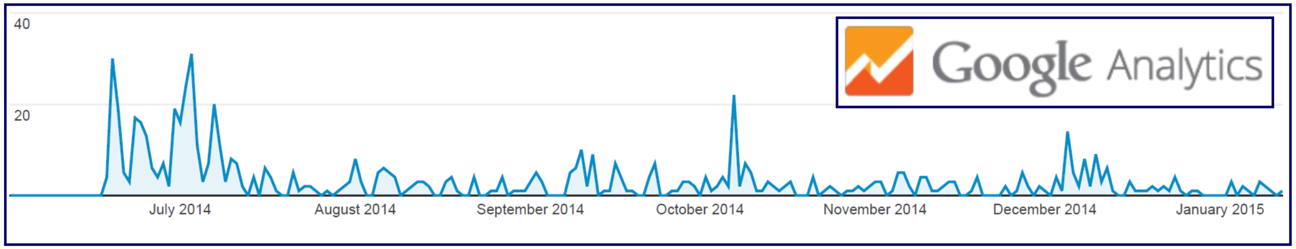



Guidelines for using FRNs to assess soil erosion and effectiveness of soil conservation strategies

TECDOC (213 p) includes 9 chapters 20 authors from 8 IAEA-MSs

http://www-pub.iaea.org/books/IAEABooks/10501/Guidelines-for-Using-Fallout-Radionuclides-to-Assess-Erosion-and-Effectiveness-of-Soil-Conservation-Strategies-

TECDOC impact in MSs (8 months)



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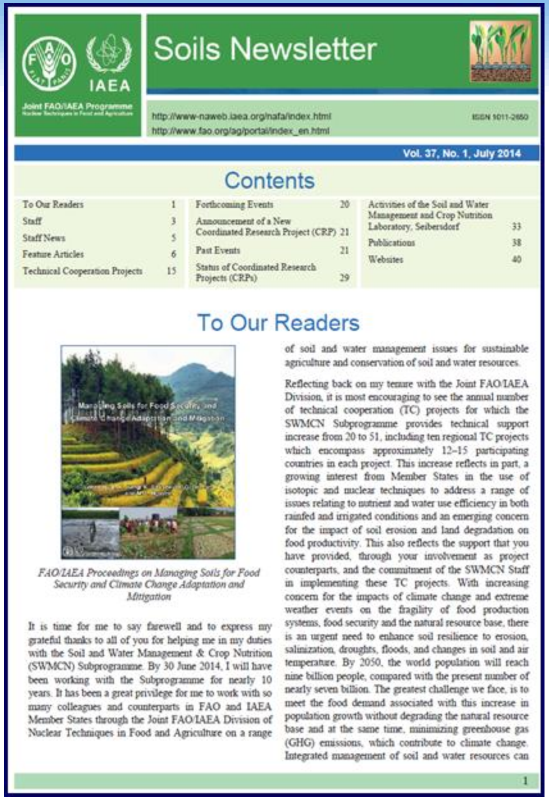
Soils Newsletter

Joint FAO/IAEA Programme

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To Our Readers

FAO/IAEA Proceedings on Managing Soils for Food Security and Climate Change Adaptation and Mitigation

It is time for me to say farewell and to express my grateful thanks to all of you for helping me in my duties with the Soil and Water Management & Crop Nutrition (SWMCN) Subprogramme. By 30 June 2014, I will have been working with the Subprogramme for nearly 10 years. It has been a great privilege for me to work with so many colleagues and counterparts in FAO and IAEA Member States through the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture on a range of soil and water management issues for sustainable agriculture and conservation of soil and water resources.

Reflecting back on my tenure with the Joint FAO/IAEA Division, it is most encouraging to see the annual number of technical cooperation (TC) projects for which the SWMCN Subprogramme provides technical support increase from 20 to 51, including ten regional TC projects which encompass approximately 12–15 participating countries in each project. This increase reflects in part, a growing interest from Member States in the use of isotopic and nuclear techniques to address a range of issues relating to nutrient and water use efficiency in both rainfed and irrigated conditions and an emerging concern for the impact of soil erosion and land degradation on food productivity. This also reflects the support that you have provided, through your involvement as project counterparts, and the commitment of the SWMCN Staff in implementing these TC projects. With increasing concern for the impacts of climate change and extreme weather events on the fragility of food production systems, food security and the natural resource base, there is an urgent need to enhance soil resilience to erosion, salinization, droughts, floods, and changes in soil and air temperature. By 2050, the world population will reach nine billion people, compared with the present number of nearly seven billion. The greatest challenge we face, is to meet the food demand associated with this increase in population growth without degrading the natural resource base and at the same time, minimizing greenhouse gas (GHG) emissions, which contribute to climate change. Integrated management of soil and water resources can

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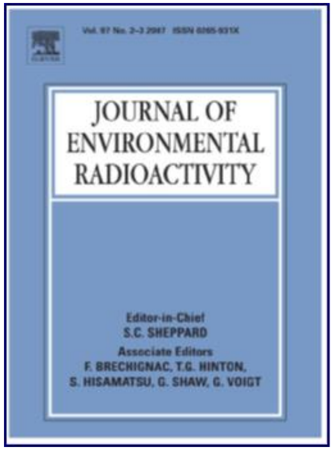

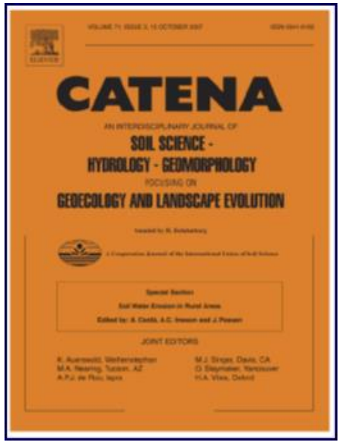

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http://www-naweb.iaea.org/nafa/swmn/index.html

http://www-naweb.iaea.org/nafa/swmn/public/newsletters-swmcn.html

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Video

Thank you !