The Characteristics of Soil Nutrients in Terracing Land under Different Land Use Patterns in Three Gorges Reservoir Area

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Abstract In this study, taking the typical terracing land in Wushan County of Chongqing Municipality for example, we study the distribution of soil nutrients in the terracing land under different land use patterns in Three Gorges Reservoir Area. We conduct field survey and sampling on three different land use patterns (cash crop land, food crop land and abandoned land), and do the indoor experimental analysis of soil nutrient indicators. The results indicate that there is significant or very significant impact on soil nutrients under different land use patterns. The content of soil organic matter declines in sequence from abandoned land, food crop land to cash crop land; the content of soil N declines in sequence from cash crop land, abandoned land to food crop land; the content of soil P declines in sequence from cash crop land, food crop land to abandoned land; the content of soil K declines in sequence from abandoned land, cash crop land to food crop land. The result is in close relation to land use patterns, human cultivation activity, land disturbance and application of fertilizer.

Key words Three Gorges Reservoir Area, Terracing land, Land use patterns, Soil nutrients

1 Introduction

The soil is not uniform and is a constantly changing continuum. Land use, as a comprehensive reflection of human land use activities, is the most direct and most profound factor affecting the content of soil nutrients[1]. Many domestic and foreign scholars suggest that different land use patterns, different farming systems and management modes will inevitably lead to changes in soil properties and land productivity[2-4]. From the current research, the studies on the soil nutrient characteristics under different land use patterns have been related to a variety of typical areas, including mountains, plateaus, hills, plains, basins, etc. These areas also relates to a variety of soil types (such as aquic brown soil, red soil, paddy soil, aeolian sandy soil, purple soil) and various kinds of ecological environment (such as wetland ecology, alpine subtropical climate)[5-9], but there are few studies on soil nutrients in terracing land of Three Gorges Reservoir Area. This paper studied the content of soil nutrients in terracing land under different land use patterns in Wushan County of Three Gorges Reservoir Area, in order to provide reference and basis for reasonable fertilization and establishment of positive agro-ecosystems.

2 Materials and methods

2.1 Overview of the study area The typical terracing land is selected from Longshan Village, Longjing Township, Wushan County, Chongqing City, and the soil is yellow soil. The landform is dominated by denuded and eroded low mountains, and the plot altitude is 890 - 1065 m. It features a subtropical humid monsoon climate, and there are significant seasonal variations. The average annual temperature is 18.4℃, and the seasonal distribution of rainfall is very uneven. Rainfall is mainly concentrated in May-October, and the strong rainfall causes serious soil erosion. The soil erosion type is water erosion, and the soil erosion pattern is based on sheet erosion and channel erosion. In the sampling area, the sloping fields were reformed to terraced fields in the 1970s. The three typical land use patterns include food crop land, cash crop land and abandoned land. Food crops include maize, sweet potato and wheat, with coverage of <20%; cash crops include rape, tobacco and sunflower, with coverage of <30%; abandoned land is mainly covered with shrubs, weeds and pines, in the form of waste hills and slopes without human interference, with coverage of 35% to 55%.

2.2 Methods and materials

2.2.1 Soil sample collection. The sampling site is the terracing project area, and the sampling time is April. The soil sample collection is in accordance with the basic principle of equidistance, and the topsoil is collected in each sampling point according to "S" type distribution. The cross-section soil samples are taken in representative places, and processed with the quartering method after being mixed. Finally, 1 kg of remaining sample is brought back to the laboratory for analysis. In this study, a total of 151 sampling points from top to down (see Table 1). At the same time, the GPS locator is used to determine the latitude and longitude, and record many parameters such as soil type, gradient, slope position, elevation and vegetation coverage. The nutrient input, field management and other factors that affect soil nutrient cycling are investigated and recorded.

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Table 1 Soil sampling point

Classification	Number of samples	Location	Altitude	Topography	Land use pattern	Soil type
Cash crop land	56	109°47′42E 31°29′18N	991 – 1032m	Low hills	Rape, flue-cured tobacco, sunflower, *etc.*	Yellow soil
Food crop land	46	109°47′16E 31°06′15N	692 – 1021m	Low hills	Maize, sweet potato, wheat, *etc.*	Yellow soil
Abandoned land	49	109°47′29E 30°59′15N	940 – 1165m	Low hills	Bushes, weeds, pines, *etc.*	Yellow soil

2.2.2 Analysis and calculation of soil samples. The plant roots, leaves and gravel are firstly removed, and the samples are placed in room for air-drying. The air-dried soil samples are poured onto a wooden plate with steel glass bottom and pulverized with a stick so that they all pass through a 2 mm sieve. After being mixed thoroughly, the samples are divided into two parts by quartering method, and one part of them are used for further pulverization so that they can pass through 1 mm and 0. 25 mm sieves for chemical analysis. The soil organic matter, total N, NH_4-N, total P, available P, total K and available K are selected as 7 indicators, and the measuring methods for indicators are shown in Table 2[21].

Table 2 Soil analysis items and determination methods

Analysis items	Determination methods
Organic matter	Potassium dichromate method
Total N	Semi-micro Kjeldahl method
NH_4-N	2 moloL^{-1} KCl extraction-distillation method
Total P	NaOH melting-Mo-Sb colorimetric method
Available P	Hydrochloric acid-sulfuric acid extraction method
Total K	NaOH melting-atomic absorption spectrometry
Available K	Neutral NH_4OAc extraction-atomic absorption spectrometry

2.2.3 Data processing. The sample recording table and nutrient data are classified according to the land type. SPSS 17.0, one-factor analysis of variance, multiple comparisons of mean and nonparametric test method are used for significance analysis of soil testing data. The single sample KS test method is used for normal distribution testing.

3 Results and analysis

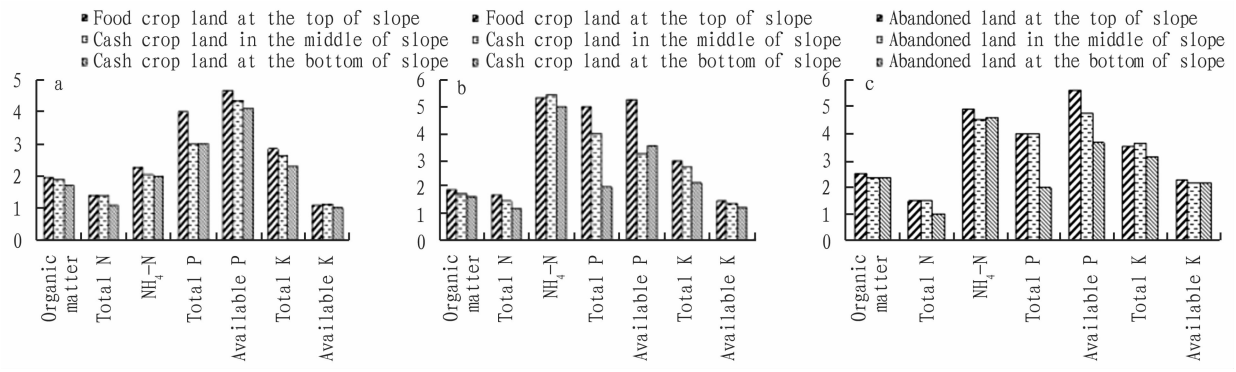
3.1 Content of soil nutrients From Table 3, it is found that the content of soil organic matter in the sampling area is 0.95 – 2.94%; the content of total N, NH_4-N, total P, available P, total K and available K is 0.07 – 0.18%, 15.87 – 66.29 mg/kg, 0.03 – 0.05%, 1.26 – 10.06 mg/kg, 1.81 – 2.61%, 79.70 – 235.50 mg/kg, respectively. According to the national classification standard of soil nutrient levels, the content of the 7 indicators is at the middle and lower level, and the content of soil organic matter is low, with an average of 1.93%, lower than the average content of yellow soil organic matter in Three Gorges Reservoir Area, in a state of shortage; the content of total N, total P and available K is at the middle level, with an average of 0.13%, 0.04%, 148.55 mg/kg, respectively; the average content of total K is 2.27%, in a state of serious shortage; the average content of available P is 3.59 mg/kg, in a state of serious shortage, reaching Level 5 of National Soil Survey Standards[22], and 55% of samples reach Level 6 (available P content < 3 mg/kg). The coefficient of variation of 7 indicators is 10% – 100%, falling within moderate variation; the coefficient of variation of available P is highest, reaching 62.5%, which is related to the low mobility of phosphorus in the soil; the coefficient of variation of NH_4-N is 41.3% and the coefficient of variation of total K is lowest, reaching 11.8%. There is a significant positive correlation between soil organic matter and total N in all samples ($\alpha = 0.0$, $R = 0.949^{**}$), because soil organic matter is an important source of nitrogen in the soil, and the soil organic N accounts for 80 – 98% of total N.

Table 3 Statistical analysis of different soil nutrients

Indicators	Minimum	Maximum	Mean	Standard deviation	Coefficient of variation	Distribution type
Organic matter//%	0.95	2.94	1.93	0.59	0.309	Normal
Total N//%	0.07	0.18	0.13	0.03	0.228	Normal
NH_4-N//mg/kg	15.87	66.29	37.45	15.48	0.413	Normal
Total P//%	0.03	0.05	0.04	0.01	0.625	Lognormal
Available P//mg/kg	1.26	10.06	3.59	2.24	0.169	Lognormal
Total K//%	1.81	2.61	2.27	0.27	0.334	Normal
Available K//mg/kg	79.70	235.50	148.55	49.65	0.118	Lognormal

3.2 Different slope position characteristics of soil nutrients As can be seen from Fig. 1, the content of nutrients shows a trend of gradual increase from the top of the slope to the bottom of the slope. The abundant rainfall in the study area causes many mineral components to migrate from the top to the bottom with surface runoff and subsurface runoff, so the soil layer gradually thickens from the top to the bottom and soil nutrients gradually increase. However, the content difference among many soil nutrients is not significant. The small relative elevation difference may be one of the reasons why nutrient difference is not significant in different slope po-

sition. This also shows that the content of soil nutrients in different slope position is more dependent on the difference of land use patterns.



Note: a. food crop land; b. cash crop land; c. abandoned land

Fig. 1 The content of soil nutrients in different slope position

3.3 The content of soil nutrients under different land use patterns Because of different land use patterns, vegetation cover will be different, having a direct impact on soil nutrient input and output, thus affecting the storage of soil nutrients. As can be seen from Table 4, three different land use patterns have a significant impact on the content of soil organic matter and nutrients, and the degree of impact is in the order of NH_4-N > available K > total K > total N > organic matter > total P > available P.

Table 4 The content of soil nutrients under different land use patterns

Indicators	Organic matter//%	Total N//%	NH_4-N//mg/kg	Total P//%	Available P//mg/kg	Total K//%	Available K//mg/kg
Food crop land	1.77^{b}(0.190)	0.11^{b}(0.009)	19.74^{c}(2.47)	0.03^{a}(0.0014)	4.23^{a}(1.360)	2.40^{b}(0.033)	104.61^{b}(12.440)
Cash crop land	1.61^{b}(0.310)	0.15^{a}(0.006)	50.72^{a}(3.95)	0.03^{a}(0.0017)	4.89^{a}(0.530)	2.47^{b}(0.039)	135.88^{b}(9.260)
Abandoned land	2.40^{a}(0.230)	0.12^{b}(0.012)	41.90^{b}(1.63)	0.04^{a}(0.0011)	3.95^{a}(0.390)	3.13^{a}(0.054)	205.17^{a}(8.860)
sig.	0.041 *	0.038 *	0.002 **	0.07	0.402	0.003 **	0.002 **

Note: The organic matter, total N are compared using single factor analysis of variance, and other indicators are compared using non-parametric test; the least significant difference (LSD) method is used for multiple comparison; there are no significant differences in the mean of the same letter in each column, * represents 0.05 significance level and ** represents 0.01 significance level; what inside brackets is standard error.

3.3.1 The content of soil organic matter. The soil erosion is serious in the region, and the content of organic matter in the local yellow soil is generally low, having become the limiting factor for the fertility of this soil type[23]. By analyzing the data, it is found that the content of soil organic matter in abandoned land is high, significantly higher than that of the other two land types; there is a small difference in organic matter content between food crop land and cash crop land. In the state of abandonment, there is little human interference, and the high vegetation coverage, rapidly growing biomass and high organic matter accumulation lead to high content of soil organic matter. The chemical fertilizers are mainly used for arable land, and great human disturbance, serious soil erosion and rapid decomposition of organic matter result in low content of soil organic matter. Obviously, reverting farmland to forest and grassland is an important way to increase soil organic matter and restore soil fertility.

3.3.2 The content of soil N. Soil N is mainly from decomposition of animal and plant residues, use of human organic or inorganic fertilizer and fixation of soil microbes. Table 4 shows that under different land use patterns, the ranking of soil total N content and NH_4-N content is the same; highest for cash crop land while lowest for food crop land. The total N and NH_4-N content of flue-cured tobacco, rape and sunflower is significantly higher than that of food crop. After the woodland or abandoned land is reclaimed into arable land, the available N drains away with the soil erosion, thus leading to a rapid decline in soil N content. There is a big difference in soil N content between cash crops and food crops, which is mainly due to the difference in fertilization level.

3.3.3 The content of soil P. Table 4 shows that under three land use patterns, there is no significant difference in the content of soil total P and available P. The average content of available P is in the order of cash crop land > food crop land > abandoned land. On the whole, the soil P content of crop land is higher than that of woodland and unused grassland, which is related to farming and fertilization. With the application of compound fertilizer, special fertilizer and soil testing and fertilizer recommendation, the current farmers pay more attention to the use of P fertilizer, which has a positive impact on the rapid increase of P in arable land. Compared to other regions, the content of P in land of this area is still at a low level, possibly because when the serious local rainfall erosion results in a huge loss of top soil nutrients and low content of P in soil.

3.3.4 The content of soil K. Since IPI was established in 1995, many countries have attached great importance to soil P[24]. There are significant differences in P content under three land use patterns. The total K and available K content is highest in abandoned

land, followed by cash crop land and food crop land. There is a small difference in K content between cash crop land and food crop land. This is because the vegetation coverage is low in crop land, the human disturbance is intense and soil erosion is serious, which not only washes away a lot of sediment, but also causes the loss of soil soluble nutrients (such as K) with the runoff[25]. Contrastingly, the soil erosion is light in abandoned land, the soil nutrients including P are not easy to be lost, and the decomposition of dead twigs and withered leaves or rotted grass roots can return some nutrients (such as K) to the soil, which makes the content of K in abandoned land much higher than in cash crop land and food crop land.

4 Conclusions

Taking the typical terracing land in Wushan County for example, we study the distribution of soil nutrients in the terracing land under different land use patterns in Three Gorges Reservoir Area. We conduct field survey and sampling on three different land use patterns (cash crop land, food crop land and abandoned land), and do the indoor experimental analysis of soil nutrient indicators. The results indicate that there is significant or very significant impact on soil nutrients under different land use patterns. The content of soil organic matter declines in sequence from abandoned land, food crop land to cash crop land; the content of soil N declines in sequence from cash crop land, abandoned land to food crop land; the content of soil P declines in sequence from cash crop land, food crop land to abandoned land; the content of soil K declines in sequence from abandoned land, cash crop land to food crop land. The result is in close relation to land use patterns, human cultivation activity, land disturbance and application of fertilizer. In short, rational land use patterns and moderately making land lie fallow can effectively improve soil fertility, which is of great significance to maintaining soil and water resources in mountainous areas and increasing agricultural efficiency.

References

[1] GUO XD, FU BJ, CHEN LD, *et al.* Effects of land use on soil quality in a hilly area——A case study in Zunhua County of Hebei Province[J]. Acta Geographica Sinica, 2001, 56(4): 447 – 455. (in Chinese).

[2] ZENG XB, SUN N, GAO JS, *et al.* Effects of cropping system change for paddy field with double harvest Rice on the crops growth and soil nutrient [J]. Scientia Agricultura Sinica, 2007, 40(6): 1198 ~ 1205. (in Chinese).

[3] JEFFREY AH, JPNATHANAS. Anthropogenic effects on soil quality of ancient agricultural systems of the American Southwest[J]. Catena, 2011, 85(2): 144 – 154.

[4] HOU XY, HAN XZ, WANG SQ, *et al.* Different land uses and management effects on soil fertilities in black soil[J]. Journal of Soil and Water Conservation, 2008, 22(6): 99 – 103. (in Chinese).

[5] WANG TM, ZHU B, GAO MR. Nutrient content in different land use types in a watershed in the soil of central hilly area of Sichuan, China [J]. Journal of Mountain Research, 2006, 24(B10): 88 – 91. (in Chinese).

[6] WANG F, XIAO HL, SU YZ, *et al.* Effects of land use type on soil quality in marginal oasis of the middle Heihe River[J]. Journal of Arid Land Resources and Environment, 2010, 24(7): 165 ~ 170. (in Chinese).

[7] LI QY, YU XX, XIN ZB, *et al.* Analysis on soil physical properties of different land uses in a typical watershed of the Loess Plateau[J]. Research of Soil and Water Conservation, 2010, 17(6): 106 ~ 114. (in Chinese).

[8] ZHANG LP, ZHANG RB, CHEN ZY, *et al.* Spatial distribution of soil nutrient on sloping land with changed land utilization ways in suburbs[J]. Bulletin of Soil and Water Conservation, 2007, 27(1): 39 – 46. (in Chinese).

[9] ISLAM KR, WEIL RR. Land use effects on soil quality in a tropical forest ecosystem of Bangladesh[J]. Agricultule, Ecosystem and Environment, 2000, 79: 9 – 16.

[10] CHEN SW, DENG W, QIU JG. Study on environmental effects under different terracing ways[J]. Journal of Anhui Agricultural Sciences, 2008, 36(19): 8251 – 8254. (in Chinese).

[11] XIONG PS, XIE SY, MO XX. The characteristics of soil erosion and ways of ecologic restoration in Three Gorges Reservoir of Changjiang River[J]. Research of Soil and Water Conservation, 2006: 13(2): 272 – 273. (in Chinese).

[12] CAI QG, ZHANG GY, WU SA, *et al.* An analysis on the stability of terracein the Three Gorges Reservoir Area[J]. geographical Research, 1997, 16(1): 46 – 52. (in Chinese).

[13] YANG YS, LIANG Y, LIU JJ. A study on soil loss in slope land and oravitational erosion in the Yangtze Three-Gorge Region[J]. Journal of Soil and Water Conservation, 1991, 5(3): 29 – 35. (in Chinese).

[14] FANG QZ, HU YF. Countermeasures for integrated management of sloped farmlands in upper and middle reaches of the Yangtze River[J]. Soil and Water Conservation in China, 2010(9): 44 – 48. (in Chinese).

[15] DENG JN, TANG CX, HE BH. Ecological benefits of turning slopes into terraced fields by different ways at the middle and upper reaches of Yangtze River[J]. Soil and Water Conservation in China, 2011, 6: 32 – 34. (in Chinese).

[16] WANG ZW, MA Y, TANG Y, *et al.* Effect of long-term soil and water conservation techniques on soil organic matter and nitrogen content of slope farmland[J]. Southwest China Journal of Agricultural Sciences, 2014, 27(2): 688 – 693. (in Chinese).

[17] NI JP, WEI ZF, GAO M, *et al.* Research on nutrient loss from slope land in Three Gorges Reservoir Area[J]. Journal of Soil and Water Conservation, 2008, 22(5): 38 – 43. (in Chinese).

[18] DONG HW, CHEN GJ, GUO Y, *et al.* Study on the evaluation of quality evaluation of quality evaluation of different slope cropland years in Three Gorges Reservoir Area[J]. Soil and Water Conservation in China, 2014, 6: 35 – 38. (in Chinese).

[19] CHEN GJ, LI CJ, ZHANG C, *et al.* Situation and change trend of soil nutrients in terraced fields from sloping land in Three Gorges Reservoir Area[J]. Guizhou Agricultural Sciences, 2016, 44(3): 172 – 174. (in Chinese).

[20] LIU T, SHAO JA. Spatial and temporal variation of soil erosion under different land uses in the Three Gorges Reservoir Region[J]. Science of Soil and Water Conservation, 2016, 14(3): 1 – 9. (in Chinese).

[21] BAO SD. Soil agrochemistry analysis[M]. Beijing: China Agriculture Press, 2007: 25 – 114. (in Chinese).

[22] ZHU KG, DU GH, ZHANG SY, *et al.* Chinese soil species[M]. Beijing: China Agriculture Press, 1993. (in Chinese).

[23] GUAN LZ. Common soil science[M]. Beijing: China Agricultural University Press, 2007: 154 – 163. (in Chinese).

[24] Chengdu Branch, Chinese Academy of Sciences. Chinese purple soil [M]. Beijing: Science Press, 1991: 214. (in Chinese).

[25] LIAO XY, CHEN ZJ, LIU SQ, *et al.* Effects of land use types on soil fertility in small watershed in the Three Gorges Reservoir[J]. Ecology and Environmnet, 2005, 14(1): 99 – 101. (in Chinese).