PLANTS COVERING INFLUENCE TO THE RADIOISOTOPES EXISTENCE OF ^{137}Cs AND $^{210}Pb_{EX}$ IN THE SOIL

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ABSTRAK

PENGARUH TUMBUHAN PELINDUNG TERHADAP KEBERADAAN ISOTOP ^{137}Cs dan $^{210}Pb_{ex}$ DI TANAH. Radioisotop alam ^{137}Cs dan $^{210}Pb_{ex}$ yang terdapat di tanah dapat digunakan sebagai perunut untuk mengestimasi besarnya laju erosi/deposit di suatu lahan, dengan membandingkan nilai inventori ^{137}Cs atau $^{210}Pb_{ex}$ di suatu lokasi penelitian dengan nilai inventori suatu lokasi acuan. Radioisotop alam tersebut melekat sangat kuat pada permukaan tanah (lempung) sehingga dapat digunakan sebagai perunut pada proses pergerakkan tanah. Keberadaan radioisotop alam ^{137}Cs dan $^{210}Pb_{ex}$ pada suatu lahan sangat dipengaruhi oleh tumbuhan penutup, karena tanpa tumbuhan penutup radioisotop alam akan mudah hilang karena terbawa oleh aliran air hujan yang langsung jatuh pada permukaan tanah. Penelitian ini bertujuan untuk melihat pengaruh dari tanaman pelindung terhadap keberadaan radioisotop alam ^{137}Cs dan $^{210}Pb_{ex}$ di tanah. Pengambilan sampel dilakukan pada dua lahan tak diolah pada saat masih ditanami tanaman keras (2016) dan pada saat telah terbuka (2018), menggunakan alat coring (di 10 cm) untuk kedalaman 2 cm dan alat coring (di 7 cm) untuk kedalaman 20 cm. Hasil penelitian menunjukan bahwa aktivitas radioisotop alam ^{137}Cs dan $^{210}Pb_{ex}$ pada permukaan tanah berkurang sangat signifikan, sedangkan nilai inventori total pada kedalaman 20 cm berkurang cukup signifikan untuk lahan yang telah terbuka. Besarnya laju erosi di lahan terbuka jauh lebih tinggi dibandingkan ketika lahan masih tertutup, yaitu untuk metode ^{137}Cs adalah 44,1 t/ha.thn (CBG), -4,3 t/ha.thn (BMC) dan 4 t/ha.thn (CBG) -27,1 t/ha.thn (BMC), masing-masing untuk lahan tertutup dan terbuka, sedangkan untuk metode $^{210}Pb_{ex}$ adalah -8 t/ha.thn (CBG), -36,9 t/ha.thn (BMC), dan -58 t/ha.thn (CBG), -79,9 t/ha.thn (BMC), masing-masing untuk lahan tertutup dan lahan terbuka.

Kata kunci: Cesium-137, DAS Ciujung, erosi, radioisotop alam, Timbal-210

ABSTRACT

PLANTS COVERING INFLUENCE TO THE RADIOISOTOPES EXISTENCE OF ^{137}Cs and $^{210}Pb_{ex}$ IN THE SOIL. *Cs-137 and Pb_{ex}-210 of environmental radioisotope content in the soil can be useful to estimate the rate of erosion/deposition in an area, by comparing the inventory value of ^{137}Cs or $^{210}Pb_{ex}$ in observed site with those in a stable reference site. ^{137}Cs and $^{210}Pb_{ex}$ stick very strongly at the surface of the soil (clay), so it can use as a tracer for the movement of soil. Plants very influence the existence of ^{137} Cs and ^{210} Pb_{ex} environmental radioisotopes as a cover. If without a plant cover, then this environmental radioisotope at the soil would be gone by rain off. This experiment aims to observe the effect of plant cover on the existence of ^{137}Cs and $^{210}Pb_{ex}$ at the soil in uncultivated land. Sampling had been done in two uncultivated lands when the land still covering by plants (2016) and after becoming vacant land (2018), using coring (10 cm) for the surface layer and coring (7 cm) for the depth of 20 cm. The result showed that the activity of ^{137}Cs and $^{210}Pb_{ex}$ environmental radioisotopes at the surface layer decreased very significantly, and total inventory values until the depth of 20 cm decreased quite significantly at a vacant land condition. The corrosion rate for the vacant land is higher than the planted land. The value of erosion rate using the ^{137}Cs method is 44.1 t/ha.y (CBG); -4.3t/ha.y (BMC) and 4 t/ha.y (CBG); -27.1 t/ha.y (BMC) for planted land and vacant land, respectively. Meanwhile, using the ^{210} Pb_{ex} method is -8 t/ha.y (CBG); -36.9 t/ha.y (BMC) for planted land and -58 t/ha.yrs (CBG), -79.9 t/ha.yrs (BMC) for vacant land.*

Keywords: ^{137}Cs, Ciujung Watersheds, erosion, environmental radioisotope, ^{210}Pb

INTRODUCTION

Cover plants that grow on lands such as perennials (rambutan, durian, acacia, mahogany, teak, rubber), grass, and weeds can prevent and reduce the loss of soil particles. The scouring of rainwater that flows on the surface of the ground can cause damage to soil particles or often refer to as erosion. Erosion is a big problem in Indonesia because it can cause reduced soil fertility, river silting, and flooding. This decay occurs as a result of open forest clearing so that the reservoir area that can control the balance of nature has lost its function. The amount of erosion can be determined conventionally by looking at all field conditions and carrying soil samples to analyze some nutrients and organics (N, P, C organic). However, this method requires a long observation time, namely in the rainy season and the dry season (minimum one year). Due to limitations in conventional methods of documenting erosion distribution, the use of natural radioisotopes as an alternative approach to research soil erosion and sediment origins has begun to develop. The natural radioisotopes of ^{137}Cs and ^{210}Pb are tools to obtain information about the distribution of erosion/deposition that has occurred in the past for 40 years and 100 years [1].

The cover plants greatly influence the existence of ^{137}Cs and ^{210}Pb isotopes in the soil because the radioisotope is attached to the surface of soil particles. For ^{137}Cs isotopes whose formation only occurred around the 1950s - 1960s, so that in vacant fields, the content may be very small or absent, because it has been carried away by the flow of rainwater. In Indonesia, many researchers have used natural radioisotopes in the soil. These studies include the determination of natural radioisotope profiles in stable soils [2] and the determination of erosion rates in processed and unprocessed land [3]. Besides, it also includes research on the origin of sediments [4] and studies of sedimentation rates in rivers [5]. Based on the results of these studies, future research can still utilize radioisotope ^{137}Cs. However, because its concentration is minimal, it takes a long time to analyze.

Cs-137 is a natural radioisotope with a half-life (t½) of 30.2 years. The presence of ^{137}Cs radioisotopes in nature is a fallout from the atmosphere as a result of nuclear weapons testing. ^{137}Cs globally have been detected in nature since 1954, and the highest flux in the northern hemisphere occurred in 1973 due to the massive nuclear weapons experiment that took place at the time. After the nuclear weapons test agreement in 1963, it caused the fall of ^{137}Cs from the atmosphere to decrease significantly. Since the 1970s, the fall of 137Cs from the atmosphere has become very insignificant, even almost non-existent. Aside from nuclear weapons testing, for several regions in Europe and regions adjacent to Russia, the addition of the fall of ^{137}Cs originated from the Chernobyl accident in 1986 [6]. The fall of ^{137}Cs, when it touches the surface of the earth, will be adsorbed quickly and firmly on the ground surface and then distributed vertically and laterally together with the movement of soil particles. The strong binding of ^{137}Cs to soil particles makes ^{137}Cs function as a tracer in the movement of soil and sediment [7].

Pb-210 is a natural radioisotope (half-life of 22.2 years), which is the result of a series of decay from the parent radioactive ^{238}U. A series of short-life radioactive decay can produce ^{210}Pb, namely from ^{222}Rn gas decay (half-life of 3.8 days), which is a decay of ^{226}Ba natural radioactive (half-life 1622 years) [8]. The ^{210}Pb found in soil and rocks is the natural decay product of ^{226}Ra. ^{222}Ra will decay into ^{222}Rn by short-lived (t½ = 3.8 days), which is a small portion of this ^{222}Rn gas will diffuse upward and release into the atmosphere. ^{222}Rn gas trapped in the ground and rocks will decay to ^{210}Pb, which is in equilibrium with its parent; this is known as ^{210}Pb supported.

Meanwhile, ^{222}Rn gas released into the atmosphere will decay to ^{210}Pb and then fall to the ground through rainwater. This ^{210}Pb fall at ground level is not in equilibrium with its parent, and this ^{210}Pb drop is known as ^{210}Pb unsupported or excess (Pb_{ex}). Because of the strong absorption capacity of soil particles and sediments, the ^{210}Pb fall when touching the ground surface will quickly be adsorbed and adhere very firmly to soil particles and sediments. ^{210}Pb movements in the soil and sediments vertically and horizontally are caused due to the erosion, transportation, and deposit processes. Because of this phenomenon, the function of ^{210}Pb unsupported or excess is like ^{137}Cs as a tracer for soil erosion and sediment origin research. The process of the presence of radioscopy ^{137}Cs and ^{210}Pb$_{excess}$ in the soil can be seen in Fig. 1 [9].

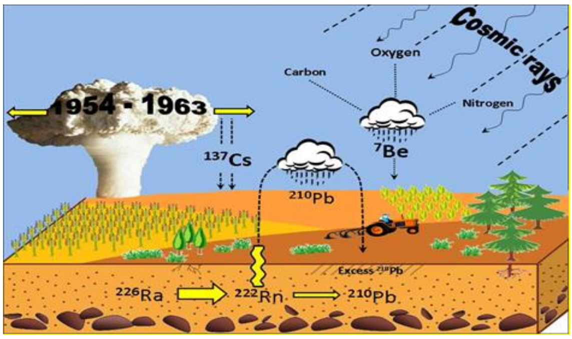

Figure. 1. The process of the existence of radioisotopes ^{137}Cs and ^{210}Pb$_{excess}$ in the soil

The use of radioisotopes ^{137}Cs and ^{210}Pb$_{excess}$ to determine the rate of erosion of land, in addition to the inventory value of the land, it is necessary to find the inventory value from a reference site where the erosion/deposition process is tiny or does not occur. The reference site is a location that does not experience damage or tillage so that the reduction of the ^{137}Cs radioisotopes at that location is only due to the decay process. The location of this site is ideally on the top of a hill, flat, and vacant land. The inventory value of this location will be a comparison of the erosion rate calculation. If the inventory value of the research location is smaller than the inventory value of the reference location, it indicates that an erosion process has occurred (-). If the inventory value of the research location is higher than the reference location, then it indicates that a deposition process (+) has occurred [10].

This study will determine the influence of cover plants on the presence of radioisotopes in the environment, which are ^{137}Cs and ^{210}Pb excess or unsupported. The research location chosen was the sub-watersheds of Ciujung Hulu-Lebak-Banten, which is part of the Ciujung Watersheds. The purpose of this text is to present the presence of ^{137}Cs and ^{210}Pb$_{excess}$ from two uncultivated lands when it was still planted and after it became vacant land, also its effect on the rate of erosion. The results of this study came from the ground surface and a depth of 20 cm.

METHOD

This study aims to see how much loss of ^{137}Cs and ^{210}Pb $_{excess}$ radioisotopes in the land when perennials still planted it and after it became vacant land. The method used is the analysis of the ^{137}Cs and ^{210}Pb$_{excess}$ radioisotope content found in the soil. Soil sampling is carried out on the surface using a coring tool (d = 10 cm) to a depth of 2 cm and coring tool (d = 7 cm) to a depth of 20 cm, then pretreatment of the soil sample before being analyzed using a gamma spectrometer. The location of this study is a land located in the sub-watershed of Ciujung Upstream.

Research sites

Sampling carried out in two locations (Fig. 2), CBG and BMC, located in the Ciboleger village, Cimarga sub-district. The sampling process was carried out when it was still planted (2016) and after it became vacant land (2018).

Sampling

Sampling was carried out using several tools. Scrapper (20 x 50) cm for radioisotope distribution profiles of ^{137}Cs and ^{210}Pb$_{ex}$ at the reference location, coring (d = 10 cm) for surface samples, and coring (d= 7 cm) for determining inventory values of radioisotope ^{137}Cs and ^{210}Pb$_{ex}$. Then, the soil sample is put in a plastic clip and labelled (code and date).

Pre-treatment of the sample

Soil samples are taken to the sedimentology laboratory of PAIR - BATAN, then preliminary treatment before the content of ^{137}Cs and ^{210}Pb are analyzed. The pre-treatment samples consisted of: drying the soil sample, weighing the total dry weight of the sample, filtering to pass through a 1 mm sieve, and grinding for samples that do not pass through a 1 mm sieve.

Analysis of ^{137}Cs and ^{210}Pb content

A total of 400 g of dry and delicate soil samples were put into marinelli, tightly closed, then sealed using masking tape for 21 days. This treatment was carried out to ensure that an equilibrium between ^{226}Ra and its deceased ^{222}Rn had occurred. Then, the content of ^{137}Cs and ^{210}Pb in soil samples analyzed using a High Purity Germanium (HPGe) detector with 30% efficiency connected to the GENIE 2000 spectrum master and Multi-Channel Analyzer (MCA). The energy range of this gamma spectrometer is 1.54 keV (in channel 1) to 1777.05 keV (in channel 4095). Soil samples after undergoing pretreatment will be analyzed using a gamma spectrometer, which has a minimum detection (MDC) for ^{210}Pb total = 7.7 Bq/kg, ^{210}Pb supported = 5 Bq/kg, and ^{137}Cs = 0 Bq/kg. The analysis is carried out for a minimum of 80,000 seconds using secondary standards; it is soil taken from the Nganjuk area, which has known activity of ^{137}Cs, a total of ^{210}Pb, and ^{210}Pb supported. Secondary standard soil is also included in marinelli as much as 400 g and sealed using masking tape for a minimum of 21 days. Environmental isotope activity of ^{137}Cs is obtained at 661 keV energy, while a total ^{210}Pb activity is determined at 46.5 keV energy, and ^{214}Pb or ^{210}Pb supported radioactivity is determined at 351.9 keV energy. Radioactivity of ^{210}Pb unsupported or excess is obtained by reducing the ^{210}Pb supported radioactivity to a total ^{210}Pb [11]. After counting, the soil sample is returned to plastic or remains in sealed marinelli; it can be re-analyzed if needed.

Figure. 2. Ciujung watershed map and location of sampling points

Conversion of count to radioisotope radioactivity

Determination of the detector correction factor using soil standard (secondary standard) with the known activity of ^{137}Cs, ^{210}Pb and ^{210}Pb supported (^{137}Cs = 1.20 Bq/kg, ^{210}Pb total about 27.09 Bq/kg, and ^{210}Pb supported about 12.13 Bq/kg in December 2006). Correction of activities from ^{137}Cs dan ^{210}Pb total dan ^{210}Pb supported for the secondary standard to current activities using Eq. (1) with A_o is the activity of ^{137}Cs, ^{210}Pb in total or ^{210}Pb supported in standard samples on December 2006 (Bq/kg), A is activity of ^{137}Cs, ^{210}Pb in total or ^{210}Pb supported currently (Bq/kg), k is constant, and t is decay duration (years) [2].

$$A = A_o . e^{-kt} \qquad (1)$$

The measurement results of isotopes of ^{137}Cs, ^{210}Pb in total, and ^{210}Pb supported in a standard sample using MCA then compared to the actual ^{137}Cs, ^{210}Pb, and ^{210}Pb supported activities at the same time. This measurement uses Eq. (2) with *c.f.* is the correction factor for ^{137}Cs, ^{210}Pb in total or ^{210}Pb supported, and w is the weight of standard sample analyzed (kg) [2].

$$c.f. = A/((Stdr - BG)/(w*t)) \qquad (2)$$

The correction factor is used to correct the activity of ^{137}Cs, ^{210}Pb total activity, and ^{210}Pb supported of soil samples obtained through measurements using an MCA tool (assuming that the marinelli geometry conditions and sample weight are the same as the standard sample). This calculation uses Eq. (3) As is the activity of ^{137}Cs, ^{210}Pb in total or ^{210}Pb supported in the corrected sample (Bq/kg)[2].

$$As = c.f * ((Sample - BG)/(w*t)) \qquad (3)$$

Rate of erosion/deposition

Calculation of erosion/deposition rates for each trial point uses the Mass Balance Model 1, which is contained in the conversion model software developed at the University of EXETER-United Kingdom. This model is presented in Eq. (4) with Y is annual erosion rate (t/ha/year), d is the depth of tillage (m), B is bulk density (kg/m^3), X is the percentage loss of total environmental isotope inventory, and t is the year of sampling [12].

$$Y = 10\ d\ B\ (1 - (1 - X / 100)^{1/(t-1963)}) \qquad (4)$$

RESULTS AND DISCUSSION

Reference location

The selected reference location is an unprocessed land located at position (S = 06 ° 35 '02.6 ", T = 106 ° 13' 19.0") in Ciboleger Village - Leuwidamar sub-district. A sampling at the reference location is done at 1 point using a scrapper tool for the vertical distribution profile and 6 points using a coring tool for inventory values. Inventory value from this reference location will be used as a comparison whether erosion or deposition has occurred, and also used in the calculation of erosion/deposition rates. By using Eq. (1) to Eq. (3), activities and inventory of radioisotopes found in the ground will be obtained. Table 1 shows the results of the calculation of activities and inventory for ^{137}Cs radioisotopes from each layer.

Table. 1. Activity (Bq/kg) and Inventory (Bq/m^2) of ^{137}Cs in the Reference location of Ciboleger Village - Leuwidamar sub-district - Lebak

Distribution profile		**Inventory**	
Depth (cm)	***Bq/kg***	***Code***	***Bq./m²***
(0 – 2)	1.44	Scrapper (0-20) cm	229
(2 – 4)	1.54	COR 1	290
(4 – 6)	1.47	COR 2	183
(6 – 8)	1.46	COR 3	186
(8 – 10)	1.85	COR 4	206
(10 – 12)	1.83	COR 5	192
(12 – 14)	1.82	COR 6	209
(14 – 16)	1.99		
(16 - 18)	0.78		
(18 – 20)	1.16	Average	213 ± 35
(20 – 30)	0.00		

The vertical distribution profile from the radioisotope 137Cs in the soil layer at the reference location is shown in Fig. 3. Data in Fig. 3 shows the profile of the ^{137}Cs radioisotope's distribution does not match the theoretical vertical distribution process, in which the maximum is on the surface and decreases exponentially with increasing depth [10].

This reference location is an untreated land that is planted with perennials less than 50 years old and covered with grass and weeds. It is estimated that this land was once used as a processed field before it was converted to untreated land.

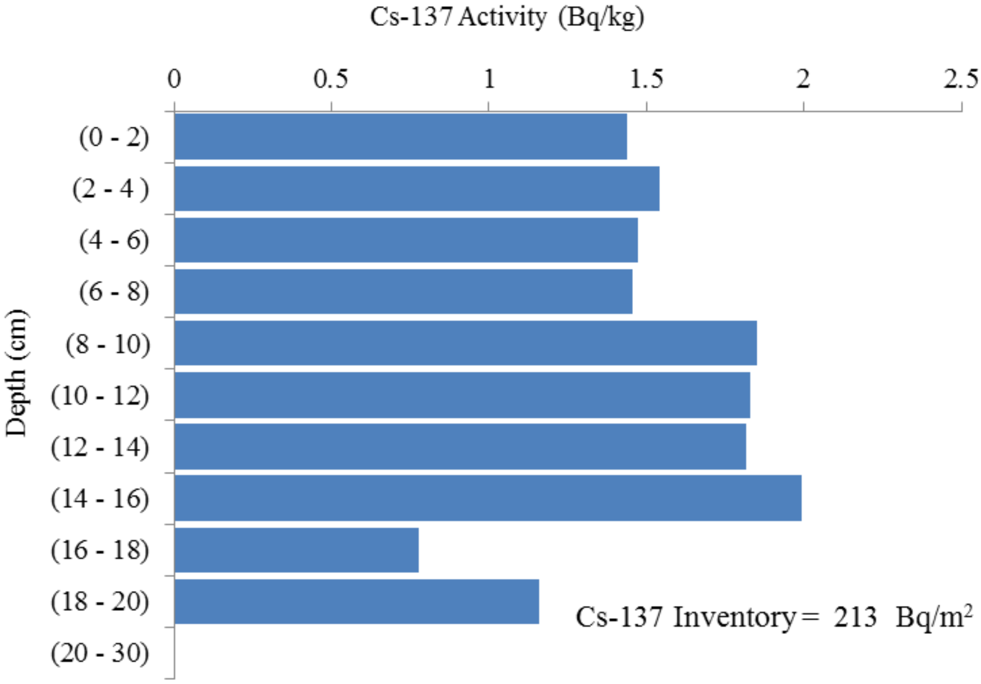

Figure. 3. Profile of the vertical distribution of ^{137}Cs in the soil layer at the reference location

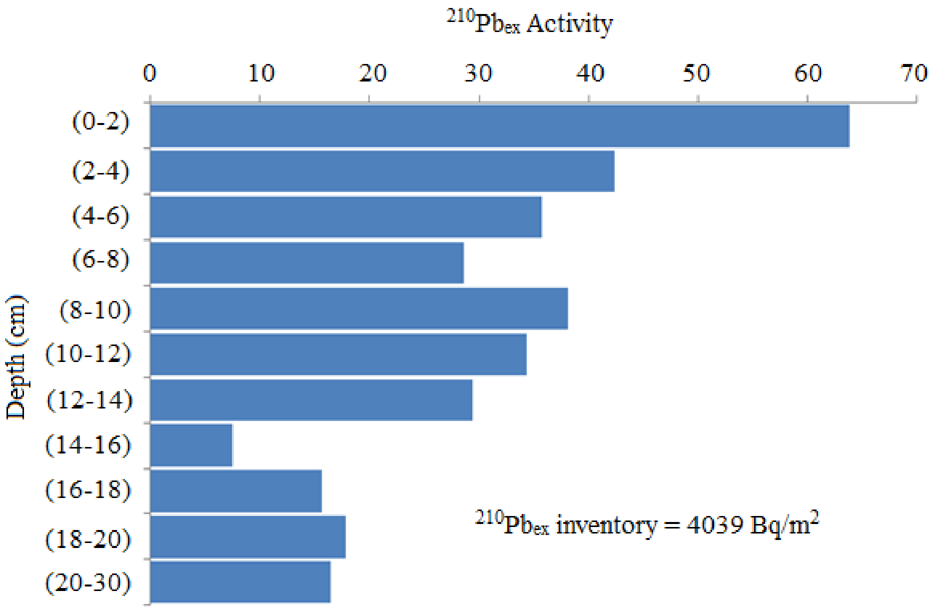

Figure. 4. Profile of the vertical distribution of $^{210}Pb_{ex}$ natural radioisotopes in the soil layer at the reference location

For radioisotopes ^{210} Pb $_{excess}$, the value of the activity and inventory can be obtained using the same method. Table 2 shows the results of the calculation of activities and inventory of each soil layer.

The data in Table 2 were analyzed and obtained the profile of the vertical distribution of $^{210}Pb_{ex}$ natural radioisotopes in the soil layer, as shown in Fig. 4. Theoretically, the profile of the distribution of natural radioisotopes in the soil is the maximum concentration found in the upper layer and decreases with increasing depth. In Figure 4, it appears that the maximum concentration found in the upper layer then decreases. At a depth (8-10) cm, the distribution pattern increases then decreases again. The profile of the $^{210}Pb_{ex}$ natural radioisotope vertical distribution is expected to be the same as the theoretical distribution profile, which is the maximum in the surface layer and decreases exponentially with increasing depth. It is because the fallout from this radioisotope continues to this day.

Table. 2. Activity (Bq/kg) and Inventory (Bq/m^2) of ^{210}Pb in the Reference location of Ciboleger Village - Leuwidamar sub-district - Lebak

Distribution profile		**Inventory**	
Depth (cm)	***Bq/kg***	***Code***	***Bq./m²***
(0 – 2)	63.86	Scrapper (0-20)cm	4123
(2 – 4)	42.36	COR 1	3644
(4 – 6)	35.69	COR 2	6768
(6 – 8)	28.61	COR 3	2518
(8 – 10)	38.13	COR 4	4489
(10 – 12)	34.31	COR 5	1870
(12 – 14)	29.38	COR 6	4866
(14 – 16)	7.46		
(16 - 18)	15.70		
(18 – 20)	17.88	Average	4039 ± 1489
(20 – 30)	16.41		

Research sites

The research site is located in the village of Ciboleger. The sampling process was carried out when the land was still planted (2016) and after it became vacant land (2018). The research location is in the position (S = 06 ° 35 '08 "; T = 106 ° 12' 32") for the planted land with several perennials such as durian, jackfruit, rambutan, and acacia (CBG) and (S = 06 ° 34 '33.8 "; T = 106 ° 11' 48.1") for teak gardens (BMC). Surface samples are taken at random points (minimum 10 points) with a depth of sampling of 2 cm and then mixed until homogeneous, stored in the plastic clip, and coded. The activities of these surface samples are calculated using Eq. (1) to Eq. (3) Moreover, the results are shown in Table 3.

Data in Table 3 shows natural radioisotopes at the ground surface are significantly reduced. This condition is caused by rainwater falling on the surface of the soil will directly carry natural radioisotope particles that have been attached to the soil grains. The radioisotope activity of ^{137}Cs at this location becomes minimal because it has been lost carried away by rainwater that flows directly above the surface of the ground and the effect of the decay process. $^{210}Pb_{ex}$ natural radioisotopes can increase over time because they come from rocks and will continue to exist.

Table. 3. The activity of natural radioisotopes of ^{210}Pb excess and ^{137}Cs on the soil surface when the conditions are planted and vacant land

CODE	**Activity of ^{137}Cs (Bq/kg)**		**The activity of $^{210}Pb_{excess}$ (Bq/kg)**	
	Planted Land	***Vacant Land***	***Planted Land***	***Vacant Land***
CBG	1.59	0.86	23.58	7.05
BMC	1.26	0.72	32.01	15.11

The natural radioisotope inventory value of ^{137}Cs and ^{210}Pb is used to estimate the rate of erosion that occurs in this land, both in planted and vacant land conditions. In 2016, sampling was conducted at two study sites (CBG and BMC), each with 3 points. Meanwhile, when the condition of the location was vacant land in 2018, sampling was conducted at 2 points for the CBG location and 5 points for the BMC location. Table 4 presents the results of calculating the activity and inventory values from the experiment points.

Table. 4. Value of activities and inventory at the research site when conditions are planted and vacant land

CO DE	**Activity and Inventory of ^{137}Cs**				**Activity and Inventory of $^{210}Pb_{ex}$**			
	Planted Land		***Vacant Land***		***Planted***		***Vacant Land***	
	(Bq/ kg)	*(Bq/ m²)*	*(Bq/ kg)*	*(Bq/ m²)*	*(Bq/ kg)*	*(Bq/ m²)*	*(Bq/ kg)*	*(Bq/ m²)*
CB	1.8	314	1.2	238	30.	528	4.5	854
G	4	216	7	272	93	5	7	507
	1.3	256	1.4		32.	531	26.	2
	0		3		35	3	56	
	1.5				25.	423		
	3				31	3		
B	1.3	224	0.6	120	26.	280	18.	322
M	0	163	6	90	76	4	91	9
C	1.2	197	0.8	66	38.	237	23.	395
	9		1	90	84	8	23	5
	1.3		0.7	91	50.	762	12.	217
	4		9		35	3	75	7
			0.6				11.	209
			3				49	6
			0.5				12.	219
			4				52	3

Data in Table 4 shows the concentration of ^{137}Cs to a depth of 20 cm was also significantly reduced in both study sites, as well as for natural radioisotopes $^{210}Pb_{ex}$. The reduction in natural radioisotopes at a depth of 20 cm is not as significant as on the surface layer. It has occurred because the land has not been cleared for a long time and the vacant land has not been processed. The rate of erosion that has occurred at both locations can be calculated using the inventory value in Table 4 and the inventory value of the reference location. The analysis was carried out using Eq. (4) contained in software created by the Department of Geography-Exeter University-UK. The results of the erosion/deposition calculation shown in Table 5.

Table. 5. The results of the calculation of the rate of erosion/deposition when the condition conditions are planted and vacant land

KODE	Rate of erosion/deposition (t/ha.y) ^{137}Cs Method		Rate of erosion/deposition (t/ha.y) $^{210}Pb_{ex}$ Method	
	Planted Land	*Vacant Land*	*Planted Land*	*Vacant Land*
CBG	44.1	4.0	-8.0	-58.0
BMC	-4.3	-27.1	-36.9	-79.9

The results in Table 5 show erosion in vacant land increased by more than doubled because many of the surface layers were lost due to rainwater, which fell directly to the ground surface. By the results of calculations in Tables 3 through 5, it can be seen that perennials such as rambutan, durian, banana, jengkol, acacia, or teak can hold the surface layer of the ground from the scour of rainwater. This ability is supported by the roots of these plants, which can suck rainwater into the ground.

CONCLUSION

This study provides the conclusion that without cover plants (perennials), the surface layer of the soil will experience the highest erosion due to rainwater scour. Without cover plants, the presence of natural radioisotopes of ^{137}Cs will disappear more quickly, making it difficult to exploit for the future. Meanwhile, because of $^{210}Pb_{ex}$ comes from ^{238}U found in rocks, so the natural radioisotopes of Pb can still exploit. Perennials can prevent and reduce erosion because the roots of perennials can absorb rainwater on the soil surface into the soil.

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