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Extent to which pH and topographic factors control soil organic carbon level in dry farming cropland soils of the mountainous region of Southwest China

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ABSTRACT

Soil organic carbon (SOC) in agricultural land is influenced greatly by indeterminate human activity, making it difficult to understand the spatial pattern of SOC. Soil pH and topographic conditions are key indices in the Chinese Soil Genetic Classification System (CSGCS) and manage some critical factors that control the dynamics of SOC either directly or indirectly. To identify the extent to which pH and topographic factors control SOC levels in dry farming cropland soils of the mountainous region of Southwest China, we compared the differences along topographic gradients, and analysed the contribution of different factors in determining SOC status using analysis of variance (ANOVA) and linear regression. Our results indicated the SOC levels ranged from 10.46 g•kg^{-1} to 37.60 g•kg^{-1} and were significantly correlated with soil pH, landscape position, slope and elevation ($p < 0.05$). On a large scale, the combined effects of landscape position and elevation contributed to fluctuating SOC levels along the elevation gradient. SOC levels slightly, but significantly, decreased from base to summit. The difference of SOC levels along a 200 m elevation gradient exhibited statistical significance ($p < 0.05$). A slope range, from 0 to 42°, was categorized into three groups, namely, 5° to 15°, 15° to 30° and others. The slope range 15° to 30° had significantly greater SOC values than the other groups. These variables could all together explain approximately 40% of total variation in SOC, of which approximately 70% was attributable to soil pH, suggesting soil pH plays a key role in forming the spatial pattern of SOC levels in dry farming cropland soils of the mountainous region of Southwest China. The combined effect of landscape position and elevation could further explain 7.3% of SOC variation, which is more apparent than the effect of elevation alone.

1. Introduction

Soil organic carbon (SOC) is the largest pool of carbon in terrestrial ecosystems (Lal, 2008). Large emissions of carbon dioxide (CO_2) from soils can occur when land-use conversion occurs (Mooney et al., 1987; Smith, 2008), greatly influencing the atmospheric concentration of CO_2 (Smith, 2012). Change in SOC stocks has received considerable attention as global annual average temperature and CO_2 concentration have increased in recent decades. However, estimates of global SOC storage based on different methods differ due to shortage of observed data (Batjes, 1996; Bohn, 1976; Lal, 2004). To improve our estimates of CO_2 fluxes from soils, a better understanding of the factors determining SOC levels is required.

Soil pH, a measure of soil acidity or alkalinity, influences crop yields, soil nutrient release, and soil microbial activity, to a large extent. Thus, it could be used as a predictor of soil biotic and abiotic properties that control the stability of soil organic matter (SOM), either directly or indirectly (Heggelund et al., 2014; Lauber et al., 2009; Oades, 1984; Zhalnina et al., 2015). Soil pH value is also a key index that is used to identify soil type in the Chinese Soil Genetic Classification System (CSGCS), as well as to assess soil quality. However, soil pH value is adjustable because it can be impacted by many factors. For instance, soil-forming factors, including parent material, topography, climate and vegetation, affect soil pH to differing extents. Agricultural practices such as fertilization, liming and tillage also influence soil pH, but few reports have quantified the relationship between soil pH and SOC levels on a large scale (Weil and Brady, 2016).

In mountainous regions, topographic factors regulate the redistribution of heat, water, clay, ions and minerals, indirectly influencing SOC accumulation and decomposition (Applegarth and Dahms, 2001;

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Lybrand and Rasmussen, 2015). For instance, Wiaux et al. (2014) observed 30% more soil respiration at the downslope and 50% more respiration at the backslope, relative to the summit position. Many papers reported that SOC stock had a good relationship with elevation (Dahlgren et al., 1997; Jobbágy and Jackson, 2000). Meanwhile, there was a higher potential risk of soil particle mobility in mountain areas than on flat land. Therefore, SOC levels in mountainous areas are highly variable, mainly due to local-scale heterogeneities in the soil environment, such as elevation, slope and landscape position (Griffiths et al., 2009).

Human activities such as tilling, grazing and land management can become the dominant factors controlling SOC levels after the conversion of natural land for agricultural production (Lal, 1999; Nayak et al., 2012). Currently, cropland soils are widely distributed across the world and occupy approximately 34% of the global land surface (Betts et al., 2007; Schlesinger and Bernhardt, 2013). Evidence increasingly shows that the conversion of most natural land to cropland has resulted in carbon losses by influencing the rate of SOC mineralization (Sun et al., 2013) and soil erosion (Quine and Van Oost, 2007). Fortunately, farmers have come to realize the importance of SOM as a critical soil property determining land productivity under long-term cultivation practices (Xiao, 2013). To sustain soil fertility, many farmers use measures such as crop rotation, organic amendments and tillage modifications to maintain SOM levels (Poeplau et al., 2011; Söderström et al., 2014). However, estimating SOC levels on a large scale is still a challenge (Zhang et al., 2008).

Southwest China is characterized by a mountainous and complex topography, contributing to the great spatial variability of SOC (Office of National Soil Survey, 1998). In Guizhou province, the mountainous areas account for 92.5% of total land. The elevation in the region increases from 147.8 m in the southeastern part to 2900 m in the west, with an average elevation of 1000 m. The annual mean temperature and rainfall show significant changes with elevation. In addition, the well-known Karst landscapes prevail throughout an area of 109,084 km^2, and there is an extensive outcrop of carbonate rock (Zhang et al., 2008). All of the above make it very difficult to estimate soil coverage or soil stock. Approximately 40 million people live in this province. Given the food requirements of this population, large areas of mountainous land have been converted to cropland. SOC distribution in this region has become more complex due to the combined effects of anthropogenic and natural factors. On the other hand, it is well-known that pH plays an important role in controlling the dynamics of SOC (Rousk et al., 2009). It is also a key index used to identify soil type in the CSGCS and to assess soil quality. Based on this situation, the aims of this paper are: 1) to establish the relationship between SOC, soil pH, and topographic factors; and 2) to estimate the extent to which pH and topographic factors control SOC levels in dry farming cropland soils of the mountainous region of Southwest China.

2. Materials and methods

2.1. Study site description

The study area is Xinyi County, located at the centre of Southwest China, lying between 140°32′-150°11′E longitude and 24°38′-25°23′ N latitude, with an agricultural area of 30,400 km^2. Xinyi County has a population of 830,000 people and includes 180 administrative villages (Fig. 1). The climate is subtropical with an annual average temperature of 14–19 °C, and rainfall of 1300–1600 mm. Its topography is characterized by mountainous landscapes with various elevations from 625 m to 2200 m. Based on CSGCS, the soils in this region can be categorized into four types: red soil, yellow soil, limestone soil and yellow-brown soil. The distribution of natural soil types is significantly influenced by elevation and geological conditions (Table 1). However, due to a lack of investigation into the extent of the anthropogenic disturbances of soil properties, the soil under the dry farming cropland has not been accurately and uniformly identified, or simply classified, at the lowest level (Guizhou Soil Survey Office, 1994). The prevalence of carbonate outcrops is very high and is considered the main parent material of the soil in this region (Guizhou Soil Survey Office, 1994). Dry farming land occupies > 80% of the total agricultural land. The main crops of most dry farming land are corn and rapeseed, which are rotated.

2.2. Data processing and statistical analysis

Data used in this study are derived from an agricultural census carried out by Guizhou University from 2008 to 2010. This agricultural census included almost all administrative villages of XinYi County. Soil samples to a depth of 25 cm were collected using a shovel. Each one was composed of at least 6 points. Slope, landscape position and elevation at each site were recorded in the field. Landscape positions of sites were grouped into four categories: Summit, Shoulder, Footslope, Toeslope and Plain (Toeslope and Plain were classified as a single group). To provide input for the regression models, the landscape positions were transformed into continuous variables of 1, 2, 3 or 4.

Visible plant residues and > 2 mm rocks were removed before grinding. All soil samples were air-dried and ground in order to be able to pass through a 0.154 mm (100 mesh) stainless-steel sieve. SOM content was determined by dichromate digestion based on the Walkley–Black method, and divided by 1.72 to obtain the SOC value (g•kg^{-1}). Soil pH was measured with an electrode in a ratio of 1:2.5 (m/v) soil-to-water suspension (Bao, 2005). To control the quality of data and ensure representativeness, the Triple Standard Difference Method (Pauta Criterion) was used to exclude any anomalous values of SOC (Redeker and Kalin, 2012).

To identify the effect of pH and topographic factors on SOC and to ensure comparability within soils cultivated in a similar way, we selected the dry farming cropland soils for analysis. Analysis of variance (ANOVA) was used to assess the difference of SOC levels under different conditions. A correlation matrix (Pearson correlation) was used to identify the relationships between factors. Multiple regression analyses were carried out for SOC levels on a range of related factors. The regression analyses were performed using the stepwise procedure and interactions with an F ratio probability of 0.05 were included in the model. The normality of the model's residuals was tested using the non-parametric Kolmogorov–Smirnov test, and its independence was checked using the Durbin–Watson test. All analyses were performed using the SPSS 17.0 statistical package.

3. Results

The SOC levels in the dry farming cropland soils exhibited large variations, ranging from 10.46 to 37.60 g•kg^{-1} (mean ± S.D.: 24.11 ± 4.58 g•kg^{-1}) (Table 2). SOC levels had significant relationships with pH, landscape position, slope and elevation ($p < 0.05$). Soil pH correlated closely with slope ($p < 0.05$), but the correlations between landscape, elevation and soil pH did not exhibit a statistical significance ($p > 0.05$) (Table 3).

For landscape position, over 56% of soil samples were scattered along the Footslope, where SOC levels ranged from 10.46 to 37.51 g•kg^{-1} with a mean value of 24.39 g•kg^{-1}. The order of mean SOC levels was Toeslope or Plain > Footslope > Shoulder > Summit. There were significant differences among the four landscape positions ($p < 0.05$), but not between the Summit and Shoulder (Table 4).

The slope ranged from 0° to 42°, with a mean value of 14° (Table 2). Nearly 74% of soil samples were collected between 5 and 25°, which is representative of the distribution of dry farming croplands in the mountainous region of Southwest China. The sample sites were classified as 7 groups, based on 5° intervals (the sample sites above 30° were classified as one group) (Table 5). In terms of averages, the value of SOC in the 25–30° group was the highest (24.88 ± 4.38 g•kg^{-1}).

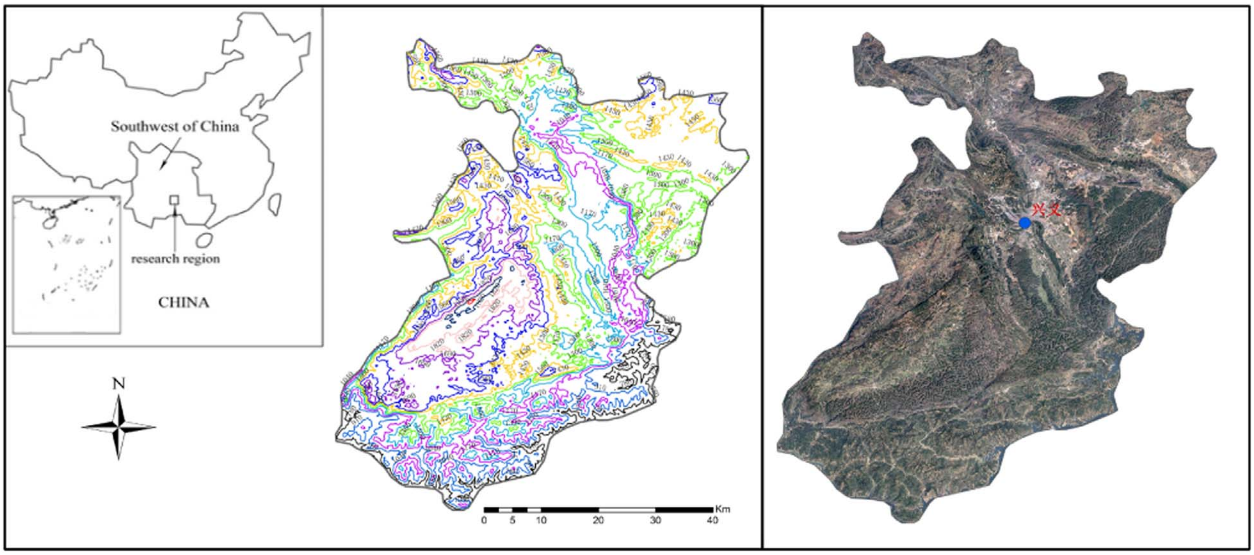

Fig. 1. Map of research area (Left is a terrain map. Right is an image extracted from Google Earth).

Average SOC levels showed an increasing trend between 5° and 20°. These data could be further merged into three groups, namely, 5–15°, 15–30° and others, but only the difference of SOC between 5 and 15° and 15–30° was significant ($p < 0.05$).

Using 100 m intervals, the elevation of dry farming land was divided into 13 groups (Table 6). Overall, SOC levels increased with elevation. Below an elevation of 1000 m, only 54 samples were collected, and the mean SOC levels were much lower above 30% than others. Over 86% of soil samples were collected between an elevation of 1100 m and 1700 m, and their mean SOC levels ranged from 23.70 to 24.93 g•kg^{-1}. SOC levels fluctuated slightly with increasing elevation. SOC levels between 1400 and 1700 m were significantly higher than those between 1100 and 1400 m ($p < 0.05$).

The variation in soil pH is shown largely to be consistent with SOC. To ensure a normal distribution of model residuals (Fig. 2), the SOC levels were converted into natural logarithms. After using the stepwise procedure and interactions with an F ratio probability of 0.05, some indices (pH, slope, landscape position, and elevation) were selected for a multiple regression model. The best-fit model of multiple regression analysis is shown in Eq. (1). The model explained 40.2% of Ln(SOC) variability. Of the variables examined, pH explained 31.7%, combined effect of elevation and landscape position explained 7.3%, and elevation explained 1.2% (Table 7). The influence of slope on Ln(SOC) was negligible.

$$\mathrm{Ln(SOC)} = -1.716 + 0.293 \times pH + 0.731 \times lg(E) + 0.155 \times lg(E \times G) \tag{1}$$

where E is elevation; G is landscape position; E × G is combined effect of elevation and landscape position.

Table 2
Descriptive statistics of soil of dry farming croplands.

	Mean	Min	Max	St.D	Mean squares
SOC (g kg^{-1})	24.11	10.46	37.60	4.58	20.95
pH	6.89	5.79	7.71	0.37	0.14
Slope (°)	15	0	42	8	68
Elevation (m)	1408	694	1959	197	39,132

Table 3
Pearson correlation coefficients (r) between Landscape variables and SOC, pH.

		Landscape position	Slope	Elevation	SOC	pH
SOC	r	0.070	0.043	0.221	1	0.555
	p-value	**0.000**	**0.029**	**0.000**		**0.000**
pH	r	0.015	0.145	0.017		1
	p-value	0.430	**0.000**	0.388		

Note: Bold in the table means that the relationship between two variables reaches significant level ($p \leq 0.05$).

4. Discussion

In natural ecosystems, SOC levels are the result of the net balance between inputs and outputs of carbon, which are controlled by a number of factors including climate, vegetation type, soil inherent physico-chemical properties and topography (Stockmann et al., 2013). After land is converted for agricultural use, human activities, directly and indirectly, influence the sources of SOC, the organic matter flux in the soil, and the rates of decomposition. Due to the uncertainties relating to human disturbance, the SOC storage pattern in cropland is very complex. From Table 1, we can determine that red soil is mainly distributed in the areas below an elevation of 1000 m. It is a very sticky and barren soil type (Guizhou Soil Survey Office, 1994). After conversion to dry farming land, SOC in the surface layer is easily eroded. Consequently, SOC levels below an elevation of 1000 m are significantly lower than those above 1000 m ($p < 0.05$). From 1000 m to

Table 1
Distribution and chemical properties of original surface soil (Office, G.S.S., 1994).

Type of soil	pH	SOC (g•kg^{-1})	N (g•kg^{-1})	Parental material	Elevation (m)
Limestone soil	6.5–8.5	11–58 (29.4)[*]	1–4 (2.5)	Carbonate rock	All region with carbonate rock outcrop
Yellow soil	4.0–5.7	5–35 (27.3)	1–5 (2.2)	Quaternary residue or sand rock or carbonate rock	800–1600
Yellow-brown soil	4.2–5.0	10–63 (52.2)	1–6 (3.8)	Quaternary residue or sand rock or carbonate rock	> 1600
Red soil	3.7–6.5	5–32 (25.6)	1–4 (1.72)	Quaternary residue	< 1000

[*] Range (average value).

Table 4
SOC and pH distribution along landscape position for soil samples.

Landscape position	Number of samples	Mean of SOC* (g•kg^{-1})	Min of SOC (g•kg^{-1})	Max of SOC (g•kg^{-1})	pH
Summit	76	22.51 ± 4.25^{a}	11.90	34.78	6.93 ± 0.31^{ad}
Shoulder	375	23.54 ± 5.12^{a}	11.53	37.60	6.84 ± 0.33^{d}
Footslope	1738	24.08 ± 4.63^{b}	10.46	37.51	6.90 ± 0.37^{b}
Toeslope or Plain	407	25.02 ± 3.94^{c}	17.17	36.63	6.97 ± 0.35^{ac}

* Mean ± St.D. Means with different letters indicate there are significantly different at $p \leq 0.05$ probability level (LSD) within each column.

Table 5
SOC and pH distribution along different slope categories.

Slope (°)	Number of samples	Mean of SOC* (g•kg^{-1})	Min of SOC (g•kg^{-1})	Max of SOC (g•kg^{-1})	pH
0–5	347	24.04 ± 5.22^{ab}	13.09	37.51	6.85 ± 0.38^{ab}
5–10	448	23.51 ± 4.30^{a}	13.20	36.40	6.83 ± 0.34^{a}
10–15	542	23.86 ± 4.41^{a}	11.90	39.60	6.86 ± 0.37^{ab}
15–20	572	24.64 ± 4.61^{b}	10.80	37.48	6.90 ± 0.38^{b}
20–25	347	24.29 ± 4.51^{b}	10.46	36.12	6.95 ± 0.39^{d}
25–30	71	24.88 ± 4.38^{b}	14.57	33.50	7.01 ± 0.36^{cd}
≥ 30	269	24.11 ± 4.42^{ab}	11.63	35.96	6.99 ± 0.37^{ce}

* Mean ± St.D. Means with different letters indicate there are significantly different at $p \leq 0.05$ probability level (LSD) within each column.

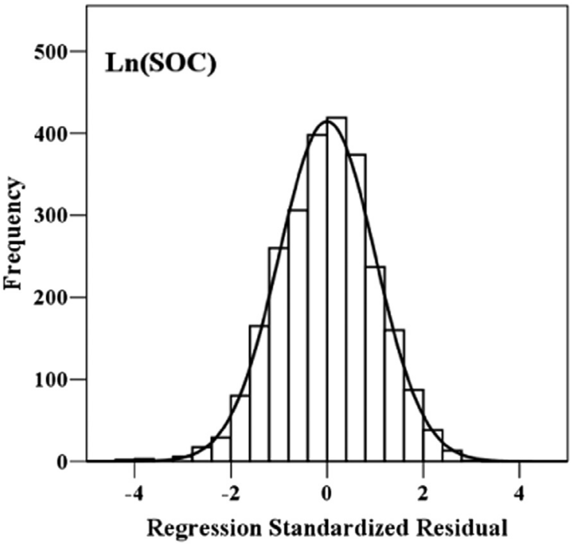

Fig. 2. Distribution of standardized residual of Eq. 1.

Table 7
Summary of the results obtained from a multiple regression.

Source	Parameters	MS	SS(%)
pH	0.293	31.74	31.7
lg(E × G)	0.713	19.55	7.3
lg(E)	0.155	13.45	1.2
Residuals			59.8

MS, mean squares; SS, proportion of variances explained by the variable; S, slope degree; E, elevation; G, landscape position.

2000 m, SOC levels tended to increase though they fluctuated. Furthermore, increases in SOC levels using 200 m elevation intervals were significant with an average difference between intervals of 1.55 g•kg^{-1}. This value is smaller than in Swiss agricultural soils (0.75–2.1 g•kg^{-1}per 100 m increase in elevation) (Leifeld et al., 2005) and in tropical forests (Dieleman et al., 2013).

Climatic conditions and soil properties co-vary strongly with the increase of elevation and play an important role in controlling the dynamic processes of SOC (Dahlgren et al., 1997; Jobbágy and Jackson, 2000; Longbottom et al., 2014). Temperature normally declines with increasing elevation, whereas soil moisture normally increases. SOC turnover is significantly positively correlated with soil temperature, and has a more complex correlation with soil moisture (Salinas et al., 2011; Sousa Neto et al., 2011; Townsend et al., 1995). The accumulation of SOC at higher elevations might partly be explained by reduced temperatures and increased moisture with increasing elevation (Raich et al., 2006). Some studies suggest that the decomposition rate of slowly decomposing SOC is more sensitive to temperature than that of more rapidly decomposing SOC (Zimmermann et al., 2012), though others suggest equal sensitivity among soil pools (Fang et al., 2005). In the field, it is almost impossible to control other parameters that co-vary with temperature. Thus, although many previous studies have reported significant relationships between temperature and SOC stock, or turnover rate of SOC (Conant et al., 2011), it is difficult to identify to what extent temperature influences the turnover rate of SOC in this study. In the area of this study, dry farming cropland soils were distributed throughout an elevation range between 700 m and 2000 m. Annual cumulative temperatures (≥ 10 °C) from meteorological stations decrease by approximately 200 °C a year with each increment of 100 m in elevation (Xiaoping, 2009). However, because the microclimatic conditions in mountain areas are generally influenced by landscape, there are many cases where positions at greater elevations have a higher

Table 6
SOC and pH distribution along different elevation gradients in soil samples.

Elevation (m)	Number of samples	Mean of SOC* (g•kg^{-1})	Min of SOC (g•kg^{-1})	Max of SOC (g•kg^{-1})	pH
700–800	3	14.71 ± 3.45^{a}	10.80	17.32	6.46 ± 0.59
800–900	16	14.51 ± 2.29^{a}	11.38	18.25	6.09 ± 0.33
900–1000	38	14.87 ± 3.80^{b}	12.31	26.24	6.78 ± 0.57
1000–1100	127	21.18 ± 4.88^{c}	11.53	35.14	7.07 ± 0.47
1100–1200	219	23.70 ± 5.94^{dm}	10.46	36.12	7.01 ± 0.46
1200–1300	291	24.38 ± 5.14^{de}	11.28	37.51	6.99 ± 0.40
1300–1400	485	23.66 ± 3.97^{mf}	13.28	37.60	6.89 ± 0.35
1400–1500	620	24.76 ± 4.12^{dgn}	11.38	36.79	6.85 ± 0.34
1500–1600	367	24.93 ± 4.15^{gh}	15.65	33.41	6.88 ± 0.31
1600–1700	255	24.90 ± 4.21^{gi}	14.64	36.12	6.97 ± 0.33
1700–1800	118	24.06 ± 2.62^{dj}	15.20	29.89	6.91 ± 0.27
1800–1900	50	25.78 ± 1.96^{ek}	20.97	31.79	6.89 ± 0.27
1900–2000	7	27.95 ± 3.36^{nl}	24.78	34.02	7.07 ± 0.40

* Mean ± St.D. Means with different letters indicate there are significantly different at $p \leq 0.05$ probability level (LSD) within each column.

annual cumulative temperature (≥ 10 °C) or drier conditions (Xiaoping, 2009), which may partly explain the fluctuation of SOC with elevation.

SOC levels show a growth trend from Summit to Toeslope. (Table 4). Most agricultural lands were distributed throughout the Footslope areas. Since the more mountainous parts of the landscape are not suitable for agricultural machinery, cultivation practices mainly depend on manual labour in most villages. In fact, local farmers work in the lower lands more intensively, with Summit and Shoulder areas receiving less fertilizer, especially organic fertilizer, than other positions. In addition to this, high landscape positions drain freely and suffer from the erosion of soil particles, which can then be deposited in lower lying areas and influence their soil properties (Lybrand and Rasmussen, 2015; Pierson and Mulla, 1990). All of these factors contribute to the lower productivity and SOC levels of Summit and Shoulder soils. Pierson and Mulla (1990) also reported that SOC in Footslope and Toeslope positions were significantly higher than other positions in southeastern Washington. Gregorich and Anderson (1985) found that organic C levels increased from the shoulder position to the foot slope in prairie soils in Canada. Furthermore, thousands of mountains scattered all around the region have different initial elevations, and the northern and eastern mountains are usually higher than those in the south and west. The combined effects of elevation and landscape position might, therefore, result in the fluctuation of SOC along the elevation gradient (Table 6).

Theoretically, a greater slope gradient probably means a higher potential for runoff and soil loss. However, some observations found there was no relationship between SOC stock and slope (Dieleman et al., 2013) and that the degree of soil erosion in crop land is greatly influenced by the cultivation methods used (Basic et al., 2004; Putthacharoen et al., 1998). For instance, El Kateb et al. (2013) reported that the slope gradient had an impact on runoff and soil loss, but this was mediated by land cover in Southern Shannxi Province, China. Ziadat and Taimeh (2013) revealed that cultivated soil has a rougher soil surface than uncultivated soil, because of tillage and other operations, so the effect of slope was more obvious on uncultivated soils in southeast America. In this region, a large proportion of mountain land with steep slopes was cultivated to meet living requirements due to a shortage of flat land. That is why approximately 70% of samples were collected from sites with a slope of > 10° (Table 5). The slope could be further categorized into three groups. Slopes between 15° and 30° had significantly greater SOC levels than other groups. Cultivation strength in Plain areas used to be more intensive than other places, which could accelerate the turnover rate of SOC (Álvaro-Fuentes et al., 2008). In addition, slight terracing and transverse reclamation are popular practices in the mountain areas, which may reduce the risk of soil erosion and be partly responsible for this larger value.

It is well known that soil pH is a key soil property and easy to obtain, but it is adjustable. As a result of chemical fertilizer use and the erosion of surface layers, soil pH will change dramatically when conversion from forest or grassland to cropland occurs (Belay et al., 2002; Liu et al., 2010). In Xinyi County, agricultural soils are mainly derived from 4 types of soil with large differences in pH (Table 1). We collected and paired cultivated and uncultivated soil samples, and compared the change in soil pH (Fig. 3). The results show that the average soil pH of limestone soil dropped by approximately 0.5 units, and others increased by > 1 unit. Based on our investigation in this region, the soil pH values of dry farming land show no notable differences between cultivated periods. This means the pH values can be used roughly to deduce the parental soil of these dry farming cropland soils.

In this study, the soil pH value had a significant positive relationship with SOC ($p < 0.01$; Table 3), which was similar to the findings of Dieleman et al. (2013). From the soil pH in Table 2, we can deduce that most agricultural soils are derived from limestone soils that contain a large amount of calcium carbonate components. These calcium carbonates can largely determine soil pH values (Daikuan et al., 2008; Guizhou Soil Survey Office, 1994). In addition, the free calcium binds readily with organic material and produces humus with a complex structure and a high molecular weight. This might raise the resistance of SOC to microbial decomposition, and thereby increase SOC stocks.

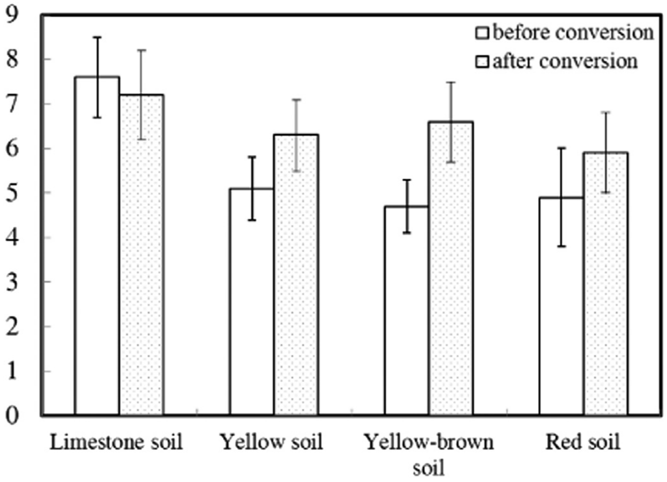

Fig. 3. Change of soil pH during conversion of landuse condition.

Regression analysis was used to examine the relative contribution of soil pH, elevation, slope and landscape position to SOC levels (Eq. 1 and Table 7). These four parameters explained 40% of the SOC variation, but topographic factors could explain no > 10% of the SOC variation. It is worth noting that the variation of soil pH has a strong relationship with slope ($p < 0.01$) (Table 3) although SOC changes are not significantly determined by slope. Consequently, slope is excluded in Eq. (1). Similarly, Liu et al. (2011) found that SOC was not impacted by slope in the Loess Plateau region of China. Hontoria et al. (1999) reported that slope and elevation explained no > 2% of SOC variation by using stepwise regression in Spain, partly because slope and elevation have a weak correlation with water distribution in mountainous cultivated land (Tan et al., 2004). However, soil moisture plays a very important role in controlling SOC dynamics (Yang et al., 2008). As mentioned above, soil pH could be considered a comprehensive indicator of soil inherent physico-chemical properties and could control SOC turnover rate indirectly. The soils, derived from carbonate rocks in Southwest China, are rich in calcium, which enhances the pH value of the soil and protects SOC very well. In this region, soil pH accounts for more SOC variation in dry farming cropland soils than in Jiangsu province in East China (20.9%).(Liao et al., 2016).

5. Conclusion

Studies of factors affecting SOC levels can be used to reduce errors in the estimation of SOC stocks, especially in cropland soils mainly influenced by human activities. We combined pH and topographic factors to reveal the SOC distribution pattern, and assess the relative contribution of different variables to SOC levels. Our observations show that soil pH and topographic factors significantly impact the SOC levels in the dry farming cropland soil of the mountainous region of Southwest China. In terms of landscape position, SOC levels slightly, but significantly, increase by approximately 10% from Summit to base. However, the combined effects of landscape position and elevation on a large scale mean that SOC levels increase, but fluctuate, along the elevation gradient. From an elevation of 1000 m to 2000 m, the average SOC levels increased by 30%. The average values of SOC under a 5° gradient did not differ significantly, which probably reflected the uncertainty introduced by human disturbance of croplands, however, the average values on slopes ranging from 15° to 30° were significantly larger than for other groups. Overall, multiple linear regressions showed that topographic variables and soil pH together could explain approximately 40% of total variation in SOC, of which only 30% was attributed to topographic variables, suggesting that soil pH plays a key role in shaping the spatial distributions of SOC levels in these dry farming cropland soils. The combined effect of landscape position and elevation is more apparent than elevation alone.

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