10th High Energy Physics International Conference (HEPMAD 18)
Madagascar – Antananarivo, 6 – 11 September 2018

Soil erosion study of Madagascar highland by ^{137}Cs technique

Martin Rasolonirina, Asivelo F. Solonjara, Heritiana N. Ravoson, Naivo Rabesiranana, Raoelina Andriambololona

Institut National des Sciences et Techniques Nucléaires (INSTN - Madagascar)

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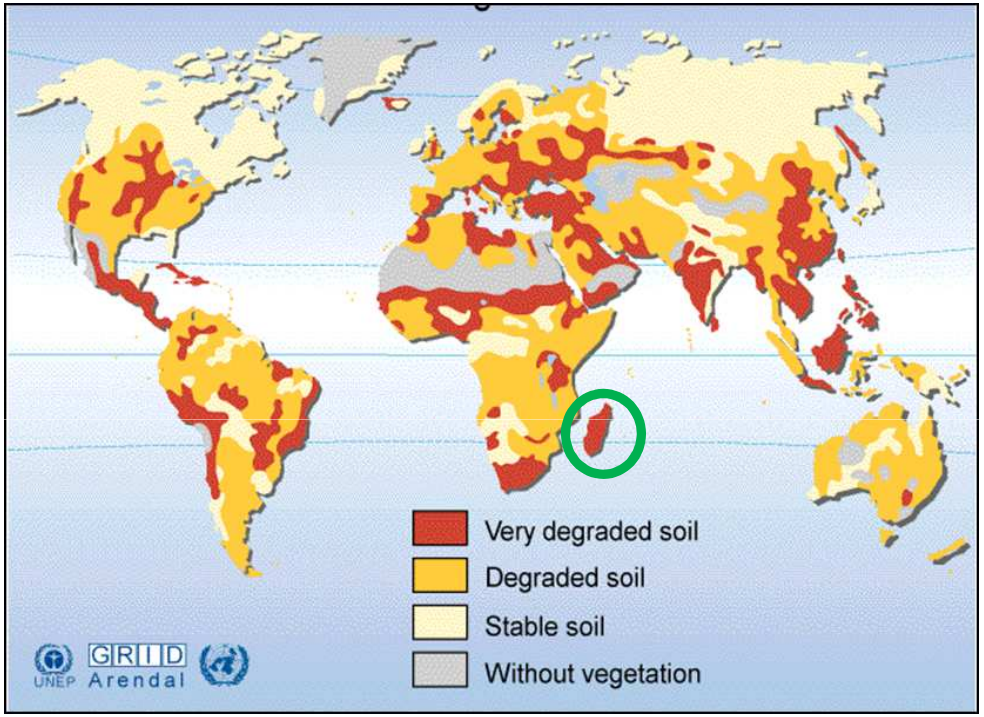
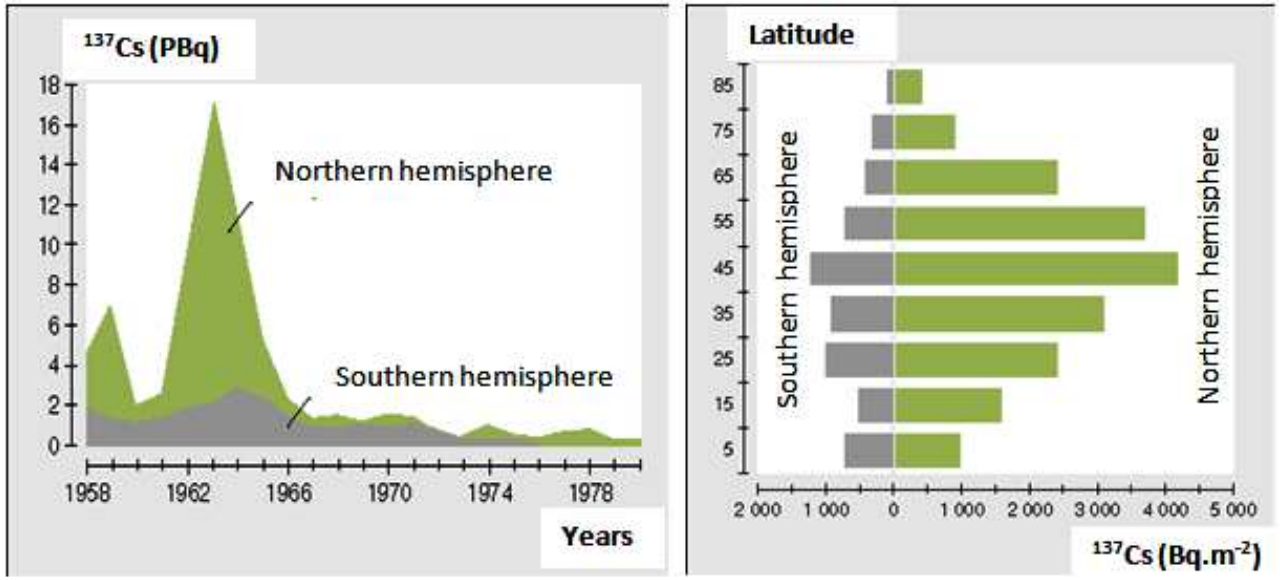


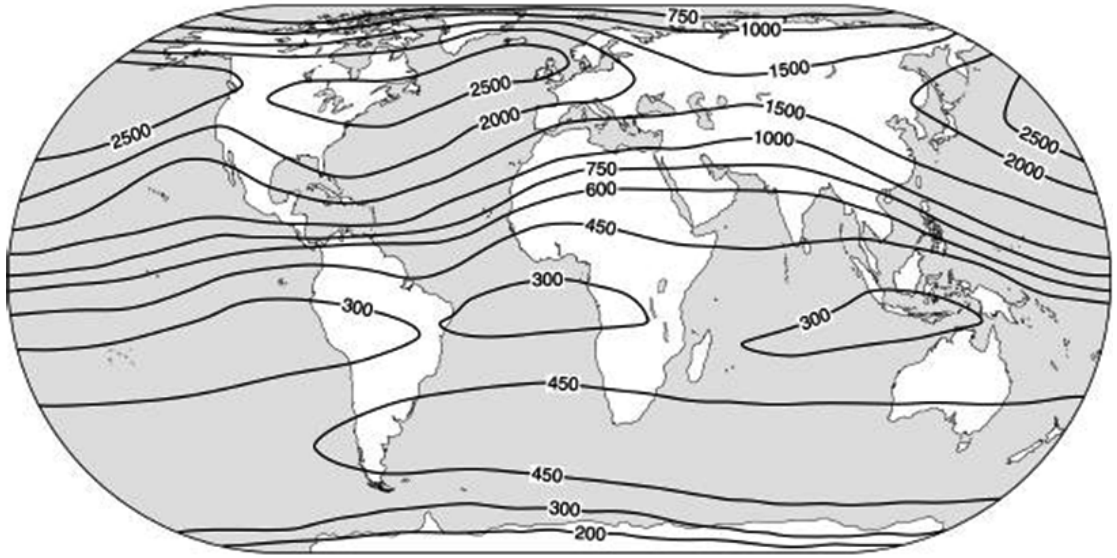
- High risk of soil degradation
- Water erosion accentuated by human activities and agricultural practices,
- Use of conventional technique,
- Use of fallout radionuclide technique

Cesium-137 (^{137}Cs)

- Artificial radionuclide, half-life of 30 years,
- Atmospheric testing of nuclear weapons during 1950s and 1960s,
- Rapidly and strongly absorbed by fine soil particle-size (< 2 mm),
- Deposition on soil surface by precipitation

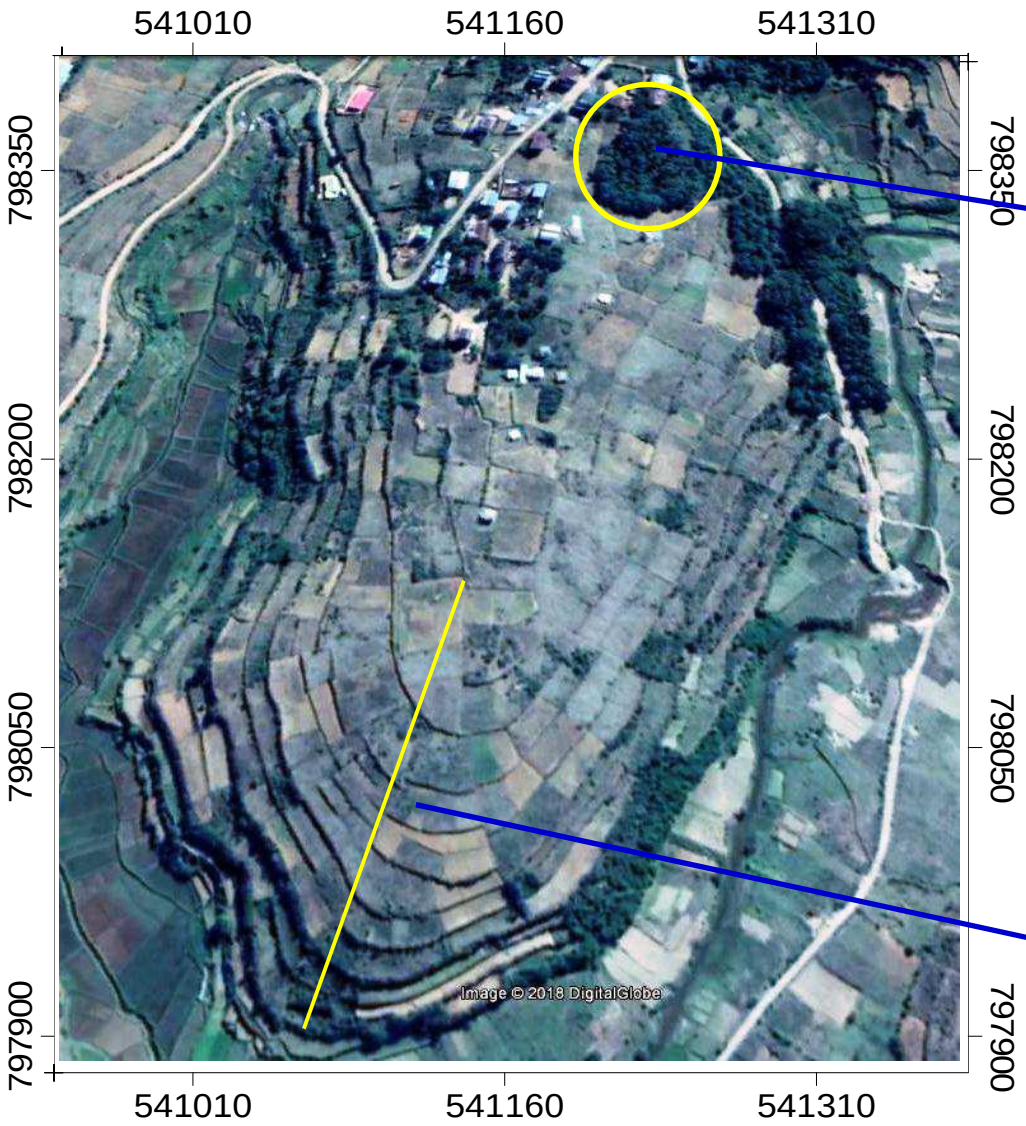
Global distribution of ^{137}Cs





Based on Walling, 2002

Localisation of study site



Reference site

Terraced plots

Sampling

Equipment :

- Motorized percussion corer with a long tube of 1 m and a diameter of 10 cm

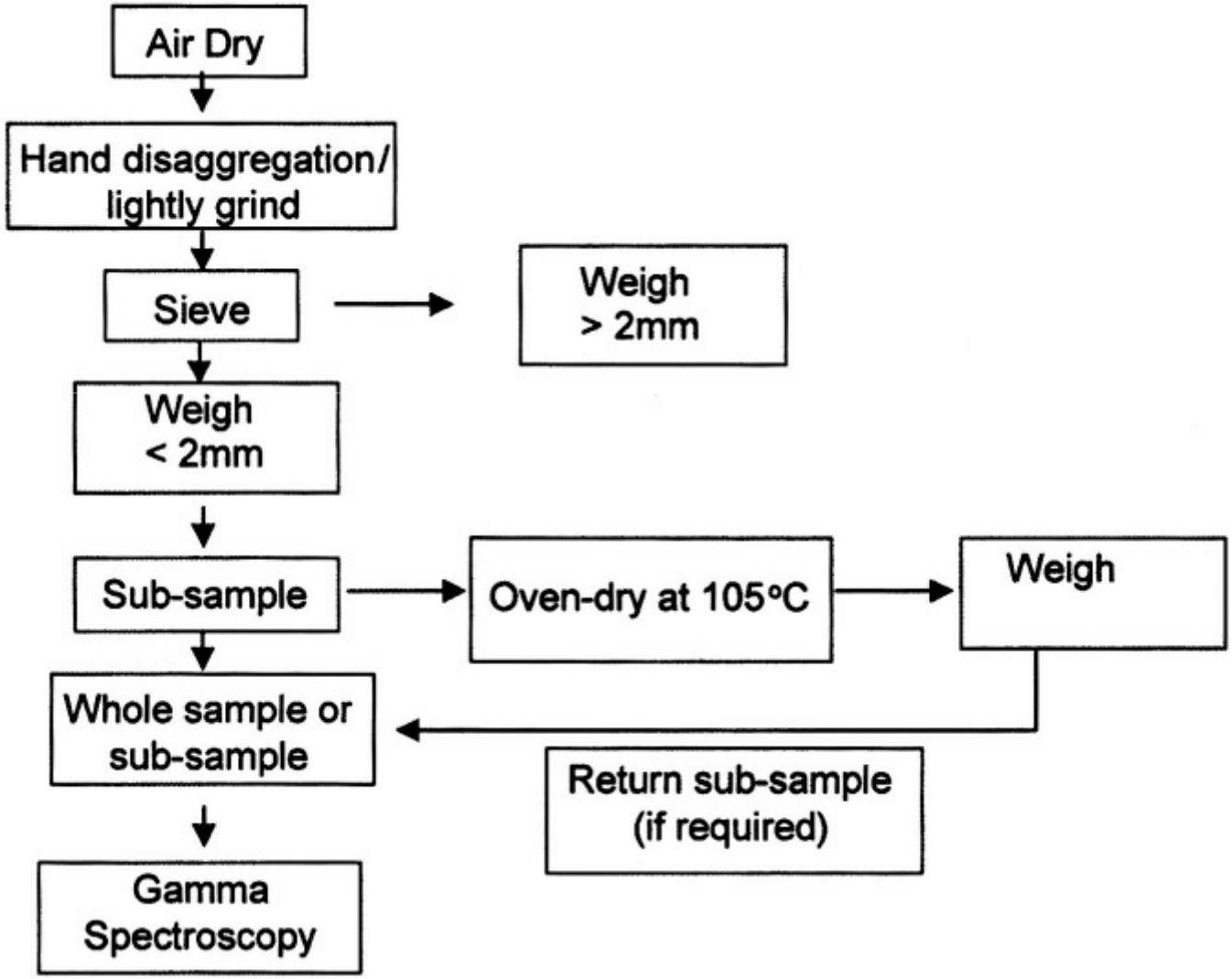
At reference site :

- 18 random bulk soil cores,
- 01 sectioned core for ^{137}Cs profile distribution,
- Core depth : 40 cm

At cultivated site :

- 18 bulk soil core along 170 m downslope transect (spaced 10 m),
- 01 sectioned core for ^{137}Cs profile distribution,
- Core depth : 40 cm

Sample preparation



Sample analyses

Activity calculations, (Bq.kg^{-1}) :

$$A = \frac{C}{f \times I_\gamma \times t_c \times m}$$

C : total counts,

f : detection efficiency,

I_γ : intensity of gamma-ray,

t_c : count time (s),

m : mass of sample (kg)

Gamma spectrometry system, HPGe detector

Inventory calculations, (Bq.m^{-2}) :

$$I = \frac{A \times M_T}{S}$$

A : specific activity of the analysed sample (Bq.kg^{-1}),

M_t : total dry mass of the bulk core (kg),

S : corer area (m^2)

Conversion model :

Inventory (Bq.m^{-2}) ⟶ Erosion/deposition rates (t.ha^{-1}.y^{-1})

Soil redistribution

Reference site :

- uncultivated or undisturbed site,
- site as close as possible to the study area (~1 km),
- no erosion/deposition processes, generally a flat area,
- no high bio-disturbing area

Erosion/depositional area :

- individual inventory **<** reference inventory → erosion
- individual inventory **>** reference inventory → deposition

Mass Balance Model 2 (MBM2)

$$\frac{dI}{dt} = (1-\Gamma)\Phi(t) - \left(\lambda + P\frac{R}{d}\right)I(t)$$

Freshly deposited fallout before incorporating into the plough layer

Effects of particle-size selectivity in sediment mobilization, transport and deposition

With, $\Gamma = P\gamma\left(1-e^{-R/H}\right)$: Proposition of the freshly deposited ^{137}Cs fallout removed by erosion before being mixed into the plough layer by cultivation

I : inventory (Bq.m^{-2}),

γ : proposition of the annual ^{137}Cs input susceptible to removal by erosion,

H : relaxation mass depth of the initial distribution of fallout ^{137}Cs in the soil profile (kg.m^{-2}),

Φ : annual ^{137}Cs deposition flux at time t (Bq.m^{-2}.y^{-1}),

λ : decay constant (y^{-1}),

P : ratio of the ^{137}Cs concentration of mobilized sediment to that of the original soil,

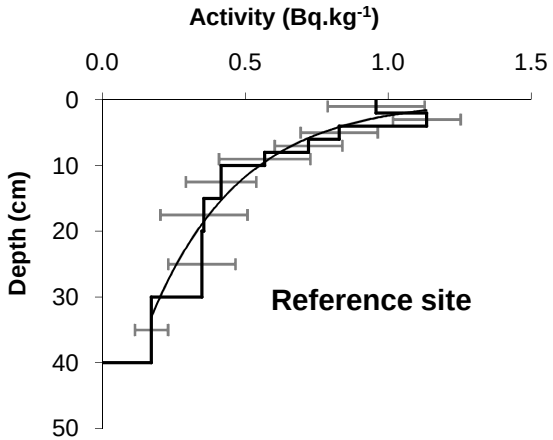
R : erosion rate (kg.m^{-2}.y^{-1}),

d : average plough depth expressed as cumulative mass depth (kg.m^{-2})

Specific activity

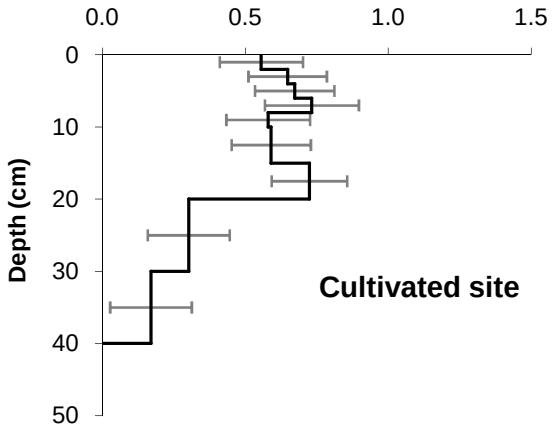
Reference site :

- maximum activity below soil surface (2-4 cm),
- timescale radionuclide and downward diffusion effects,
- decrease exponentially with depth,
- similarly of ^{137}Cs vertical distribution found elsewhere in the reference sites



Cultivated site :

- sample collected at eroded area,
- maximum activity mixed within plough layer (20 cm),
- no significant activity detected below plough layer



Inventory

Reference site

- average fallout inventory : 216 Bq.m^{-2} ± 20% (CV),
- range : 162 Bq.m^{-2} to 330 Bq.m^{-2},
- spatial variability relatively similar to Zimbabwe results (170 Bq.m^{-2} to 334 Bq.m^{-2}) (Owens and Walling, 1996) and reported elsewhere in the world (Correchel et al., 2005; Basher, 2000),

Cultivated site

- range : 145 Bq.m^{-2} to 280 Bq.m^{-2},
- average value : 176 Bq.m^{-2} < reference value,
- lower value indicates in general the soil loss moving towards outside the study area,

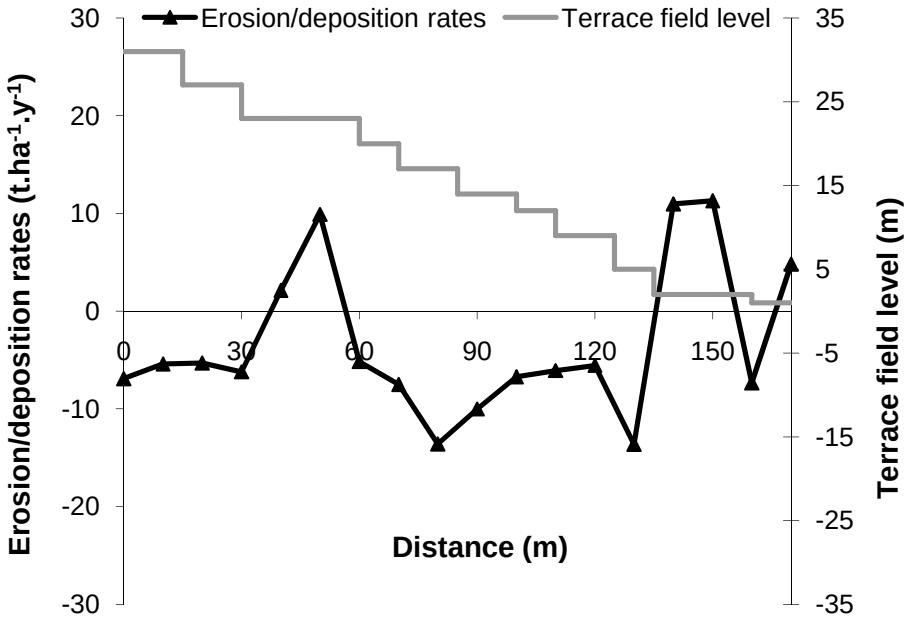
Model parameters :

Parameter	Symbol	Value	Unit
Reference inventory	I_{ref}	216	$Bq.m^{-2}$
Proportional factor	γ	0.7	-
Relaxation depth	H	4.0	$Kg.m^{-2}$
Plough depth	d	240	$Kg.m^{-2}$
Particle size factor	P	1	-

All parameters were based on local conditions

Erosion/deposition rates

- soil deposition observed in the middle and lower slopes of terrace plots,
- reduction runoff movement within the stable area,
- net soil erosion: terrace < slope,
- efficient technique for soil conservation management



Component	Estimate
Number of eroded points	13
Number of deposited points	5
Mean erosion rate ($t.ha^{-1}.y^{-1}$)	7.5
Gross erosion rate ($t.ha^{-1}.y^{-1}$)	5.4
Net erosion rate ($t.ha^{-1}.y^{-1}$)	3.3
Sediment delivery ratio (%)	61
Eroding area (%)	72

Conclusion

- potential use of ^{137}Cs technique of soil erosion and redistribution study in different agricultural sites,
- to obtain the average, gross and net values of soil erosion rate for medium-term (~50 years),
- only one sampling is enough to have a reliable results,
- to find an ideal reference site,
- to choose the appropriate conversion model,
- to take into consideration of other radiotracers ^{210}Pb or ^{7}Be with ^{137}Cs

Thank you!