Assessment on Nutrients and Fertilities of Soils in Different Land Use Types within Dazhai Village Watershed in Yunnan Province, China

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Abstract. Soil nutrient and fertility are two important factors of the recovery of agricultural production in remote and impoverished area. The study of small watershed of Yiliang County Dazhai village is carried out by researching on soil fertility of different land use, and evaluating the soil fertility by comprehensive index. The results showed that the soil in this area was mainly acidic and weak acid, organic matter, total nitrogen, total phosphorus and cation exchange capacity was very high. Total potassium, alkali solution nitrogen, available potassium was in the medium level, while the available phosphorus was in the lower level. The relationship of soil fertility coefficient in this watershed was that the dry land area (1.32) > forest land (1.24) > paddy field area (0.96). It means that soil fertility of dry land was the best, while soil fertility of paddy field was the worst, and soil fertility of forest land was in the middle level. Based on the “soil fertility diagnosis and evaluation of arable land in the South” (NY/T1749-2009), these three different areas were all in the second level. Effective phosphorus was a key limiting factor.

1. Introduction

As the most important constituent part of agricultural sustainable development, soil is the basis on which human survival depends on[1-2]. Soil fertility is soil ability of providing nutrients, moisture and excellent environmental conditions for plant growth. The soil fertility is one of the main factors for land evaluation [3]. As comprehensive reflection of all kinds of human land use activities, land use is the most common, direct and profoundest factor influencing soil fertility change[4]. Reasonable land use mode can improve quality of surrounding air and moisture so as to improve soil structure, enhance soil resistance against external environmental change and improve soil fertility; however, unreasonable land use mode will result in degraded soil quality and finally cause severe land degradation [5].

Soil fertility evaluation is an important foundation for sustainable land use and management. Scientific, reasonable and pragmatic evaluation of soil fertility provides theoretical basis for guiding agricultural production, land use planning and management[6]. Soil fertility evaluation contents include selection of evaluation units, determination of evaluation indicators, soil sampling and

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comprehensive evaluation method[7]. Evaluation units consist of a series of factors influencing soil fertility and are also the basic units for soil fertility evaluation. Determination of evaluation indicators need to consider soil functions, detect direction, velocity and degree of soil change and determine improvement or degradation of multiple ecosystems[8-9]. Soil sampling mainly includes selecting representative soil samples through random sampling method based on statistical principles and grid sampling method suitable for geographic information system analysis[10]. Comprehensive evaluation method of soil fertility is the key of evaluation, but there is no unified standard yet, and there are mainly scoring method and numerical method. Accuracy degree of scoring method is restricted by professional level of evaluators. Corrected Nemerow formula is mostly used as the main numerical method and comprehensive evaluation method in recent years. Corrected Nemerow formula can highlight influence of the poorest factor among soil property factors on soil fertility and reflect minimum factor law for plant growth in ecology, so it can improve confidence level of evaluation results[11-12].

Yiliang County, Zhaotong City in Yunnan Province is located in the middle of Zhaotong City (east longitude 103°51′-104°45′ and north latitude 27°16′-27°57′) and transitional zone from the Yunnan-Guizhou Plateau to Sichuan Basin, the mountain range belongs to Wumeng Mountain system, and total mountain area is 2,804.16 square kilometers. At 11:09 on September 7, 2012, 5.7-magnitude earthquake burst at border between Yiliang County and Weining Yi, Hui and Miao Autonomous County in Bijie prefecture in Guizhou Province, and focal depth reached 14km; at 12:16, 5.6-magnitude earthquake attacked Yiliang County again and focal depth was about 10km[13]. Yiliang is both a minority area and a poverty-stricken area with few arable lands, so post-earthquake reconstruction and repair is of vital importance.

Dazhai Village watershed, Luoze River Town, Yiliang County, was selected as study object. Soil nutrients and fertilities in arid slope cropland, paddy field and forestland in this basin were studied. Study results can provide fundamental basis for post-earthquake repair.

2. Materials and method

2.1. Study object

Dazhai Village watershed is located in Luoze River Town, Yiliang County, Zhaotong City, total land area in the small watershed is 1,600 hm2, it belongs to strongly erosive medium alpine and gorge landform, the general terrain is high in the north and low in the south, the highest elevation is 2,478m and the lowest elevation is 1,383m. There are mainly three land use modes in this small watershed namely forest land, arid slope cropland and paddy field, partial arid slope cropland has realized conceding the land to forestry, and main grain crops in this watershed are corn and rice. Main commercial crops are potato, sweet potato, konjac and other vegetables. Sampling points are seen in the following Figure There are 10 sampling points in forest land, 11 ones in arid slope cropland and 9 ones in paddy field (Figure 1). 0-20cm topsoil was acquired from all sampling points. One representative sampling point was respectively selected from the three land use types—forest land (1,507m-2,478m), arid slope cropland (1,498-1,709m) and paddy field (1,495-1,540). Rectangular soil profile pits were dug, and then profile soils at 0-20cm, 20-40cm and 40-60cm depths were respectively taken. 10cm×10cm×10cm undisturbed soils were taken using a knife during soil sampling process.

Determination of soil physical and chemical properties mainly monitored pH, organic matters, total nitrogen, alkali-hydrolysable nitrogen, total phosphorus, available phosphorus, total potassium, rapidly available potassium, cation exchangeable capacity and base saturation degree. These chemical methods are used to analyze these indicators such as pH meter, capacity act, automatic nitrogen determination instrument, alkaline solution diffusion method, molybdenum anti-colorimetric method, spectrophotometry and flame photometry. Test data were processed using SigmaPlot 12.5

and Excel2016, SPSS software was used for statistical analysis, mean values and standard deviations of measured values in the sample plot were calculated, and multiple comparisons and significance test were conducted for measured values.

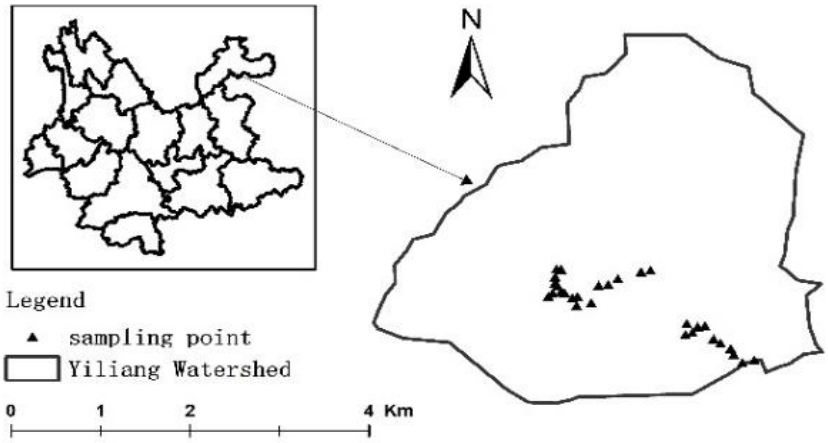

Figure 1. The distribution map of samples in the study area in Yunan Province Indicators and data analysis.

2.2. Evaluation criteria

Fertility degree evaluation was based on Soil Fertility Diagnosis and Evaluation in Arable Land in South China (NY/T1749-2009), and corrected Nemerow index method was used for evaluation[14]. pH, organic matters, total nitrogen, alkali-hydrolysable nitrogen, total phosphorus, available phosphorus, total potassium, rapidly available potassium and cation exchangeable capacity were taken as evaluation factors. As the monitored area contained arid land and paddy field, standard values of main physical and chemical indicators are seen in Table 1 and 2.

Table 1. Main physical and chemical indicators standard value of S_i.

term	standard value recommended	
	Dry land	Paddy land
organic matter(g/kg)	12.5	22.5
total nitrogen(g/kg)	1.0	1.2
available phosphorus(mg/kg)	7.5	12.5
rapidly available potassium(mg/kg)	80	100
cation exchangeable capacity(cmol/kg)	12	15
alkali-hydrolysable nitrogen(mg/kg)	105	
total phosphorus(g/kg)	0.59	
total potassium(g/kg)	16	

Table 2. Main physical and chemical indicators standard value of P_i in Soil fertility assessment.

term	Individual Fertility Index(P_i)
pH	$P_i(C_i / S_i)$=1.0; when pH≤5.0 or pH≥9.0
	$P_i(C_i / S_i)$=1.5; when pH is within 5.0-5.5 or 8.5-9.0;
	$P_i(C_i / S_i)$=2.0; when pH is within 5.5-6.0 or 8.0-8.5;
	$P_i(C_i / S_i)$=2.5; when pH is within 6.0-6.5 or 7.5-8.0;
	$P_i(C_i / S_i)$=1.0; when pH is within 6.5-7.5 (equal 6.5 or 7.5);

2.3. Soil fertility indexes

Comprehensive index Pcom of soil fertility is computed according to the following formula

$$\text{Pcom} = \sqrt{\frac{((Ci/Si)^2_{min}+(Ci/Si)^2_{ave})}{2} \cdot \frac{(N-1)}{N}} \quad (1)$$

Where P_{com}——comprehensive index of soil fertility;
C_i——measured data of the index i in soil;
S_i——evaluation standard value of the index i in soil;
$(C_i/S_i)^2_{min}$——square of minimum value of a single fertility index among all soil indexes;
$(C_i/S_i)^2_{ave}$——square of mean value of all soil fertility indexes;
N——number of indexes participating in soil fertility evaluation.
(note: when a single fertility index satisfied $P_i > 3$, this index would be calculated by $P_i=3$)

2.4. Soil fertility rating

Comprehensive soil fertility index comprehensively reflects soil fertility level, and soil fertility rating is graded into I, II and III, specifically seen in the following Table 3.

Table 3. Soil fertility rating.

Grading	Soil fertility index	Evaluation descriptions
Grade I	$P_{com} \geq 1.7$	Soil fertility is under high level, it's fertile or very fertile without lack of fertilizers, crop yield is high, and marginal effect of yield increase through fertilizer application is reduced
Grade II	$0.9 \leq P_{com} < 1.7$	Soil fertility is under general level, individuals' indicators may be deficient, and crop yield increases obviously with increase of fertilizer application amount.
Grade III	$P_{com} < 0.9$	Soil fertility is under low level, it's barren, crops are under fertilizer deficiency, most fertility indicators are lacked, and some indicators are severely lacked or inappropriate, and yield increase is significant through fertilizer application.

3. Results and analysis

3.1. Total nitrogen and hydrolyzed nitrogen contents in soil

Total nitrogen content in forest land was the highest and mean value reached 3.55g/kg (1.47 -6.52 g/kg), followed by arid slope cropland (3.38 g/kg (2.15 -4.69 g/kg)) and paddy field (3.07 g/kg (2.32 -4.55 g/kg)), and the differences among the three were insignificant. According to nutrient grading standard in national second soil survey, all of the three reached grade I level. Due to stable plant population and community system, forest land had high plant species abundance. Influenced by plant root system, the forest land was of abundant soil nitrogen with great nitrogen supply potential. In addition, livestock breeding industry existed in this watershed, and cow and sheep manures provided nutrient sources for forest land soil as fertilizers. However, in arid slope cropland and paddy field within this watershed, total nitrogen in soil also presented high level because farmers used industrial chemical fertilizers. Hydrolyzed nitrogen content and total nitrogen content in soil presented consistent tendencies under different use modes. Hydrolyzed nitrogen content in forest land was the highest, and the mean values were sorted from high to low as forest land 138.22mg/kg (49.02 -221.23mg/kg), arid slope cropland 125.96mg/kg (97.51 -152.32 mg/kg) and paddy field (76.97 -167.43 mg/kg) in succession (Figure 2). The differences among the three were unobvious either. Forest land and arid slope cropland reached grade II level and paddy field reached grade III level.

From vertical distribution of total nitrogen (Figure 3), total nitrogen contents in arid slope cropland, paddy field and forest land reduced with increase of soil depth. However, from vertical distribution of hydrolyzed nitrogen, hydrolyzed nitrogen in arid slope cropland reduced with increase of soil depth, that in forest lad reached the highest at 20-40cm soil layer, and that in paddy field reached the highest at 40-60cm soil layer while presenting a low level at 20-40cm soil layer.

Correlation analysis indicated that: total nitrogen had extremely significant positive correlation with hydrolyzed nitrogen with correlation coefficient being 0.560 ($p < 0.01$), indicating that soil total nitrogen content under three different land use modes affected hydrolyzed nitrogen content to a certain degree, and hydrolyzed nitrogen content needed by plant growth relied on total nitrogen content.

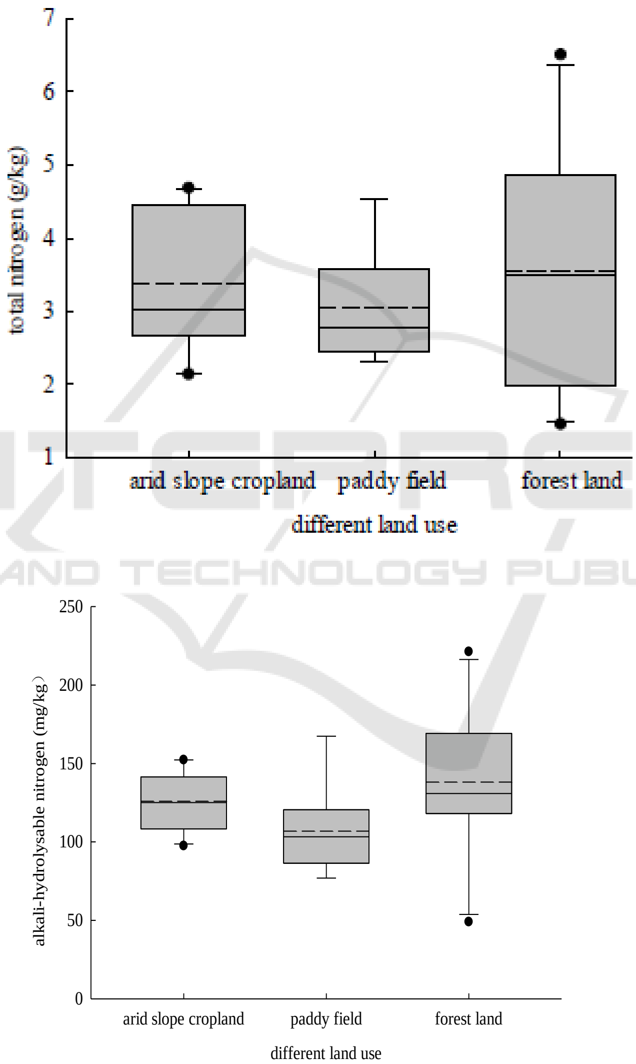

Figure 2. Total nitrogen and alkali-hydrolysable nitrogen in the soil (0-20cm soil layer).

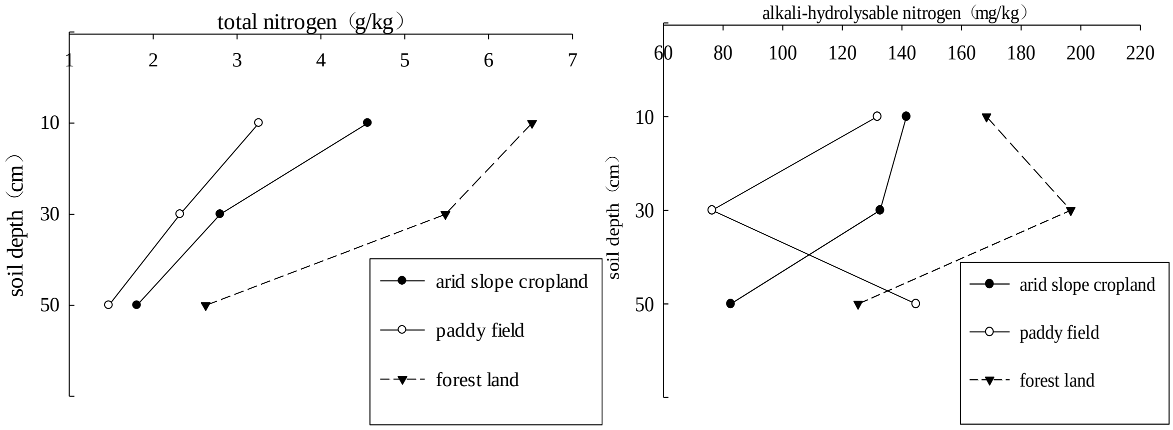

Figure 3. The characteristics of total nitrogen and alkali-hydrolysable nitrogen in the soil.

3.2. Soil total phosphorus and available phosphorus contents

Total phosphorus content in arid slope cropland was the highest, being 1.95g/kg (0.97-2.42 g/kg). Total phosphorus in the small watershed presented high levels, total phosphorus in forest land was 1.44 (0.74-2.22 g/kg) which was slightly higher than that (1.66, (0.73-1.71 g/kg)) in paddy field, and the two didn't present obvious difference. According to nutrient grading standard in national second soil survey, all of the three reached grade I level. Available phosphorus content in this watershed was the highest in arid slope cropland, being 5.27mg/kg (2.96-8.88 mg/kg), followed by that in paddy field namely 3.21 mg/kg (1.97-5.92 mg/kg) which was slightly higher than that 2.86 mg/kg (1.48-4.93 mg/kg) in forest land, and the two didn't present significant difference (Figure 4). Arid slope cropland, paddy field and forest land respectively reached grade IV, V and VI levels. On the whole, available phosphorus content in this watershed was low, and local farmers scarcely used phosphate fertilizers, and consequently, available phosphorus content in soil within this watershed was under low level for a long term.

From vertical distribution of total phosphorus, total phosphorus in arid slope cropland and paddy field both reduced with increase of soil depth, and that in forest land presented the highest level at 20-40cm soil layer (Figure 5). Vertical distribution law of available phosphorus was obviously different from that of total phosphorus. Available phosphorus in three land use types presented rising trends at 0-20cm to 20-40cm soil layers. At 40-60cm soil layer, available phosphorus contents in paddy field and arid slope cropland reduced to the lowest level while that in forest land presented the highest level.

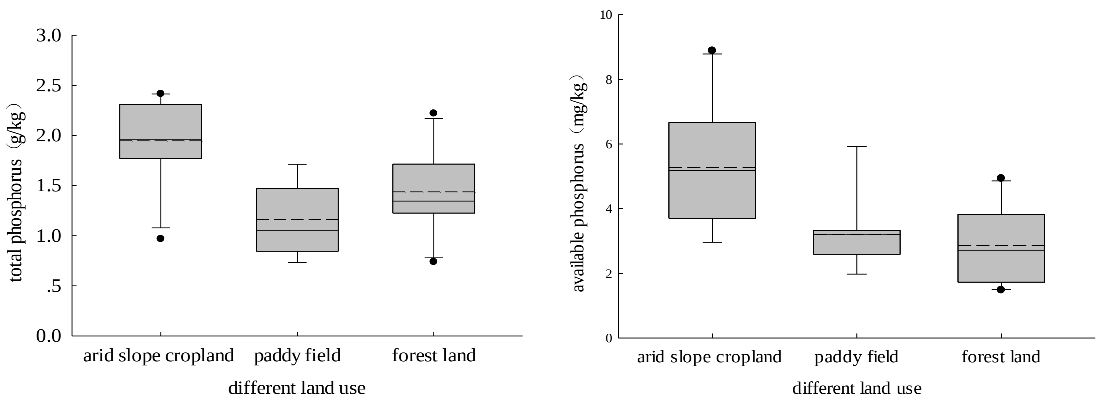

Figure 4. Total phosphorus and available phosphorus in the soil (0-20cm soil layer).

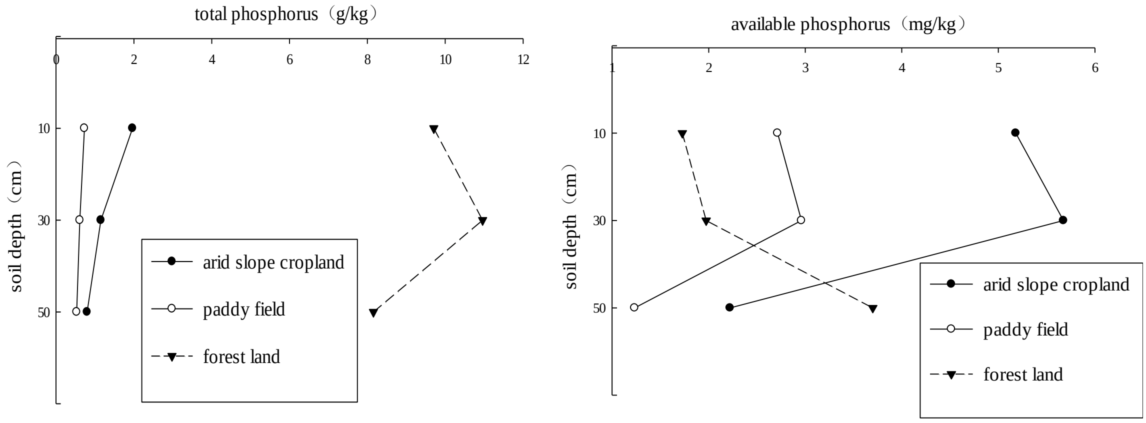

Figure 5. The characteristics of total phosphorus and available phosphorus in different soil layers.

Correlation analysis showed that: total phosphorus and available phosphorus presented significant positive correlation and correlation coefficient was 0.367 ($p < 0.05$), indicating that soil total phosphorus contents under three land use modes affected available phosphorus content to a certain degree. Available phosphorus content needed by plant growth depended on total phosphorus content. Local soil total phosphorus content was extremely high while available phosphorus content was low, indicating that available phosphorus content needed increasing by man-made means so as to facilitate better crop growth.

3.3. Soil total potassium and available potassium contents

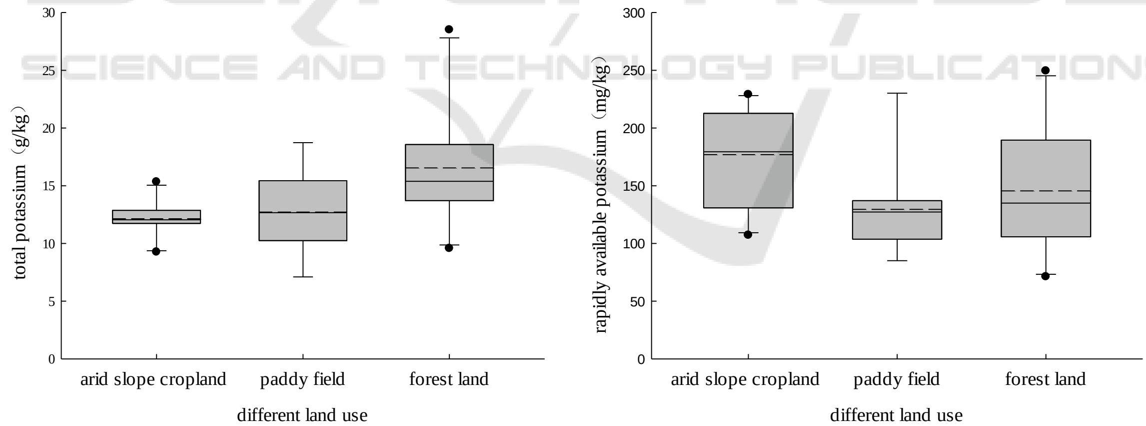

Figure 6. Total potassium and available potassium in the soil (0-20cm soil layer).

The highest mean value of total potassium content in forest land was 16.55g/kg (9.57-28.51 g/kg), and that in paddy field was 12.72 (7.10-18.73 g/kg) which was slightly higher than that (12.14 (9.26-15.34 g/kg)) in arid slope cropland and the two didn't have significant difference. According to nutrient grading standard in national second soil survey, forest land reached grade III level while paddy field and arid slope cropland reached grade IV level. Potassium element returned to soil in forest land mainly in the form of dry branches and fallen leaves so as to present high total potassium content. Available potassium content was the highest in arid slope cropland and the mean value was 176.94mg/kg (107.14-228.99 mg/kg), and that in forest land was 145.59 mg/kg (71.17-249.49 mg/kg) which was slightly higher than that in paddy field (129.54 mg/kg (85.10-230.15 mg/kg)) (Figure 6) and the two didn't present significant difference. Arid slope cropland reached grade II level while forest land and paddy field reached grade III level, which was mainly related to local use of potassium fertilizers, and arid slope cropland had favorable fertility conditions.

From vertical distribution of total potassium, total potassium contents in forest land and paddy field didn't change obviously with increase of soil depth, and total potassium in arid slope cropland presented the highest level at 40-60cm soil layer and the lowest level at 20-40cm soil layer (Figure 7). Overall trends of rapidly available potassium contents in three land use types were approximate. Rapidly available potassium contents in arid slope cropland and paddy field both reduced with increase of soil depth. Rapidly available potassium content in forest land was the lowest at 0-20cm soil layer and then presented firstly increasing and then decreasing trend.

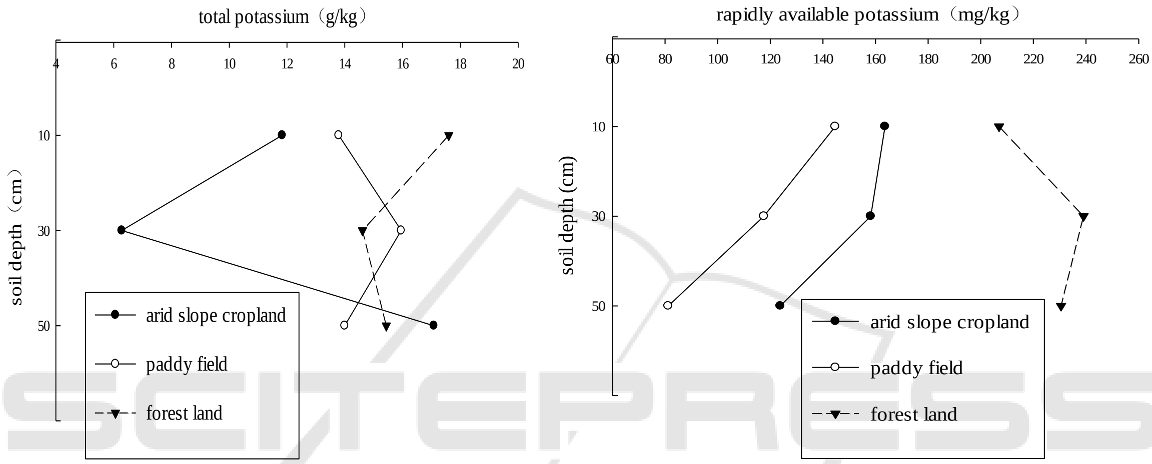

Figure 7. The characteristics of potassium and available potassium in different soil layers.

Correlation analysis indicated that: correlation between total potassium and rapidly available potassium was insignificant, verifying that available potassium content needed by plants was not completely affected by total potassium content.

3.4. Soil pH (H_2O/kcl) value

Distribution trends of pH(H2O) and pH(kcl) were consistent. Because soil in paddy field was immersed in water for a long time, which exerted certain diluting effect on soil pH, pH value in paddy field was the highest with 5.68 pHH2O (4.47-7.53) and 4.54 pHkcl (3.66-5.21) and it's weak-acid soil. pH in arid slope cropland was the lowest with 4.66 pHH2O (4.10-5.88) and 3.69 pHkcl (1.17-4.95), so it's acid soil. Thus, difference between paddy field and arid slope cropland was obvious, but forest land was insignificantly different from paddy field and arid slope cropland, namely it's at intermediate level with 5.20 pHH2O (4.45-6.66) and 3.92 pHkcl (1.06-5.44), so it's acid soil. Soil pH value in the whole watershed was low, because soil in this watershed was mainly yellow soil, it belonged to moderate weathering intensity leaching, and exchangeable Al3+ was water-soluble active acid which had great toxic effect on plants[15].

In terms of vertical distribution of pH, pH H2O and pHkcl also presented consistency. pH value in arid slope cropland increased with increase of soil depth, that in paddy field presented firstly increasing and then decreasing trend, and the difference in forest land was unobvious

Correlation analysis indicated that: pH H2O and pHkcl presented extremely significant positive correlation and correlation coefficient was 0.489 ($p < 0.01$).

3.5. Organic matters and carbon/nitrogen ratio

Organic matters within this watershed presented extremely high levels, paddy field had the highest organic matter content (89.64g/kg (59.55-123.91 g/kg)) while forest land had the lowest organic matter content (72.45g/kg (21.45-133.66 g/kg)). Arid slope cropland had intermediate organic matter content (80.54 g/kg (42.50-124.75 g/kg)), and the differences among the three were insignificant (Figure 8). According to nutrient grading standard in national second soil survey, all of the three reached grade I level, mainly because this region was of high altitude, low mean temperature throughout the year and great humidity, and then organic matters were accumulated at high level. Distribution trend of carbon/nitrogen ratio was consistent with that of organic matters. Mean value of carbon/nitrogen ratio was the highest in paddy field being 14.49 mg/kg (7.01-17.74 mg/kg) and the lowest in forest land being 9.76 mg/kg (7.30-13.46 mg/kg), and arid slope cropland had intermediate mean value of carbon/nitrogen ratio being 12.20 mg/kg (6.31-19.00 mg/kg). There were many factors influencing carbon/nitrogen ratio, including structural factors like soil parent material, terrain factor and soil type; random factors like all kinds of human activities such as fertilization, farming measures and cropping system, etc. As paddy field was under drowned and low-temperature state, organic matters were degraded slowly with easy accumulation so that soil carbon/nitrogen ratio in paddy field was under relatively high level

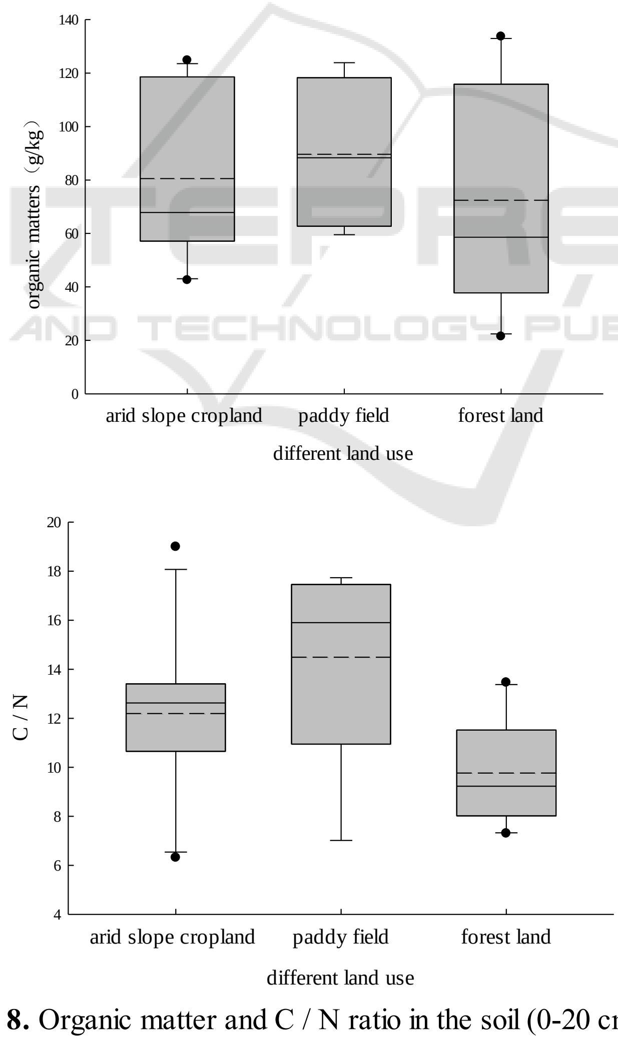

Figure 8. Organic matter and C / N ratio in the soil (0-20 cm soil layer).

Vertical distribution of organic matters in arid slope cropland was consistent with that in forest land, presenting decreasing trend with increase of soil depth, but that in paddy field presented the contrary trend, namely increasing with increase of soil depth. In a similar way, carbon/nitrogen ratio in arid slope cropland was approximate to that in forest land, namely presenting small change amplitude with increase of soil depth. However, carbon/nitrogen ratio in paddy field presented obvious increasing trend with increase of soil depth (Figure 9).

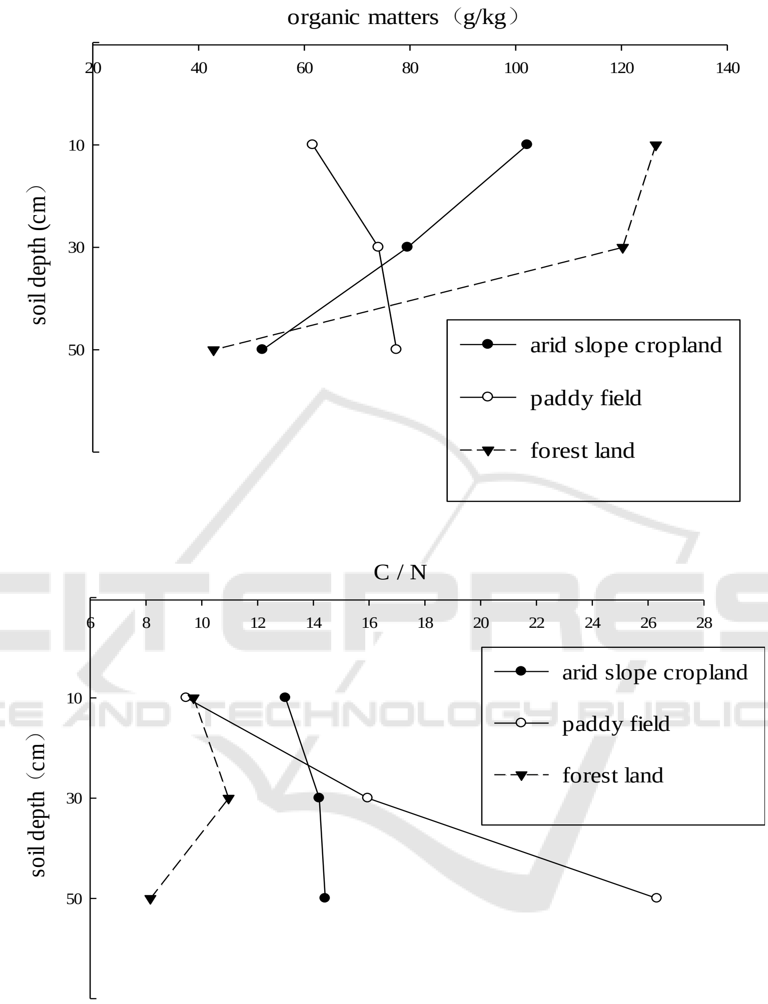

Figure 9. The characteristics of organic matter and C / N ratio in different soil layers.

Correlation analysis indicated that: organic matters presented extremely significant positive correlation with total nitrogen and correlation coefficient was 0.690 ($p < 0.01$). As most nitrogen elements in soil were under organic binding form and nitrogen content in organic matters was relatively fixed, then the two presented extremely significant positive correlation. It could be obtained from correlation analysis among organic matters, total nitrogen and carbon/nitrogen ratio that organic matters in this watershed presented extremely significant positive correlation with carbon-nitrogen ratio and correlation coefficient was 0.634 ($p < 0.01$), but total nitrogen and carbon/nitrogen ratio didn't have significant correlation.

3.6. Cation exchangeable capacity, base composition and base saturation degree

Cation exchangeable capacity (CEC) in arid slope cropland was the maximum and its mean value was 48.35cmol/kg (40.32-69.44 cmol/kg), that in forest land was close to that in arid slope cropland being 46.83cmol/kg (42.08-51.52 cmol/kg), and the two didn't have significant difference. CEC was the lowest in paddy field, being 35.41 cmol/kg (28.80-43.52 cmol/kg) as seen in Figure 10. According to nutrient grading standard in national second soil survey, all of the three reached grade I level. Base saturation degree results indicated that base saturation degree in paddy field was the highest being 65.19% (26.15-94.17%); that in arid slope cropland was the lowest being 24.82% (6.30-43.07%); that in forest land was at intermediate level being 42.60% (1.48-92.23%). The latter two were base unsaturated soils which could be improved using modifying agents like limestone.

From vertical distribution of CEC, arid slope cropland had consistent trend with forest land, namely CEC presented firstly increasing and then decreasing trend, and CEC in paddy field presented firstly decreasing and then increasing trend (Figure 11). Base saturation degree in forest land increased with increase of soil depth but change amplitude was not great; base saturation degree in arid slope cropland decreased with increase of soil depth; base saturation degree in paddy field presented significant increasing trend with increase of soil depth.

According to correlation analysis, CEC presented significant negative correlation with base saturation degree and correlation coefficient was -0.429 ($p < 0.05$); exchangeable Ca_2+ and Mg_2+ presented extremely significant positive correlations and correlation coefficients were 0.957 ($p < 0.01$) and 0.732 ($p < 0.01$) respectively, but CEC had no significant correlation with K+ Na+. As for contributions of exchangeable base ions and base saturation degrees in soil within this watershed, the contribution of Ca2+ was the greatest, followed by Mg2+, K+ and Na+ in succession. This was identical with descriptions in related literatures [16].

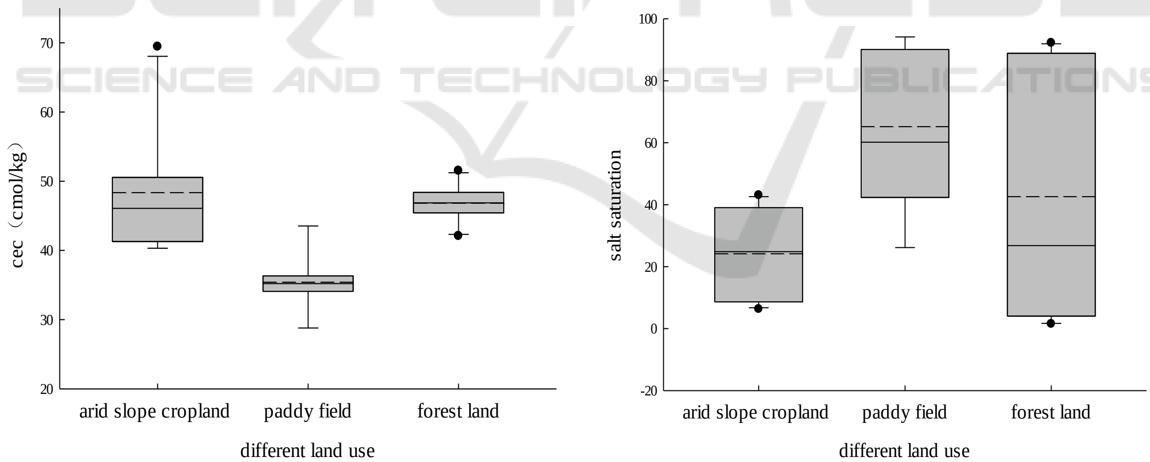

Figure 10. CEC and salt saturation in the soil (0-20 cm soil layer).

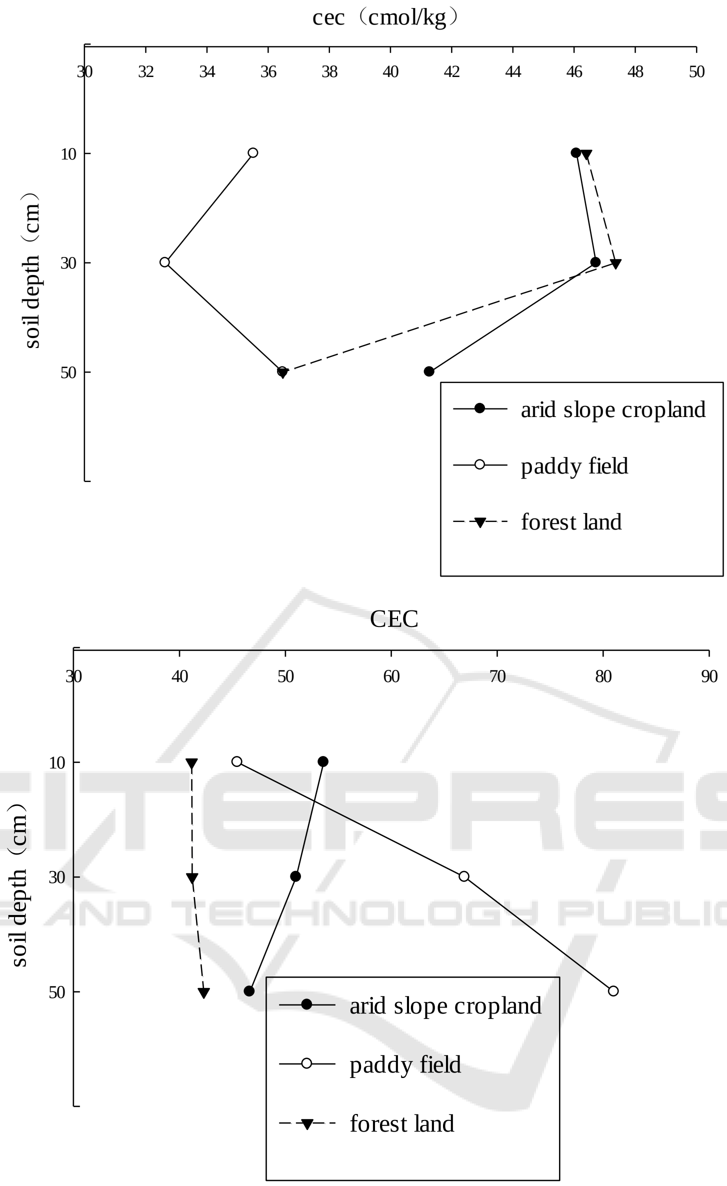

Figure 11. The characteristics of CEC and salt saturation in different soil layers.

3.7. Comprehensive evaluation of soil fertility

Soil fertility indexes in arid slope cropland, paddy field and forest land in the study area were calculated. Generally speaking, comprehensive fertility index in arid slope cropland was the largest while that in paddy field was the smallest. Comprehensive fertility index in arid slope cropland was 1.375 times of that in paddy field and 1.06 times of that in forest land, and that in forest land was 1.29 times of that in paddy field, so the following sorting was satisfied: arid slope cropland (1.32) > forest land (1.24) > paddy field (0.96). This indicated that fertility in arid slope cropland was the optimal and that in paddy field was the poorest, and that in forest land was intermediate. All of the three were at grade II level, so it’s okay for soil fertility to be at a general level, and individual indicators might show deficiency. Crop yield increased obviously with fertilization amount. The indicator-available phosphorus—was under obvious deficient state. Results are seen in Table 4.

Table 4. The comprehensive evaluation of soil fertility.

land use type	p_i									P_{com}	Grading
	pH (H_2O)	organic matters	total nitrogen	total phosphorus	total potassium	alkali-hydrolysable nitrogen	available phosphorus	available potassium	CEC		
arid slope cropland	1.00	6.44	3.38	3.31	0.76	1.20	0.70	2.21	4.03	1.32	Grade II
paddy field	2.00	3.98	2.56	1.97	0.80	1.02	0.26	1.30	2.34	0.96	Grade II
forest land	1.50	5.80	3.55	2.44	1.03	1.32	0.38	1.82	3.90	1.24	Grade II

4. Discussion

Soil within this watershed is mainly yellow soil which is rich in hydrated iron oxide (goethite) and formed under subtropical humid climate. Relevant physical and chemical indicator results basically conform to essential features of the soil in yellow soil region. On the whole, soil pH in this watershed presents faintly acid and acid with high contents of organic matters, total nitrogen, total phosphorus and CEC, all reaching national grade I level. Total potassium, alkali-hydrolysable nitrogen and rapidly available potassium are at intermediate level. Content of rapidly available phosphorus is under medium and low level. Fertility indexes in forest land are approximate to those in arid slope cropland, while paddy field presents low fertility indexes. Generally speaking, soil nutrients will reduce with increase of man-made interference degree under different land use modes [17]. Bearing relatively small influence from human activities, forest land keeps natural or semi-natural state, so it can reflect natural state of soil within the watershed. Much influenced by human activities, arid slope cropland and paddy field have input many nutrients into soil, like application of chemical fertilizers and organic fertilizers, and meanwhile, their outputs are large. Nutrients absorbed from soil will be brought away after the crops are harvested[18]. Immersed in water for a long time with a certain hydraulic settlement effect, nutrients in paddy field soil are at a low level compared with arid land. On the whole, soil nutrients among the three present approximate change trends with depth at 20-40cm and 40-60cm soil layers, and soil nutrients present approximate change trends with depth between forest land and arid slope cropland at 20-40cm and 40-60cm soil layers. This certifies that local human cultivation activities have changed vertical distribution of soil nutrients to a certain degree.

Available phosphorus within this watershed becomes a key restrictive factor of soil comprehensive index. Total phosphorus content in this region is high and reaches grade I level, but total phosphorus content can't decide available phosphorus, so input of phosphorus fertilizer should be enlarged into soil in this region. Meanwhile, in consideration of acid soil condition in this watershed, soil in this watershed can be improved by using organic fertilizers, calcined lime, humic acid and other soil conditioners so that the soil in this watershed is more suitable for crop growth and yield increase[19]. Based on base saturation degree analysis with high correlation with pH, it can be found that within this watershed, base saturation degree presents high peak value (being about 90%) when pH is about 6. Afterwards, it presents descending trend, and relevant studies indicate that pH and base saturation degree present quadratic functional relation[16]. Because base saturation degree can't realize unlimited growth, and instead it has an upper limit, base saturation degree in soil is generally high when pH is close to 6 within Dazhai Village watershed. pH can be considered as an indicator so as to rapidly predict fertilizer maintenance effect of soil.

5. Conclusions

1) Soil fertility indexes in arid slope cropland and paddy field within this watershed present consistent change trends with soil depth at 0-20cm and 20-40cm soil layers. Change trends of soil nutrients with soil depth are approximate between forest land and arid slope cropland at 20-40cm and 40-60cm soil layers.
2) Contents of organic matters, total nitrogen and CEC are high in this region, all reaching national grade I level. Total potassium, alkali-hydrolysable nitrogen and rapidly available potassium are at intermediate level. Available phosphorus content is partially low, being at medium and low level.
3) Nemerow index is used to calculate soil comprehensive fertility coefficients P_{com} in all land use types, and they are sorted as: arid slope cropland (1.32) > forest land (1.24) > paddy field (0.96), indicating that fertility in arid slope cropland is optimal, that in paddy field is the poorest and that in forest land is intermediate. All of three are at grade II level. Comprehensive fertility index in arid slope cropland is the greatest while that in paddy field is the smallest. Comprehensive fertility index in arid slope cropland is 1.375 times of that in paddy field and 1.06 times of that in forest land, and that in forest land is 1.29 times of that in paddy field.

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