

## ARTICLE

# Effect of Land Cultivation on Soil Nutrient Sedimentation in Water at Southern China

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## ABSTRACT

Soil erosion associated with land cultivation exerts a great impact on ecological environment. Such an impact is specific of land, crop, tillage, management and so on. This study aimed to investigate the effects of crop cultivation on water quality by comparing nutrient distribution in the sediment at Southern China. Two sedimentation sites adjacent to the uncultivated (S1) and cultivated upland (S2) were selected and samples were analyzed. Results showed that soil pH decreased with the increasing depth above 20 cm and then kept relatively stable of the both sediments. Soil organic matter, nitrogen and phosphorus contents decreased with the increasing depth. There was no significant difference between two sediments in organic matter and nitrogen contents, but the total phosphorus and extractable phosphorus contents in S2 were much higher than that in S1. The data indicated that soil eroded from S2 could possess much high potential to deteriorate water quality. Nutrient sedimentation can reflect the history of soil erosion and provide useful information for sustainable soil management and water conservation through improving cultivation and tillage measures.

## 1. Introduction

Eutrophication of surface waters is one of the important factor governing environmental problems in the worldwide <sup>[1]</sup>. The effects of eutrophication can be potentially caused catastrophic with blue-green algal blooms which have resulted in livestock deaths and human sickness and interfered with water supplies <sup>[2,3]</sup>. Nutrients from point and nonpoint sources play important roles in accelerating eutrophication of water resources. Nutrients from agricultural lands are a main nonpoint source and responsible for the eutrophication of river and

lake in the rural regions <sup>[4]</sup>. Soil erosion and runoff from agriculture are serious in the laterite region because of the highly intensive rainfall and land use associated with increasing population and the requirement of economic development <sup>[5,6]</sup>. Sediment in the waters receives materials from wet and dry precipitation from air as well as soil erosion and runoff from uplands <sup>[7]</sup>. But due to adjacent to the lands, the sediment may be resulted from the soil erosion and runoff from the land <sup>[8]</sup>. Therefore, the distribution of nutrients in the sediment can represent the status of soil erosion and then reflect its implications on water quality <sup>[9]</sup>.

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Eroded soil enters water body and deposits in the form of sediment<sup>[10]</sup>. The exchange of energy and material between water and sediment can represent and reflect the effect of eroded soil on water quality, while this exchange is determined in a main extent by the characteristic and property of the sediment<sup>[11]</sup>. Nutrient distribution in the sediment is therefore the first important step to concern the complex relationship between soil erosion and water quality<sup>[12,13]</sup>. Thus, the aim of this study is to describe the distribution pattern of nutrients in the sediment dominated by soil erosion in a typical erosion region, which can provide useful information of the effects of soil erosion on the water quality and environment. Moreover, the <sup>137</sup>Cs isotope tracer technique was successful used in soil erosion rate estimation and sediment source identification<sup>[14]</sup>. The measurement of <sup>137</sup>Cs in the sediment here was to verify and confirm the source of sediment from eroded soil.

## 2. Materials and Methods

### 2.1 Study Area

The sample area was located near the Ecological Experimental Station of Red Soil, Yujiang County, Jiangxi Province, China. This area is in a typical subtropical monsoon climate region with a mean temperature 17.8°C and annual precipitation approximately 1800 mm during the year of 1988-1998. The topography in the study area is mainly of low hills varied from 30 to 60 m with slopes ranging from 3° to 15°. The soils can be classified as a fine, mixed, hyperthermic, Typic Hapludult<sup>[15]</sup>.

The selected uncultivated land is located at the position of 28.12°N, 116.56°E and has approximate 5 ha with an average slope of 12°. The area is covered predominantly with sparse masson pines (*Pinus massoniana*). The cultivated land lies at the position of 28.23°N, 116.35°E and its area is 6 ha with a slope of 10°. A peanut-cape rotation is adopted traditionally on the cultivated land with an average tillage depth of 15 cm.

### 2.2 Sampling Method

Soil samples in the uncultivated and cultivated lands were collected using a method of multi-point mixture. Sediment samples (S1 and S2) were taken from the downward deposit places neighboring to the uncultivated and cultivated land, respectively. Three sediment columns within one square meter were collected using a sediment corer. The vertical depth of S1 sediment column was 44 cm and that of S2 sediment column was 42 cm. Soil samples in each column were cut into 2 cm segment. Sample collection date was April of 2018.

## 2.3 Soil Analysis

The samples were air dried and crushed to pass through a 2-mm sieve. pH was determined by glass electrode with 2.5:1 ratio of water to soil. Organic matter was analyzed with wet combustion described by Nelson and Sommer<sup>[16]</sup>. Total nitrogen was determined by Kjeldahl method<sup>[8]</sup>. Total phosphorus (P) and extractable P were determined by the digestion method and extracted with 0.5 M NaHCO<sub>3</sub>, respectively<sup>[17]</sup>. Phosphorus contents were determined by molybdenum-blue spectrometer method. Cation-exchange capacity (CEC) of soils was determined as described by Jackson<sup>[18]</sup>. The <sup>137</sup>Cs activity was measured by g-ray energy spectrometry. The samples were placed in a standard Marinelli beaker which was then located on a horizontally oriented 25% relative efficiency hyper-pure germanium (HPGE) g-ray detector (Ortec, USA). The detector was coupled to spectroscopy-grade amplifiers and a PC-based data collection system. Calibration samples were used to derive the absolute <sup>137</sup>Cs activity in each sample. The average g-ray detection efficiency was dependent upon the mass of the sample in the beaker, a further correction was made.

## 3. Results

### 3.1 Soil pH

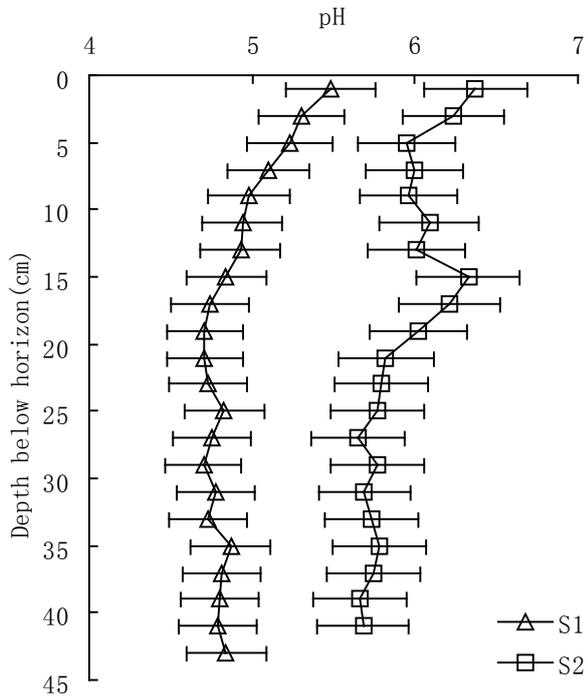
pH in the sediments was shown in Figure 1. In general, the pH of S2 was higher than that of S1 with pair comparison (Figure 1). Obviously, pH decreased with increasing depth in the profile above 20 cm and then was kept relatively stable. pH in the uncultivated lands in laterite region is commonly lower than 5, however pH of the cultivated lands in laterite region is usually higher than 5 (Table 1).

**Table 1.** Selected chemical and physical properties of soil in uncultivated and cultivated uplands

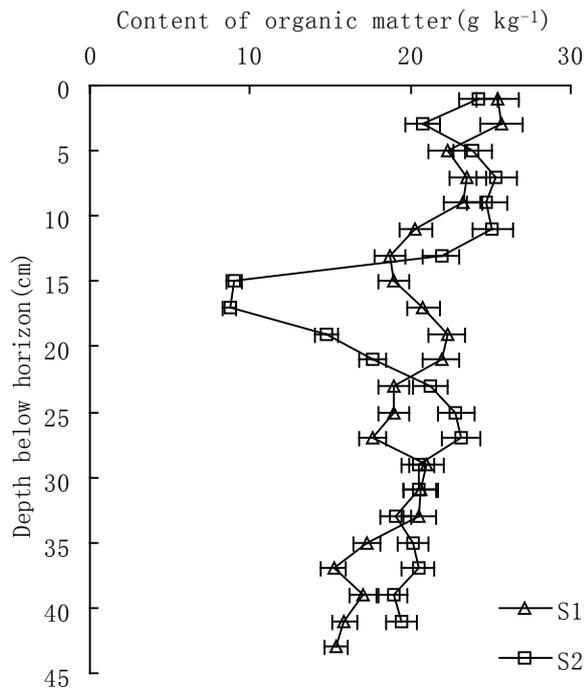
Soil	pH	Organic matter	Total N	Total P	Extractable P	CEC
	(2.5:1)	(g kg <sup>-1</sup> )	(g kg <sup>-1</sup> )	(g kg <sup>-1</sup> )	(mg kg <sup>-1</sup> )	(cmol kg <sup>-1</sup> )
Cultivated	5.15±0.25	28.81±4.56	1.59±0.11	0.31±0.09	0.96±0.12	84.58±3.21
Uncultivated	4.87±0.26	15.23±3.78	0.87±0.13	0.22±0.08	0.06±0.03	75.56±3.45

### 3.2 Soil Organic Matter

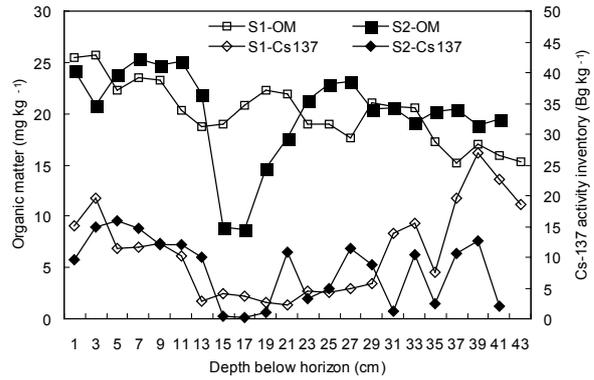
It can be seen from Table 1 that the organic matter content in the cultivated land was significantly higher than that in uncultivated upland. As shown in Figure 2, in both sediments, organic matter contents almost decreased with increasing depth. But there was no significant difference between two sediments except for an abrupt decrease in



**Figure 1.** Value of pH varied with the depth in sediment S2 at about 15 cm depth. However, there was only slight difference between the two sediments in organic matter contents (Figure 2). As can be seen from the Figure 3, there is a good correlation between the <sup>137</sup>Cs activity list and the organic matter content in the sediment.



**Figure 2.** Content of organic matter in the sediment varied with the depth



**Figure 3.** Organic matter and <sup>137</sup>Cs activity inventory in sediment

### 3.3 Soil Nitrogen

The contents of nitrogen (N) and organic matter (C) always had a good linear relationship in the laterite region. Here, the relationship between N and C of two sediment points (S1 and S2) in current study could be described as:

$$N=0.0615C-0.1149, R=0.8727^{**} \quad (n=22, S1)$$

$$N=0.0698C-0.1712, R=0.9627^{**} \quad (n=21, S2)$$

The C:N ratio in this study ranged from 14.5 to 22.8 with an average of 17.4 at both sediment points.

### 3.4 Soil Phosphorus

The total phosphorus distribution is shown in the Figure 4. Except for the fluctuation, total P content in S2 was higher than that in S1. Similarly, the extractable P in S2 was much higher than that in S1 (Figure 5). These results were accordant to that in the corresponding uplands (Table 1).

Inferred from the pH result, the surface layer of 20 cm in the sediment may contribute extractable P to the water. Assumed that extractable P in the 20 cm layer can diffuse and mixed completely with the surface water, we can make a simple estimation to determine the water depth ( $H_w$ ) for achieving the P concentration meeting the goal of water management. Here, the following equation can be used to estimate the depth,  $H_w$ ,

$$\frac{\int_0^h C_p \cdot Ha \cdot S \cdot \rho_s}{H_w \cdot S \cdot \rho_w} \leq C_0,$$

where,  $C_p$  is the extractable P concentration in the sediment,  $Ha$  is the active layer depth of sediment (i.e., 20 cm in this study),  $S$  is the area,  $\rho_s$  is the density of the sediment,  $\rho_w$  is water density,  $C_0$  is the P concentration for

a goal to control, and  $H_w$  is the water depth for achieving the goal concentration,  $C_0$ . Assumed  $C_0=0.02 \text{ mg kg}^{-1}$ , which is the threshold concentration for water eutrophication, we obtained that  $H_w$  was 12 and 140 m in the sediment of S1 and S2, respectively.

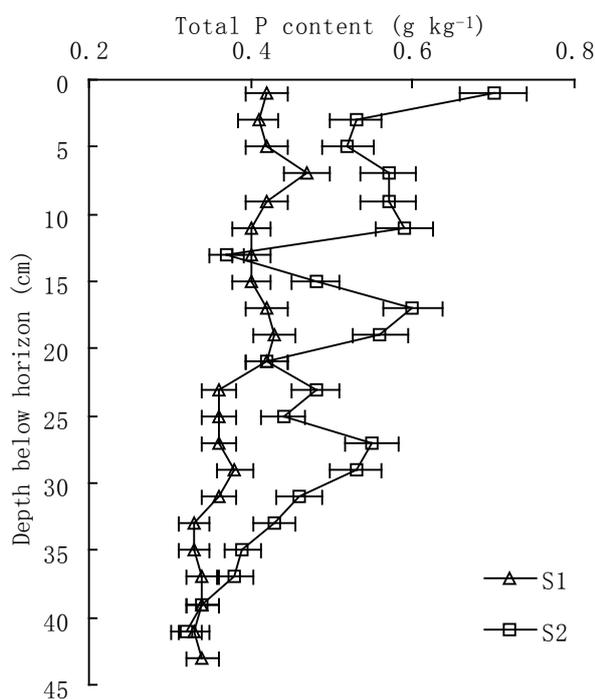


Figure 4. Vertical distribution of total P in sediment

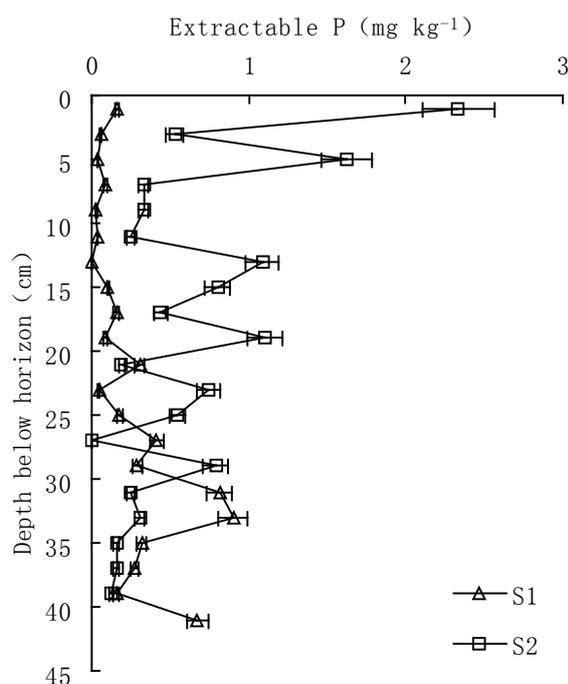


Figure 5. Extractable P distribution with depth in sediment

#### 4. Discussion

pH is a comprehensive indicator of the physical and chemical properties of the medium environment (including water, soil, etc.)<sup>[19,20,21]</sup>. In this study, we found that the pH of uncultivated land in the laterite area is usually less than 5 (Table 1). But pH varied with different field managements and practices in the cultivated lands, e.g. it was higher when upland was changed to paddy rice field under the same conditions<sup>[22,23]</sup>. According to pH variation in sediment profile, the surface layer of 20 cm depth is an active layer between water and sediment in material and energy exchange. This surface layer plays the most important role on water quality and vice versa. Hence, it can be inferred that the measurement of pH is an effective and rapid method to determine the depth of active layer between sediment and water in lake.

Soil organic matter is an important component of soil, and it plays a decisive role in the formation of soil structure and the improvement of soil physical conditions<sup>[24,25]</sup>. The level of soil organic matter reflects the level of soil productivity<sup>[26,27]</sup>. With long term cultivation and high nutrients input, soils, such as rice and vegetable soils contain high organic matter in the laterite regions<sup>[22,28,29]</sup>. Therefore, it was a common phenomenon that organic matter content in cultivated land was much higher than that in uncultivated land (Table 1). However, there was only slight difference between the two sediments in organic matter contents (Figure 2). It remained not fully comprehension.

The characteristic of organic matter distribution in the sediment is always determined by the deposit rate in lakes, and oxygen exposure time to organic matter may be responsible for the preservation of organic matter in the sediments<sup>[30,31]</sup>. In the lake sediment, organic matter mainly comes from biomass of plankton<sup>[32,33]</sup>. Because influenced greatly by soil erosion, the sedimentation points in this study differed great to the common sedimentation points. The inflexion point in organic matter vertical distribution of S2 (i.e. 14-18cm) demonstrated the influence obviously by soil erosion (Figure 2). This phenomenon can be confirmed through the good correlation between the inventory of <sup>137</sup>Cs activity and the content of organic matter in the sediment (Figure 3). Therefore, the dilution effect resulted from soil erosion was the main reason to shrink the discrepancy between two sediments. Moreover, organic matter in the soil eroded from cultivated land may be easily decomposed than that from uncultivated land<sup>[34,35,36]</sup>. Some other reasons difficult to be identified may also be responsible for the reason.

Similarly, the nitrogen contents in both sediments

showed the same distribution pattern as that of organic matter. The contents of nitrogen (N) and organic matter (C) always had a good linear relationship in the laterite region<sup>[37]</sup>. The C:N ratio in this study ranged from 14.5 to 22.8 with an average of 17.4 at both sediment points, which means those organic matter mainly came from upland not plankton. This once again suggested that the effect of soil erosion controlled the material source in sediment near two uplands.

Total phosphorus (P) distribution pattern was similar to that of organic matter in the sediment (Figure 4). Except for the fluctuation, total P content in S2 was higher than that in S1. Similarly, the extractable P in S2 was much higher than that in S1 (Figure 5). These results were accordant to that in the corresponding uplands (Table 1). In agricultural systems, adequate supplies of phosphorus are essential for seed and root formation, crop quality, and strength of straw in cereals and the accumulation and release of energy during cellular metabolism<sup>[38,39]</sup>. In order to sustain productivity, P in fertilizers, manures and animal fodders are imported to the agriculture system. With soil erosion and runoff, P moves from agricultural system into the environment. But even a small transfer of P from agricultural land can apparently contribute to eutrophication and the proliferation of undesirable biota in surface waters from a limnological perspective<sup>[40,41]</sup>. This means P is the most important limitation factor in fresh water system<sup>[42]</sup>. With the effective control and management of point-sources, there is an increasing concern that P losses from agricultural land considered to be a growing environmental problem around the world<sup>[43,44]</sup>.

P enters waters in the forms dissolved in liquid and contained in soil particle<sup>[45]</sup>. Particulate movement of P, often associated with soil erosion, is a physical mechanism for diffuse transfer from agriculture to waters and is an important process in determining P transfer<sup>[46]</sup>. Except for the release of P during transferring, the exchange of P between sediment and water also makes an important impact on water eutrophication<sup>[47,48]</sup>. The high content or concentration of P in the sediment is a main factor to accelerate the eutrophication process in waters. Especially, the sediment came from the cultivated land with high fertilizer and manure inputs<sup>[49,50]</sup>.

In the study, assumed  $C_0=0.02 \text{ mg kg}^{-1}$ , which is the threshold concentration for water eutrophication<sup>[51]</sup>, we obtained that  $H_w$  was 12 m and 140 m in the sediment of S1 and S2, respectively. Despite of the simple and overestimated data, it obviously indicated that the sediment from cultivated land had much higher potential to contribute to water eutrophication than that from uncultivated land.

Overall, the sediment near upland reflects and preserves

the history of agricultural management on soil erosion. Compared with the history of management practice, it can be useful for providing reasonable information for agricultural cultivation, consequently controlling soil erosion and minimizing the influence on waters.

## 5. Conclusions

The active layer in the sediment can be determined using pH measurement. P content is an effective index to indicate the influence of eroded soil on water rather than organic matter and nitrogen in the sediment, because P is stable and not decomposable in the process of soil erosion. The results elucidated that eroded soil from cultivated land had higher potential to damage water quality than that from the uncultivated land. Through investigating the nutrient distribution in the sediment near upland, it can provide a piece of useful information for evaluating the effect of soil erosion on water quality.

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