# Use of Caesium-137 technique for the assessment of soil erosion in two selected sites in Uma Oya Catchment in Sri Lanka

Champa K Dissanayake[A], P Mahawatte[B], K Abeynayake[C] and TSB Weerasekera[D]

[A]Atomic Energy Authority, 60/460, Baseline Road, Orugodawatte, Wellampitiya. Sri Lanka, Email champa@aea.ac.lk
[B]Department of Nuclear Science, University of Colombo. Sri Lanka, Email pm@nuclear.cmb.ac.lk
[C]Department of Plant Sciences, University of Colombo, Sri Lanka
[D]Land Use Division, Department of Irrigation. Sri Lanka, Email weerasek@sltnet.lk

**Abstract**
The $^{137}$Cs technique for investigating rates and patterns of soil erosion has now been successfully applied in a wide range of environments. $^{137}$Cs is a product of atmospheric nuclear testing, which commenced in the 1950s. $^{137}$Cs strongly adheres to soil particles and therefore can be used as a tracer in soil movement studies. Soil erosion rates in two different land use types with no soil conservation methods common in the Uma Oya catchment located in the up country of Sri Lanka have been investigated using the $^{137}$Cs technique. The soils in these sites were Humults, locally referred to as red-yellow podzoilc soils. The $^{137}$Cs content in soil was measured using core samples obtained up to a depth of 35 cm. The mean reference inventory was 753 Bq/m$^2$ and showed exponential decline with depth. The mean $^{137}$Cs inventory in the two study sites were 290 and 491 Bq/m$^2$. This corresponded to an average soil loss rate of 44 t/ha/yr and 24 t/ha/yr, respectively. These results were comparable to erosion data obtained using the conventional methods. This method is very effective in finding the range of soil erosion rates at different areas and different land uses for proposed developmental projects so that steps could be taken by the policy makers for prevention of soil degradation.

**Key Words**
Caesium-137, Uma Oya, reference inventory, exponential decline, soil erosion

## Introduction
Soil erosion and associated land degradation are major environmental problems encountered worldwide in the development of agriculture. Soil erosion and deposition cause not only on-site effects, but also off-site problems such as downstream sediment deposition in fields, floodplains, and water bodies. The use of fallout radionuclide $^{137}$Cs affords an effective and valuable means of studying erosion and deposition within the landscape. $^{137}$Cs technique has now been used to investigate soil erosion and redistribution in many areas in the world (Colling *et al.* 2001).

$^{137}$Cs has a half life 30.17 years. Absence of any natural source of $^{137}$Cs in the environment, strong and rapid adsorption to soil particles and its relatively long half life makes $^{137}$Cs a suitable tracer for soil erosion and sedimentation studies. The technique is based on comparing the $^{137}$Cs inventory (Bq/m$^2$) at a given location with that of a nearby 'reference' location (Walling and Quine 1990b). A loss or gain of the $^{137}$Cs inventory at that location in comparison with the inventory at the reference location represent an erosion or a sedimentation. These comparisons of measured inventories with the local reference values provide useful qualitative information on the spatial distribution of erosion and deposition in the landscape. The derivative of quantitative estimates is required to obtain the magnitude of the soil erosion and associated land degradation. Walling and He (2001) provide a useful review of many different approaches which have been used to convert $^{137}$Cs measurements to quantitative estimates of soil erosion and deposition rates. The key advantage of this technique is that it provides retrospective information on medium-term (30-40 years) erosion/deposition rates and spatial patterns of soil redistribution without the need for long-term monitoring programme.
Therefore this study was undertaken for the preliminary assessment of soil erosion in a small catchment in Sri Lanka, using $^{137}$Cs technique. The proportional model described by Walling and He (2001) was used to convert the $^{137}$Cs measurement to erosion data.

## Study site
The area selected for this study was the Uma Oya catchment in Nuwara Eliya District in Sri Lanka. The Nuwara Eliya district is in the upcountry of Sri Lanka, at an elevation of about 1900m above sea level. The Uma Oya is estimated to have a total catchment area of about 740 km$^2$ and forms one of the main tributaries of the Mahaweli river. This catchment has a variety of land uses. The highest elevation of the catchment is covered by natural forest. In addition to this, the catchment is occupied by tea estates, rice, potato, vegetable

and home-garden cultivation on steep slopes without any effective soil conservation measures. In this catchment, two cultivated sites, one with potato and other under pasture, were selected for study. Undisturbed reference sites were selected according to the criteria described by Pennock and Appleby (2002). The forest site, located close to the selected cultivated sites at a higher elevation, was identified for establishing the reference $^{137}$Cs inventory. The dominant soil in this area was referred to as red-yellow podzolic soils (Pannabokke 1996).

## Materials and Methods

*Sampling methods for determining fallout radionuclide inventory*

Sampling programme for the reference site was carried out using the procedures described by Owens and Walling (1996). The samples were taken by the scraper plate method at 2 cm intervals up to 40 cm to determine the appropriate depth of penetration of $^{137}$Cs. The area of the scraper plate was 50 ×20 cm$^2$. In order to define the spatial variability of soil $^{137}$Cs inventory, bulk soil cores were collected from five transects in a 40 m× 50 m grid network. The core area was 88.0 cm$^2$. The cores were collected to a constant depth of 35 cm. Each transect consisted of 4 sampling points with the spacing of 10 cm. At each sampling point, three cores were collected within an area of 1 m$^2$. The three replicated samples were mixed and one composite sample was made for each sampling point.

*Sampling strategy in cultivated sites*

Two cultivated sites were selected to measure the soil erosion rates. The bulk soil cores were obtained using the cylindrical core sampler used in the previous section. The cores were taken from 20 sampling points in three transects placed in a zigzag manner. The spacing between two sampling points was 3.0 m and the total sampling area was 20 × 20 m$^2$.

*Sample preparation and analysis*

Soil samples were air dried, disaggregated and passed through 2 mm mesh to separate the gravel from soil. A sub sample from the weighed fine fraction was filled into a Marinelli beaker whose geometry was similar to that used for system calibration. The activity of $^{137}$Cs was measured using a Hyper Pure Germanium (HPGe) detector with the relative efficiency of 30% and the resolution of 2.20 keV at the gamma energy of 1332.5 keV of $^{60}$Co. The detector was surrounded by a 10 cm thick lead shield, to reduce the background. Each sample was counted for 20 hrs. The background of the system was measured using an empty Marinelli beaker. A mixed radionuclide standard (LU 466) obtained from the International Atomic Energy Agency was used for the efficiency calibration. The reference material, IAEA Soil - 6 of known $^{137}$Cs content was used for method validation. The net area under peak at 661.5 keV was used to determine the $^{137}$Cs concentration of soil in Bq/kg. The spectra were analyzed using the software packages Genie 2000. The minimum detection activity of $^{137}$Cs was 0.4 Bq/kg for the counting time and the geometry used. The areal activity of $^{137}$Cs was calculated using the equation:

$$S = cmA^{-1} \tag{1}$$

Where c is the $^{137}$Cs concentration in the sample < 2mm (Bq/kg), m is total sample dry mass of the fine fraction (kg) and A is the cross-section area of the sampling device (m$^2$)

## Estimation of soil erosion rates

The proportional model was used to quantify the erosion rates in this study.

## Results and discussion

The depth distributions of $^{137}$Cs at the reference site is shown is Figure 1. The vertical distribution of $^{137}$Cs obtained at the reference sites is similar to that obtained from undisturbed sites by other workers (Walling and Quine 1990b; Owens and Walling 1996). The total $^{137}$Cs inventory in depth incremental samples was 772 ± 88 Bq/m$^2$.

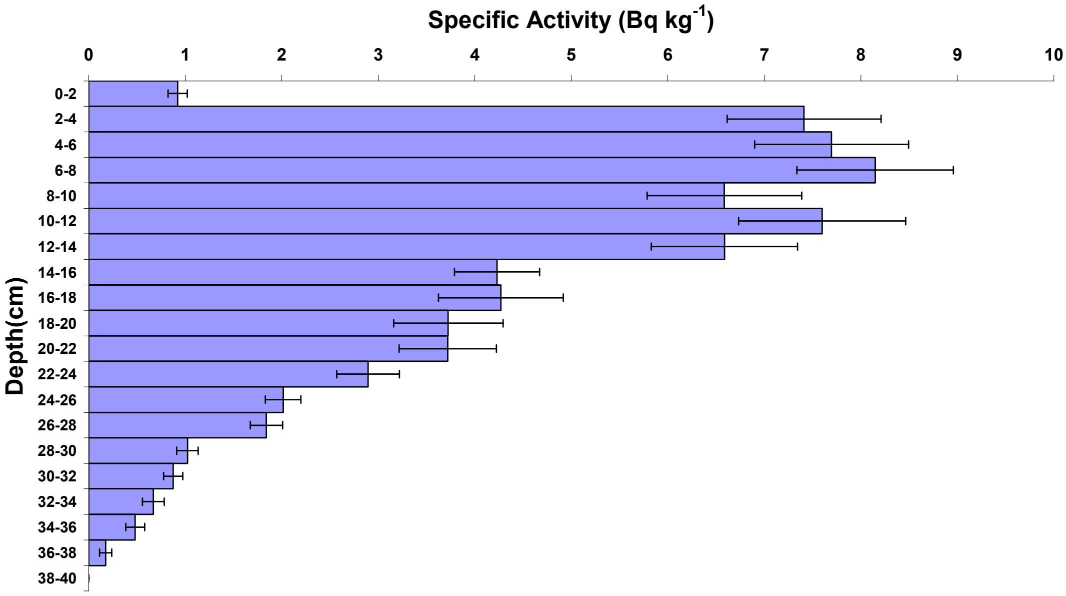


**Figure 1. The depth distribution of $^{137}Cs$ within the soil profile at the reference site.**

For bulk samples, a mean reference inventory of 753 Bq/m$^2$ was obtained. The coefficient of variation was 17.32% and the standard error was 30 Bq/m$^2$. Based on the approach of Owen and Walling (1996) where the reference inventory is expressed as the mean ± 2SEM the $^{137}Cs$ inventory at the reference site range from 693 - 813 Bq/m$^2$.

The mean reference value of 753 Bq/m$^2$ was used to determine the percentage loss or gain of $^{137}Cs$ at the respective study site. The mean $^{137}Cs$ inventory at the potato cultivation site and the pasture site were 290 Bq/m$^2$ and 491 Bq/m$^2$ respectively. Figures 3 and 4 indicate the $^{137}Cs$ activities (Bq/m$^2$) of each sampling points in potato and pasture sites respectively. The calculated mean erosion rate in the potato cultivated site was 44 t/ha/yr where as for the pasture site it was 24 t/ha/yr.

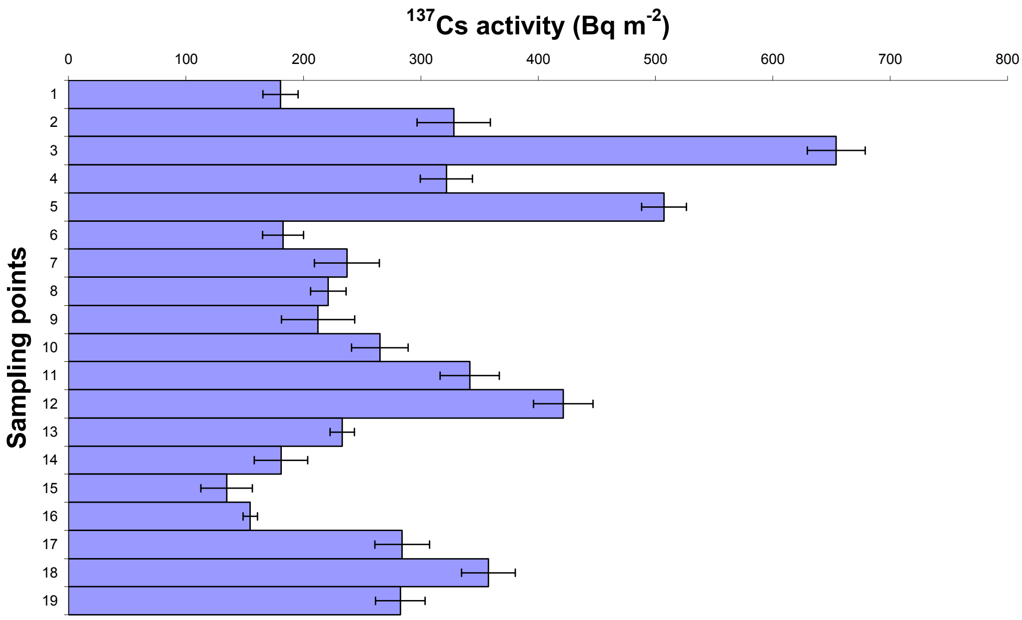


**Figure 2. $^{137}Cs$ activities under potato cultivation.**

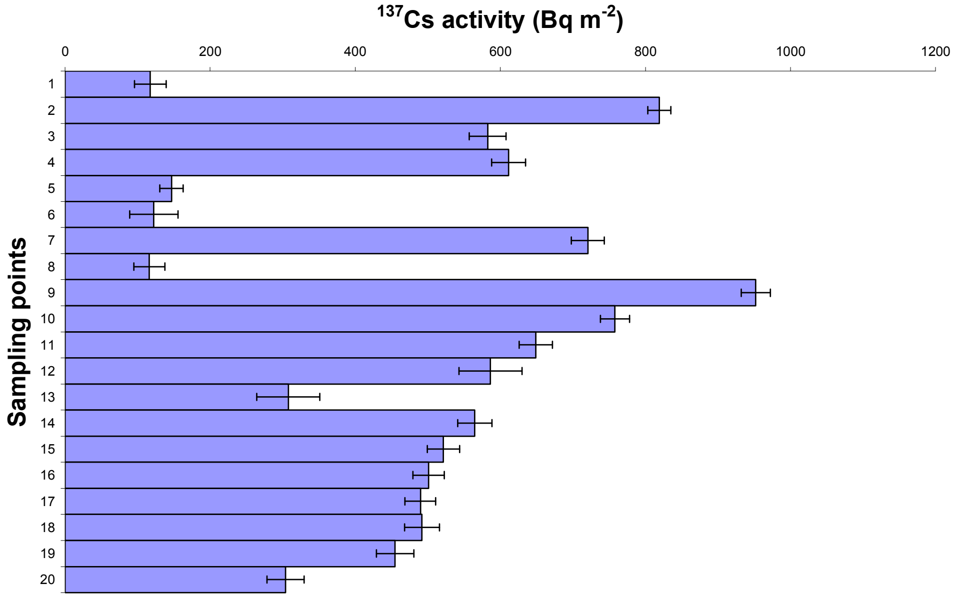


**Figure 3. $^{137}$Cs activities in under pasture.**

## Conclusions

This study investigated the possibility of using $^{137}$Cs measurements to quantify soil erosion in two cultivated sites in Sri Lanka. The results confirm the significance of soil erosion. These preliminary results display considerable potential for the use of $^{137}$Cs technique for further soil erosion and redistribution studies in Sri Lanka.


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