Assessment of soil erosion using nuclear techniques

E. Fulajtar
Typical soils of loess hilly lands in Western Slovakia
(Soil classification according to WRB, 1994)

Luvi-Haplic Chernozem  
Calcic Luvisol  
Calcaric Regosol

Original soils  
Final stage of erosion
Tunnel erosion
Methods for soil erosion assessment

Pedomorphic method (estimation based on the changes of soil horizonation)
Volumetric method (measuring the volume of rills and gullies).
Geodetic method (measuring the changes in soil surface as referred to stable points).
Erosion measurements at experimental plots (total collection of soil sediments)
Hydrological methods (suspended sediment load)
Rain simulation (use of artificial rainfall to create erosion: a) in field, b) in laboratory)
Erosion models (USLE, EPIC, WEPP, EUROSEM …)
Fallout radionuclide methods ($^{137}$Cs, $^{210}$Pb, $^7$Be)
Direct measurement of erosion rates and sediment accumulation

- surveying methods
- erosion plots
- indirect methods (e.g. suspended sediment monitoring)
- nuclear techniques
Erosion plots
Hydrological profile with suspended sediment sampler
Erosion plots (Japan)
Erosion pins measure soil accumulation or loss along pins. Precision low: ± 1 mm => 12 t ha\(^{-1}\) point values.
Rainfall simulation reproduces impact of natural rain with known KE control on experimental conditions. Investigate quickly varied systems. Limitation of slope length.
Field rain simulator
Laboratory rainfall simulator
Fallout radionuclide methods

Origin of fallout radionuclides

$^{137}$Cs (half-life of 30.2 years) originated from (a) atmospheric bomb tests (fallout from 1954 to mid-1980s with peak in 1963) and from (b) the Chernobyl power plant accident in 1986.

$^{210}$Pb (half-life of 22.8 years) has geogenic origin. It is a product of $^{222}$Rn decay taking part in both soilscape and atmosphere. $^{210}$Pb originating in atmosphere deposits on land surface and enriches the soil upper layer ($^{210}$Pb$_{ex}$)

$^7$Be (half-life of 53.3 days) is a cosmogenic radionuclide produced by the bombardment of the atmosphere by cosmic rays causing spallation of O and N atoms.
## Overview of Environmental Radionuclides

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Origin</th>
<th>Half-life</th>
<th>Emission</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^7$Be</td>
<td>Natural: cosmogenic</td>
<td>53 days</td>
<td>Gamma (10,3)</td>
<td>477 keV</td>
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<tr>
<td>$^{134}$Cs</td>
<td>Artificial: Chernobyl</td>
<td>250 days</td>
<td>Gamma (98,0)</td>
<td>604 keV</td>
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<tr>
<td>$^{210}$Pb</td>
<td>Natural: geogenic</td>
<td>22 years</td>
<td>Gamma (4,06)</td>
<td>46 keV</td>
</tr>
<tr>
<td>$^{137}$Cs</td>
<td>Artificial: Atmospheric bomb tests and Chernobyl</td>
<td>30 years</td>
<td>Gamma (85,0)</td>
<td>661 keV</td>
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<tr>
<td>$^{239}$Pu</td>
<td>Artificial: Atmospheric bomb tests</td>
<td>24000 years</td>
<td>Alfa</td>
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<tr>
<td>$^{90}$Sr</td>
<td>Artificial: Atmospheric bomb tests</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Origin of fallout radionuclides (FRN)

Three radionuclides (\(^{137}\text{Cs}\), \(^{210}\text{Pb}\) and \(^{7}\text{Be}\)) falling with precipitation from atmosphere (hence termed "fallout radionuclides") can be used to measure the soil erosion rates.

\(^{137}\text{Cs}\) – anthropogenic origin:
- Release of \(^{137}\text{Cs}\) by nuclear weapon tests
- Release of \(^{137}\text{Cs}\) by nuclear power plant accidents
- Global circulation of \(^{137}\text{Cs}\)

\(^{7}\text{Be}\) – cosmogenic origin:
- Spallation of O and N, release of \(^{7}\text{Be}\)
- \(^{7}\text{Be}\) fallout with precipitation

\(^{210}\text{Pb}\) – geogenic origin:
- Evaporation of \(^{222}\text{Rn}\) from soil
- Decay of \(^{222}\text{Rn}\) to \(^{210}\text{Pb}\) in atmosphere
- \(^{210}\text{Pb}\) fallout with precipitation
Origin of fallout radionuclides: $^{137}\text{Cs}$, $^{210}\text{Pb}$ and $^7\text{Be}$
Global distribution of bomb-derived $^{137}\text{Cs}$

Fallout records of $^{137}\text{Cs}$
Fallout Radionuclides: atom bomb testing

Global fallout (clear time-scale)

Bq/m²

60° N
30° N
equateur
30° S
60° S

(Playford et al., 1990)

Food and Agriculture Organization of the United Nations
International Atomic Energy Agency
Fallout radionuclides: Chernobyl accident

Clear time-scale, regional, and spatially heterogeneous

[Map of Europe with a focus on Chernobyl and a bar chart showing the fallout record over time]
Geographical distribution and spatial variability of radionuclide deposition

Regional scale → Local scale → Field scale

Map of caesium-137 deposits over Europe immediately after the Chernobyl accident (source: European Atlas EC/IGCE 1998 and IRSN). No data is available for the Balkans.

Source: European Atlas EC/IGCE 1998
and IRSN

Results of airborne monitoring by MEXT and DOE (Total surface deposition of Cs-134 and Cs-137 inside 50 km zone of Fukushima Daiichi NPP)

As of April 29 2011;
Source: MEXT and DOE
Origin of $^{210}\text{Pb}$ and $^7\text{Be}$

**Half-life:** 22.3 years  
**Origin:** Natural geogenic

**Half-life:** 53.3 days  
**Origin:** Natural cosmogenic

Walling, 2004
Origin of $^{210}$Pb and $^7$Be

Half-life: 22.3 years
Origin: Natural geogenic

Half-life: 53.3 days
Origin: Natural cosmogenic

Walling, 2004
Principle of $^{137}$Cs method

$^{137}$Cs and soil erosion

$^{137}$Cs fallout with precipitation (P)

Strong binding of $^{137}$Cs to soil particles

Undisturbed (reference site):

$^{137}$Cs = P

Erosion site: $^{137}$Cs < P

Deposition site:

$^{137}$Cs > P
Principle of $^{137}\text{Cs}$ method
Depth distribution of $^{137}$Cs method

Undisturbed (reference) site

Cultivated site
Distribution of $^{137}\text{Cs}$ in soils

Source: Walling, 2004
Soil sampling for FRNs determination

Recording of site and sample information

Sampling approach
The depth incremental sampling (Bq kg\(^{-1}\))
The bulk sampling (Bq m\(^{-2}\))

Sample distribution
Single transects
Multiple transects
Regular grid
Irregular grid

*Incremental depth sampling using the mechanical core sampler*
Principle of $^{137}\text{Cs}$ method
Bulk core sampling for $^{137}$Cs method
Depth incremental sampling
(scraper plate)
In situ measurements of $^{137}$Cs method using portable gamma detector
Sample preparation

Air drying, grinding and sieving
Weighting and bulk density determination
Sample measurement

Laboratory measurement using HPGe gamma spectrometry. Low background shielding
Use of appropriate software for data acquisition
Quality assurance/quality control
Stability of detectors background
Stability of detector efficiency and calibration
Participation on inter-comparison exercises
FRNs determination

The deposited $^{137}$Cs, $^{210}$Pb, and $^7$Be can be measured using the Gamma-ray spectrometry.

The FRN quantity can be expressed as concentration (Bq kg$^{-1}$) or as total inventory or total areal activity (Bq m$^{-2}$).

Fig 2. Gamma spectrometer, Soil Science Unit, IAEA Laboratories, Seibersdorf
Measurements of $^{137}\text{Cs}$
Principle of FRN conversion models:

- Models for non-cultivated land
- Models for cultivated land
Determination of soil erosion rates with aid of conversion models

Models for cultivated sites:
- Proportional model
- Simplified mass balance model
- Standard mass balance model
- Tillage mass balance model

Models for non-cultivated sites:
- Depth distribution model
- Incremental model
MODELS INCLUDED IN THE SOFTWARE

- **Cs-137**
  - Proportional model
  - MBM1, MBM2, MBM3
  - Profile distribution model
  - Diffusion and migration model

- **Excess Pb-210**
  - MBM2, MBM3
  - Profile distribution model
  - Diffusion and migration model

- **Be-7**
  - Profile distribution model
Conversion models (Walling et al., 2005)

**Proportional Model**

\[
Y = \frac{Bd \left( 100 \frac{Ar - A}{Ar} \right)}{10TP}
\]

- **Y** - mean annual soil loss (t ha\(^{-1}\) y\(^{-1}\))
- **B** - soil bulk density (kg m\(^{-3}\))
- **d** - plow depth (m)
- **Ar** - reference \(^{137}\)Cs inventory (Bq m\(^{-2}\))
- **A** - \(^{137}\)Cs inventory of eroded point (Bq m\(^{-2}\))
- **T** - time since the beginning of \(^{137}\)Cs fallout (y)
- **P** - particle size parameter

**Model hypothesis:**

- \(^{137}\)Cs fallout is completely mixed within the cultivation layer
- Soil loss is directly proportional to the amount of \(^{137}\)Cs removed from the soil profile since the beginning of the fallout

**Advantages:**

- Simple to use, needs only tillage depth and \(^{137}\)Cs inventories

**Limitations:**

- Overestimates erosion if fallout is removed before being incorporated in the soil profile
- Underestimates erosion by not accounting for gradual dilution of \(^{137}\)Cs concentration by incorporation of subsoil
Proportional model

\[ Y = \frac{Bd \left(100 \frac{Ar - A}{Ar}\right)}{10TP} \]

- **Y** - mean annual soil erosion rate (t ha\(^{-1}\) rok\(^{-1}\)),
- **B** - soil bulk density (kg m\(^{-3}\)),
- **d** - thickness of plowed horizon (m),
- **Ar** - reference 137Cs inventory (Bq m\(^{-2}\)),
- **A** - 137Cs inventory of investigated point (Bq m\(^{-2}\)),
- **T** - 137Cs fallout time (year),
- **P** - particle size factor for eroded point
- **P'** - particle size factor for accumulated point
Mass Balance Model I

Model hypothesis:

- $^{137}\text{Cs}$ fallout occurred entirely in 1963
- Progressive reduction of $^{137}\text{Cs}$ in the soil of the plow layer due to loss by erosion and incorporation of subsoil

Advantages:

- easy to use, requires few parameters
- considers the gradual inclusion of $^{137}\text{Cs}$ poor soil material in the plow layer

Limitations:

- considers all fallout occurred in 1963
- does not consider potential removal of fresh fallout before incorporation in the soil

$$Y = \frac{10Bd}{P} \left[ 1 - \left( 1 - \frac{Ar - A}{Ar} \right)^{\frac{1}{t-1963}} \right]$$

- $Y$ - mean annual soil loss (t ha$^{-1}$ y$^{-1}$),
- $B$ - soil bulk density (kg m$^{-3}$),
- $d$ - plow depth (m),
- $Ar$ - reference $^{137}\text{Cs}$ inventory (Bq m$^{-2}$),
- $A$ - $^{137}\text{Cs}$ inventory of eroded point (Bq m$^{-2}$),
- $t$ - time of $^{137}\text{Cs}$ sampling (y),
- $P$ - particle size parameter
Mass Balance Model II

Model hypothesis:

- $^{137}$Cs fallout variable in time
- Integrates fate of FRN deposition before incorporation in soil by cultivation

Advantages:

- Soil redistribution estimates more realistic than with MBm1

Limitations:

- Potential difficulty to establish the value of some parameters

\[
y = \frac{(1 - \Gamma) I(t) d}{P A(t)} - \frac{\lambda d}{P} - \frac{dA(t)d}{A(t)dt}
\]

- $y$ - mean annual soil loss (t ha$^{-1}$ rok$^{-1}$)
- $\Gamma$ - proportion of deposited $^{137}$Cs removed before ploughing
- $I(t)$ - annual $^{137}$Cs fallout (Bq m$^{-2}$ rok$^{-1}$)
- $d$ - weight of lowed layer (kg m$^{-2}$)
- $P$ - particle size factor
- $A(t)$ - total $^{137}$Cs inventory in year $t$ (Bq m$^{-2}$)
- $\lambda$ - decay constant for $^{137}$Cs ($y$)
- $t$ - time since the beginning $^{137}$Cs fallout ($y$)
Mass Balance Model 2
Parameters Required

- Local Reference Inventory
- Annual fallout input record
- Year of tillage commencement
- Proportion Factor
- Relaxation depth of Initial Distribution
- Tillage Depth
- Particle Size Correction
Profile Distribution Model

- Assumes current depth distribution established in 1963
- Assumes exponential depth distribution and uses the reduction in inventory to estimate the depth of soil loss and thus the mean annual rate of soil loss
- A relatively simple model to apply
Profile Distribution Model
Parameters Required

- Local Reference Inventory
- Profile shape factor – relaxation depth
Diffusion and Migration Model
Parameters Required

- Local Reference Inventory
- Fallout input record (synthesised)
- Diffusion and migration parameters (calculated from Cs-137 depth distribution obtained for reference site)
- Relaxation depth of Initial Distribution
Software for FRN conversion models
World-wide application of the $^{137}$Cs technique

Assessment of medium term rates and spatial distribution patterns of both erosion and sedimentation at the catchment scale.

Harmonised application through two CRPs.
Harmonising the $^{137}$Cs technique

Assessment of medium term rates and spatial distribution patterns of both erosion and sedimentation at the catchment scale.

Harmonised world-wide application through two CRPs
The $^{137}$Cs technique

Assessment of medium term soil erosion and deposition rates as well as spatial distribution patterns at the catchment scale.

Harmonised worldwide application through two CRPs.
Measuring soil erosion and sedimentation

The $^{137}$Cs technique provides medium term soil erosion and sedimentation rates as well as their spatial distribution patterns at the catchment scale. Harmonised world-wide application through two CRPs
Sediment dating

Radio-isotope content
Chemical composition
Magnetic properties
Mixing models

Ionita and Margineanu, 2000
Soil redistribution inventorz at plot scale at Bohunice site, Slovakia

Emil Fulajtar
Results from Bohunice site

Multiple transect grid
Calculated by Tab. 12.

### Transect B

<table>
<thead>
<tr>
<th>Sample point</th>
<th>Position</th>
<th>$^{137}$Cs activity (Bq.kg$^{-1}$)</th>
<th>Soil erosion - deposition (t.ha$^{-1}$.year$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mass ballance model I</td>
<td>Mass ballance model II</td>
</tr>
<tr>
<td>Transect A</td>
<td></td>
<td>Proportional model</td>
<td></td>
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<tr>
<td>A1</td>
<td>ESS</td>
<td>2455.7</td>
<td>-20.67, -28.88</td>
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<tr>
<td>A2</td>
<td>VB</td>
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<td>58.08, 68.96</td>
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<tr>
<td>A3</td>
<td>WSS</td>
<td>3932.0</td>
<td>33.15, 50.77</td>
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<tr>
<td>A4</td>
<td>WSS</td>
<td>2038.8</td>
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<td>A5</td>
<td>WSS</td>
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<td>A6</td>
<td>WP</td>
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<tr>
<td>Transect B</td>
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<td>B1</td>
<td>VB</td>
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<td>53.52, 70.32</td>
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<td>WSS</td>
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<td>WSS</td>
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<td>B4</td>
<td>WP</td>
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<td>Transect C</td>
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<td>C1</td>
<td>ESS</td>
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<td>-64.34, -127.06</td>
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<td>ESS</td>
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<td>29.34, 59.26</td>
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<td>VB</td>
<td>4539</td>
<td>50.15, 101.78</td>
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<td>WSS</td>
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<td>50.45, 101.88</td>
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<td>C5</td>
<td>ESS</td>
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<td>-41.02, -65.51</td>
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<td>C6</td>
<td>WSS</td>
<td>2526</td>
<td>-16.44, -22.40</td>
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<td>C7</td>
<td>MP</td>
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<td>C8</td>
<td>ESTV</td>
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<td>C9</td>
<td>TVB</td>
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<td>C10</td>
<td>WSTV</td>
<td>3063</td>
<td>1.32, 2.24</td>
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<td>C11</td>
<td>WP</td>
<td>2979</td>
<td>-1.46, -1.83</td>
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### Transect D

<table>
<thead>
<tr>
<th>Transect D</th>
<th>Sample</th>
<th>Erosion and deposition rate calculated by selected calibration models</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>ECVS</td>
<td>1538, -49.12, -83.68, -56.07</td>
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<td>ESS</td>
<td>1117, -63.05, -122.75, -90.19</td>
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<td>4801, 58.82, 110.33, 75.38</td>
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<td>VB</td>
<td>4310, 42.57, 79.86, 54.56</td>
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<td>D5</td>
<td>WCSS</td>
<td>3244, 7.31, 13.71, 9.37</td>
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<td>D6</td>
<td>WSS</td>
<td>3226, 6.72, 12.60, 8.61</td>
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<td>WCSS</td>
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<td>D8</td>
<td>MR</td>
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<td>WSTV</td>
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<td>WP</td>
<td>2630, -13.00, -17.37, -9.82</td>
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### Transect E

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<th>Erosion and deposition rate calculated by selected calibration models</th>
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<tr>
<td>E1</td>
<td>ECVS</td>
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<td>2967, -1.85, -2.34, -1.28</td>
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<td>ESS</td>
<td>1797, -40.56, -64.55, -41.18</td>
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<td>2502, -17.23, -23.58, -13.53</td>
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<td>2641, -12.64, -16.85, -9.51</td>
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<td>E6</td>
<td>ESTV</td>
<td>2744, -9.23, -12.09, -6.74</td>
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<td>WSTV</td>
<td>3059, 1.19, 1.94, 1.22</td>
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<td>3812, 26.10, 42.47, 26.77</td>
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### Transect F

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<td>F1</td>
<td>EP</td>
<td>2391, -20.91, -29.22, -17.01</td>
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<td>ECVS</td>
<td>2593, -14.22, -19.14, -10.86</td>
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<td>F5**</td>
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<td>F6**</td>
<td>MR</td>
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<td>F7</td>
<td>ESS</td>
<td>2117, -29.97, -44.31, -26.82</td>
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<td>WSTV</td>
<td>2081, -31.16, -46.43, -28.26</td>
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<tr>
<td>F9</td>
<td>WP</td>
<td>1931, -36.12, -55.68, -34.71</td>
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### Transect G

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<th>Erosion and deposition rate calculated by selected calibration models</th>
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<tr>
<td>G1</td>
<td>EP</td>
<td>2381, -23.39, -33.14, -1.39</td>
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<tr>
<td>G2</td>
<td>ECVS</td>
<td>2436, -21.39, -29.98, -9.37</td>
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<td>ESS</td>
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<tr>
<td>G4</td>
<td>ECVS</td>
<td>4036, 36.95, 52.93, 20.14</td>
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<tr>
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<td>VB</td>
<td>3608, 21.32, 30.54, 11.62</td>
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### Transect K

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<td>K2</td>
<td>ECVS</td>
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<tr>
<td>K3</td>
<td>ESS</td>
<td>2259, -25.27, -36.27, -2.50</td>
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<tr>
<td>K4</td>
<td>ECVS</td>
<td>2864, -5.26, -6.75, -2.72</td>
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<td>K5</td>
<td>VB</td>
<td>5304, 75.45, 106.96, 64.41</td>
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<tr>
<td>K6</td>
<td>WCSS</td>
<td>2362, -21.87, -30.74, -17.66</td>
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### Fig.3 137Cs distribution along transects

- **A**: w. plateau
- **B**: w. conv. slope
- **C**: w. mid. slope
- **D**: w. conc. slope
- **E**: valley bottom
- **F**: e. conc. slope
- **G**: e. mid. slope
- **H**: e. conv. slope
- **I**: e. plateau

**Slope position**
$^{137}$Cs spatial distribution

$^{137}$Cs depth distribution at depositional sink area
Spatial pattern of erosion/deposition processes (1:10 000), Jaslovské Bohunice, soil erosion rates (t ha\(^{-1}\) y\(^{-1}\)) calculated by mass balance model
Results from Mochovce site

Multiple transect grid

Atoms for Food and Agriculture: Meeting the Challenge
### Total $^{137}$Cs inventories and soil erosion/deposition rates calculated by conversion models

<table>
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<tr>
<th>Sample profile</th>
<th>Sample depth (cm)</th>
<th>Slope position</th>
<th>$^{137}$Cs inventory (Bq.m$^{-2}$)</th>
<th>Soil redistribution</th>
<th>Sample profile</th>
<th>Sample depth (cm)</th>
<th>Slope position</th>
<th>$^{137}$Cs inventory (Bq.m$^{-2}$)</th>
<th>Soil redistribution</th>
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$^{137}$Cs distribution along the transects

Topographical position

137 Cs inventory

Transect B
Transect C
Transect D
Transect E
Transect F
Transect G
Transect H
Mean
$^{137}\text{Cs}$ spatial distribution
Spatial distribution of soil erosion and deposition at Mochovce site, Slovakia

The erosion rates at the steepest central parts of the slopes are between 17 and 63 t ha$^{-1}$ y$^{-1}$ with an average of 39 t ha$^{-1}$ y$^{-1}$ (Mass Balance Model II).

The deposition rates in the valley bottom range from 3 to 69 t ha$^{-1}$ y$^{-1}$ with an average of 32 t ha$^{-1}$ y$^{-1}$.
### Comparison of soil erosion rates obtained by $^{137}$Cs method at Jaslovské Bohunice and Mochovce sites

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<th>Site and Authors</th>
<th>Site scale</th>
<th>Process</th>
<th>Period</th>
<th>Slope length</th>
<th>Slope inclination</th>
<th>Vegetation</th>
<th>Mean erosion rate</th>
<th>Range of rates</th>
<th>Number of data</th>
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<td>cca 40 ha</td>
<td>overall on-site soil redistribution</td>
<td>1954-1998</td>
<td>80 m</td>
<td>4-8°</td>
<td>ArL</td>
<td>26.1 t ha$^{-1}$</td>
<td>11.4-54.4</td>
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<td>Mochovce</td>
<td>cca 50 ha</td>
<td>overall off-site sediment transport</td>
<td>1954-1998</td>
<td>100 m</td>
<td>4-12°</td>
<td>F+ArL</td>
<td>39.0 t ha$^{-1}$</td>
<td>17.0-63.0</td>
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### Soil erosion rates measured at experimental plots

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<th>Process</th>
<th>Period</th>
<th>Slope length (m)</th>
<th>Slope inclination (°)</th>
<th>Vegetation</th>
<th>Mean erosion rate (g.m⁻²)</th>
<th>Data range (t ha⁻¹)</th>
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<td>25x2 (50)</td>
<td>sheet and initial rill erosion</td>
<td>1981-82 (growing seasons)</td>
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<td>OR, WW</td>
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<td>1986-88 (growing seasons)</td>
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<td>sheet and initial rill erosion</td>
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<td>tipping buckets</td>
<td>100x10 (1000)</td>
<td>sheet and mature rill erosion</td>
<td>1997-99 (whole years)</td>
<td>100</td>
<td>4-12°</td>
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<td>42.4</td>
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Compound Specific Stable Isotope Analyses (CSSI)

$^{13}$C in fatty acids of different ecosystems

Clear felled Pine

Exotic Pine

Native Forest

Pasture
δ¹³C of grassland (Source 5)

δ¹³C of coniferous forest (Source 3)

δ¹³C of deciduous forest (Source 4)

δ¹³C of wheat (Source 1)

δ¹³C of maize (Source 2)

δ¹³C of sediment (Mixture of Sources 1-5)
Assessment of long term impact of soil erosion under the large scale mechanized agriculture using remote sensing
Data from individual transect sites
Mathematical classification of SPOT PAN Image

Procedure comprise of four steps:
1. Land typization
2. Uncontrolled mathematical classification
3. Uncontrolled aggregation
4. Expert aggregation

Three land types:
1. winter wheat
2. stubble
3. bare soils

Four classes of electromagnetic reflectance (1, 2, 3, 4)

1 Step. Land typization
2 Step. Uncontrolled classification
Explanation:

- Agricultural land
- Moderately eroded soils
- Strongly eroded soils
- Forests
- Urban areas

Approximately 4,637 ha (31% of agricultural land) in loess hilly lands of Levice district are strongly eroded.
Achievements of the technical cooperation in Africa: Example of TC project in Uganda (UGA5037)
Soil and Water Management & Crop Nutrition Newsletter

New issues
New issues
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New issues
Methodological handbooks

- **Handbook for the Assessment of Soil Erosion and Sedimentation Using Environmental Radionuclides**
- **Guidelines for Using Fallout Radionuclides to Assess Erosion and Effectiveness of Soil Conservation Strategies**
- **Guidelines for Sediment Tracing Using the Compound Specific Carbon Stable Isotope Technique**

Atoms for Food and Agriculture: Meeting the Challenge
Combatting Soil Erosion to Help Achieve Zero Hunger and Clean Water: IAEA Commemorates World Soil Day

Joanne Liu, IAEA Office of Public Information and Communication

DEC 5 2019

Isotopes were used to determine soil erosion rates of experimental plots with no tillage (front) and conventional tillage (back) and management in Zimbabwe. (Photo: E. Fujii/IAEA)

Over 45 billion tons of soil are lost to erosion every year. Farmers in several countries have succeeded in slowing down erosion with the help of nuclear techniques. Here are their stories from Zimbabwe, Argentina and Sri Lanka.

All over the world, the Earth's fine soil particles are losing ground to erosion. As 95 percent of food is cultivated in soil, the health and availability of Earth's living surface impacts the quality and quantity of the food we produce.

“Agricultural landscapes lose valuable soil mainly through soil redistribution processes,” said Emmanuel Chikwari, Head of the Chemistry and Soil Research Institute in Zimbabwe. “Once the soil resource is lost, it cannot be replaced for generations.”

Related Stories

- World Soil Day: How Can Nuclear Techniques Be the Solution to Soil Pollution and Increased Productivity?
- Nuclear Techniques Help Reveal High Rate of Soil Erosion in Benin
- How to Win a Fight Against Soil Erosion: Nuclear Science Helps Farmers in Morocco
- Isotope Techniques Trace Erosion Source to Sri Lanka’s Terraced Tea Plantations

Related Resources

- World Soil Day 2019
- Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture
- Soil erosion control
- Guidelines for Using Fallout Radionuclides to Assess Erosion and Effectiveness of Soil Conservation Strategies
- Studying Erosion with the Help of Radionuclides
Soil erosion is a major problem for Benin's farmers. Nuclear techniques help scientists find its exact causes, so that they can tackle erosion. (Photo: E. Fulajtar/IAEA)

Harmless traces from nuclear testing more than half a century ago are helping researchers assess soil erosion rates. In Africa, about 65 percent of the continent's farm land is affected by erosion-induced losses of topsoil and soil nutrients, according to the Food and Agriculture Organization of the United Nations (FAO). Benin is among those countries severely impacted by soil erosion, which poses a major problem for economic development since agriculture represents approximately 35 percent of the country's GDP and 80 percent of its export income. A recent study applied a nuclear technique to assess rates of soil erosion and support land conservation in Benin.

"Evidence shows that over 90% of soils in Benin have a high level of degradation," said Pascal Houngnantan, Director of the Laboratory of Soil Microbiology and Microbial Ecology at the Faculty of Agricultural Sciences,
Soils are critical for all life—they act as a water filter and growing medium, supply nutrients for plant growth and contribute to biodiversity. Yet, despite the universal importance of healthy soil, we continue to lose approximately 5 to 7 million hectares each year through soil degradation - 24 billion tons of this non-renewable resource have been lost over the last century from the world’s arable land. Today, land and soil degradation affect approximately 1.5 billion people, and not just in arid or dry environments.

June 17 is World Day to Combat Desertification, and this year’s theme is ‘Land Belongs to the Future – Let’s Climate Proof’. The International Atomic Energy Agency (IAEA), through its technical cooperation programme and the Joint FAO/IAEA Division, is helping Member States to address this goal by
Atoms for Food and Agriculture: Meeting the Challenge

On solid ground: IAEA celebrates World Soil Day

More than 50% of the Earth's land is moderately or severely affected by soil degradation. Without sustainable practices, this trend will unfortunately continue, jeopardizing biodiversity, threatening global food prices, and endangering more than 2.6 billion small-scale farmers whose livelihoods depend on healthy soil. Although the challenge is great—both in size and complexity—the UN celebration of World Soil Day on 4 December reminds us that we have the tools to confront, and eventually resolve, the challenge.

Whereas it may take 1,000 years for a single centimetre of healthy soil to form, that same plot of land can be degraded or destroyed in moments. This is the central message of World Soil Day—arable land is fragile and limited, which means that our land-use must be respectful and sustainable. Through its technical cooperation (TC) programme, the IAEA works closely with its...
The erosion that plagues Morocco’s hillsides affects more than the agricultural fields that are losing soil. The eroding soil that sweeps down the hillsides eventually ends up as sediment in water reservoirs, leaving them with less water storage capacity. The Joint FAO/IAEA Division, working with Morocco’s nuclear institution and other partners, adapted and introduced a package of isotopic techniques to identify the most erosion-prone areas. Having this information allowed for development and introduction of...
World Soil Day: Madagascar Combats Soil Erosion with Tradition and Nuclear Science

Nicole Jawerth, IAEA Office of Public Information and Communication

An age-old agricultural method is helping to combat soil degradation and protect a source of food and income for more than 75% of the population in Madagascar. Through a study using isotopic techniques on the mountainous island, scientists working with the IAEA, in cooperation with the Food and Agriculture Organization of the United Nations (FAO), found that traditional terrace farming can reduce soil erosion andrun-off in the country by up to 40% when compared to unprotected agricultural fields.
World Soil Day: Caring for the Planet Starts from the Ground and Nuclear Techniques can Help

Nicole Jawerth, IAEA Office of Public Information and Communication

Erosion threatens soil resources worldwide. Nuclear science offers ways to study and protect this finite, non-renewable resource. (Photo: M. Benmansour/CNESTEN)

Have you ever thought about soil? Thought about this vast limited resource where your food grows? This finite, non-renewable resource is under threat worldwide. Intensive agricultural practices, pollution and climate change threaten its health and the life-sustaining support it offers people and the planet.

But soil has an ally: nuclear science.
How to Win a Fight Against Soil Erosion: Nuclear Science Helps Farmers in Morocco

Nicole Jawerni, IAEA Office of Public Information and Communication

FEB 26 2018

Farmer El Haj Abdeslam’s son drives a tractor to help with the farm work while scientists take soil samples from the fields. (Photo: R. Moussadek/INRA)

Farmer El Haj Abdeslam and his three helpers spent years fighting soil erosion that swept away their crops’ fertile ground, taking their incomes with it. Now Abdeslam and many Moroccan farmers like him are saving their soil and their source of food and money using soil-conservation methods selected with the help of nuclear science.
How to win the fight against soil erosion: saving fertile land and preserving water quality with the help of nuclear techniques

By Nicole Jawerth and Miklos Gaspar

Erosion eats away at fertile land, threatening food production and farmers' income alike. The top layer of the soil, which is the first to go, is the most nutritious. Often this nutritious soil ends up in rivers and lakes where it encourages algae to grow, causing the amount of oxygen in the water to decrease. This in turn compromises water quality and harms fish populations.

Nuclear techniques can help scientists and farmers find erosion hot spots and identify the right soil conservation technique to save both farmland and fresh water sources (see The Science box on page 17). The IAEA, in cooperation with the Food and Agriculture Organization of the United Nations (FAO), provides support to 70 countries on erosion research. This article profiles two of them: Morocco, where the focus is on saving agricultural land, and Myanmar, where they are fighting off an algae boom in the country's second largest lake.

Saving farmland in Morocco

Farmer El Haj Abdelsalam's son drives a tractor to help with the farm work while scientists take soil samples from the fields. (Photo: G. Buddle/AFP)

Farmer El Haj Abdelsalam and his three helpers spent years fighting soil erosion that swept away their crops' fertile ground, taking their incomes with it.

"Your year after, soil erosion was making the quality of my land worse and that made my farm less productive," said Abdelsalam, whose 5-hectare chickpea and sesame farm feeds his family of seven and is his sole source of income. "Since the scientists helped me conserve my soil, my farm has been producing 20 to 30% more with less input, and my income has gone up."

The scientists used fallout radionuclides and compound-specific stable isotope techniques (see The Science box on page 17) to pinpoint erosion-prone areas and evaluate the effectiveness of various conservation methods. The technique was introduced in response to Morocco's more than 100 million tonnes of soil losses each year.

"Once we knew where the erosion hotspots were, we tested several soil-conservation methods using nuclear techniques to see how we could improve the situation. We adapted and combined different conservation methods.
Egypt and Senegal Receive Gamma Detectors to Help Combat Soil Erosion

Matt Fisher, IAEA Office of Public Information and Communication

A portable gamma detector provided to the National Centre of Energy, Sciences and Nuclear Techniques in Morocco (CNESTEN). (Photo: CNESTEN)

Experts in Egypt and Senegal will be better able to fight soil erosion thanks to two gamma spectroscopy detectors which have just been delivered through the IAEA's technical cooperation programme. The detectors will be used for soil erosion assessment in areas that have experienced severe land degradation, a phenomenon that jeopardizes agriculture in many regions of the world, including in arid and semi-arid lands in Africa.

Related Stories

- How to Win a Fight Against Soil Erosion: Nuclear Science Helps Farmers in Morocco
- World Soil Day: Caring for the Planet Starts from the Ground and Nuclear Techniques can Help
- Viet Nam Tackles Soil Erosion With Nuclear Techniques

Related Resources

- Studying Erosion with the Help of Radionuclides
- Soil Erosion Control
- Land and water management
- Guidelines for Using Fallout Radionuclides to Assess Erosion and Effectiveness of Soil Conservation Strategies
- Impact of Soil Conservation Measures on Erosion Control and Soil Quality
Atoms for Food and Agriculture: Meeting the Challenge
Success stories: awareness rising articles in IAEA fact sheets

Reducing soil erosion in Morocco

**THE CHALLENGE**

Soil erosion is the mainland degradation process in Morocco, which is affecting up to 40% of its land area. About two million hectares of Moroccan agricultural lands are affected by water erosion. On average soil erosion ranges from 5 to 20 t/ha/yr, but exceeds these magnitudes in northern and north-western agricultural basins. For example, in the pre-Rif hills, soil erosion is exceeding 50 t/ha/year. Out of a total area of 20 million ha of watershed in Morocco, 50% is estimated to be subjected to very high erosion risks with a yearly soil loss of around 100 million tons. This annual soil loss leads to a reduction of 75 million m³ of downstream dam water storage capacity. Each year about 0.5% of the country’s reservoir storage capacity is lost. This water loss is equivalent to an annual water volume permitting the irrigation of 10,000 ha of arable lands. In Morocco, reducing soil erosion and land degradation is a national priority for improving soil quality and protecting downstream water quality and quantity.

**THE PROJECT**

Through IAEA Technical Cooperation and research projects with the financial support of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, the Centre National de L'Énergie, des Sciences et des Techniques Nucleaires (CNESTEN) in partnership with the Institut National de Recherche Agronomique (INRA), Ecole Nationale Forestière d’Ingénieur (ENFI), the Centre de Recherche Forestière (CRF) and the Institut Agronomique et Vétérinaire Hassan II (IAV) quantified soil erosion rates and assessed the effectiveness of no-tillage soil conservation practices.

Under no tillage management soil loss was reduced from 14 to 10 t/ha/year in the south east of Rabat (Morchouch site) and from 38 to 23 t/ha/year in the Tétouan region.

In addition, using a combination of fallout radionuclides (FRNs) and compound-specific stable isotope (CSS) techniques (see below), the CNESTEN estimated soil loss of 23 t/ha/year in the Moulay Bouchta watershed and identified that around 90% of the sediment in the downstream Talembout water reservoir originated from the surrounding agricultural areas indicating the effectiveness of forest plantations in protecting soil resources against erosion. Sedimentation rates were established for the downstream reservoir at 60 t/ha/year.

**THE TECHNOLOGY**

Fallout radionuclides (FRNs) such as anthropogenic caesium-137 ($^{137}$Cs), geogenic lead-210 ($^{210}$Pb) and cosmogenic beryllium-7 ($^{7}$Be), are strongly bound to fine soils particles. Therefore, these radionuclides are very conservative soil tracers, which can assist in establishing soil erosion and sedimentation rates and evaluating the efficiency of soil conservation measures to control soil erosion and associated excess of sedimentation.

Compound-specific stable isotope (CSS) techniques are based on the measurement of carbon-13 ($^{13}$C) natural abundance signatures of specific organic compounds (natural fatty acid biomarkers) in the soil. By linking fingerprints...
MADAGASCAR

Return to traditional terracing improves farm production in Madagascar

In Madagascar, where farming has moved toward modern intensive agricultural practices in recent decades, a study has demonstrated that the country’s farmers would be much better off if they returned to the traditional terrace farming of their ancestors. Using isotopic techniques to study erosion patterns of the island country’s mountainous regions, where more than 30 percent of the agricultural area is already degraded, the Joint FAO/IAEA Division found that terracing systems could reduce soil erosion by 40 percent.

Astronauts once reported that Madagascar looked as if it were bleeding to death. Today, looking at a satellite view of the country makes it easy to see what they meant. The image shows reddish rivers and reservoirs—not filled with blood but with the country’s red ferrallitic soil that is eroding down the island’s steep slopes, leaving agricultural land barren and adding sediment and its polluting nutrients of nitrogen, phosphorus and potassium to water systems.

Due to deforestation and improper farming practices, Madagascar, one of the world’s poorest countries, loses more topsoil per hectare each year than just about any other country in the world. The soil itself is not particularly fertile and now it has to deal also with the impacts of climate change, such as drought, floods and unpredictable rainfall that further break down the soil structure and makes it more likely to erode.

In order to help Madagascar’s farmers with conservation practices, scientists at the Institut National des Sciences et Techniques Nucléaires (INSTN-Madagascar) in the capital, Antananarivo, worked with Joint FAO/IAEA Division experts to address the problem and identify the country’s most erosion-prone areas. The Joint FAO/IAEA Division assists countries in quantifying soil erosion rates and assessing the effectiveness of their soil conservation practices. In the case of Madagascar,
Presentations on meetings and conferences

Side Event at COP12 of the UN Convention to Combat Desertification (TC and Joint FAO/IAEA Division)


Organisation of a special IAEA event
at the 12th session of the Conference of the Parties (COP) to the UN Convention to Combat Desertification (UNCCD)

Ankara, Turkey, 19 October 2015
IAEA emphasizes link between nuclear techniques and soil sustainability at COP12 side event

For the world’s 2.6 billion small-scale and subsistence farmers, healthy soils can be the difference between stability and poverty, a full plate and an empty stomach, life and death. But despite the universal value of healthy soils, human economic activity continues to cause land erosion and soil degradation, placing approximately 5 to 7 million hectares in danger each year. Against this backdrop of threatened soils, and as climate change further complicates the challenge, the IAEA has organized a side-event to highlight the benefits of soil science for sustainable land management, to be held on the margins of the 12th session of the UNCCD Conference of the Parties

Atoms for Food and Agriculture: Meeting the Challenge
Contribution to Combat Desertification

Conference of the Parties
Twelfth session
Ankara, Turkey, 12–23 October 2015
Item 3(b) of the provisional agenda
Effective implementation of the Convention at national, subregional and regional level
Leveraging of synergies among the Rio conventions, including land-based adaptation to climate change and related advice from the Science-Policy Interface

Leveraging of synergies among the Rio conventions

Note by the secretariat

Summary
Decision 9/COP.11 calls for a review and assessment of the progress made by the secretariat of the United Nations Convention to Combat Desertification (UNCCD) in promoting and strengthening relationships with other relevant conventions and international organizations, institutions and agencies. This document provides a summary of a select number of such activities and highlights their efficacy in promoting and strengthening these relationships.

The review and assessment includes the various initiatives undertaken with (1) other Rio conventions and the Global Environment Facility with regard to the development of common indicators and other synergies in reporting processes and capacity-building; (2) other entities such as the Food and Agriculture Organization of the United Nations, UN-Water, the World Meteorological Organization and the International Atomic Energy Agency on the issues of water, drought, forests and soil management; and (3) other organizations and institutions such as the Convention on Wetlands of International Importance especially as Waterfowl Habitat (the Ramsar Convention), the International Union for Conservation of Nature and the International Organization on Migratory and UNCCD related collaborations.

Finally, following a brief conclusion, the document outlines recommendations for future work priorities for promoting and strengthening these relationships.
Effectiveness of soil conservation strategies on erosion in Morocco

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INTRODUCTION
- For Morocco, reducing soil erosion and land degradation is a national priority for improving soil quality and protecting downstream water quality and quantity.
- Possible measures on the magnitude of erosion and the effectiveness of soil conservation practices are required for decision makers.
- The aim of this work is to illustrate the role of fallout radionuclides (i.e., 137Cs and 10Be) for supporting soil conservation strategies through case studies in three Moroccan sites: Marrakesh, Tarbena (Fig. 1) and Oued Meflah (Fig. 2). Located in Rabat, Tetouan, and Chorcha, respectively, the regions were used for land survey and field work (Fig. 3).

RESULTS AND DISCUSSIONS
- Long term soil erosion rates of the three regions evaluated by the 137Cs method, ranged from 6 to 85 t/ha/yr.
- The soil erosion rates appeared to be related to the rainfall, slope, and the past land use (Fig. 1).
- The 10Be results indicated that soil loss has been reduced significantly under morrocan conventional tillage in Rabat and Tetouan regions, where soil erosion rates were reduced by 50% for the Marrakesh site (Fig. 4) and by 45% for the Tarbena site (Fig. 5).
- For the Oued Meflah watershed, the results highlighted that high density Arbuscular plants have reduced soil loss by approximately 67 to 85% compared to Arbuscular plantations with low density while for the site under these conditions and seasons, soil erosion has been decreased by 56% compared to bare soil (Fig. 6).

CONCLUSIONS
- The Moroccan study demonstrated the potential of the 137Cs and 10Be techniques to estimate long- and short-term soil erosion rates and to assess the effectiveness of soil conservation strategies. In addition, these techniques are increasingly applied in agricultural fields and landscapes in Morocco for providing useful and reliable information to decision makers.

MATERIAL AND METHODS
- In the Rabat and Tetouan regions, with sand and Mediterranean climates respectively, the most techniques have been tested as soil conservation practices and compared to conventional tillage.
- In the Chorcha-Chorcha region (southward climate), the efficiency of conservation practices based on Arbuscular plants and cover and fruit plantations was assessed within the framework of management of "Oued Meflah" watershed.
- The methods used: (a) Followed 137Cs for retrospective assessment of long term (5000 yr) soil redistribution rates and (b) Followed 10Be (half-life of 1.26 ys) for Geomantling short-term soil erosion.
- Reference sites were investigated near the study areas. In the agricultural studied fields, the soil sampling strategy was based on a trapezoidal approach.
- 137Cs and 10Be were measured by gamma spectrometry using a high purity germanium (HPGE) detector with high resolution and 30% efficiency.
- Estimates of erosion/deposition rates from 137Cs and 10Be data set have been produced using conversion factors (i.e., Rako; Sololec Model and the Profile-Diffusion Model).
Assessing the effectiveness of conservation agriculture practices with Caesium-137 radionuclide techniques in semi-arid areas of Zimbabwe

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2 Joint FAO/IAEA Programme, International Centre for Integrated Project Management, Vienna, Austria
3 Institute for Nuclear Sciences and Nuclear Techniques (INSNT), Amersham, Buckinghamshire

INTRODUCTION

- Soil formation in Zimbabwe is very low (e.g. 0.5-0.8 y), whereas rates of soil erosion are much higher.
- It has been estimated that in some agricultural areas, the cultivation of cereals may only be possible for another 15 years before soils become too degraded to allow any cultivation.

RESULTS AND DISCUSSIONS

- The 137Cs inventory at the reference site was 214 Bq/m² (CV =10%, n=10).
- The mean 137Cs inventories for DSM, CBMF, and DSM/F were 124, 100, and 214 Bq/m², respectively.

MATERIALS AND METHODS

- The study site is located in the Mucheke research station situated 280 km south of Harare (Zimbabwe).
- Semi-arid climate; the soils include coarse sandy sands (gypseous loam).
- Since 1986, the conservation agriculture (CA) practices include (i) direct seeding with mulch (DSM), (ii) CA fertilizer application (CBMF), and (iii) 10 years direct seeding, left fallow for seven years (DSM/F).

CONCLUSIONS

- Despite the high 137Cs soil content, the 137Cs technique has been successfully tested for assessing bed-scale variations in soil loss and soil redistribution.
- This study highlights that soil erosion can be significantly reduced by using proper soil conservation strategies.
Terraced agriculture protects soil from erosion: Case studies in Madagascar

OBJECTIVES

➢ To produce Malagasy data on soil erosion/sedimentation rates under various agricultural practices
➢ To assess soil conservation efficiency of traditional agricultural practices

STUDY SITE AND METHODS

➢ STUDY SITE

➢ Two adjacent cultivated fields (i.e., sloped field & terraced field), located 40 km west of Antananarivo, in Madagascar highlands
➢ One reference site selected close to the 2 study sites

➢ SAMPLING AND LABORATORY WORK

➢ Mechanical soil corer was used for soil sampling
➢ Soil samples collected (n = 50)

➢ Reference sites: 18 bulk + 1 profile
               Sloped field: 18 bulk + 1 profile
               Terraced field: 18 bulk + 1 profile

➢ 

RESULTS AND DISCUSSIONS

➢ INVENTORY

➢ Reference site: 
  137Cs and 
  210Pb daughters inventories are 218 Bq m⁻² and 2.20% (Mean ± Coefficient of Variation) and 3076 Bq m⁻² and 13%, respectively.

➢ Sloped field: 
  137Cs and 
  210Pb daughters inventories vary from 110 Bq m⁻² to 268 Bq m⁻² and from 2036 Bq m⁻² to 4110 Bq m⁻², respectively.

➢ Terraced field: 
  137Cs and 
  210Pb daughters inventories vary from 145 Bq m⁻² to 285 Bq m⁻² and from 2141 Bq m⁻² to 4293 Bq m⁻², respectively.

➢ SOIL REDISTRIBUTION

➢ Soil redistribution:

<table>
<thead>
<tr>
<th>Soil redistribution</th>
<th>Sloped field</th>
<th>Terraced field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean erosion (t ha⁻¹ yr⁻¹)</td>
<td>9.1</td>
<td>7.9</td>
</tr>
<tr>
<td>Gross erosion (t ha⁻¹ yr⁻¹)</td>
<td>9.2</td>
<td>8.2</td>
</tr>
<tr>
<td>Net erosion (t ha⁻¹ yr⁻¹)</td>
<td>7.4</td>
<td>5.9</td>
</tr>
<tr>
<td>Sediment delivery rate (%)</td>
<td>89</td>
<td>81</td>
</tr>
<tr>
<td>Erosion area (%)</td>
<td>91</td>
<td>91</td>
</tr>
</tbody>
</table>

➢ SOIL EROSION RATES

➢ For the sloped field, using the 
  137Cs and 
  210Pb methods, net soil erosion rates are 7.4 t ha⁻¹ yr⁻¹ and 5.9 t ha⁻¹ yr⁻¹, respectively.
➢ For the terraced field, net soil erosion rates are 3.4 t ha⁻¹ yr⁻¹ and 3.0 t ha⁻¹ yr⁻¹, respectively.

CONCLUSIONS

➢ Timeframe discrimination showed that erosion phenomenon has increased in the last 50 years (from 
  137Cs data) compared to the last 100 years (from 
  210Pb data).
➢ However, results highlight that terraced agricultural practices reduce soil erosion magnitude and therefore, provide an efficient solution to protect soil resources of the Malagasy highlands.
Test of a new stable isotope fingerprinting technique (i.e. Compound Specific Stable Isotope) in a sub-catchment to establish agricultural soil source contribution to deposited sediment

M. Mbaye (1), L. Mabit (2), M. Gibbs (3), K. Meusburger (4), A. Toloza (2), C. Resch (2), A. Klik (5), A. Swales (3), and C. Alewell (6)

1. Background & Objectives of the study

- To test the compound-specific stable isotope (CSSI) approach to distinguish different sediment sources which contribute to the sedimentation area;
- To distinguish the best fatty acids (FA) indicators according to the land use of the sources and the sedimentation area;
- To assess the contribution of each connected source to the sedimentation area.

2. Selection of the best isotopic tracers

- Principal Component Analysis to establish correlation among FAs & sources
- Based on PCA results, one-way analysis of variance is used to exclude tracers which have no significant difference

3. Apportioning source contribution

- Sources contribution to the mixture using mixing models (IAA, Wi00, SIAAr, 2014MBC, PISOFA)
- Bayesian approach of source apportioning is given by equation (1): $y = N \left( \sum_{i=1}^{n} p_i \mu_i + \sum_{i=1}^{n} \sigma_i \right)$

4. Results & Discussions

- The output of each mixing model was expressed as isotopic proportions.
- These isotopic proportions were compared to soil proportions based on the bulk 13C (Table 2) using the linear conversion equation (2) from Gibbs (2008):

$$\delta_{13}C_\text{soil} = \frac{\delta_{13}C_\text{mixture}}{1000} x \epsilon_{13}C_\text{bulk}$$

5. Conclusion

- An alternative statistical approach for selecting the best suitable FAs as soil/sediment fingerprints has been tested & validated
- All mixing models highlight that 5% is the main contribution to the sediment mixture
- This study demonstrates the complementarity of FRNs and CSSI techniques
Managing agricultural water and land degradation

Emmanuel Chikwari
Chemistry and Soil Research Institute
Department of Research & Specialist Services
Ministry of Lands, Agriculture and Rural Resettlement
Zimbabwe

Atoms for Food and Agriculture: Meeting the Challenge
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EN AGRICULTURE

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Vulnerability of the Mediterranean soils to water erosion:
State of knowledge and adaptation strategies in the face of global change

20 - 21 November 2018
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Contact:
Prof. Mohamed CHIKHAOU
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EFFECT OF TILLAGE AND MULCHING ON SOIL WATER EROSION IN LINSINLIN WATERSHED, CENTRE OF BENIN

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ABSTRACT

Soils degradation in Benin is most commonly reported thread for the agricultural production and this situation became more crucial in the Centre of Benin. This study has been carried out to evaluate the contribution of farmer’s soil conservation practices to combat soil erosion in the agricultural watershed of Linsinlin. A field experiment was conducted on loamy-sand soil using Fisher Block design under researcher management. The factors which testified during study were tillage and mulching. The “Runoff plot” system was installed to collect erosion data. Three rainfall episodes viz., June 15, 19 and 27, 2016 with 52, 27 and 37 mm of water were used for the data collection. Rain distribution was generated for each rain episode using a rain gun. Three rain events episode constitute a experiment.
ASSESSMENT OF THE LEVEL OF SOIL DEGRADATION IN THREE WATERSHEDS AFFECTED BY INTENSIVE FARMING PRACTICES IN BENIN

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Watershed
Soil degradation
Soil properties
Soil evaluation
Benin

ABSTRACT

Soil degradation is a serious problem for people living in watersheds of Benin. This degradation is mainly due to poor farming practices and because of this poor management annual maize production reduced critically. This study was aimed to estimate the state of physical and chemical soil degradation of three watersheds of southern Benin. One reference site representing sacred forest was also chosen for comparing the results of watersheds. Soil cores were also collected from these selected sites. Physical and chemical parameters were determined from the collected soil samples. Results of study revealed that the watershed soil is more compact and lower in nutrients than the soil of reference sites. The bulk soil density was significantly higher in Gouvie and Lokoaga watersheds compared to their reference site. As a result of intensive farming and water erosion, root biomass of the soil has significantly decreased from 86 to 92% in Gouvie, 69 to 67% in Lokoaga and 75 to 70% in Limain. The total soil nitrogen of watershed declined significantly, from 33 to 24% in Gouvie, 32 to 30% in Lokoaga and 38 to 25% in Limain. Available soil phosphorus decreased from 10.92 ppm to 7.11 ppm in the Lokoaga watershed. The soil phosphorus of Limain watershed was reported highest from 5.5 ppm to 8.00 ppm compared to the reference site. The soil organic matter of watershed declined from 38 to 37% in Gouvie and 68 to 60% in Lokoaga. Lokoaga watershed is the most degraded one compared to three watersheds studied.

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Assessment of soil redistribution rates by $^{137}\text{Cs}$ and $^{210}\text{Pb}_{\text{ex}}$ in a typical Malagasy agricultural field

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ABSTRACT

Soil degradation processes affect more than one-third of the Malagasy territory and are considered as the major environmental threat impacting the natural resources of the island. This innovative study reports about a pioneer test and use of radio-isotopic techniques (i.e. Cs-137 and Pb-210ex) under Madagascar agroclimatic condition to evaluate soil erosion magnitude. This preliminary investigation has been conducted in a small agricultural field situated in the eastern central highland of Madagascar, 40 km east from Antananarivo. Both anthropogenic Cs-137 and geogenic Pb-210 soil tracers provided similar results highlighting soil erosion rates reaching locally 18 t ha$^{-1}$ yr$^{-1}$ a level almost two times higher than the sustainable soil loss rate under Madagascar agroclimatic condition. The sediment delivery ratio established with both radionuclides was above 90% indicating that most of the mobilized sediment exits the field.

Assessing soil erosion rate through fallout radionuclides in Madagascar is a first step towards an efficient land and water resource management policy to optimise the effectiveness of future agricultural soil conservation practices.

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1. Introduction

Soil degradation induced by human activity is a major concern in Madagascar. Its severity is very high for 21.0% percent of the area (130 081 km$^2$), high for 48.2 percent (285 007 km$^2$), moderate for 24.5 percent (145 153 km$^2$) and low for only 4.6 percent (27 094 km$^2$) (FAO, 2004). To summarise, more than 30% of the island’s total soil area, covering 184 338 km$^2$, is degraded.

Soil erosion, the most common form of soil degradation, is present in all its aspects: rill and sheet erosions, landslides, gully erosion and its most emblematic form, the “désertification”. Soil erosion and sedimentation cause not only on-site degradation of non-renewable natural resources, but also off-site problems such as downstream sediment deposition in agricultural fields, floodplains and water streams. These impacting problems on soil fertility and crop productivity in agricultural land, on water well documented (e.g. Pimentel, 2006; UNEP, 1992; Walling, 2009). Due to their impact on the sustainability of agricultural production, there is a clear need to acquire quantitative data on the extent, magnitude and actual rates of erosion/sedimentation as well as on their economic and environmental consequences.

From the mid-1990s, research activities on soil erosion and soil protection have been conducted intensively in Madagascar, resulting in more than 4200 scientific articles and technical documents (Chabalier, 2006). Studies were performed mainly using Wischmeier erosion plots, for 6 climatic zones in 20 sites, and at the catchment level in 11 sites. Experiments involved quantification of erosion extent, determination of Wischmeier equation parameters for local conditions, investigation on vegetation covering and agricultural practice effects (Chabalier, 2006). Most of the studies lasted 2-7 years. Long term experiments were rare because of logistic difficulties and maintenance cost.
Assessment of soil erosion and deposition rates in a Moroccan agricultural field using fallout $^{137}$Cs and $^{210}$Pbex

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ABSTRACT

In Morocco land degradation — mainly caused by soil erosion — is one of the most serious agro-environmental threats encountered. However, only limited data are available on the actual magnitude of soil erosion. The study site investigated was an agricultural field located in Marchoud (6° 42' W, 33° 4' N) at 68 km south east from Rabat. This work demonstrates the potential of the combined use of $^{137}$Cs, $^{210}$Pbex as radiotracer soil tracers to estimate mid and long term erosion and deposition rates under Mediterranean agricultural areas. The net soil erosion rates obtained were comparable, 14.3 t ha⁻¹ yr⁻¹ and 12.1 t ha⁻¹ yr⁻¹ for $^{137}$Cs and $^{210}$Pbex respectively, resulting in a similar sediment delivery ratio of about 90%. Soil redistribution patterns of the study field were established using a simple spatialisation approach. The resulting maps generated by the use of both radionuclides were similar, indicating that the soil erosion processes has not changed significantly over the last 100 years. Over the previous 10 year period, the additional results provided by the use of the prediction model RISE 2 provided results of the same order of magnitude. Based on the $^{137}$Cs dataset established, the contribution of the tillage erosion impact has been evaluated with the Mass Balance Model 1 and compared to the result obtained with the Mass Balance Model 2. The findings highlight that water erosion is the leading process in this Moroccan cultivated field, tillage erosion under the experimental condition being the main translocation process within the site without a significant and major impact on the net erosion.

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1. Introduction

With only 15% of its land arable, Morocco faces major environmental challenges and pressure on soil and water resources. This is true for many developing countries in Africa experiencing economic growth which is the consequence of urbanisation, limited funds available for natural resource management and a nascent legal and regulatory framework for environmental protection. Due to the intensification of agricultural practices leading to unsustainable farming practices (e.g. inappropriate tillage practices, straw exportation, overgrazing) and specific bioclimatic conditions (e.g. recurring and severe droughts), more than 15 million hectares of the Moroccan agricultural land is under on-site impact of erosion on the agricultural Moroccan landscape is the reduction of soil fertility, the main off-site impact being dominated by an increase of silitation processes in water reservoirs. It was estimated that out of 22.7 million hectares potentially exploitable in the Northern part of Morocco, 77% are exposed to very high erosion risks (Belkheiri, 1988). The Global Assessment of Human Induced Soil Degradation (GLASOD) survey carried out during the 1980s by the United Nations Environment Programme (UNEP) and the International Soil Reference and Information Centre (ISRIC) established that the severity of human induced degradation has been classified as severe and very severe for more than 20% of the Moroccan territory (FAO, 2005).

In fact, around 100 million tons yr⁻¹ of soil is lost and the annual cost of the environmental degradation is...
Promoting the use of isotopic techniques to combat soil erosion: An overview of the key role played by the SWMCN Subprogramme of the Joint FAO/IAEA Division over the last 20 years

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Abstract
The International Atomic Energy Agency (IAEA), through the Joint Division with the Food and Agriculture Organization (FAO) of the United Nations, assists its Member States in applying nuclear techniques to alleviate challenges in food safety, food security, and sustainable agricultural development. The Soil and Water Management & Crop Nutrition (SWMCN) Subprogramme, within the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, has made significant contributions to the development of isotopic techniques for the assessment of soil degradation and the development of efficient soil and land conservation approaches. These techniques include fallout radionuclides such as 137Cs, 210Pb, 7Be, and 239-240Pu as well as 13C stable isotope and compound-specific stable isotope analyses. These methodologies were developed and refined through the work of researchers from developed and developing countries who were selected to work within the frame of IAEA’s Coordinated Research Projects (CRPs). Internal research activities implemented in the Joint FAO/IAEA’s SWMCN Laboratory in Seibersdorf supported the work accomplished in the CRPs.

The methodologies thus developed have been subsequently disseminated to developing countries by IAEA’s Technical Cooperation Programme to assist Member States to adopt climate-smart agriculture and reduce soil degradation that poses a threat to food security and the environment. This review paper provides an overview of the activities conducted in the frame of CRPs for combating soil erosion over the last 20 years and highlights the major achievements. Examples of the success and the impact obtained in Morocco, Madagascar, and Vietnam in using these isotopic techniques are presented.

Keywords
climate change, fallout radionuclides, soil degradation, soil tracers, stable isotopes

Atoms for Food and Agriculture: Meeting the Challenge
Exploitation of the results of TCPs for cooperation with international organizations and education institutions

Cooperation with International Institute for Applied Systems Analysis (IIASA) and University Colleague of London (UCL)

Working with IIASA’s Resources and Environment Group.

Objectives: To test the use of soil erosion data based on FRN for validation of erosion model EPIC (USLE, RUSLE, MUSLE, MUSS) for erosion prediction at regional level

Steps undertaken:

• Participating on the IIASA Workshop (Laxemburg, October 24th, 2017)
  • Presenting information on the NAFA activities related to soil erosion
  • Discussing the work plan for cooperation
• Investigation of published data on soil erosion rates derived from FRN from tropical and arid regions (South China, South Asia, Australia, Africa and Latin America)
• Building the database, processing of metadata and data preparation for model validation

IIASA Workshop ‘Joint Land Potential and Modeling Soil Erosion with EPIC in Humid and sub Humid Tropical Regions, October 24th, 2017

Presentations on NAFA Activities:
- Fulajtar, E.: Principles of fallout radionuclide methods (FRN) for soil erosion assessment with focus to Cs-137 method
- Fulajtar, E.: Soil erosion rates on tropical and sub-tropical regions estimated by FRN methods collected by IAEA and collaborating partners
- Fulajtar, E.: IAEA activities at the field of soil erosion and possible cooperation with IIASA
African Network for Soil Erosion, Fallout Radionuclides and Gamma Spectrometry
https://atanasovs.000webhostapp.com

About Us

Africa, with 15% of the world’s population, is projected to see 34% of the globe’s population increase over the next 50 years. The population of the African continent is expected to rise from 0.91 billion now to 1.94 billion in 2050. Most of the population increases will occur in the countries, where the agriculture represents a major livelihood source for significant part of the population. Many African countries will face challenges to achieve food security in a sustainable manner, considering their available land area per capita, severe scarcity of fresh water resources and limited infrastructure and socio-economic conditions. These challenges will further become more difficult due to severe global soil degradation, in particular in Sub-Saharan Africa, and increased rate of soil erosion.
Establishing Regional Network in Africa (11 countries):
African Network for Soil Erosion, Fallout Radionuclides and Gamma Spectrometry

Objectives:

• Exchange of experience in gamma spectroscopy laboratory works and maintenance of equipment
• Exchange of experience in field work (sampling strategy, design and sample collection)
• Exchange of experience in data processing, interpretation, geostatistics and modelling
• Building information base on erosion spatial and temporal distribution in Africa

Steps undertaken:

• Establishing the network through the communication with member states
• Establishing website https://atanasovs.000webhostapp.com
• Starting to build database on soil erosion and initiating information exchange

• Communication towards the Land degradation group of UNEP
Thank you for your attention