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A Study of Soil Erosion on a Steep Culti vated Slope in the Mt. Gongga Region near Luding, Sichuan, China, using the ^{137}Cs Technique

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ABSTRACT

This paper reports the results of an investigation of soil erosion on a steep cultivated slope in the Mt Gongga region of the Upper Yangtze River Basin, Southwest China, using the ^{137}Cs technique.

The effective ^{137}Cs reference inventory for the study field, estimated from the bottom layer of a ^{137}Cs depth profile at the deposition zones, is 2373.9 Bq/m^2, accounting for 65.8% the local ^{137}Cs reference inventory of 3607.7 Bq/m^2. It strongly indicates that a considerable amount of ^{137}Cs input was lost prior to incorporation into the ploughing layer from the study field during the nuclear weapons testing period because of ^{137}Cs surface enrichment. The average erosion rate is estimated to be 4914 t/km^{2}yr for a typical cultivated steep slope with an angle of 34°at the subtropical zone in the Mt Gongga region. It can reach to 22856 t/km^{2}yr for a failure slope under cultivation.

Key words: Erosion rate. Cultivated slope. Caesium-137. Upper Yangtze River

INTRODUCTION

The Upper Yangtze River Basin, with an area of 1×10^6 km^2, is one of the most severely eroded areas in China. The Three Gorge Project is now being constructed near Yichang, at the outlet of the basin. To mitigate the sediment-related problems of the project, great attention has been paid to control severe erosion in the basin. Most of cultivated land is located on hillslopes in the basin, particularly in the western high mountain regions where some slopes of up to 35º are still under cultivation. Cultivated land on steep slopes is one of the important sources for river sediment in the mountain regions, and soil erosion has significant influences on land degradation and reduction of crop productivity. There is a need for information on the erosional behaviour and its severity on cultivated land on steep slopes in the remote high mountain regions of the basin. This paper reports the results of a preliminary investigation of the potential of using ^{137}Cs measurements for this purpose on a sloping cultivated field in the Mt Gongga region near Luding, Sichuan, China.

Figure1. Location map of study site.

STUDY AREA

The study area is located in the lower reaches of the Heiluogou River in the Mt Gongga region, 3 km south of Muxi Town , Luding County, Sichuan Province, China (Fig 1). Mt Gongga is the highest mountain in Sichuan with an elevation of 7565 m. The river originated from the Mt Gongga glacier, which exists from the peak of Mt Gongga to the head of Heiluogou River Valley and flows eastwards to join the Muxi River, a tributary of the Dadu River. The River has a drainage area of 194 km^2, and a channel length of 16 km between the foot of the glacier (2850 m above sea level) and its conjunction to the Muxi River (1536 m above sea level), with a longitudinal gradient of 8.2%. The relative relief between the valley and the ridge in the middle and lower reaches of the river is about 2000 m and the hillslopes are very steep, with an average angle of 35º. Granite, schist and marbles mostly underlie the catchment. A high terrace of moraine deposits of the last glacier period is widely distributed at the foot of hillslopes along the valley, and the elevation difference between the valley and the terrace surface is about 120 m. A low terrace of fluvial deposits since the last glacier period is distributed on sides of the river channel.

Natural forest is basically intact in the Heiluogou River catchment except in its lower reach where forests on the low terrace and some hillslopes have been cleared for cultivation and a few villages have been settled for more than 100 years. Because of its largely intact natural forests and spectacular glacial landscape, the Heiluogou River Basin was selected as a national park in the earliest of 1990s.

Climate varies with elevation in the Mt Gongga region. Precipitation increases and temperature decreases as elevation increases. The study area has an elevation of 1700 - 1800 m in the lower reach region and has annual precipitation of about 1100 mm, 80% of which occurs during the wet season (May-October) and 20% during the dry season (November-April). Rainfall intensity is quite low in the Mt Gongga region: 74% of annual precipitation occurs with a rainfall intensity of <10 mm / day, 20% of it with a rainfall intensity of 10-30 mm/ day, and only 6% and 0.6% of annual precipitation occurs with a rainfall intensity of >30 mm / day, and > 50 mm/ day, respectively. Average annual temperature is 12ºC for the study area and the minimum and maximum mean monthly temperature is 4.5ºC (January), and 20ºC (July), respectively.

Average annual runoff depth is 1400 mm in the Hailuogou River catchment with a runoff index of 0.81. 75% of the annual runoff takes place during the wet season and 25% during the dry season. Seasonal variation in runoff is not as great as precipitation, because of steady water supply from the melting glaciers in the head of the River and from the groundwater seepage of moraine deposits and fractured bedrock covered with dense forests. Floods usually occur during summer, caused by either melting glaciers or heavy storms. Mass movements, such as avalanches, landslides, slumps, rockfalls are quite active in the catchment. Water erosion on hillslopes under intact dense forest is apparently very limited. Little is known about the severity of soil erosion of sloping cultivated field in the region.

METHODOLOGY

A sloping cultivated field on a steep slope of the high moraine terrace in the lower reaches of Heiluogou River was selected for the study. The field has a slope length of 60 m, an average slope angle of 34º, and a width of 60 m across slope. A dense evergreen broadleaf forest occurs on the slopes beside the field. There is a 10 m cliff in height upslope the field. When we collected samples in September 1995, near the end of the wet season, some small slumps and avalanches from the cliff were deposited at the head of the field. The western part of the field is divided into three subfields by two slumps, of which the lower subfield is unstable. No flat grassland can be found in the lower Heiluogou River Basin to use as a reference site. A flat artificial terrace 1 km away from the study field was selected to collect samples for the local ^{137}Cs reference inventory. In both of the cultivated slope and the artificial terrace, soil is young and stony, and for-

Table 1. Variations of ^{137}Cs content and percentage of >2 mm particles with depth.

	Profile A		Profile B		Profile C		Profile D	
Depth (cm)	^{137}Cs content (Bq/kg)	>2 mm (%)	^{137}Cs content (Bq/kg)	>2 mm (%)	^{137}Cs content (Bq/kg)	>2 mm (%)	^{137}Cs content (Bq/kg)	>2 mm (%)
0-5	12.53	14.8	7.75	49.0	14.33	44.9	12.45	50.0
5-10	13.05	14.3	8.50	47.1	14.67	56.8	12.85	54.2
10-15	12.38	12.5	8.30	40.5	13.80	57.5	13.11	52.6
15-20	13.08	16.9	0.00	41.1	14.75	52.4	15.11	45.2
20-25	14.38	27.8	0.00	58.4	14.08	54.3	16.57	44.3
25-30	13.66	13.8			14.92	55.3	16.45	55.3
30-35	4.56	0.0			14.87	63.0	8.82	54.2
35-40	0.00	16.5			13.56	40.8	1.34	61.7
40-45					11.51	56.1	0.95	78.2

med in the underlying moraine deposits of granitic materials. The soil has 48% of >2 mm particles content is 48% on the steep slope and 15% on the flat terrace, respectively. The lower proportion of coarse particles in the later field may be caused by intensive cultivation.

The two fields have been reclaimed for cultivation for more than 100 years. Summer maize and winter wheat in the reference field, while a crop of summer maize is grown in the sloping field. Ploughing depth is about 30 cm in the flat reference field, and 20 -25 cm in the sloping field.

29 core samples were collected along three transects downslope to investigate variations of ^{137}Cs inventory and ^{137}Cs depth distribution from the sloping field. Transect 1 is located on the central slope of the field and has a slope length of 42.0 m and an average angle of 33.93º. Transect 2 on a shallow hollow of the eastern part of the field with a slope length of 59.0 m and an average angle of 33.62º, and Transect 3 on the western part of the field with a slope length of 36.0 m and an average angle of 34.66º (downslope forward looking). The interval between adjacent transects across a slope is 10 m and the interval between two adjacent cores downslope is typically 5-7 m. Five cores were collected to obtain the local ^{137}Cs reference inventory from the reference field.

Depth incremental samples were collected using a 9.5 cm-diameter core tube comprising two segments, which could be separated to facilitate sectioning of the core. The tube was driven into the ground manually typically to a depth 40-50 cm. All samples were air dried, disaggregated, passed through a 2 mm sieve and weighed. The ^{137}Cs content of the < 2mm fraction of each samples was measured by gamma spectrometry using a hyperpure coaxial germanium detector and multichannel analyser system. Caesium-137 was detected at 662keV and counting times, which were typically about 25000 to 55000 s, provided results with an analytical precision of approximately 6% (2SD).

Analysis of grain size distribution was undertaken for <2 mm particles of all samples of the 9 cores at Transect 1 to investigate variations in grain size distribution along the transect as well as with depth. The >0.063 mm fractions were measured by sieving. The <0.063 mm fractions were measured using laser-diffraction apparatus.

RESULTS

Depth distribution of ^{137}Cs in profile

In general, ^{137}Cs is evenly distributed within the top soil horizons, which reflects the mixing caused by tillage, in both the flat reference field and the sloping study field (Table1). Ploughing depth is 30 cm for the reference field (Profile A), 15-20 cm for the upper parts of the sloping field (Profile B), where erosion is very severe and subsoil is hard for ploughing. ^{137}Cs is found at depths greater than 25 cm of the ploughing depth at the deposition zones of the middle or lower slopes in the sloping field (Profile C-D).

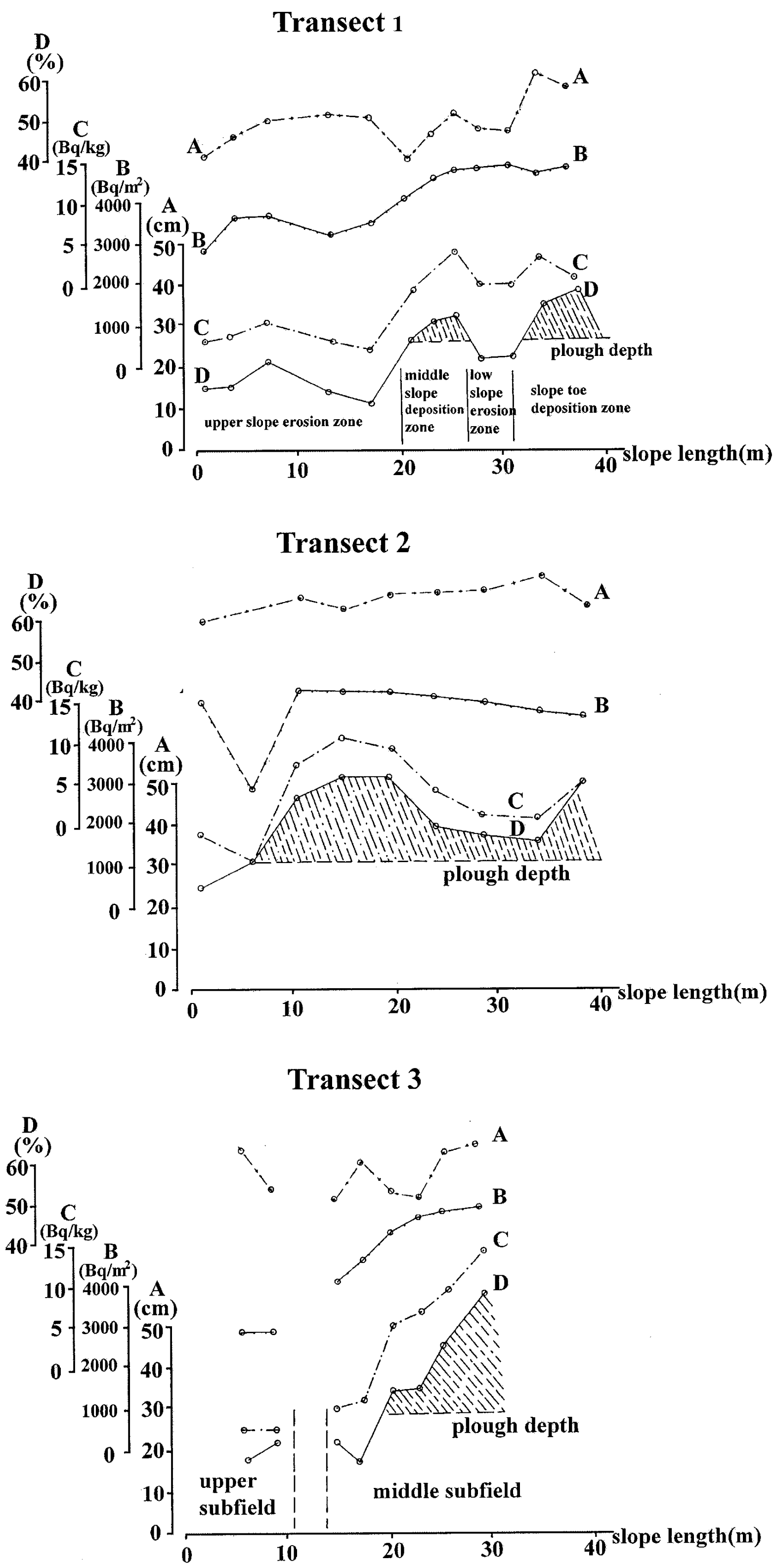

Figure 2. Variations ^{137}Cs distribution depth (A), ^{137}Cs inventory(B), and ^{137}Cs concentration(C) and percentage of >2 mm particles (D) along three transects.

^{137}Cs reference inventory

Of the 5 cores, collected from the reference field, ^{137}Cs inventories of 4 cores were very close (3502.5 Bq/m^2, 3605.4 Bq/m^2, 3613.9 Bq/m^2, and 3701.1 Bq/m^2), one core had a value of 4129.7 Bq/m^2 and a ^{137}Cs distribution depth of 35 cm. The mean value of 3607.7 Bq/m^2 of the former 4 cores is considered to be the local ^{137}Cs reference inventory for the study area. The ^{137}Cs reference inventory of 3607.7 Bq/m^2 is much higher than the values of 2300-2500 Bq/m^2 in the Central Hilly Sichuan Basin with a similar precipitation and latitude as the study area (Quine, 1992).

Variations of ^{137}Cs distribution along transects

Of 12 cores on Transect 1 on the central slope of the study field (Fig. 2), there are 5 cores where ^{137}Cs distributed depth is greater than ploughing depth, of which 3 cores in the middle slope deposition zone (20.4 - 26.4 m, downslope), and 2 cores in the slope toe deposition zone (31.0-36.21 m, downslope). The total horizontal slope length of the deposition zones is 11.21 m, which accounts for 31.0 % of the total horizontal slope length.The maximum deposition depth over the deposition slope is greater than 10 cm and it was estimated that 0.8 m^3 of soil had deposited on the slope in one metre width across slope (1963-1995).

The ^{137}Cs inventory on Transect 1 ranges between 500.9 and 2759.2 Bq/m^2 with a mean value of 1388.5 Bq/m^2, which accounts for 38.5 % of the ^{137}Cs reference inventory. ^{137}Cs inventory is generally related to ^{137}Cs distributed depth on Transect 1, but the maximum value of 2759.2 Bq/m^2 occurs at the core in the middle deposition zone while it is 1911.9 Bq/m^2 at the bottom core of the transect, which didn't reach the bottom of ^{137}Cs distributed layer. In the lower slope erosion zone (26.4-31.0 m, downslope) between the two deposition zone, ^{137}Cs inventories (1831.4 and 1923.5 Bq/m^2) are lower than those in both deposition zones. It is apparent that considerable amount of ^{137}Cs fallout has also lost from the slope of the transect even in the deposition zone: the maximum ^{137}Cs inventory (22759.2Bq/m^2) only accounts for 76.2% of the reference inventory. ^{137}Cs concentration in top 20 cm soil ranges between 3.59-5.78 Bq/kg in the upper slope erosion zone, which is lower than the value with a range of 10.1-13.7 Bq/kg on the rest of the transect.

Although only 3 cores reached the bottom of ^{137}Cs distributed layer on Transect 2, the variation in ^{137}Cs distribution depth and ^{137}Cs inventory along the transect can be distinguished and similar to Transect 1. Soil deposition on the slope of the transect is much greater than on the slope of Transect 1. 69.4 % of the slope of the transect is depositional and the deposition depth ranges between 7 - 27 cm. At least, 6.41 m^3 of soil had deposited on the slope of Transect 1. ^{137}Cs inventory ranges between 610.4 - 1634.1 Bq/m^2 for the 3 cores that reached the bottom of ^{137}Cs distributed layer , of which one core was located on the upper slope of the transect. The ^{137}Cs inventory ranges between 1138.0 - 3069.9 Bq/m^2 for the rest 6 cores that didn't reach the bottom of ^{137}Cs distributed layer. ^{137}Cs concentration in top 20 cm soil ranges between 8.84-12.14 Bq/kg and it slightly decreases downslope on the transect except for the two cores on the top slope of the transect.

On Transect 3, the two cores located in the upper subfield have very low ^{137}Cs inventories (77.7 and 190.5 Bq/m^2), and low ^{137}Cs concentrations of cultivated soil (1.18 and 1.35 Bq/kg). The variation patterns in ^{137}Cs inventory and in ^{137}Cs distributed depth in the middle subfield of the transect are different from Transect 1, and Transect 2. The middle subfield can be easily be divided into the upper erosion zone with a horizontal slope length of 4.0 m and the lower deposition zone with a horizontal slope length of 12.0 m which accounts for 64.5 % of the total slope. The average deposition depth over the deposition slope is 8.1 cm and the total deposited soil volume is 0.96 m3 in a one metre width across slope. The ^{137}Cs inventory ranges between 649.8 Bq/m^2 (the top core) and 3956.9 Bq/m^2 (the bottom core) with a mean value of 1816.33 Bq/m^2. This accounts for 50.4 % of the ^{137}Cs reference inventory. The ^{137}Cs concentration in top 20 cm soil rapidly increases as slope length increases from 6.28 Bq/kg to 8.46 Bq/kg in the upper erosion zone, and slightly increases as slope length increases from 11.65 Bq/kg to 14.26 Bq/kg in the lower deposition zone.

Variation in soil texture (Table 1 and Figure 2)

The proportion of >2 mm particles in the cultivated soil on the study field ranges between 20.0 % and 74.3 % with a mean value of 48.5 % (Table 1). The proportion of >2 mm particles in top 20 cm soil seems to slightly increase as slope length increases along the three transects (Fig. 2). There is no apparent variation in the proportion of >2 mm particles within the sampling depth, but the percentage of >2 mm particles is lower in the ploughing layer than in the subsoil at eroding sites. Particle size analyses of <2 mm fractions have been done for all soil

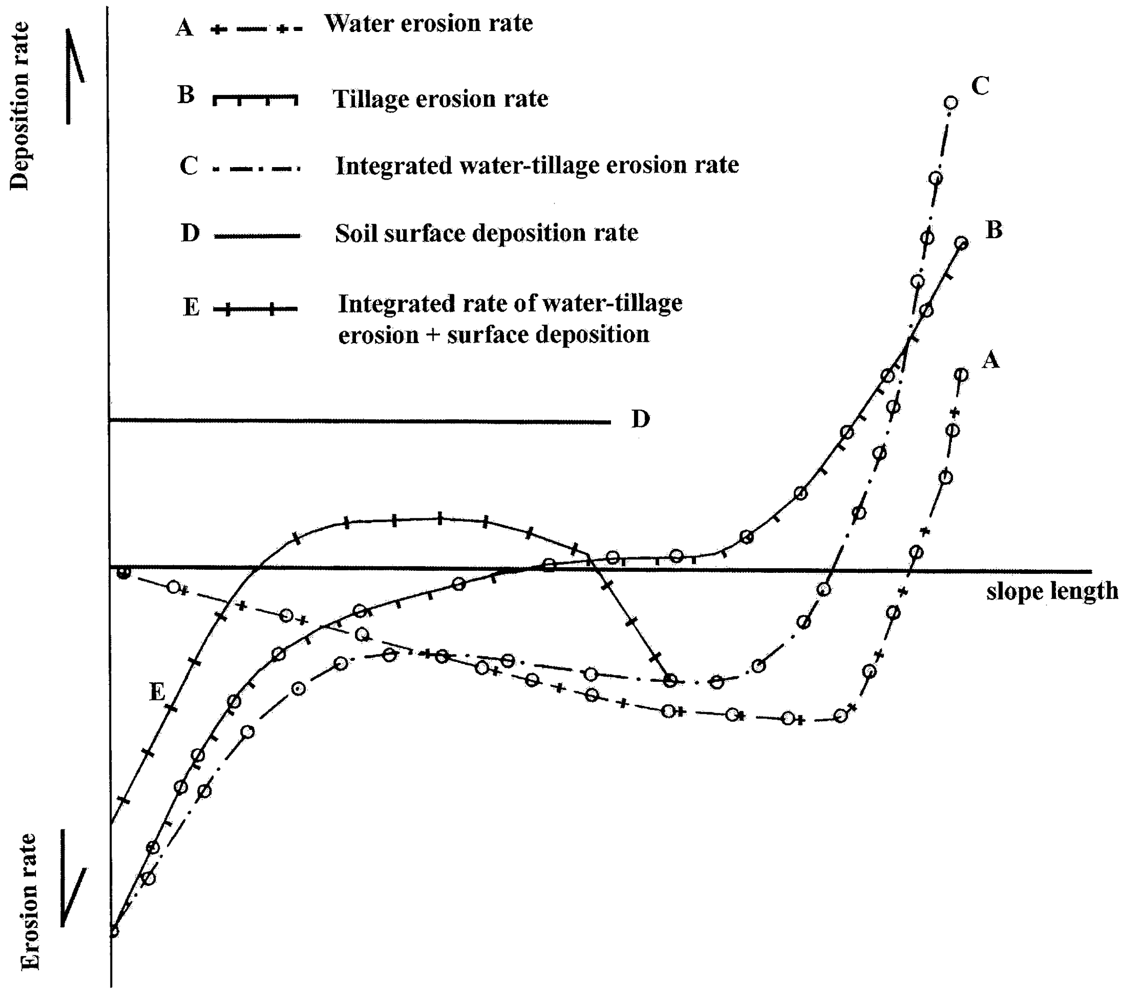

Figure 3. A sketch map of integrated of water and tillage erosion rates and soil surface deposition rate along a cultivated slope.

samples of Transect 1. The particle size composition of <2 mm fractions is very uniform both in profile and along the transect. The average composition is 47.7% sand (2-0.063 mm), 46.5 % silt (0.063 mm-0.002 mm), and 6.7% clay (<0.002 mm).

DISCUSSION

Effective ^{137}Cs reference inventory

When ^{137}Cs fallout is deposited with precipitation, part of ^{137}Cs may be lost directly with overland flow prior to being fixed with the surface soil particles. In addition, part of the fixing ^{137}Cs fallout enriched within the surface horizons may be lost prior to mixing into the ploughing layer by water erosion, mainly by inter-rill erosion, during the nuclear weapons testing period of 1950's-1970's. It is difficult to obtain the values of the ^{137}Cs loss directly with overland flow and of the surface-enriched ^{137}Cs loss by water erosion, although some progresses have been made to assess the values (Walling and He, 1997). The assessment needs necessary information, which is impossible to be obtained in the study area of a remote high mountain region. The mixing ^{137}Cs fallout into the ploughing layer during the nuclear weapons testing period, which has involved in the erosion-ploughing integrated processes on cultivated land, is called the effective ^{137}Cs reference inventory.

For most of the cores either in the middle slope deposition zone or in the toe slope deposition zone on Transects 1 and 3, the maximum ^{137}Cs concentration usually occurs at the bottom of the ^{137}Cs distributed layer, then the concentration slightly decreases upward. During the nuclear weapons testing period, part of ^{137}Cs fallout might be lost directly with runoff during a storm , and part of surface enriched ^{137}Cs might be lost when the surface soil was eroded . Then, the eroded surface soil was replaced by mixing of the subsoil by cultivation, and the ^{137}Cs concentration in the ploughing layer was diluted by the mixing. It is apparent that the replacement and mixing had little influence on the ^{137}Cs concentration of the bottom soil of the ploughing layer. The effective ^{137}Cs reference inventory can be estimated from the ^{137}Cs concentration of the bottom layer of the ^{137}Cs distributed layer. It is expressed as:

$$A'_0=10Ce\cdot H\cdot\gamma \quad (1)$$

where, A'_0= the effective ^{137}Cs reference inventory, Bq/m^2; γ = the soil bulk density, g/cm^3; Ce = the maximum ^{137} Cs concentration of the bottom layers in a ^{137} Cs depth profile at a deposition zone, Bq/m^2; H= the depth of ploughing layer, cm.

The mean ^{137}Cs concentration of the bottom layer at deposition sites of Transect 1 and 3 is 14.83 Bq/kg (13.76-16.58 Bq/kg) and the mean bulk density of <2 mm fractions soil is 0.64 g/cm^3 (n=6), taking ploughing depth = 25cm, the effective ^{137}Cs inventory is 2373.9 Bq/m^2 which accounts for 65.8 % of the true ^{137}Cs reference inventory obtained from the flat reference field.

Soil redistrib ution processes along a slope of the study f ield

Runoff and tillage on a cultivated slope commonly cause soil redistribution. For a long and even cultivated slope with a short concave toe, water erosion usually increases as slope length increases until near the toe of the slope (Fig 3 A). Manual hoe-tillage has a maximum erosion rate at the top of the slope and a maximum deposition rate at the toe of the slope and tillage erosion rate slightly decrease as slope length increases on the middle slope (Fig.3 B). A integrated water - tillage erosion rate decreases as slope length increases at the top of the slope, then increases as slope length increases along the most of the slope until near the toe of the slope where it sharply decreases as slope length increases (Fig 3 C). If soil is deposited on the ground surface of a certain part of a cultivated slope with a uniform deposition rate (Fig.3 D), the integrated erosion rate (Fig.3 E) is the sum of water and tillage erosion and the soil surface deposition, and the variation pattern of this integrated rate along a slope is different from the water-tillage integrated erosion rate.

For a short cultivated slope where water erosion is limited, deposition of either transported sediment by runoff or transported soil by tillage at the toe of a slope often immediately follows the tillage erosion at the top of the slope. Therefore, the integrated water - tillage erosion rate always decreases as well as slope length increases from the top to the toe for a short cultivated slope.

The variations of ^{137}Cs inventory along Transects 1 are different from the variation of water-tillage erosion integrated rate along a long cultivated slope. The ^{137}Cs inventory increases as slope length increases from the upper slope erosion zone to the middle slope deposition zone, then decreases as slope length increases from the middle deposition zone to the lower slope erosion zone, finally sharp increases from the lower slope erosion zone to the slope toe deposition zone, along the slopes of Transects 1. The ^{137}Cs depth distribution indicates that net deposition occurs at the middle slope deposition zone. The variation of ^{137}Cs inventory along the slope of Transect 1 (Fig.2) is similar to that of the water-tillage erosion + soil surface deposition integrated rate along a long cultivated slope (Fig.3 E). Soil deposition on the ground surface is caused by spreading of the cliff failure products of small slumps or debris avalanches, which deposit at the top of the slopes in the study field. Farmers usually spread the failure products at the head of the field. The integrated erosion rate of water-tillage erosion + soil surface deposition of spreading failure products is different from the water-tillage integrated rate as previously described.

Soil redistrib ution r ates

For an eroding point on cultivated land, the loss of cultivated soil containing ^{137}Cs due to either water erosion or tillage will be replaced by subsoil containing no ^{137}Cs in order to maintain a constant depth for the ploughing layer. The erosion rate can be estimated by using the refined simplified mass balance model:

$$A=A'_0\left(1-P\frac{h}{H}\right)^{n-1963} \quad (2)$$

where: A'_0= the effective ^{137}Cs reference inventory (Bq/m^2), A= the ^{137}Cs inventory at an eroding point (Bq/m^2), P= the parameter for particle size selectivity; h= the annual eroded soil depth (cm); H= the ploughing depth (cm); n= the sampling year.

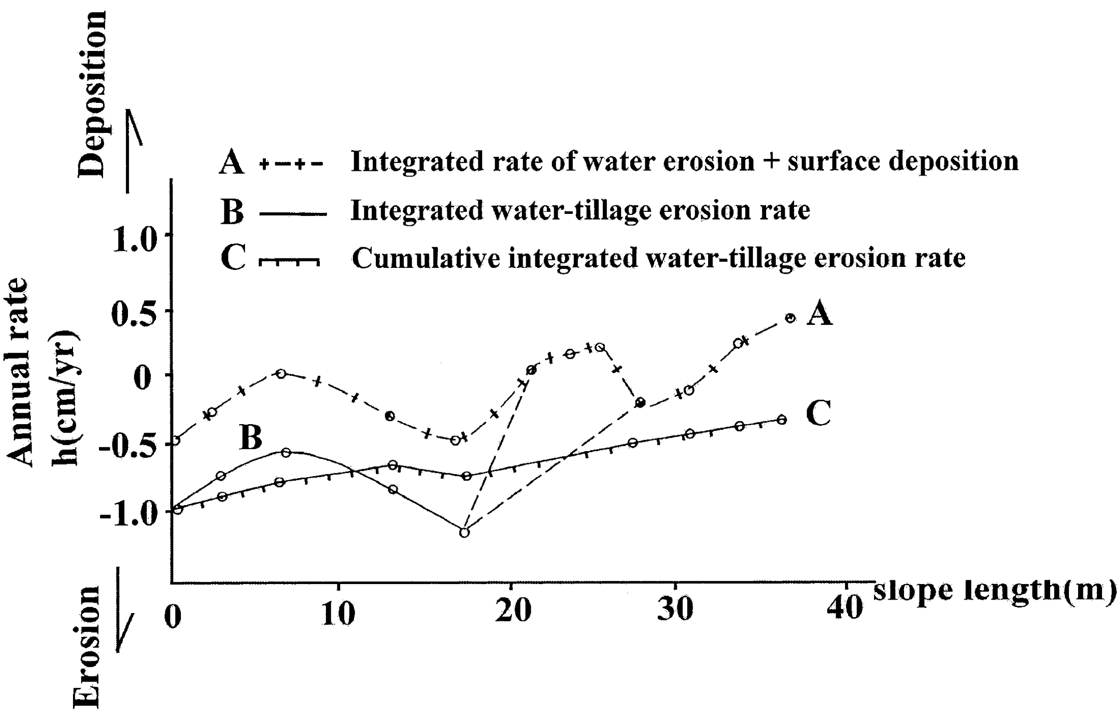

Figure 4. Variation of different erosion rates along transect 1.

On the sloping field under study, where eroded cultivated soil may be replaced by soil surface deposits of slope failure products, Equation 2 can still be used to estimate erosion rates if deposition rates are less than erosion rates, because the failure deposits contain little ^{137}Cs. The uniform texture of <2 mm fractions over Transect 1 indicates that there is no significant particle size selection for <2 mm fractions, and ^{137}Cs inventory is measured from the <2 mm fractions, so, P = 1.

An accumulative value of the water -tillage erosion integrated rate at the toe of a cultivated slope is representative of the average water erosion rate over the slope, because tillage doesn't remove cultivated soil out of a field. It can be expressed as:

$$\bar{h} = \frac{\sum_{i=1} h_i \, \Delta L_i}{L} \tag{3}$$

where: $\bar{h}$ = the average annual water eroded soil depth by runoff (cm); L= the slope length (m); hi = the annual eroded soil depth at a point (cm); ΔLi = the segment slope length (m).

Variations of different soil redistribution rates along the slope of transect 1 are illustrated in Fig.4. The point erosion rate in the upper slope and the lower slope erosion zones is derived from the ^{137}Cs depletion. The point erosion rate in the middle slope and the slope toe deposition zones, derived from the ^{137}Cs distribution depth, is the integrated rate of water erosion, tillage erosion and soil surface deposition at a point (Fig.4 A). The integrated rate in both the upper slope and lower slope erosion zones, derived from the ^{137}Cs depletion, can be representative of the water-tillage integrated erosion rate because the water-tillage integrated erosion rate is greater than the soil surface deposition rate there. The integrated rate in the slope toe deposition zone, can also be representative of the water-tillage erosion integrated rate, because there is no soil surface deposition. The integrated rate in the middle slope deposition zone can't be representative of the water-tillage integrated erosion rate, because the soil surface deposition rate is greater than the water-tillage integrated erosion rate and only the upper part of the ploughing layer involves ^{137}Cs fallout loss through the ploughing-erosion processes.

The line between the last point in the upper erosion zone and the first point in the lower erosion zone is suggested to represent the water-tillage integrated erosion rate on the slope of the middle slope deposition zone. It is also suggested that the middle slope deposition zone suffered severe erosion although net deposition occurred there and that the cliff failure products may contribute majority of the lost soil from the slope of Transect 1. The average of annual soil loss depth is estimated to be 0.43 cm which is equal to an erosion rate of 2752 t/km^{2}yr for <2 mm fractions (γ= 0.64 g/cm^3), and 4914 t/km^{2}yr for bulk soil. The annual soil loss volume is 15.4 m^3 over the slope of Transect 1 in a one-metre width. The total net soil deposition volume over the slope in a one metre width across slope was 0.8 m^3 from 1963 to 1995 and the average annual net deposition volume was 0.025 m^3, which accounts for 0.16% of the annual soil loss from the slope.

On the slope of Transect 2, it was impossible to estimate water erosion rates for the slope of the transect, because most of the cores on the transect didn't reach the ^{137}Cs distributed depth.

On the slope of Transect 3, the upper subfield on a failure slope suffered severe erosion and the average annual soil loss depth is estimated to be 1.98 cm from the ^{137}Cs depletion. It is apparent that all mobilised sediment enters the middle subfield and some cultivated soil is also removed by tillage into the subfield, because there is no bank at the downslope boundary of the upper subfield. The average annual soil loss depth is estimated to be -0.03 cm for the middle subfield. The negative soil loss indicates that the local cultivated soil has not been eroded .The eroded soil in the middle subfield is predominantly contributed by the upper subfield. Assuming that all lost soil from the upper subfield is transported into the middle subfield, the average annual soil loss depth over the total slope of Transect 2 is estimated to be 0.75 cm which equal to 8571 t/ km^2 yr for bulk soil. The average annual soil loss volume is 21.8 m^3, while the average annual net soil deposition volume is 0.03 m^3 which accounts for 0.13% of the annual soil loss

CONCLUSIONS

1. Clearance of natural forests for cultivation on steep hillslopes in high mountain regions, such as the Mt.Gongga region in the upper Yangtze River Basin, induces not only severe water erosion, but also slope failures, which may contribute considerable amount of earth to water erosion.

2. The ^{137}Cs technique has the potential to investigate soil redistribution processes and to assess soil erosion rates as well as soil deposition rates for steep slopes. It should be noted that the ^{137}Cs depletion at a certain part of a cultivated slope may not be related to the soil loss, if the deposition rate is greater than the erosion rate or the deposited sediment and soil has considerable ^{137}Cs concentration.

3. The effective ^{137}Cs reference inventory for the study field, estimated from the bottom layer of a ^{137}Cs depth profile at the deposition zones, is 2373.9 Bq/m^2, which only accounts for 65.8% of the local ^{137}Cs reference inventory of 3607.7 Bq/m^2. It strongly indicates that a considerable amount of ^{137}Cs input was lost prior to incorporation into the ploughing layer from the study field under the conditions of stony soil, steep topography, and subtropical humid climate during nuclear weapons testing period.

4.The average water erosion rate is estimated to be 4914 t/km^{2}yr for a typical cultivated steep slope with an angle of 34º in the subtropical mountain ever green broad leaves forest zone in the Mt Gongga region. It can reach to 22856 t/km^{2}yr for a failure slope under cultivation. Although soil deposition occurs at slope toe or even on the middle slope, the deposited soil only accounts for less than 1% of the lost soil.

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