



# The Science of Soil: Using radionuclides to support soil conservation



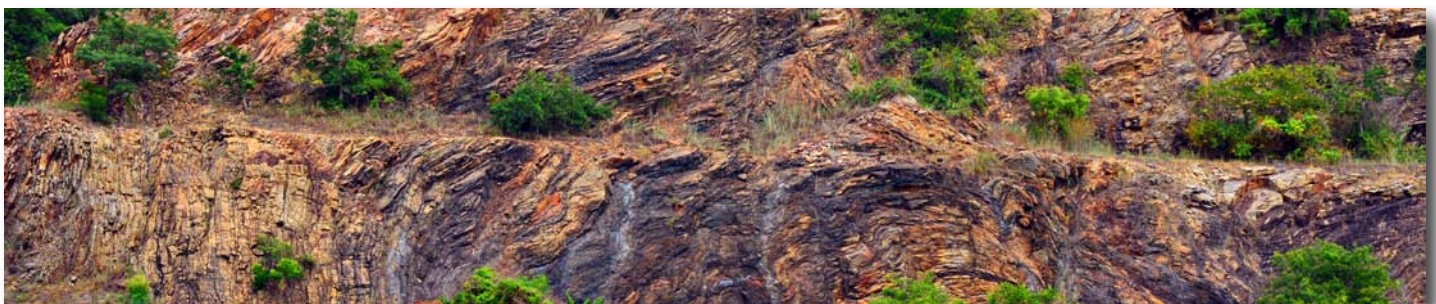
**Land degradation and soil erosion** threaten agricultural productivity, food security and environmental sustainability. Because formation of new soil takes place over a period of thousands of years, in human terms it is essentially a finite resource. Human activity has accelerated erosion rates through inappropriate land management practices, most importantly soil sealing, deforestation and intensive agriculture. The Food and Agriculture Organization of the United Nations (FAO)<sup>1</sup> and the European soil thematic strategy<sup>2</sup> have identified accelerated soil erosion as one of the major land degradation threats. Furthermore, world population growth, combined with increasing climate change and related natural hazards, is likely to worsen the impact of soil erosion and land degradation. The severity of

the problem of depletion of this vital resource is only now becoming widely appreciated.

**Soil erosion** causes damage to infrastructure, and also has broader environmental consequences. Besides providing the medium for plant growth and food production, soil plays a key role in the supply of clean water and resilience to flood and drought. It is also the largest store of terrestrial carbon; its preservation contributes to climate change adaptation and mitigation. Soil erosion may also lead to the damage or even destruction of infrastructure such as roads and buildings. The global cost related to soil loss due to erosion has been estimated to be in the order of US\$400 billion per year.

The IAEA, in partnership with the FAO, helps Member States use radionuclide and stable isotopic techniques to study soil erosion and land degradation problems. IAEA technical cooperation projects assist Member States to improve soil fertility and increase crop yields, and build capacities for soil conservation, land use planning and decision making.

**Soil conservation**, reducing erosion and maintaining soil fertility, have become very important issues for sustainable land management. In many parts of Australia, Europe and North America for instance, integrated land and water management have been officially adopted as the most effective methods of soil conservation. These methods involve policy makers, farmers and end users, and make use of scientific knowledge in the management of land and water resources.



<sup>1</sup>See the World soil charter (FAO, 1982; <http://www.fao.org/docrep/T0389E/T0389E0b.htm>), Keeping the soil alive (Hubert W. Kelley, 1990, FAO; <http://www.fao.org/docrep/T0389E/T0389E00.htm>) and more recently the Global Soil Partnership launched in 2012 (<http://www.fao.org/globalsoilpartnership/en/>).

<sup>2</sup>See: [http://ec.europa.eu/environment/soil/three\\_en.htm](http://ec.europa.eu/environment/soil/three_en.htm)

**Soil erosion research** provides the basis for regulatory policy in land management. Soil loss calculations and geomorphological expertise are used to support soil conservation planning, both through agricultural legislation that defines maximum tolerable soil loss rates, and through federal and local legislation that requires soil erosion controls on many roads and highway construction sites.

In support of soil conservation, **soil erosion research** focuses on:

1. Accurately assessing and quantifying soil erosion rates as well as identifying the exact source of eroded sediments for each environment; and
2. Identifying, developing and evaluating the best land management practices, including cultural practices, for soil conservation.



### ***Radionuclides: A tool of choice for soil scientists***

The most widely used radionuclides to characterise and quantify soil erosion and sedimentation are  $^{137}\text{Caesium}$ ,  $^{210}\text{Lead}$  and  $^7\text{Beryllium}$ . A radionuclide is an atom with an unstable nucleus that undergoes radioactive decay, resulting in the emission of gamma rays that can be detected. Radionuclides that have not been observed to undergo decay are called stable isotopes. Radionuclides occur naturally or can be produced artificially. Radionuclides with suitable half-lives play an important part in a number of technologies, for example in scanners for nuclear medicine (PET, SPECT), in smoke detectors, in gamma radiation detectors (Geiger counters), as tracers to detect air and water pollution, and as tracers for detecting sedimentation rates and the movement of soil particles.

Radionuclides are present in soils all over the world and are either leftovers from the creation of the earth or deposited in the soil through cosmic ray bombardment. They persist in the environment because their rate of decay is so slow. These elements are radioactive, but their concentration in soil is in such tiny quantities that these have no harmful effects on human health. Therefore, no specific protection is required when performing soil sampling or measuring the radioactivity of these elements in soil samples.



## Examples assessing soil erosion and the effectiveness of soil conservation practices

The assessment of soil erosion encompasses both the determination of the origin of eroded sediments and the quantification of soil erosion and deposition rates. In some regions, the movement of sediments (erosion and deposition) have been clearly characterised and quantified. However, identifying the area from which most of the sediments originate remains a challenge, though a crucial issue when seeking a targeted and cost effective remediation solution. Isotopic technologies based on radionuclides can provide this information in an effective way.

The Timah Tasoh river catchment in northern **Malaysia** was experiencing sedimentation through soil erosion that contributed to deteriorating water quality in a nearby lake. Isotopes for measuring soil erosion, in this case fallout radionuclide (FRN) and compound-specific stable isotope (CSSI) analysis, enabled precise measurement of the sedimentation rate and identified the sources of the sediments. Mixed cropping was identified as the major contributor (55%) to sedimentation to the lake. Other major contributing factors were the recently planted areas of rubber and sugar cultivation. Appropriate soil conservation practices were then applied to mixed cropping and other land uses in order to reduce soil erosion and improve water quality in the lake.



In the Loess Plateau in northern **China** these techniques have been used to measure soil erosion and determine sedimentation patterns. This analysis led to the implementation of improved soil conservation measures in the region, including terracing and vegetated hill slopes, and contour cultivation. Soil erosion rates were thereby reduced by between 16 and 80%.

In **Viet Nam** 75% of the territory is comprised of sloping land and there is therefore a high level of vulnerability to soil erosion loss. A study comprised of 27 sites in the region of Lamdong province measured soil erosion rates through isotope techniques. This improved understanding, allowed the adoption of appropriate soil conservation practices such as inter-cropping, growing green-manure plants, creating basins near coffee trees, contouring and terracing in different landscapes, ultimately leading to a 45% reduction in soil erosion.



## ***Soil erosion research with radionuclides: The tool in practice***

The measurement of soil erosion and sedimentation and the determination of soil particles origin using radionuclides technology requires:

- ✓ Laboratory analysis of basic soil characteristics and for establishing radionuclides inventories using a gamma detector, measuring radionuclide activity. Portable gamma detectors are now available.
- ✓ Soil sampling at a representative site (with soil erosion) and reference site (without soil erosion)
- ✓ Soil erosion models to provide erosion and sedimentation rates. Different models exist with various levels of complexity and accuracy, relying on soil characteristics, climate and land use data. IAEA has developed a user-friendly software package, which can be accessed at the following address: [http://www.naweb.iaea.org/nafa/swmn/models\\_tool\\_kits.html](http://www.naweb.iaea.org/nafa/swmn/models_tool_kits.html)

The IAEA has recently published a guideline on the use of fallout radionuclides (FRNs). This provides comprehensive step-by-step guidance for investigating soil erosion and soil redistribution affecting agro-ecosystems.



## ***A tool for evidence-based land use planning in support of sustainable land management***

Sustainable land management policies need to be based on evidence that soil erosion assessments are accurate and that soil conservation practices are effective. The combination of geostatistics with radionuclide technology allows for the spatial distribution of soil erosion and soil deposition rates. Such a tool is useful in devising regional and national soil maps and land use plans, based on data about the causes and level of soil erosion. Radionuclides can be used to characterize and quantify sediment movement, and to trace the origin of soil particles and their redistribution inside a watershed. The identification of the precise

origin of soil sediments allows for the identification of 'hot spots' of land degradation that require focused conservation practices, reducing remediation costs in the long run.

Furthermore, radionuclide technology requires less time to determine soil erosion and deposition rates than other methods. It also allows for obtaining information at different time scales (short, medium and long term), and therefore does not require continuous monitoring over long time frames. Radionuclide field measurements are also used to validate existing GIS models that monitor or predict soil particles movements.

The IAEA has long-standing experience in using radionuclides for identifying and quantifying erosion and sedimentation, and assessing the effectiveness of soil conservation practices in many different countries and regions of the world. Through the IAEA's technical cooperation programme Member States benefit from this knowledge and experience, allowing them to better develop and implement their own soil and land management policies and practices.

**For more information on partnerships in the field of soil erosion and conservation, please contact:**

Strategic Partnerships Section, Division for Programme Support and Coordination,  
Department of Technical Cooperation, International Atomic Energy Agency  
[www.iaea.org/technicalcooperation/Develop/Soil.html](http://www.iaea.org/technicalcooperation/Develop/Soil.html)  
<http://www.naweb.iaea.org/nafa/swmn/index/html>

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