Indian Journal of Plant and Soil
Volume 4 Number 2, July - December 2017
DOI: http://dx.doi.org/10.21088/ijps.2348.9677.4217.1

Original Article

Using Fallout Cs-137 and Be-7 to Assess Soil Erosion and the Effectiveness of Soil Conservation Measures in Ea Kao Catchment of Vietnam

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Abstract

Soil erosion were assessed at 30 sites in Ea Kao catchment of Vietnam by using fallout radio-nuclides. The soil samples was taken from top to foot of hill, in rectangular for Be-7 and cylindrical for analyzing Cs-137. The radio-nuclides were determined by gamma spectrometry using high purity germanium detectors with a 30% relative efficiency.

Soil erosion were estimated by models of He Q et al. (2002), Walling DE et al. (2002) and Tu TC and Hai PS (2014). The study results showed that soil erosion rates varied in a wide range and depended significantly on cover crops, slope, farming practices and soil conservation measures. Rate of soil loss in 2016 was higher than in average of 52 years (1964-2016), because 20-30 years ago the land surface really covered by forest, which protected quite effectively soil from erosion.

Land of annual crops had the highest rate of soil erosion, with 27.2-30.7 t ha-1 y-1 for upland rice and 29.8-33.6 t ha-1 y-1 for cassava, depend on model of Cs-137 or Be-7 applied. Coffee land had the least soil erosion rates. On high sloping land (more 25 degree), difference of average erosion in 52 years among land use types (coffee, tea, rubber, cashew, upland rice and cassava) were narrowed, due to the lands have just been used in recent time, 30-40 years before that they had been covered by forest.

Making hedgerows of tephrosia between coffee rows, intercropping cassava and legumes, building terraces for upland rice were simple practices but high effectiveness to protect soil from erosion.

Keywords

Catchment; Farming Practices; Radio-Nuclides; Sloping Land; Soil Erosion.

Introduction

Ea Kao catchment is 12 km to the south of Buon Ma Thuot city of Vietnam, with area of 7,737.77 hectares. Its topography is hilly and rolling with slope ranging 12-40° and being covered by many kinds of crops (coffee, tea, rubber, cashew, upland rice and cassava). The precipitation in Ea Kao catchment ranged in 1,606.8-1,946.7 mm a year and distributed in 6 months, from April to October, with peaks in July, August and September. Therefore erosion caused by rainfall is unavoidable.

Over the past 50 years, many scientists all over the world have made many efforts to research on the possibility of using natural and artificial radioactive isotopes in the fields of soil erosion and sediment. Isotope of ^{7}Be (half-life cycle is 53.28 days) is a natural radioactive material, created by interaction of universal rays for oxygen and nitrogen in atmosphere (Wallbrink PJ and Murray AS, 1994). Isotope of ^{137}Cs (half-lifecycle is 30.14 years) appeared in the atmosphere by nuclear weapon tests in 1950s and 1960s. In that time, a large amount of ^{137}Cs emitted to the stratospheric and transferred to around the globe before settling back to the ground, this was admitted by the monitoring stations on both the Northern and Southern Hemisphere. Both of them have a similar trait: the concentration of ^{137}Cs appeared significantly in the atmosphere in 1954 , rose up and reached on maximum amount for 1963 - 1964, fell down until 1984, and then it was not detectable anymore (Hai PS *et al.*, 2003). After falling down the ground, ^{7}Be and ^{137}Cs were absorbed strongly and quickly by

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Received on 17.10.2017, **Accepted on** 30.10.2017

exchanging positions with other elements, and they had no ability to decompose in most of the environment (Tamura T, 1964; Cremers A *et al.*, 1988; Robbins JA, 1978; Olsen CR *et al.*, 1986). Therefore, any redistribution of those isotopes occured due to redistribution of soil surface and this isotopes act as the indicators for erosion process. The isotope of ^{7}Be and ^{137}Cs were used successfully for surveying soil erosion in some countries (Walling DE *et al.*, 1990; Quine TA *et al.*, 1994; Tu TC and Hai PS., 2005, Hai PS *et al.*, 2011).

This paper discusses on using fallout radionuclides to assess soil erosion and the effectiveness of soil conservation measures in short time (some months) and long time (more 50 years) in Ea Kao catchment of Vietnam.

Materials and Methods

Study Site

Soil erosion were assessed in Ea Kao catchment, where belongs to Central Highlands of Vietnam. The area has hilly terrain, steep slopes and monsoon tropical climates. There were 6 land use types in the catchment, consisted: coffee, tea, rubber, cashew, upland rice and cassava (Figure 1).

Sampling

The soil samples was taken from top to foot of hill (Figure 2), in rectangular for analyzing ^{7}Be and cylindrical for ^{137}Cs. There were 30 samples devided into land use types

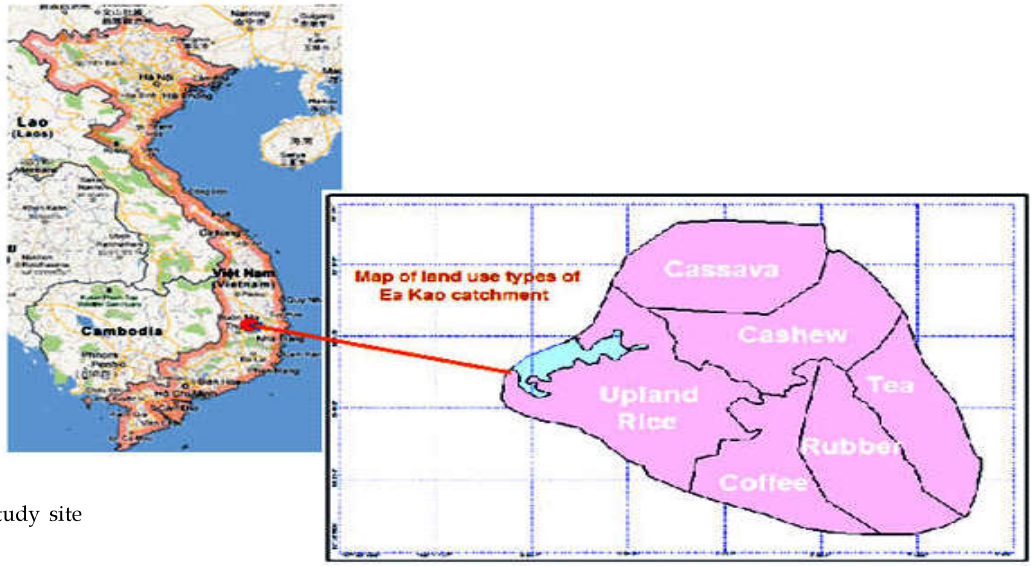

Fig. 1: Study site

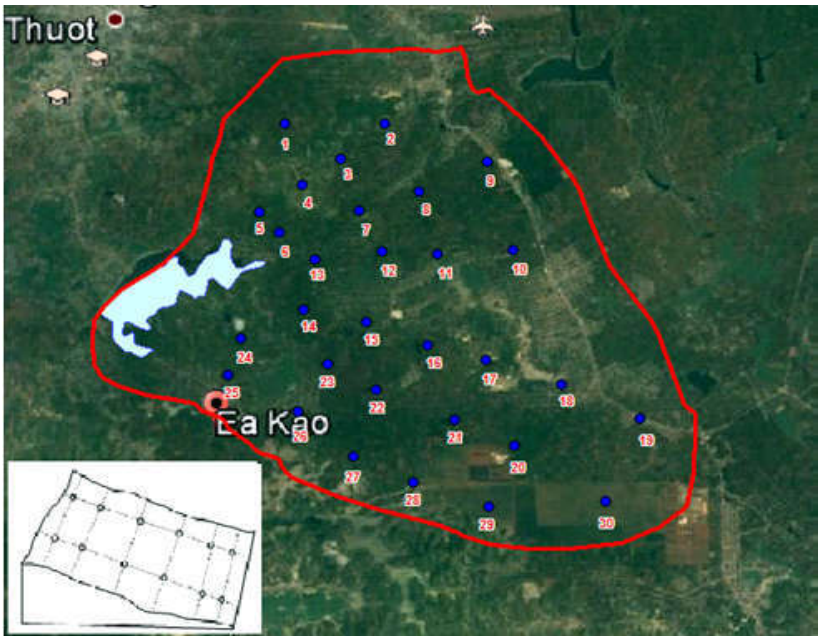

Fig. 2: Diagram of sampling

Analyzing

Radionuclides ^{137}Cs and ^{7}Be were determined by gamma spectrometry using high purity germanium detectors with a 30% relative efficiency. Gamma counting usually lasts for 24 hours. For this analysis, all samples were prepared as a fine homogeneous powder and were cast using polyester resin in the desired geometry. Radionuclide ^{137}Cs was measured by its gamma emission at 662 keV and ^{7}Be was measured at 478 keV.

Calculating Models

- Soil loss of current year: by model of He Q *et al.* (2002) [1].

$$R_{Be} = h_0 \ln \frac{PA_{Be,ref}}{PA_{Be,ref} - A_{Be,ref} + A_{Be}} \quad (1)$$

Where: R_{Be} is soil loss; *ho* is depth; $A_{Be,ref}$ is inventory of ^{7}Be at reference site (450 Bq m^{-2} for the study area); A_{Be} is inventory of ^{7}Be at study site; *P* can be estimated by using the specific surface area of the original soil, S_{sl} (m^2 g^{-1}), and that of mobilized sediment, S_{ms} (m^2 g^{-1}). An estimate of the specific surface area of a sediment or soil sample can be derived from its particle-size distribution, by assuming spherical particles. In order to determine *P* factor, some surface soil samples (20 cm wide, 40 cm long, 5 cm depth) were taken at erosion areas, and some surface soil samples (20 cm wide, 40 cm long, 2 cm depth) were taken at deposition areas. Then all soil samples at erosion areas were mixed together to make one sample for analysis of particle size. The same procedure was applied for soil samples at deposition areas. From the measured particle size distributions S_{sl} and S_{ms} were estimated and the P factor calculated from: $P = (S_{ms}/S_{sl})^{0.65}$.

- Soil loss of 52 years: by rate model of Walling DE *et al.* (2002) [2]

$$X = \frac{I_p - I_r}{I_r}.100 \quad (2)$$

Where: *X* is ^{137}Cs loss (%); I_p is inventory of ^{137}Cs at study site; I_r is inventory of ^{137}Cs at refrence site (430 Bq m^{-2} for the study area).

And the correlative equation between ^{137}Cs loss ans soil loss of Tu TC and Hai PS (2014) [3].

$$Y = 20{,}123\ X^{1{,}0967} \quad (3)$$

Where *Y* is soil loss (t ha^{-1}); *X* is percentage decrease in the total ^{137}Cs inventory per hectare (%).

Results and Discussion

The Effect of Cover Crops and Sloping Land on Soil Loss

The study resuls showed that rate of soil loss in 2016 was higher than in average of 52 years (1964-2016), because 20-30 years ago the land surface really covered by forest, which protected quite effectively soil from erosion. These data are consistent with the statement of Tu TC and Hai PS (2015).

The land of annual crops had the highest rate of soil erosion, with 27.2-30.7 t ha^{-1} y^{-1} for upland rice and 29.8-33.6 t ha^{-1} y^{-1} for cassava, depend on model of ^{137}Cs or ^{7}Be applied. Soil loss on land of perennial crops such as coffee, tea, rubber and cashew were 19.4-25.9 t ha^{-1} y^{-1} by ^{137}Cs model and 20.6-28.2 t ha^{-1} y^{-1} by ^{7}Be model, lower than on annual crop lands. Coffee land had the least soil erosion rates, with 19.4-20.6 t ha^{-1} y^{-1} depend on models of application (Table 1). Erosion rates in the study area are similar to the report of Siem NT and Phien T (1999).

Results above demonstrated that erosion rates depended on cover crops. However, on high sloping land (more 25 degree), difference of average erosion in 52 years among land use types (coffee, tea, rubber, cashew, upland rice and cassava) were narrowed (Table 2), due to the lands have been just used in recent time, 30-40 years before that they had been covered by forest.

Evaluating the Effectiveness of Soil Conservation Practices

The effectiveness of some soil conservation practices practices such as banding, intercropping, terracing in 2016 was analyzed and canculated by ^{7}Be model.

The results showed that making hedgerows of tephrosia among coffee rows reduced soil erosion by 5.4 t ha^{-1}, corresponding 38%. The soil loss in measures of monoculture cassava was 31.5 t ha^{-1}, down to 21.3 t ha^{-1} in plot of cassava and legumes intercropping. Building terraces for upland rice field reduced by 32.4% rates of erosive soil in comparison with control. The effectiveness of these practices were similar to study results of Siem NT and Phien T (1999).

In addition, applyying hedgerows of tephrosia increased coffee productivity by 0.59 t ha^{-1}, corresponding 20.8% compare to that of control. Intercropping cassava and legumes improved cassava yield by 24.7%. The upland rice productivity rised by 0.17 t ha^{-1} due to making terraces (Table 3).

Table 1: The effect of cover crops on soil erosion

Crops	Soil loss (t ha^{-1} y^{-1})	
	Curent year (2014)	Everage of 50 years (1964 – 2014)
Coffee	20.6	19.4
Tea	22.5	21.7
Rubber	26.1	22.8
Cashew	28.2	25.9
Upland rice	30.7	27.2
Cassava	33.6	29.8

Table 2: Relation of cover and slope on soil erosion (average of 52 years, t ha^{-1} y^{-1})

Crops	Slope (°)				
	< 8	8-15	15-20	20-25	> 25
Coffee	10.4	14.6	19.4	23.9	28.0
Tea	13.9	17.5	21.7	24.8	28.4
Rubber	19.5	21.0	23.8	25.3	28.9
Cashew	21.6	23.8	25.9	27.1	29.2
Upland rice	22.3	25.1	28.2	29.0	29.8
Cassava	23.7	26.3	29.1	29.6	30.3

Table 3: The effect of cultivating measures on soil erosion and crop productivity in 2016

Crops	Slope (°)	Cultivating measures	Soil loss		Productivity	
			t ha^{-1}	%	t ha^{-1}	%
Coffee	9	No protection	14.2	100.0	2.84	100.0
		Hedgerows of teprosia	8.8**	62.0	3.43**	120.8
Cassava	18	Monoculture	31.5	100.0	19.80	100.0
		Intercroping with legumes	21.3**	67.6	24.70**	124.7
Upland rice	18	No protection	27.3	100.0	0.62	100.0
		Making terraces	19.1**	70.0	0.79*	127.4

* Significant difference of means, with $P < 0.05$; ** Significant difference of means, with $P < 0.01$

Summary and Conclusion

Soil erosion were assessed at 30 sites in Ea Kao catchment of Vietnam by using fallout radio-nuclides, including ^{7}Be and ^{137}Cs. Erosion rates varied and depended significantly on cover crops, slope, farming practices and soil conservation measures. The soil loss in 2016 was higher than in average of 52 years (1964-2016), because 20-30 years ago the land surface really covered by forest.

Land of annual crops had the highest rate of soil erosion; and coffee land had the least soil erosion rates. On high sloping land (more 25 degree), the difference of average erosion in 52 years among land use types (coffee, tea, rubber, cashew, upland rice and cassava) were narrowed, due to the lands have just been used in recent time, 30-40 years before that they had been covered by forest.

Making hedgerows of tephrosia between coffee rows, intercropping cassava and legumes, building terraces for upland rice were simple practices but high effectiveness to protect soil from erosion.

References

1. Cremers A, Elsen A, De Preter P, Maes A. Quantitative analysis of radiocaesium retention in soils. Nature 1988;335:35-39.
2. Hai PS., Binh NT, Dao NV. Spatial variability of ^{137}Cs inventory at reference sites and influence of sampling strategy on the uncertainty in estimation of soil erosion rates. In proceedings of the fifth National Conference on Nuclear Physics and Techniques, Ho Chi Minh City, 27 - 28 April, 2003.p. 234-237.
3. Hai PS, Hien PD, Dao NV, Mui NT, Tu TC. Application of ^{137}Cs and ^{7}Be to access the effectiveness of soil conservation technologies in the Central Highlands of Vietnam, IAEA-TECDOC-1665, 2011.p.195-206.
4. He Q, Walling DE. Wallbrink PJ. Alternative methods and radionuclides for use in soil erosion and sedimentation investigations. Handbook for the assessment of soil erosion and sedimentation using environmental radionuclides. Kluwer Academic Publishers, 2002.p.185-215.
5. Olsen CR, Larsen IL, Lowry PD, Cutshell NH. Geochemistry and deposition of ^{7}Be in river-

estuarine and coastal water. Journal of Geophysical Research 1986;91:896-908.

6. Quine TA, Navas A, Walling DE, Machin J. Soil Erosion and Redistribution on Cultivated and Uncultivated Land Near Las Bardenas in the Central Ebro River Basin, Spain. Land Degradation & Rehabilitation 1994;5:41-55.
7. Robbins JA. Geochemistry and Geophysical application of radioactive lead. In J. O. Nriagu (Ed.), The biochemistry of lead in the environment, Amsterdam: Elsevier, 1978.p.285-293.
8. Siem NT, Phien T. Vietnam mountain soil: degredation and improving. Vietnam Agricultural Publishing House, 1999.p.148-149.
9. Tamura T. Consiquences of activity release: selective sorption reactions of cesium with soil minerals. Nuclear Safty 1964;5:262-268.
10. Tu TC, Hai PS. Survey of soil erosion through technique of ^{137}Cs measurements. Vietnam Soil Science 2005;21:178-179.
11. Tu TC, Hai PS. Study on the Correlation between ^{137}Cs Loss and Soil Erosion in Central Highlands of Vietnam. Journal of Environmental Science and Engineering A - David Publishing Company, USA 2014;3(2):117-122.
12. Tu TC, Hai PS. Using fallout radio-nuclides to assess soil erosion, land degradation and the effectiveness of soil conservation measures in Central Highlands, Agricultural science and technology, Vietnam 2015;1(62):40-45.
13. Wallbrink PJ, Murray AS. Fallout of ^{7}Be over south eastern Australia. Journal of Environmental Radioactivity 1994;25:213-228.
14. Walling DE, He Q, Appleby PG. In Handbook for the assessment of soil erosion and sedimentation using environmental radionuclides. Edited by F. Zapata, Kluwer Academic Publishers, 2002.p.111-158.