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Using the Radioactive Isotope Cesium-137 to Evaluate Soil Erosion and Sedimentation Rates in Sloping Areas at the University of Mosul

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ABSTRACT

This study aimed to estimate soil erosion and sedimentation rates in the University of Mosul campuses, Nineveh Governorate, using the cesium-137 technique. Soil samples were collected from two sites, A and B, each divided into three zones: (1) the top of the slope (undisturbed site), (2) the middle of the slope (eroded site), and (3) the sediment site at the bottom of the slope. The cesium-137 activity in each sample was measured, and its count rate was compared between undisturbed and eroded sites. Results indicated significant differences in cesium-137 count rates across the three zones. The count rates decreased from the top to the bottom of the slope. The lowest values were found at the eroded sites, with approximately 9,822 counts/2 hours at Site B and 7,040 counts/2 hours at Site A. This supports the presence of soil migration in the middle of the slope at both sites. Additionally, cesium-137 count rates varied with soil depth. At Site A, the undisturbed site, count rates ranged from 16,883 to 115 counts/hour for depths of 0-30 cm. At the eroded site, values ranged from 9,822 to 144 counts/hour, while at the sediment site, they ranged from 10,206 to 2,037 counts/hour. The low count rates observed in eroded areas indicate soil erosion, while high values at the sediment site indicate deposition.

Keywords: soil erosion; sedimentation; cesium-137; gamma spectroscopy; cesium radioactivity

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INTRODUCTION

Soil is a fundamental natural resource, playing a crucial role in sustaining ecosystems and human societies by providing essential ecosystem services and ensuring food security (Burbano-Orjuela, 2016). It supports the growth of crops, grasslands, and forests, which are vital for producing food, fiber, and timber, and it facilitates the cycling of gases, water, and nutrients, thereby maintaining environmental balance. However, soil faces significant environmental challenges, including acidification, contamination, erosion, and degradation, which threaten its ability to function effectively (Wild, 1993). These challenges are exacerbated by increasing demands for food, water, and energy, necessitating a global effort to protect soil resources while addressing climate change and land degradation. The importance of soil has been increasingly recognized in the context of achieving the United Nations' Sustainable Development Goals, highlighting the need for interdisciplinary research and policy integration to ensure sustainable soil management (Evans *et al*., 2021). Addressing these challenges is critical, as soil degradation not only impacts agricultural productivity but also affects biodiversity and ecosystem functioning, underscoring the urgency of developing effective soil conservation strategies (Wallace and Wallace, 1994). Thus, the study of soil science is pivotal in bridging knowledge gaps and formulating policies that can withstand future uncertainties, ensuring the sustainability of this vital resource (Evans *et al*., 2021). Cesium-137 is a radioactive isotope that emits gamma and beta radiation and has a long half-life of 30.2 years. Its presence in the atmosphere has been attributed to multiple sources. The most reliable source of this radionuclide was radioactive fallout from nuclear explosions in the 1950s and 1960s, which spread globally from radioactive materials and activities, and from nuclear accidents such as the Chernobyl and Fukushima reactor accidents, as well as medical and industrial waste (IAEA, 2015; Konoplev *et al*., 2016). Cesium-137 is widely used in soil studies, particularly soil erosion (Mabbett and Larder, 2002). The current and future effects of soil erosion, including the loss of natural fertility due to wind and water erosion, are being investigated. The use of cesium-137 in estimating soil and sediment loss and their spatial distribution has also been investigated in different regions of the world over the past two decades. These studies include (Ritchie and McHenry, 1990; Sack and Ishidev, 2015; Boardman and Evans, 2019; Everard *et al*., 2020). This element is important in the field of soil erosion and loss studies. Mathematical models have also been developed to assess the fate of radioactive cesium in the atmosphere and its transfer from soil to humans and animals. Several geographic information systems (GIS) have been developed in this field (Van, 2000). Cesium-137 serves as a useful tracer for determining long-term annual rates of soil erosion or deposition. However, applicants should keep in mind that this method provides an assessment of the magnitude of soil erosion rather than an accurate measure of soil loss rates. (Mabit *et al*., 2011; Petra *et al*. (2023). In addition, the cesium-137 detection method used in soil erosion investigations also relies on the chemical properties of cesium. The radionuclides diffused into the stratosphere and then gradually descended to the Earth's surface. When cesium-137 comes into contact with soil material, it is firmly integrated into soil components and is not transported by leaching or plant uptake. Instead, it can only move with soil particles, causing changes in the cesium-137 reserve, leading to a redistribution of soil components based on physical factors, i.e., soil erosion (Ritchi and McHenry, 1990). The primary purpose of erosion assessment using the cesium-137 method is to provide the information necessary to identify erosion hotspots and select conservation measures. This aids in the implementation of soil conservation programs. Thus, the cesium-137 detection method contributes to maintaining food security. However, the method's limitations are related to the availability and distribution of cesium-137 within the soil. Soil is a natural resource for humans and other living organisms. It is a food store and serves as a unique environment for a large number of organisms. Soil is a fragile and exposed resource, so many regions of the world are exposed to the problem of erosion, a serious phenomenon due to the significant damage it causes. There are many environmental problems resulting from the loss of the surface or subsurface layer of the soil, the result of which is the deterioration of soil fertility and a decrease in its productivity, and thus desertification, which will negatively affect the availability of food for humanity (Walling and Quine, 1990).

The research aims to use the radioactive cesium-137 method to assess soil erosion. This is done by converting cesium-137 activity measurements (as a count rate) to estimate soil erosion values at two sloped sites within the University of Mosul campus. This technique provides an effective means of collecting data to reveal the spatial distribution of cesium-137 at the study site, and thus determine soil erosion. Therefore, it is recommended to take appropriate measures to mitigate the erosion problem, while preserving the green vegetation cover at the site.

MATERIALS AND METHODS

Sampling and sample preparation

Soil samples were collected during the summer from two main sites (A and B) within the University of Mosul campus, north of Mosul. Site A represents a sloping area near the University Mosque, close to the College of Arts, while the second site (B) represents a sloping area near the waterfall of the Presidential Palaces Lake. Their locations were identified on the geographical map shown in (Fig. 2). Both sites are free of radioactive contamination, as confirmed using a Geiger counter and based on the research results (Yousuf R. M. *et al*., 2008; Alkhayat R.B. 2010), which confirmed that many areas of the University of Mosul, including the two study sites, are free of radioactive contamination, and that radiation concentrations were within the permissible limits. The reference site was selected on flat surfaces not exposed to any erosion or sedimentation. These sites were also selected on slightly elevated terrain (hills), as low-lying areas (such as alluvial plains) may be affected by flooding and sedimentation. Moreover, the reference site was as close as possible to the study site. The reference sites were selected in pastures (Zapata *et al.* 2002). As shown in (Fig. 1), each main site was divided into three zones according to its location within the work site, as follows: (1) undisturbed site, (2) eroded site, and (3) sedimentary site. Soil samples were taken from six depths (0-5, 5-10, 10-20, and 20-30 cm). Mixed clay soil was found to be the dominant soil at Sites A and B. Site 1 (undisturbed site) had a nearly flat soil profile, Site 2 (eroded site) had a sloping soil profile, and Site (sedimentary site) had a sedimentary soil profile, respectively, as shown in (Fig. 1) and (Fig. 2).

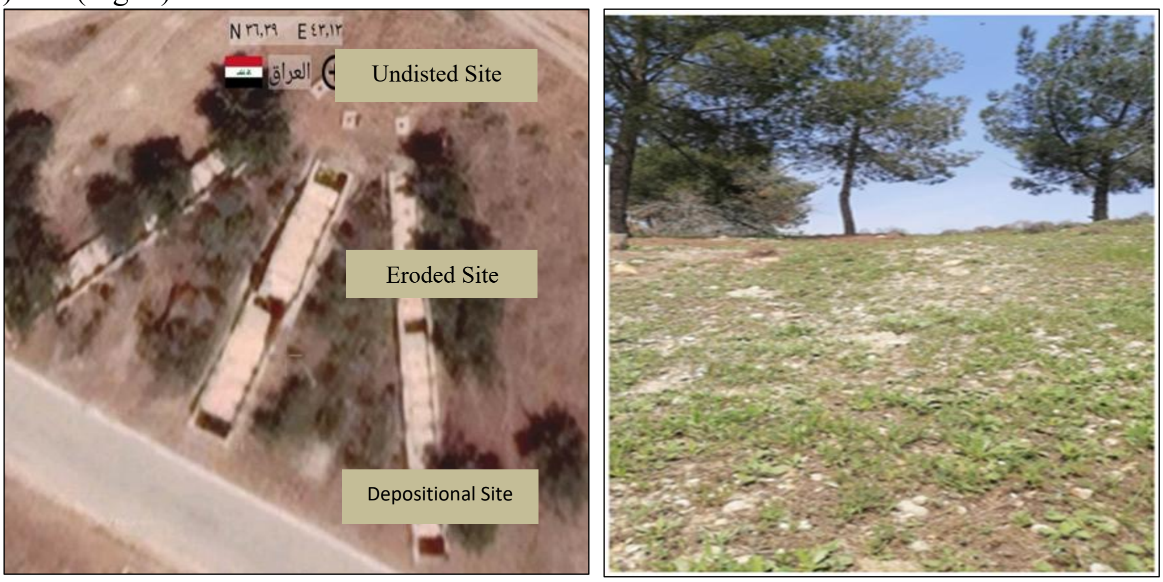


Fig .1: A photograph of the study sample sites inside the University of Mosul.

A 10 cm diameter steel tube was used for soil sampling (Wallbrink et al., 2002). Soil samples were extracted from a 20 cm x 20 cm area to a depth of approximately 30 cm per area. The total number of soil samples collected for each site, e.g., Site A, was approximately 18 samples and Site B, was approximately 18 samples. The mass of each wet sample ranged approximately 1 kg. The sample was then thoroughly mixed and dried at room temperature (15°C to 20°C) for 30 days. After mixing and crushing, the weight was taken. Each soil sample was then sieved through a 3mm mesh sieve. After sieving, the weight was measured again. Finally, a trial weight was taken with an average weight of approximately 500 g. The samples were then stored in polyethylene bags and labeled to prevent mixing until analysis. The radioactivity concentrations (count rates) were then analyzed using a calibrated gamma spectrometer. The container in which the soil was placed for measurement was surrounded by a 5 cm thick lead shield to reduce interference from the background radiation surrounding the soil sample. Note that the background radiation was taken into account when calculating the counting rate.

The activity of cesium-137 (as count rate) was measured through its emissions at 662 keV. The cesium-137 standard was used to determine the efficiency of the spectrometer. Measuring the count rate for each sample took approximately 7200 seconds. Measuring the count rate for each sample took.

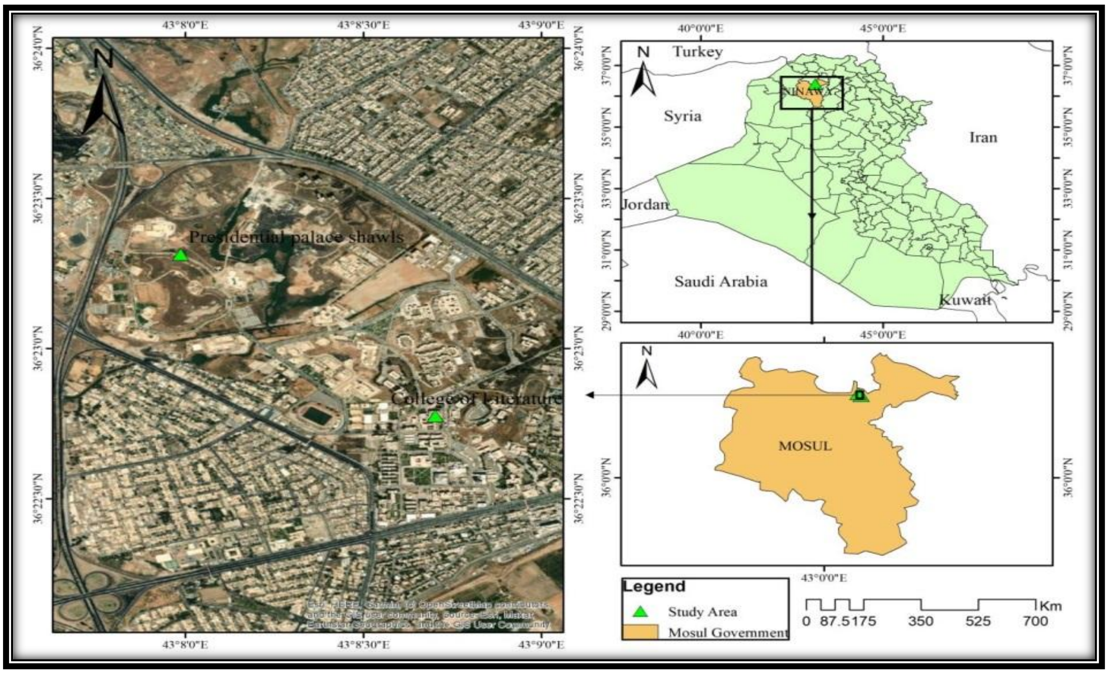


Fig. 2: The map displaying the location University of Mosul from Iraq and the study site for locals (A) and (B)

Measurement System

A Philips gamma spectrometer system was used, consisting of a variable high-voltage source (0-2.5 kV), model PW 4633, used to drive the radiation detection valves and measure levels (called the count rate meter), connected to a Canberra NaITl scintillation detector (serial number 5812136, model 802-9, USA). This system consists of a preamplifier and a high-power amplifier. In this study, the voltage used was 1000 V, which is within the stable operating voltage of the scintillation detector, as shown in Figure (3), which represents a photograph of the measuring device system. For the measurements, we first calibrated the device for energy and detection efficiency. The gamma energies of the radioactive sources 133Bi (356 keV), 137Cs (661.6 keV), and 60Co (1173 and 1332.5 keV) were used for energy calibration. Natural radioactivity was then measured by calculating the background radiation without the sample, which was then subtracted from the count values with the sample, resulting in a total net count in 2,700 seconds. The detector crystal was completely surrounded on all sides by a lead cylinder, allowing for high efficiency.

Fig. 3: Soil erosion measurement system using Cesium-137 (Cs-137)

Results And Discussion

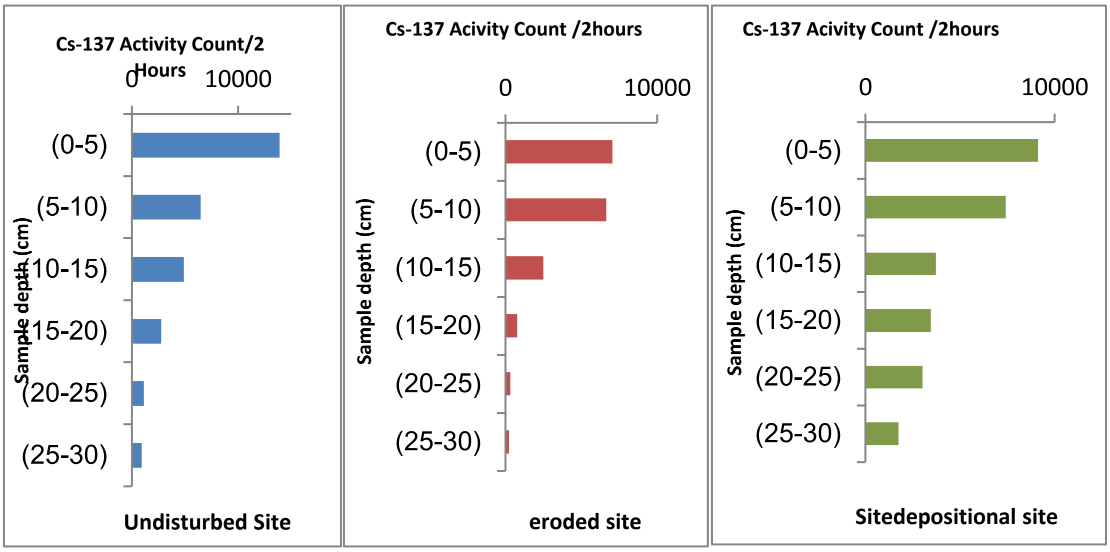
In this research, the distribution of cesium activity was studied by calculating the cesium count rate as a function of soil depth at reference sites (undisturbed site), erosion sites (erosion sites), and sedimentation sites. This information was used to determine the distribution behavior of cesium-137 within the soil. The results obtained from this study, presented in (Table 1), and shown in Fig. (6) and Fig. (7), show that the cesium-137 count rate values for reference sites A and B decrease sharply with increasing depth, which can be considered an exponential function. We also note that most of the cesium-137 levels accumulate within the top 10 cm of the surface, providing reliable confirmation of the validity of using data from these sites to establish a reference site for the study area. As shown in Fig. (4) and Fig. (5), we note that the cesium count rate values in the undisturbed area are higher than the values in the eroded and sedimentary areas. Furthermore, the values at Site 2 (eroded) were lower than those at Site 3. This indicates the presence of soil erosion through the downward movement of soil particles. The results of this research are largely consistent in some places with the results of studies such as (Walling and Quine, 1990; Afshar et al., 2010).

Table 1: The radioactivity values of Cs137against the increase in the soil depth at locations A and B.

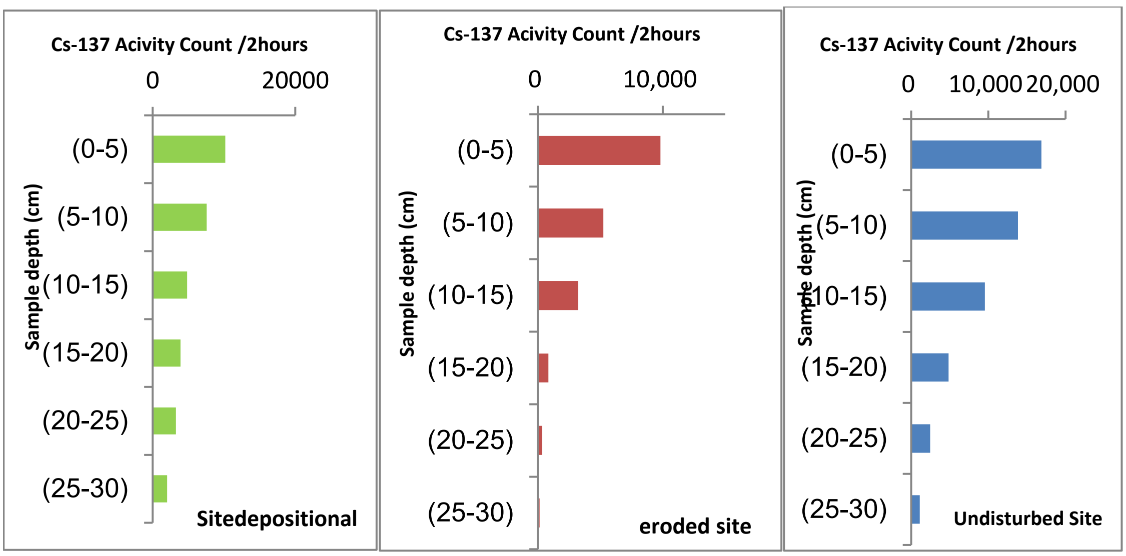
Location A							
Depth in cm		0-5	5-10	10-15	15-20	20-25	25-30
Cs-137 Activity (Count/ 2700 Sec)	Site (1) Soil (Undisturbed)	13918	6469	4904	2753	1130	934
	Site (2) Soil (Eroded)	7040	6636	2500	765	311	221
	Site (3) Soil (Deposited)	9123	7420	3722	3458	3022	1749
Site B							
Depth in cm		0-5	5-10	10-15	15-20	20-25	25-30
Cs-137 Activity (Count/ 2700 Sec)	Site (1) Soil (Undisturbed)	16883	13842	9551	4838	2470	1150
	Site (2) Soil (Eroded)	9822	5236	3247	840	362	144
	Site (3) Soil (Deposited)	10206	7576	4842	3894	3285	2037

(Table1) indicates that the highest cesium-137 counting levels were observed in soil samples collected from Site 1 (the reference site). At the undisturbed site (the reference site), cesium-137 counting rates also show a dramatic decrease with depth, which is expected for an undisturbed reference site. We note that the lowest cesium-137 counting rates were obtained for surface samples from transects of increasing depth from the sampling points (A. Azbouche et al.2017). For the eroded site of the two main sites (A and B), counting rates were low. This could be linked to the gradual loss of soil from the surface due to downward erosion, indicating that these are erosive zones, where cesium-137 counting rates decrease rapidly with depth. and the counting rates for samples collected from the slope are characterized by relatively high cesium-137 activity near the surface and at depth. Caesium-137 count activity rates were approximately 1,749 and 2,037 counts/ 2hour at both sites at depths of 25–30 cm. These characteristics, combined with the limited variation in caesium-137 count activity rates at this site, indicate that these samples were collected from a depositional area .

These results that we obtained from this study are largely consistent with the results reached by other studies in different regions, such as the studies that came up with (Roshan,1998; Murat, 2015).



.**Fig. 4: The variation of 137Cs values with depth at different soil sites of location A**



.**Fig. 5: Variation of cesium-137radioactive values with depth for the soil sites selected for Site B**

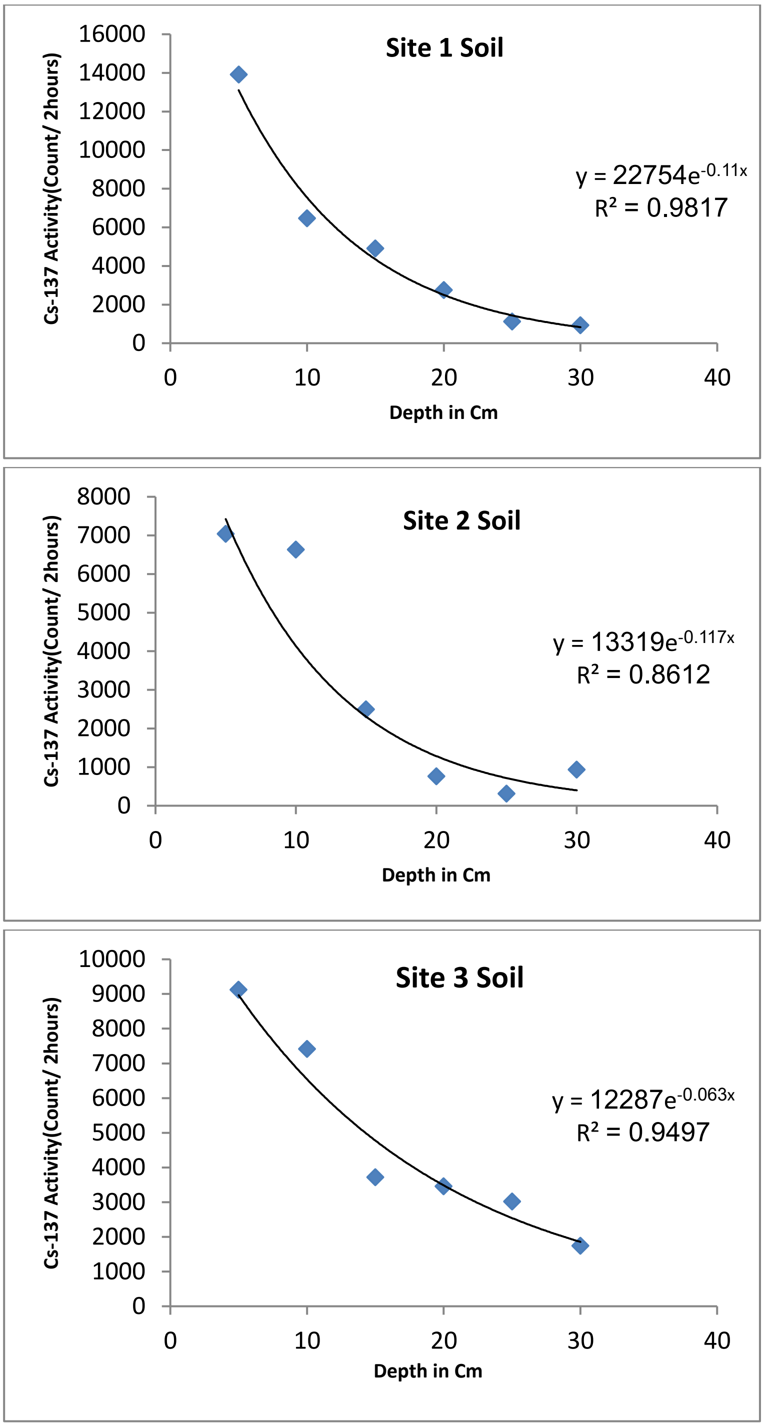


Fig .6: Exponential regression of Cs-137activity as function of soil depth at location A.

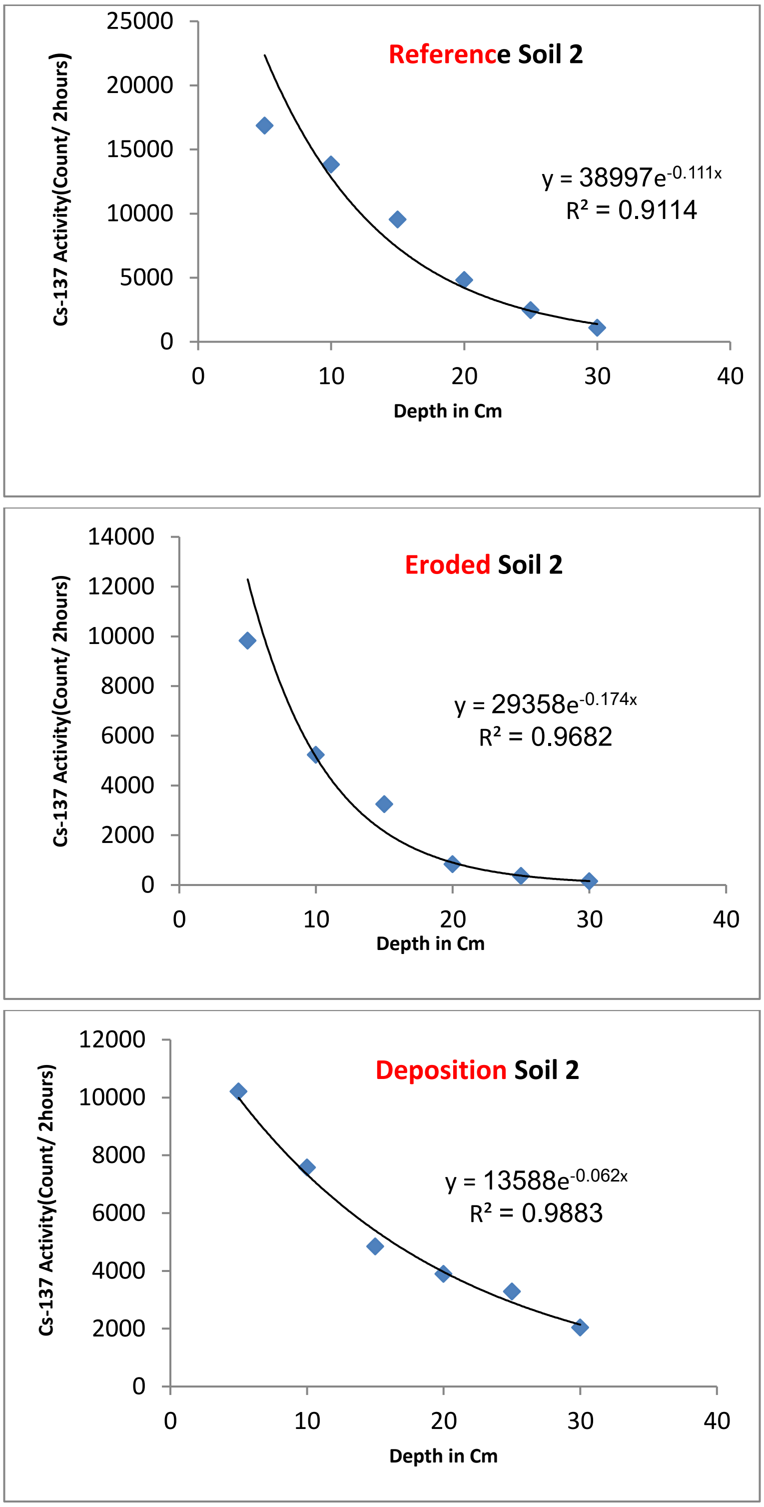


Fig .7: Exponential regression of Cs137activity as function of soil depth at location B.

CONCLUSION

The results of our current study confirm the effectiveness of using the radioactive isotope Cesium-137 as a reliable tool for assessing soil erosion rates. The data indicate that the Cs-137 count rate decreases sharply with increasing soil depth in undisturbed reference sites, reflecting an exponential distribution of cesium levels in the surface layers. This distribution supports the validity of using these sites as reference points for the study. Furthermore, comparisons between reference sites and erosion and deposition sites reveal that lower Cs-137 concentrations in eroded areas signify soil loss due to erosion, while higher concentrations in depositional areas indicate the accumulation of transported soil. These findings align with previous studies, such as (Murat, S.,2015; Yang, X., 2008). And By using the cesium-137 technique, we were able to evaluate the rates of erosion and deposition, and distinguish between erosion and deposition zones through the data of the cesium concentration counts we obtained from the two sites in the study area, as shown in Figures 6 and 7Therefore, the use of Cs-137 proves to be an effective means of understanding the dynamics of soil erosion and accumulation, contributing to the development of sustainable land management strategies and soil conservation in agricultural and natural environments.

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استخدام النظير المشع سيزيوم-137 في تقييم معدلات تآكل وترسيب التربة للمناطق المنحدرة في جامعة الموصل

شيماء طلال الدباغ

قسم الفيزياء الطبية/ كلية العلوم/ جامعة الموصل/ العراق

الملخص

تهدف هذه الدراسة إلى تقدير معدلات التعرية والترسيب في حرم جامعة الموصل بمحافظة نينوى باستخدام تقنية السيزيوم-137. تم جمع عينات التربة من موقعين، A وB، تم تقسيم كل منهما إلى ثلاث مناطق: (1) قمة المنحدر (الموقع غير المتأثر)، (2) منتصف المنحدر (الموقع المتآكل)، و (3) الموقع الترسيبي في أسفل المنحدر. تم قياس نشاط السيزيوم-137 في كل عينة، وتم مقارنة معدل العد بين المواقع غير المتأثرة والمواقع المتآكلة. أظهرت النتائج وجود اختلافات كبيرة في قيم معدل العد عبر المناطق الثلاث. حيث تراجعت قيم العد من أعلى المنحدر إلى أسفله. تم تسجيل أقل القيم في المواقع المتآكلة، حيث كانت حوالي 9822 عد/ ساعتين في الموقع B و7040 عد/ ساعتين في الموقع A، مما يؤكد وجود هجرة للتربة في منتصف المنحدر في كلا الموقعين. بالإضافة إلى ذلك، تراوحت قيم معدلات العد حسب عمق التربة. في الموقع A (الموقع غير المتأثر)، تراوحت قيم العد من 16,883 إلى 115 عد/ ساعة للأعماق من 0-30 سم. في الموقع المتآكل، تراوحت القيم بين 9,822 و144 عد/ ساعة، بينما في الموقع الترسيبي تراوحت بين 10,206 و2,037 عد/ ساعة. تشير القيم المنخفضة إلى حدوث التعرية، بينما تشير القيم المرتفعة في الموقع الترسيبي إلى الترسيب..

الكلمات المفتاحية: تآكل التربة، الترسيب، السيزيوم 137، مطيافية جاما، تقنية السيزيوم المشع..