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ASSESSMENT OF SOIL EROSION RATES IN SOUTHEASTERN SERBIA USING NUCLEAR TECHNIQUES

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ABSTRACT

Soil erosion by water presents an important environmental problem in Serbia resulting in degradation of the soil resources, reducing soil fertility and agricultural production. The highest intensity of erosion was observed at cultivated land occupying steep slopes. The conversion of pastures to arable land enhances this problem. This study presents the preliminary results of Technical Cooperation Project of International Atomic Energy Agency 'Strengthening the Capacities for Soil Erosion Assessment Using Nuclear Techniques to Support Implementation of Sustainable Land Management Practices' (SRB5003) aimed at estimation of soil erosion rates using the ^{137}Cs-method. The investigation of Pčinja and South Morava River Basins in southeastern Serbia revealed intensive erosion in the area. The investigation will continue at several other sites and the results will be used to support national soil conservation policy.

1. Introduction

Soil erosion is one of the most common and important land degradation processes. As soil erosion is identified as one of the key environmental problems in Serbia there is an increasing need for obtaining the reliable information on soil erosion rates. The use of fallout radionuclides (FRNs) such as artificial ^{137}Cs and $^{239+240}$Pu (medium-term erosion assessment, recently about 55-60 years), geogenic $^{210}Pb_{ex}$ (long-term erosion assessment, about 100 years) and cosmogenic ^{7}Be (short-term erosion assessment $\leq$ 6 m) for obtaining such information [1-4] possesses some advantages as compared to traditional methods, such as cost-effectiveness and possibility to obtain information retrospectively [5]. Advantages, as well as limitations of FRN techniques, are discussed in number of papers [1-2, 5]. The main goal of erosion assessment with ^{137}Cs method is to obtain information needed for identification of areas exposed to high erosion risk and soil conservation strategies as an important part of sustainable agriculture and food production. Over the years, many different models have been developed for cultivated and uncultivated lands in order to convert ^{137}Cs inventories into soil erosion and deposition rates, such as models developed by Walling (2006) - Proportional Model (PM), Mass Balance Model (MBM) I, II and III, Profile Distribution Model (PDM) and Diffusion and Migration Model (DMM) [1]; by Arata et al. (2014) Modelling Deposition and Erosion Rates with RadioNuclides (MODERN) [3,4], by Soto and Navas (2004; 2008) [6-7] etc.

In last years the use of ^{137}Cs method is developing abruptly in Serbia and first results were published [8]. The use of ^{137}Cs method is supported by International Atomic Energy Agency (IAEA) and Food and Agricultural Organization (FAO) through their Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. The Joint FAO/IAEA Division supports the Technical Cooperation Project „Strengthening the Capacities for Soil Erosion Assessment Using Nuclear Techniques to Support Implementation of Sustainable Land Management Practices" (SRB5003) launched in 2018 with the main objective to enhance soil conservation and environmental protection in Serbia, using environmental radionuclides; to improve national policies for sustainable soil management, based on the soil erosion assessment results; and to revise the earlier erosion map of Serbia using ^{137}Cs method. Some preliminary results of this project achieved at Pčinja study site in southeastern Serbia are presented in this study.

2. Methods

The ^{137}Cs (half-life, $t_{1/2}$ = 30.2 years) is the most widely used radionuclide tracer for studying soil redistribution. The ^{137}Cs is found in the environment worldwide due to fallout after nuclear weapon testing in the 1950's and 1960's and after nuclear power plant accident such as Chernobyl in 1986 or Fukushima-Daiichi in 2011. Once deposited on the ground, ^{137}Cs strongly bind to fine soil particles and move across the landscape together with soil particles by mechanical processes such as water, tillage, and wind erosion.

Due to the intense folding and faulting of the geological strata, the Pčinja and South Morava River valleys are narrow and dominated by steep slopes. The climate of the study area is temperate continental with mean annual precipitation of about 620 mm [9]. At most of the sampling sites the soils are dominated by Haplic Cambisols and Luvic Planosols.

The soil samples were collected on five slope transects at selected grassland site exposed to erosion processes, especially to pluvial erosion. The total inventories of ^{137}Cs (Bq m^{-2}) at sampling points were calculated from the activity concentrations of this radionuclide measured by gamma-ray spectrometry taking into account the soil bulk density and the soil profile depth increments. The details on sampling design and analysis could be found in Petrović et al. (2016) [8].

The methodology used to determine soil erosion and deposition rates was based on a comparison between the total ^{137}Cs inventories for the sampling points with the reference inventory - site where no soil redistribution processes have occurred since the ^{137}Cs main deposition. At a deposition point the ^{137}Cs inventory is greater than the reference inventory (A_u (Bq m^{-2}) > A_{ref} (Bq m^{-2})), while at an eroded point the total ^{137}Cs inventory is lower than the reference inventory (A_u (Bq m^{-2}) < A_{ref} (Bq m^{-2})) [1, 2], Fig. 1.

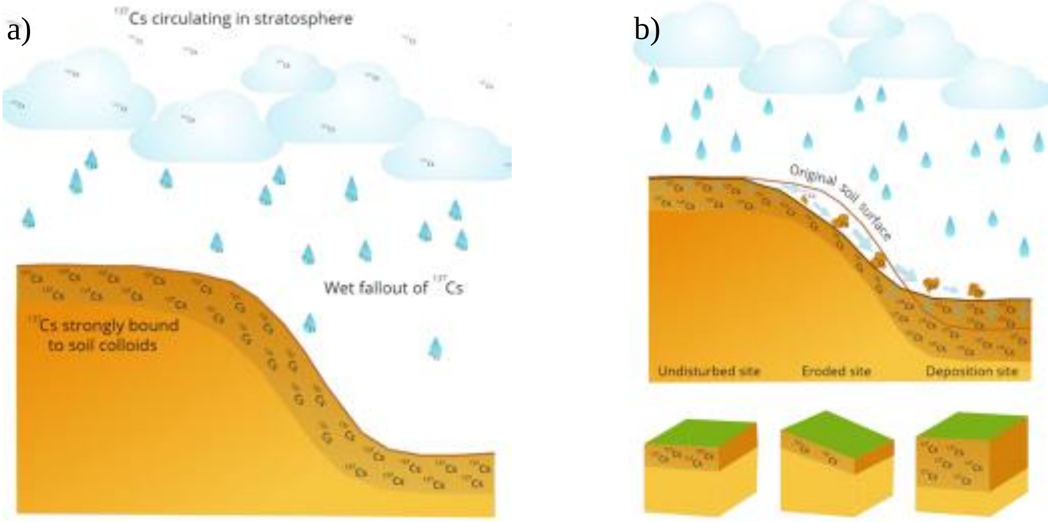

Figure 1. a) Homogenous distribution of the fallen ^{137}Cs in area not affected by soil erosion, b) ^{137}Cs and soil redistribution by erosion: undisturbed, eroded and deposition site [10].

A key step of the ^{137}Cs method is to estimate ^{137}Cs inventory at representative undisturbed reference site. Guidelines and criteria for reference sites selection were provided by Mabit et al. (2014) [2].

3. Results

The ^{137}Cs inventories of the sampling points were converted to soil erosion and deposition rates with the Profile Distribution Model and Diffusion and Migration Model. Since more than 80% of ^{137}Cs input came from Chernobyl accident [11-13], the year 1986 is selected as the main fallout ^{137}Cs input in the applied conversion models.
The erosion and deposition rates estimated using selected models are presented in Table 1. For all transects, the sediment delivery ratio is given, i.e. the ratio between net erosion rate and gross erosion rate. More details could be found in FAO/IAEA (2017) [1, 10].

Table 1. Soil redistribution rate estimated using the PDM and DMM.

	Transect 1		***Transect 2***		***Transect 3***		***Transect 4***		***Transect 5***	
	PDM	**DMM**	**PDM**	**DMM**	**PDM**	**DMM**	**PDM**	**DMM**	**PDM**	**DMM**
Gross erosion rate (t ha^{-1} yr^{-1})	-5.6	-2.4	-28.0	-8.9	-13.9	-4.7	-10.5	-4.3	-14.6	-5.8
Net erosion rate (t ha^{-1} yr^{-1})	-4.7	-1.9	-25.4	-7.5	-5.9	-0.6	-10.5	-4.3	-14.6	-5.8
Sediment delivery ratio (%)	83	81	91	84	43	13	100	100	100	100

The substantial differences in soil redistribution rates obtained by the models could be attributed to the differences in model assumptions. Namely, the PDM does not take into account the time-dependent nature of ^{137}Cs fallout deposition and the post-fallout redistribution in the soil profile which results in overestimation of soil loss. Therefore, the results of DMM are more realistic. The variation of the soil redistribution rates down the slopes of transects could be found in Petrović et al. (2016) [8]. The obtained net erosion rates (as calculated by DMM) seems to be not much at first look but considering the strong soil conserving efficiency of grass cover and the site topography the erosion should be at similar sites close to zero. The measured values indicate that at longer slopes the erosion may be relatively strong and may result in linear erosion (rills and gullies) causing serious damage. Indeed the rills and gullies were commonly observed by project team in mountainous areas of Serbia. In a pastureland from Cluj county, Romania the net erosion rate estimated by PDM was -5.8 t ha^{-1} yr^{-1} [14] and -6.6 t ha^{-1} yr^{-1} using DMM [15], which is comparable with results obtined in this study. The average erosion rates obtained using the Profile Distribution method in undisturbed soils for the Peynirli and the Kırtas Hills in Western Turkey were found to be 15 and 27 t ha^{-1} yr^{-1}, respectively [16].

4. Conclusion

The ^{137}Cs method was used to estimate soil redistribution rates at selected sites in Pčinja and South Morava River Basins, southeastern Serbia. The data gained by ^{137}Cs method have some advantages as compared to data provided by most conventional methods because ^{137}Cs method provides (i) retrospective information, (ii) estimates of medium-term average rates of soil redistribution, (iii) values representing integrated result of all mechanical soil redistribution processes running at studied site, and (iv) information on both erosion and deposition. The information presented in this paper should be further used to support soil conservation in Serbia.

5. Acknowledgements

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PROCENA INTENZITETA EROZIJE ZEMLJIŠTA JUGOISTOČNE SRBIJE PRIMENOM NUKLEARNIH TEHNIKA

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SADRŽAJ

Erozija zemljišta vodom predstavlja važan problem zaštite životne sredine u Srbiji. Posledica erozije je degradacija zemljišnih resursa, smanjenje plodnosti zemljišta i redukcija poljoprivredne proizvodnje. Najveći intenzitet erozije uočen je na obradivom zemljištu na strmim padinama. Pretvaranje pašnjaka u obradivo zemljište uticalo je na povećanje prostora zahvaćenih procesom erozije. U ovom radu prikazani su preliminarni rezultati projekta tehničke saradnje sa Međunarodnom agencijom za atomsku energiju 'Jačanje kapaciteta za procenu intenziteta erozije zemljišta korišćenjem nuklearnih tehnika u cilju podrške održivom upravljanju zemljištem' (SRB5003) čiji je cilj procena intenziteta erozije zemljišta ^{137}Cs-metodom. Istraživanja sprovedena u basenima Pčinje i Južne Morave ukazala su na intenzivnu eroziju na ovom prostoru. Istraživanja će biti nastavljena na nekoliko drugih lokacija, a rezultati će biti upotrebljeni za podršku nacionalnim programima konzervacije zemljišta.