

A comparison of measured ^{137}Cs and excess ^{210}Pb levels in the cultivated brown and cinnamon soils of the Yimeng Mountain area

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Abstract This contribution analyzes the similarities and differences between the measured activities of ^{137}Cs and excess ^{210}Pb ($^{210}\text{Pb}_{\text{ex}}$) in the cultivated brown and cinnamon soils of the Yimeng Mountain area, discusses the influence of soil texture on the measurement of $^{210}\text{Pb}_{\text{ex}}$, and presents differences between the two types of soils. Fields A and B were selected to represent the fields that contain cultivated brown and cinnamon soils, respectively. From either study field, one site of sectioned core and six bulk cores were collected to measure ^{137}Cs levels, $^{210}\text{Pb}_{\text{ex}}$ levels, and the particle-size composition of soil samples. Three undisturbed soil samples were collected to measure capillary and aeration porosities. The ^{137}Cs inventories for the two study fields are very similar. The ^{137}Cs is a man-made radionuclide, which means that its measured levels for soils are unaffected by soil texture. In contrast, levels of the naturally occurring $^{210}\text{Pb}_{\text{ex}}$ of soils from Field A were lower than those of Field B by about 50%. In contrast to aquatic sediments, levels of $^{210}\text{Pb}_{\text{ex}}$ in terrestrial surface soils are affected by the emanation of ^{222}Rn from the soils. It can be assumed that the coarser the soils, the greater the emanation of ^{222}Rn ; in addition, the lower the measured $^{210}\text{Pb}_{\text{ex}}$, the greater the underestimate of this value. The cultivated brown soils in Field A are coarser than the cultivated cinnamon soils in Field B. As a result, ^{222}Rn in Field A will diffuse more easily into the atmosphere than that in Field B. As a consequence, the measured $^{210}\text{Pb}_{\text{ex}}$ in soils from Field A is much lower than the actual value, whereas the value measured for Field B is much closer to the actual value.

Key words ^{137}Cs ; $^{210}\text{Pb}_{\text{ex}}$; brown soil; cinnamon soil; Yimeng Mountain area

1 Introduction

The ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$ techniques have been used to quantify the rates of erosion and deposition of soils (Walling and Quine, 1990; Walling et al., 1995; Zhang et al., 1990, 2006, 2008; Yan et al., 2002; Golosov, 2003; Yang et al., 2006; Onda et al., 2007; Li et al., 2009, 2012; Gaspar et al., 2013), as well as to reveal the history of sediment deposition in lakes, estuaries, and oceans (DeLaune et al., 1978; He and Walling, 1996; Ritchie et al., 2004; Zhang et al., 2007; Ahn et al., 2010; Olid et al., 2013). The artificial radionuclide

^{137}Cs (half-life 30.2 a) has been released into the environment as a result of atmospheric testing of thermo-nuclear weapons. This occurred primarily during the 1950s–1970s, with the maximum rate of ^{137}Cs fallout from the atmosphere in 1963. The ^{210}Pb (half-life 22.26 a) radionuclide is a natural product of the ^{238}U decay series derived from the decay of gaseous ^{222}Rn (half-life 3.8 d), the daughter of ^{226}Ra (half-life 1622 a). A fraction of the ^{222}Rn atoms produced by the decay of ^{226}Ra in soils and rocks diffuses upwards into the atmosphere, where it decays through a series of short-life radionuclides to ^{210}Pb . Fallout

^{210}Pb , like ^{137}Cs , is removed from the atmosphere by precipitation or dry deposition, and falls onto the land surface or into lakes and oceans (Peirson & Salmon, 1959; Nevissi, 1985; He and Walling, 1997). Unlike the highly variable rates of ^{137}Cs deposition, the natural origin of $^{210}\text{Pb}_{\text{ex}}$ means that the rates of its deposition have been essentially constant through time (Nozaki et al., 1978). Accordingly, the total ^{210}Pb concentrations in surface soils and sediments have shown there are two components: supported ^{210}Pb ($^{210}\text{Pb}_{\text{sup}}$), which is derived from the *in-situ* decay of the parent radionuclide ^{226}Ra and is in equilibrium with its parent, and unsupported or excess ^{210}Pb ($^{210}\text{Pb}_{\text{ex}}$), which is derived from this atmospheric flux and is not in equilibrium with ^{226}Ra (Robbins, 1978; Kolker et al., 2009).

Before its application to estimating soil redistribution, the $^{210}\text{Pb}_{\text{ex}}$ technique was widely used to estimate the ages of lake sediment cores (Koide et al., 1972; Appleby and Oldfield, 1978). The $^{210}\text{Pb}_{\text{ex}}$ concentrations in the sediments can be determined by subtracting the concentrations of $^{210}\text{Pb}_{\text{sup}}$ from the measured total ^{210}Pb concentrations (Joshi, 1987), as follows:

$$C_{\text{ex}} = C_{\text{tot}} - C_{\text{sup}} \quad (1)$$

where C_{ex} is the $^{210}\text{Pb}_{\text{ex}}$ concentration ($\text{mBq}\cdot\text{g}^{-1}$), C_{tot} is the total ^{210}Pb concentration ($\text{mBq}\cdot\text{g}^{-1}$), and C_{sup} is the $^{210}\text{Pb}_{\text{sup}}$ concentration ($\text{mBq}\cdot\text{g}^{-1}$).

Given that sediments are scavenged from the water column and are highly saturated, only a very small fraction of ^{222}Rn produced by ^{226}Ra decay in the sediments will escape into the overlying water column (Appleby and Oldfield, 1992; Du and Walling, 2012). In the sediments, both ^{222}Rn and $^{210}\text{Pb}_{\text{sup}}$ can usually be regarded as being in radioactive equilibrium with the parent radionuclide ^{226}Ra (Zapata, 2002). Accordingly, experimental determination of the $^{210}\text{Pb}_{\text{sup}}$ concentrations involves the measurement of *in-situ* levels of ^{226}Ra , which is measured via its daughters ^{214}Pb or ^{214}Bi .

However, the case is not true for terrestrial surface soils since some of the ^{222}Rn produced by *in-situ* ^{226}Ra decay is constantly diffused through the soils into the atmosphere. It is this escaping ^{222}Rn that decays to ^{210}Pb and is the source of $^{210}\text{Pb}_{\text{ex}}$. As a consequence, the level of $^{210}\text{Pb}_{\text{sup}}$ in soils is less than that of ^{226}Ra , and $^{210}\text{Pb}_{\text{sup}}$ is never in equilibrium with ^{226}Ra . Since the $^{210}\text{Pb}_{\text{sup}}$ activity is calculated from the ^{226}Ra activity, the levels of $^{210}\text{Pb}_{\text{sup}}$ measured in the soil samples exceed the actual levels of $^{210}\text{Pb}_{\text{sup}}$. Therefore, the measured $^{210}\text{Pb}_{\text{ex}}$ concentration in the soil samples, as determined using equation (1), will be lower than the actual value. And it can be further assumed that

the ^{222}Rn that emanates from the soils would affect the results of $^{210}\text{Pb}_{\text{ex}}$ measurement.

For different soil types, the proportion of ^{222}Rn that emanates from the soils might vary because of differences in physical texture caused by variations in parameters such as particle-size composition, capillary porosity and aeration porosity. Unlike $^{210}\text{Pb}_{\text{ex}}$, ^{137}Cs is a man-made radionuclide without any natural derivation; accordingly, its measured levels in soils are unaffected by soil texture. Previous studies focused on the emanation of ^{222}Rn and determined the emanation coefficients of different types of soils and rocks (Sakoda et al., 2010; Nabil et al., 2011; Künze et al., 2013). Du and Walling (2012) corrected the $^{210}\text{Pb}_{\text{ex}}$ measurements of sediments on river floodplains by employing the ^{222}Rn emanation coefficient. However, few studies on soil erosion have dealt with the influence of ^{222}Rn emanation on $^{210}\text{Pb}_{\text{ex}}$ measurements in soils with different textures.

This study examines the similarities and differences between the measured activities of ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$ in the cultivated brown and cinnamon soils of the Yimeng Mountain area, discusses the influences of soil texture on measurements of $^{210}\text{Pb}_{\text{ex}}$, and presents differences between the two types of soils. The findings are relevant to efforts to use the $^{210}\text{Pb}_{\text{ex}}$ technique to estimate the rates of soil redistribution.

2 Material and methods

2.1 Study area

The Yimeng Mountain area (ca. 17180 km^2) is located in the central south of Shandong Province, China ($34^\circ 22'$ to $36^\circ 13' \text{N}$, $117^\circ 24'$ to $119^\circ 11' \text{E}$). Elevations range from 150 to 1165 m, with slopes typically within the range of 2° – 30° . Geologically, it is characterized by alternating granite (or granite–gneiss) and limestone. The two main soil groups in the area are brown soils developed from granite (or granite–gneiss) weathering crusts and cinnamon soils developed from limestone weathering crusts. The area belongs to the continental monsoon climate area of the warm temperate zone. The mean annual precipitation is ca. 800–900 mm, approximately 70% of which falls between July and September. The mean annual temperature is ca. 13.6°C , and the population density is ca. 630 person km^{-2} . Two representative study fields, Fields A and B (one on each side of the Benghe River), were selected to represent the zones with brown soils and cinnamon soils, respectively, with the distance of ca. 35 km between the two study fields. Both the fields are situated in flat areas at the top of ploughed fields, where erosion over the past 100 years has been negligible.

2.2 Field sampling and laboratory analysis

From either study field, one site of sectioned core and six bulk cores were collected to measure the levels of ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$, and the compositions of particle sizes. The undisturbed soil samples were collected by means of metal cylinders (each 100 cm^3 capacity) to determine capillary and aeration porosities in triplicate. To collect the two sectioned soil cores (Cores A and B were collected from Fields A and B, respectively), two earth prisms ($25\text{ cm}\times 10\text{ cm}\times 44\text{ cm}$ for Core A, and $20\text{ cm}\times 10\text{ cm}\times 48\text{ cm}$ for Core B) were manually carved out by excavating the surrounding earth. A small spade was then used to section the straight earth prisms into 2-cm intervals from the top downwards. The bulk cores were collected randomly in the study fields surrounding the sites of the sectioned cores, using a manual percussion corer equipped with a 5-cm-diameter steel core tube. For each of the three undisturbed sampling sites, four undisturbed soil samples were collected within the depth range of 0–40 cm (one sample for every 10 cm of soil depth).

Samples of bulk cores and sectioned cores were air-dried, disaggregated, let to pass through a 2-mm sieve and weighed. A representative fraction (ca. 150 g) of each sample was then placed into a plastic Marinelli beaker and sealed with polyvinyl chloride tape for 20 days prior to the time of assay. The levels of $^{210}\text{Pb}_{\text{ex}}$ and ^{137}Cs concentrations in the samples of bulk cores and sectioned cores were measured by gamma spectrometry, using an ORTEC high-resolution, low-background, low-energy, *n*-type, coaxial germanium detector. The samples were put on the detector and counted for ca. 80000 s, providing a precision of approximately $\pm 5\%$ at the 95% level of confidence for the gamma ray measurements. The ^{137}Cs

concentrations were measured at 662 keV. The total ^{210}Pb concentration of the samples was measured at 46.5 keV. The concentrations of ^{226}Ra were assayed at 351.9 keV by measuring the levels of its short-life daughter ^{214}Pb . The absolute grain-size composition of each bulk core and sectioned core sample was determined by means of a laser particle size analyser (Mastersizer, 2000). The capillary and aeration porosities of the undisturbed soil samples were measured using the saturation method (Netto, 1993; Matko, 2004).

3 Results

3.1 ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$ activities

The experimentally determined ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$ profiles for Core A are shown in Fig. 1, and those for Core B are shown in Fig. 2. The ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$ concentrations in the two sectioned cores are both relatively uniform at a depth of $\sim 20\text{ cm}$, but then decline rapidly with increasing depth. This is consistent with the average plough depth in the area, indicating that the radionuclides are mixed by tillage within the uppermost depth of $\sim 20\text{ cm}$. For Core A collected from Field A, the measured inventories of ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$ are 995 Bq m^{-2} and 10203 Bq m^{-2} , respectively. The values for Core B collected from Field B are 1001 and 19282 Bq m^{-2} , respectively. The measured ^{137}Cs inventory for Core A is very close to that for Core B. In contrast, the measured $^{210}\text{Pb}_{\text{ex}}$ inventory for Core B is ca. 89% higher than that for Core A. Moreover, the measured ^{137}Cs concentrations in the profiles for Cores A and B are very close to each other at their similar depths; by comparison, nearly all of the measured $^{210}\text{Pb}_{\text{ex}}$ concentrations in the profile for Core B are higher than those at similar depths in the profile for Core A.

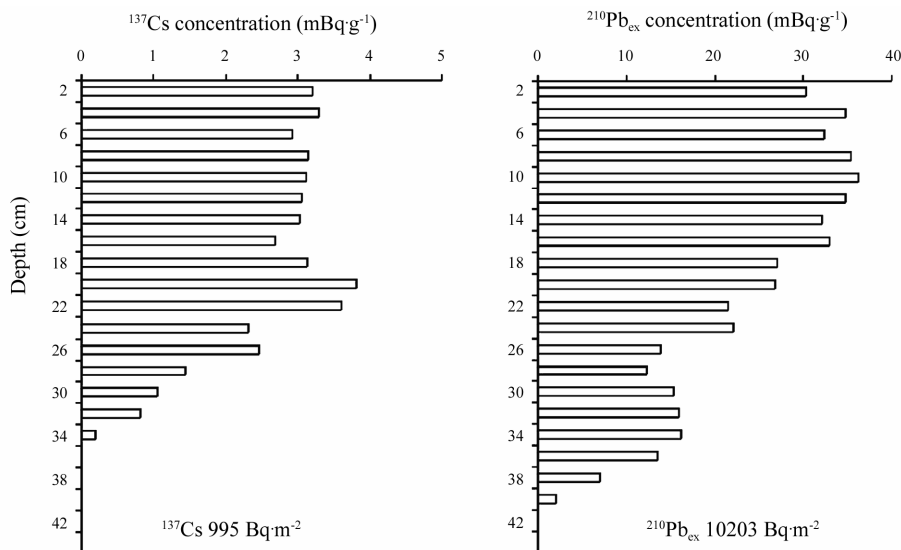


Fig. 1. ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$ measurement profiles for Core A.

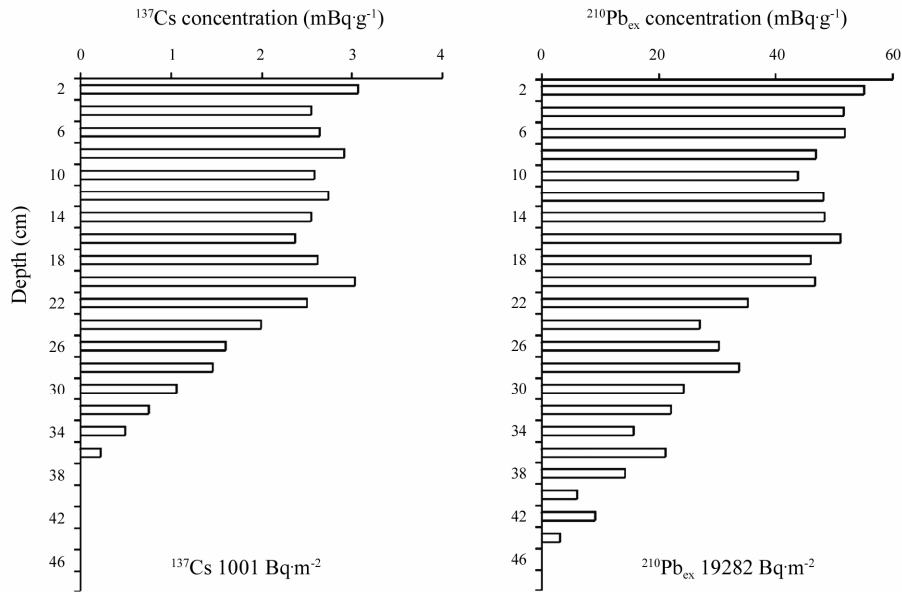


Fig. 2. ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$ measurement profiles for Core B.

The measured inventories of ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$ for the six bulk cores are presented in Table 1 (Field A) and Table 2 (Field B). The measured ^{137}Cs inventories for the six bulk cores from Fields A and B are very similar. The mean measured inventories of ^{137}Cs for the bulk cores from Fields A and B are 998 and 1012 Bq m^{-2} , respectively, which are close to the measured ^{137}Cs inventories for the two sites from which sectioned cores were collected. By comparison, the mean measured inventories of $^{210}\text{Pb}_{\text{ex}}$ for the bulk cores from Fields A and B are 10253 and 19104 Bq m^{-2} , respectively, which are close to the respective $^{210}\text{Pb}_{\text{ex}}$ measured inventories for the two sites in Fields A and B from which sectioned cores were collected. Clearly, the measured $^{210}\text{Pb}_{\text{ex}}$ inventory for any bulk core from Field B is higher than that for any bulk core from Field A, and the mean measured inventory of $^{210}\text{Pb}_{\text{ex}}$ for the six bulk cores from Field B is ca. 86% higher than the mean value for the six bulk cores from Field A.

Table 1 Measured inventories of ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$ for the six bulk cores from Field A (Bq m^{-2})

	A ₁	A ₂	A ₃	A ₄	A ₅	A ₆
^{137}Cs	969	1105	971	956	1051	935
$^{210}\text{Pb}_{\text{ex}}$	8555	10673	9254	9896	11836	11306

Note: A₁–A₆ represent the six bulk cores from Field A.

Table 2 Measured inventories of ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$ for the six bulk cores from Field B (Bq m^{-2})

	B ₁	B ₂	B ₃	B ₄	B ₅	B ₆
^{137}Cs	941	998	1035	953	1016	1127
$^{210}\text{Pb}_{\text{ex}}$	19921	17875	19119	19965	18974	18772

Note: B₁–B₆ represent the six bulk cores from Field B.

The results suggest that the measured ^{137}Cs inventory in Field A is consistent with that in Field B, whereas the measured $^{210}\text{Pb}_{\text{ex}}$ inventory in Field A is ~47% less than that in Field B.

3.2 Grain-size composition

For comparison, the median grain size profiles for Cores A and B are presented together in Fig. 3. The clay (<0.005 mm) content profiles for Cores A and B are presented together in Fig. 4. The median grain sizes for Core A range from 41 to 59 μm , with a mean value of 47 μm . In contrast, the median grain sizes for Core B range from 24 to 40 μm , with a mean value of 31 μm . The clay contents for Core A range from 8% to 10%, whereas those for Core B range from 13% to 15%. This indicates that the clay contents for Core A are less than those for Core B. Furthermore, whereas the contents of coarse sand (0.5–2.0 mm) for Core A are within the range of -7% to -12%, and the coarse sand contents for Core B are all close to 0.

Whereas the median grain sizes for the six bulk cores from Field A range from 43 to 61 μm , with a mean value of 52 μm , and the median grain sizes for the six bulk cores from Field B range from 26 to 41 μm , with a mean value of 33 μm . The clay contents for the six bulk cores from Field A range from 7% to 9%, whereas the clay contents for the six bulk cores from Field B range from 10% to 14%. Furthermore, whereas the coarse sand (0.5–2.0 mm) contents for the six bulk cores from Field A range from -9% to -13%, and those for the six bulk cores from Field B are all close to 0. Moreover, during sample preparation, the samples from Field B nearly completely passed

through the 2-mm sieve, except for some withered roots. In contrast, there were always some pieces of gravel in the samples from Field A that could not pass through the sieve.

The results suggest that the cultivated brown soils in Field A are coarser than the cultivated cinnamon soils in Field B. This is consistent with our field observations.

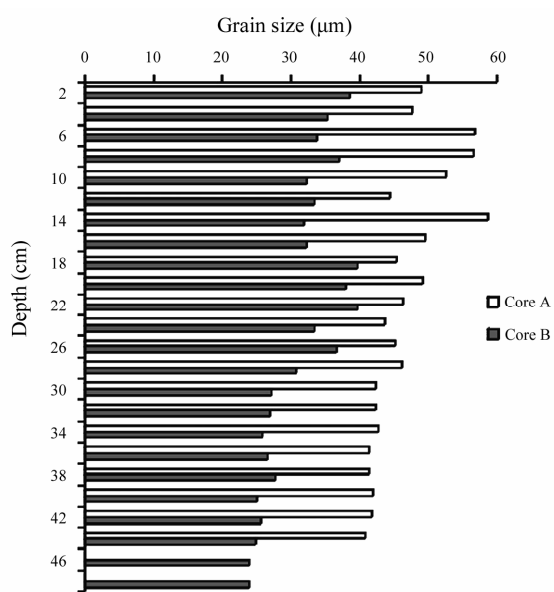


Fig. 3. Median grain size profiles for Cores A and B.

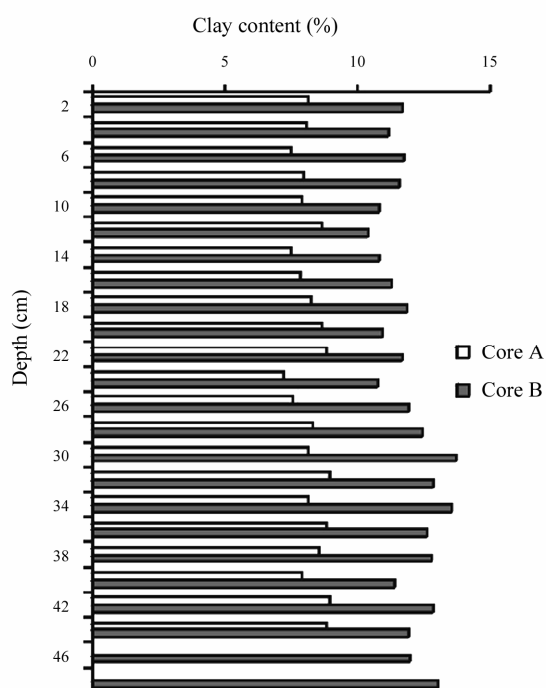


Fig. 4. Clay (<0.005 mm) content profiles for Cores A and B.

3.3 Capillary and aeration porosities

The measured capillary porosities for the soils in Field A range from -0.25 to $-0.35 \text{ cm}^3 \text{ cm}^{-3}$, and in Field B from -0.33 to $-0.40 \text{ cm}^3 \text{ cm}^{-3}$. The measured aeration porosities for the soils in Field A range from -0.06 to $-0.17 \text{ cm}^3 \text{ cm}^{-3}$, whereas the values in Field B range from -0.01 to $-0.09 \text{ cm}^3 \text{ cm}^{-3}$. The capillary and aeration porosities of the soils in Fields A and B are represented by their mean measured values (Fig. 5).

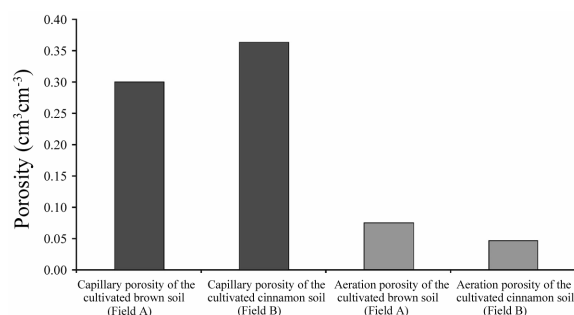


Fig. 5. Capillary and aeration porosities of the cultivated brown soils (Field A) and cinnamon soils (Field B).

As shown in Fig. 5, the capillary porosities of the soils in Field A are lower than those in Field B, whereas the aeration porosities are higher in Field A than in Field B. The moisture (capillary water) capacity of the soils in Field A is lower than that in Field B, whereas the gas permeability of the soils in Field A is greater than that in Field B, which is also consistent with our field observations.

4 Discussion

Theoretically, the activities of ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$ in soils are associated with either precipitation or dry deposition, but are independent of soil texture. Given the soil erosion in Fields A and B, and differences in the rates of either precipitation or dry deposition between the two fields are negligible, in theory, the measured inventories of both ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$ in Field A should be consistent with their respective values determined for Field B. However, the present data show that while the measured ^{137}Cs inventory for Field A is in good agreement with that for Field B, the measured $^{210}\text{Pb}_{\text{ex}}$ inventory for Field A is -47% less than that for Field B.

As mentioned in the Introduction, the measured ^{137}Cs levels in soils are unaffected by soil texture, given that ^{137}Cs is a man-made radionuclide; therefore, the measured ^{137}Cs inventories in Fields A and B are very similar. In contrast, for the naturally occurring $^{210}\text{Pb}_{\text{ex}}$, the measurement results are affected by the

^{222}Rn that emanates from the soils. If only a very little amount of ^{222}Rn has diffused into the atmosphere from the soils, the measured ^{222}Rn concentrations will be very close to the actual $^{210}\text{Pb}_{\text{sup}}$ concentrations; conversely, if more ^{222}Rn has diffused out, the measured ^{222}Rn concentrations will be proportionally greater than the actual $^{210}\text{Pb}_{\text{sup}}$ concentrations. In other words, according to equation (1), for soils that can retain substantial levels of ^{222}Rn , the measured $^{210}\text{Pb}_{\text{ex}}$ value will be closer to the actual value. In contrast, for soils that can retain limited amounts of ^{222}Rn , the measured $^{210}\text{Pb}_{\text{ex}}$ value will be even lower than the actual value.

In the study area, it can be considered that because the cultivated brown soils in Field A are coarser than the cultivated cinnamon soils in Field B, the aeration porosity or gas permeability should be higher in Field A than in Field B. In contrast, the capillary porosity or the moisture capacity of the soils in Field A is lower than that in Field B. Given that the aeration porosity or the gas permeability of the soils in Field A is higher than that in Field B, the ^{222}Rn in Field A will diffuse more readily into the atmosphere than that in Field B. In addition, given that the capillary porosity or the moisture capacity of the soils in Field A is lower than that in Field B, the moisture (capillary water) contents of the soils in Field B will be higher than those in Field A under similar physiographic conditions (e.g. precipitation, solar radiation, temperature, air humidity, and wind speed). Capillary water can restrict ^{222}Rn emanation from soils. Consequently, the capillary water in the soils of Field B is anticipated to limit ^{222}Rn emanation to lower levels than that in the soils of Field A. So, by comparing the $^{210}\text{Pb}_{\text{sup}}$ measurements for the two study fields, the measured value of Field A is much higher than the actual value, whereas the measured value of Field B is much closer to the actual value. Consequently, by comparing the $^{210}\text{Pb}_{\text{ex}}$ measurements for the two study fields, the measured value for Field A is much lower than the actual value, whereas the measured value for Field B is much closer to the actual value. Therefore, the measured $^{210}\text{Pb}_{\text{ex}}$ inventory in Field A is lower than that in Field B.

Moreover, it is known that soils developed from granites contain higher levels of ^{226}Ra than those developed from limestones (Yang et al., 2005; Al-Hamarneh & Awadallah, 2009). Consequently, the ^{226}Ra level is higher in Field A than in Field B. In addition, the proportion of ^{222}Rn emanating from Field A is greater than that from Field B, as discussed above. These observations further suggest that, according to equation (1), the measured $^{210}\text{Pb}_{\text{ex}}$ level in Field A is less than that in Field B.

It can be assumed that the coarser the soils are,

the lower the measured $^{210}\text{Pb}_{\text{ex}}$ value will be. Accordingly, the measured value will be increasingly less than the actual value. In contrast, the finer the soils, the higher the measured $^{210}\text{Pb}_{\text{ex}}$ value, and the closer the measured value will be to the actual value. It follows that the empirically determined $^{210}\text{Pb}_{\text{ex}}$ levels will approach to the actual values as soil moisture contents increase, and that the measured values will be the same as the actual values when the soils or sediments are entirely and constantly covered by the water column. In contrast, the measured $^{210}\text{Pb}_{\text{ex}}$ value will become increasingly lower than the actual value with decreasing soil moisture content. Moreover, for cultivated soils, the measured $^{210}\text{Pb}_{\text{ex}}$ value of the plough-pan layer is closer to the actual value than that of the plough layer. That is because the soils of the plough layer are annually disturbed by cultivation, which promotes the emanation of ^{222}Rn . For undisturbed soils, the measured $^{210}\text{Pb}_{\text{ex}}$ value is closer to the actual value than that of cultivated soils, because more ^{222}Rn can be retained in the undisturbed soils than in the cultivated soils. Measurements of $^{210}\text{Pb}_{\text{ex}}$ approach to the actual value with increasing depth because ^{222}Rn is easily retained in the deep-seated soils.

The downward tails in the lower parts of the ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$ measurement profiles for Cores A and B might partly reflect the downward movement of the two radionuclides. The $^{210}\text{Pb}_{\text{ex}}$ tails might also reflect the fact that ^{222}Rn is readily retained in soils at the depth of the tail compared with that at shallower depths, and this may reduce the underestimate of $^{210}\text{Pb}_{\text{ex}}$ measurements.

When the $^{210}\text{Pb}_{\text{ex}}$ technique is applied to the estimation of soil redistribution, the measurement of the reference inventory would affect the estimation results if differences in soil texture between the study area and the reference site are ignored. For the area analyzed in this study, if the reference site is selected in Field A, the erosion rates of the cinnamon soils will be underestimated, even to such an extent that deposition might be predicted for an eroded site. In contrast, if the reference site is selected in Field B, the erosion rates of the brown soils will be overestimated. In theory, the $^{210}\text{Pb}_{\text{ex}}$ measurement can be corrected by employing the ^{222}Rn emanation coefficient; however, it is difficult to calculate the value of the coefficient because it is influenced by such factors as grain size, capillary porosity, aeration porosity, moisture content, parent material, and soil depth, as discussed above. Therefore, this paper proposes that the reference site needs to be selected in a field with the same soil type as in the study area. In this way, the measurement of $^{210}\text{Pb}_{\text{ex}}$ related to soil texture would not obviously affect the rate estimates of soil redistribution.

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