^{137}Cs technology for soil erosion and soil carbon redistribution

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^{137}Cs technology has received much attention in the last few years because it can be applied both quickly and efficiently in soil erosion and soil redeposition studies. It is also a unique method for enhancing the efficiency of estimation of soil erosion in eroded and hilly areas. In the process of development of agriculture, ^{137}Cs estimations have become an important tool to reduce soil erosion for boosting food security. The key benefit of using environmental tracers is that they can provide retrospective information on medium-term (~50-yr span, ^{137}Cs) and long-term (~150-yr span, ^{210}Pb) redistribution patterns of soils within the landscapes, without the need for long-term monitoring programmes. ^{137}Cs technology has never been applied to estimate soil redistribution patterns in India, even though there have been severe land-use changes over the past few decades. Here we discuss the importance of ^{137}Cs technology for land degradation, agriculture, food security and carbon sequestration.

Anthropogenic activities and the fast-growing world population have led to global environmental destruction and ecological degradation that exert tremendous pressure on soil for food, biomass and productivity, and environmental quality. Soil is a critical life-supporting system of the earth, maintaining essential ecosystem services and food security. Unfortunately, one-fourth of the global soil resources is highly degraded, and approximately half is moderately degraded due to rapid industrialization, urbanization and agricultural activities during the last few decades[1,2]. Soil erosion is now becoming a global hazard for human beings. Some soils have lost as much as 20–80 t C ha^{-1}, of which 15–20% is emitted into the atmosphere[3,4]. Soil erosion may lead to loss of upper layer of soil formed over thousands of years. It decreases soil water capacity, soil fertility and also inhibits terrestrial growth[5–7].

The use of artificial fallout radionuclide ^{137}Cs as a soil erosion environmental tracer has gained popularity during the last decades, and the method has been applied with successive implementation in soil erosion redistribution, sediment chronology and fingerprint sediment sources all over the world[8–11]. ^{137}Cs was released into the atmosphere during nuclear-bomb tests and as a consequence of nuclear power plant accidents, such as Chernobyl in April 1986. ^{137}Cs has relatively long half-life (30.2 yrs), and worldwide distribution has made it almost an universal environmental tracer for studying upslope soil erosion and downstream sedimentation[12,13]. It reaches the land surface by dry and wet fallouts and once deposited on the ground, it is strongly bound to fine particles at the soil surface. The fixation and accumulation of cesium is controlled mainly through carbonates and humus. The environmental tracer technique has become an attractive methodology for quantifying long-term (~50-yr span) average soil erosion and accumulation rates. It is based on comparing ^{137}Cs inventory in soils of a site which is suspected to be affected by soil redistribution to that of an adjacent undisturbed reference site[12,14,15].

The measurement of ^{137}Cs activity (Bq kg^{-1}) is performed with high-resolution high-purity germanium (HPGe) detectors using a coaxial high-resolution germanium lithium (Ge–Li) detector. ^{137}Cs measurements provide information not only on the net erosion, but also on soil movement, their relative importance and their spatial distribution in the landscape. Consequently, it is expected that these estimates will prove an asset for carbon sequestration storage and raise awareness of the agriculturally induced impact of soil erosion on landscapes, agricultural systems and land–atmosphere interactions. Based on the above considerations, it could be assumed that the great challenge before the scientific community, policy makers and regulatory agencies is to develop an environmental tracer-based technique for redistribution patterns of soils within the landscapes in a warming climate.

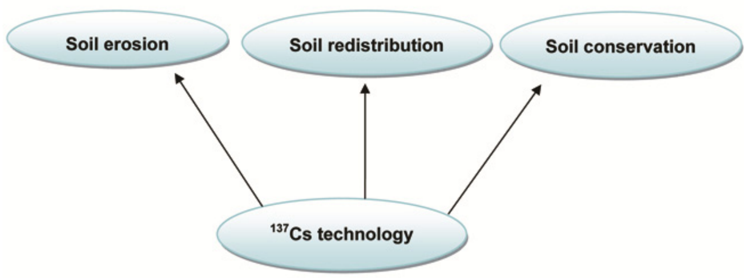

Figure 1. ^{137}Cs technology for soil conservation.

To the best of our knowledge, one of the most challenging issues is laboratory analysis, and calibration may exhibit systematic errors. Therefore, the sensitivity and spatial variability of radio-cesium technique will be a big challenge for environmental scientists, and inventive measures are required to harness the low input technology for enhanced redistribution of carbon and soil erosion in a changing climate[16,17].

Apart from these extrapolated impacts, there may be several indirect effects associated with the changing climate. Soil erosion control measurements are essential for sustainable use of agricultural soils, soil conservation (Figure 1), improving environmental quality and food security. Therefore, it is important to study the effect of climate change on environmental tracer technique. For this, a combination of strategic and applied research, including simulation experiments, modelling and ecosystem-based approaches is essential. These estimates will improve the accuracy in carbon accounting with implications for greenhouse gas mitigation and carbon sequestration.

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COMMENTARY

Carbon storage potential of mangroves – are we missing the boat?

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Increasing soil carbon stocks and protecting carbon-rich soils are crucial for achieving the Paris climate targets. Mangrove forests are the potential carbon sinks for mitigating the growing greenhouse gas emissions due to their highest carbon storage capacity per unit area compared to terrestrial forests. Furthermore, restricted global distribution of mangroves testifies their role in climate change mitigation as most effective at the national level rather than on a global scale. Nevertheless, lack of reliable estimates, insufficient data, discrepancy in the available data, increasing degradation rates and failure of conservation endeavours signify that we are missing the carbon storage potential of mangrove soil. So, here we emphasize the imperative need of country-wise site-specific precise estimates and an understanding of the spatial distribution of mangrove soil carbon stocks to recognize the actual climate mitigation potential of the mangroves as well as strengthen the conservation measures for the sustainability of mangroves.

Despite the small geographical extent of mangroves (0.1% of the earth's continental surface), they are considered as potential carbon sinks and proposed as a low-cost effective option for mitigating greenhouse gas (GHG) emissions and climate change, due to their much greater carbon storage potential per unit area[1]. However, there is no robust estimate for carbon stocks of global mangroves. According to a recent estimate[2], carbon sequestration in the mangroves amounts to 14.2 Tg C yr^{-1}, with an average sequestration rate of 171 ± 17.1 g C m^{-2} yr^{-1} and average soil accretion rate of 5.8 mm yr^{-1}. In recent times, efforts have been made to assess the carbon stocks of global mangroves; however, uncertainty still exists. For instance, the available estimates[1–6] of total global carbon stocks of mangroves are 20, 10, 4.03, 13.1, 11.2 and 4.4 Pg C respectively. The estimated mean mangrove carbon stocks per unit area are 761.4 ± 45.5, 956, 511 and 885 Mg C ha^{-1} which are higher than those of other forest ecosystems[2,4,7–9].

Unlike other tropical forests, for which the bulk of carbon storage is in the biomass, mangrove carbon is primarily stored in soil[1,5,10,11]. The estimated average soil carbon concentration of global mangroves is also highly variable. For instance, Jardine and Siikamäki[12] reported the global mangrove soil carbon stock as 5.00 ± 0.94 Pg C, whereas Atwood *et al.*[6] and Sanderman *et al.*[13] have reported values of 2.6 and 6.4 Pg C respectively, for the top metre of soil. Similarly, estimates of soil carbon stock per unit area also vary. Donato *et al.*[1] reported the average mangrove soil organic carbon as 864 Mg C ha^{-1}, whereas Alongi[4], Jardine and Siikamäki[12], Atwood *et al.*[6] and Sanderman *et al.*[13] have reported values of ~700, 369 ± 6.8 (range 272–703), 283 ± 193 (range 72–936) and 361 ± 136 Mg C ha^{-1} (range 86–729 Mg C ha^{-1}) respectively. Previous estimates of global mangrove soil organic carbon have relied solely on climate-based models[11] or mean country-level