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Application of ^{137}Cs technique for evaluation of erosion and deposition rates within cultivated fields of Salihli region, Western Turkey

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ABSTRACT

Soil erosion by wind and water is an important problem for Salihli region in Western Turkey. There are several vineyards on the cultivated soils of this region, which is a significant economic income source for the residents. This study focuses on the cultivated soils in these areas to quantify spatial distribution of ^{137}Cs using 3-D graphic method and eventually to estimate erosion and deposition using the results of ^{137}Cs spatial distribution obtained. The erosion and deposition rates were estimated using proportional and simplified mass balance models. Results obtained using simplified mass balance model gave slightly higher values than those found using proportional model. Erosion and deposition rates derived from proportional model varied from −16.02 to −19.40 t ha^{-1}y^{-1} and from +6.80 to +9.62 t ha^{-1}y^{-1}, respectively. On the other hand, values determined using simplified mass balance model ranged from −17.52 to −21.10 t ha^{-1}y^{-1} and from +7.21 to +11.31 t ha^{-1}y^{-1}. The comparison of the results obtained via these models revealed a good agreement within the range of 30 t ha^{-1}y^{-1} soil loss and gain.

1. Introduction

Soil loss from the land due to the effects of wind currents and water flow is known as soil erosion. It is also a natural process that supports transportation of soil from one area to other. In natural conditions, this process occurs at very slow phase and in a gradual manner. But due to human activities the rate of the soil erosion has drastically increased and led to the undesirable soil erosion. Some of the problems that accelerate the process of soil erosion are improper farming, over farming, over grazing, and deforestation. Several quantitative and qualitative techniques have been developed and used to estimate soil erosion and deposition throughout the world. However, most of these techniques are not able to produce any spatial patterns of soil movements and re-deposition of eroded particles within the fields to understand soil loss. Use of nuclear techniques in erosion monitoring and especially for qualification of soil loss has offered a fast and economical tool to estimate erosion rate starting with ^{137}Cs in 1970s (Cohen, Shepherd, & Walsh, 2005; Li, Lobb, Kachanoski, & McConkey, 2011; Sac, 2008).

The main reason of radioactive deposition on the soils is the infiltration of rainwater, which contains ^{137}Cs penetrated into atmosphere via nuclear weapon tests and Chernobyl. When ^{137}Cs reacts with soil by rainfall, it is absorbed and accumulated

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on small particles. Absorption by soils occurs via ion-exchange with clay minerals (Oztas, 1993), which have been empirically and mathematically modeled to estimate soil erosion (Zapata, 2002; Zhang, Higgitt, & Walling, 1990). Since tracking ^{137}Cs absorption on the soil can be used to estimate soil loss, this approach has been used in numerous studies (Ritchie & McHenry, 1990). Advantages of using ^{137}Cs tracking technique to estimate soil erosion can be listed as follows:

a) Requires one sampling trip to field,
b) Provides results promptly.
c) Allows retrospective assessment of soil erosion rates (average losses for 35–40 year period thus is less influenced by extreme events).
d) Provides estimates of soil erosion rates, deposition rates, and export rates.
e) Allows a sampling methodology to provide any spatial resolution required (Nouira, Sayouty, & Benmansour, 2003).

Recent concern on soil degradation and the offsite impacts of accelerated erosion have highlighted the need for improved methods in order to estimate the rates and patterns of soil erosion by water.

Although many studies by conventional methods have been conducted for soil erosion in Turkey, there are very few studies for the problem using nuclear techniques. Application of nuclear techniques in erosion studies in Turkey has started with our study in Gökova region in Western Anatolia. In the study, we investigated the applicability of ^{137}Cs techniques for estimation of soil loss in Yatağan basin. The erosion rates of three hills, one cultivated land and two uncultivated lands, in the basin were determined using ^{137}Cs technique with proportional model (PM), profile distribution model (PDM) and simplified mass balance model (SMBM), respectively. Results of ^{137}Cs technique were compared with the results of the Universal Soil Loss Equation (USLE) and a good agreement was observed between soil losses predicted by both ^{137}Cs and USLE techniques (Sac, 2008).

Despite the effective threat of erosion, for soil preservation and productivity in Salihli region, there is still limited information on soil loss rates. This study provides the determination of long-term erosion rates in cultivated land of Salihli region using ^{137}Cs tracking technique. Since soil erosion is the most significant agricultural problem for soil conservation throughout this region, almost every location nearby the vineyards has to deal with this problem. Consequently, the objectives of our study are: 1) to evaluate the reliability of the ^{137}Cs technique for the quantification of erosion in the Salihli region 2) to document the levels of ^{137}Cs on cultivated soils in a catchment located in Western Turkey 3) to estimate erosion or deposition rates on cultivated land using empirical model.

2. Materials and methods

2.1. *Description of study area*

The study region is located at Gediz Basin of the Aegean Region in the west of Turkey. This basin lies between northern latitudes of 38°27′–38°45′ and southern longitudes of 27°10′–28°16′. [18] It is composed of Palaeozoic-aged schist, gneiss, and crystallized calcareous. It also contains broken volcanic rocks such as limestone, sandstone, conglomerate and marble. Areas lying between the south of Gediz basin and the south of Manisa plain have limestone mixed with layers of lava and tuff, marble, conglomerate, clayey-gypsum sandstone and some rocks containing silt, sand, pebble, clay and gypsum. Alluvial rocks are observed on low hills in the form of Oligocene formations. Most of the basin has been formed by alluvial materials carried by Gediz River.

The climate in the region is Mediterranean climate, where annual precipitation varies between 450 and 1060 mm, and the mean annual temperature is 16.6 °C (Topraksu, 1971).

2.2. *Sampling sites*

Samples were collected from four different topographic cultivated regions (Fig.1 and Table 1). These areas were chosen as the study sites because of the existence of intensive agricultural activities. The study sites were sampled using a systematic grid design between 30 × 30 m^2 and 50 × 50 m^2 depending on the topographic characteristics of the site. Bulk soil cores were collected from each of moderate sloppy sites (1%–10%) up to plough depth (Table 1). The cultivation depth was estimated to be 25 cm that was the depth of a hoe or oxen-drawn. Two types of core tube were used for sampling. A stainless-steel core tube with 8.5 cm diameter was used for bulk core sampling and corer of 15.5 cm diameter was used for sliced soil profiles. Sectioned soil cores were collected in 5 cm intervals up to 40 cm soil depth for vertical distribution of ^{137}Cs along soil profiles to investigate the proper reference points and also the eroded areas. ^{137}Cs Activity concentration was found to be disturbed almost uniformly, but exponentially distributed in the reference points.

The choice of a suitable reference site is one of the most important aspects of the technique. Locations where there is no erosion or deposition occurred were examined as reference sites. As in the most used ^{137}Cs method, the ^{137}Cs loss is determined by comparing the ^{137}Cs inventory for individual sampling site to a reference value obtained from undisturbed non-eroding area. The choice of suitable reference sites should be done careful. The reference site should have received the same annual precipitation and should have similar geomorphological parameters with the sampled cultivated field. Seven uncultivated and undisturbed sites were selected near the meteorological stations in the catchment with different slope inclinations than have the reference sites in the watershed. Table 2 lists some characteristics of these sites.

2.3. *Gamma spectrometric analysis for ^{137}Cs*

The soil samples were oven dried at 105 °C, disaggregated, passed through 600 μm (30 meshes) sieves, mixed, weighted and was put in Marinelli beakers of 1200 mL with 1500 g weight. The samples were analysed for ^{137}Cs by direct gamma assay, using Tennelec/Nucleus HPGe (184 cc) planar type coaxial intrinsic germanium detector. ^{137}Cs activity was measured by its gamma emission at 662 keV. Background