The impact of land use on soil properties in a karst agricultural region of Southwest China: a case study of Xiaojiang watershed, Yunnan

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Abstract: Supported by RS and GIS, the land use change from 1982 to 2003 were analyzed and the impacts of land use changes on pH value, organic matter, total N, total P, total K, available N, available P, and available K in soil of Xiaojiang watershed, a typical karst agricultural region of Yunnan Province, Southwest China were assessed. The following aspects are concluded. (1) The total land use converted during the past 20 years in Xiaojiang watershed covers an area of 610.12 km^2, of which 134.29 km^2 of forestland was converted into cultivated land, and 210 km^2 of unused land was converted into cultivated land. (2) The rapid growth of population and the economic development were the main driving forces of land use change. (3) With the change in land use, the soil properties have been changed significantly. The pH, organic matter, total N, total P, total K, available N, available P and available K in soil in 1982 were 6.3, 38.02 g kg^{-1}, 1.86 g kg^{-1}, 1.63 g kg^{-1}, 10.94 g kg^{-1}, 114.42 g kg^{-1}, 11.65 mg kg^{-1} and 64.69 mg kg^{-1}g, respectively; and those in 2003 were 6.73, 25.26 g kg^{-1}, 1.41 g kg^{-1}, 0.99 g kg^{-1}, 12.6 g kg^{-1}, 113.43 mg kg^{-1}, 11.11 mg kg^{-1} and 151.59 mg kg^{-1}, respectively. Pared samples t-test of the tested indices of soil properties indicate that those indices have changed significantly during the last 20 years. But the soil properties changed differently, due to the differences in land use change. (4) Also, with the change in land use and management measures of soil, the modifications in soil properties which developed from carbonate rocks were more sensitive than those in the soil developed from sandstone.

Key words: karst agricultural region; land use change; soil properties; Xiaojiang watershed; Yunnan Province
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1 Introduction

Because of modifying land-cover (Turner *et al*., 1991) and management measures of soil (Dalal, 1986), land use changes can cause significant modifications in soil properties (Islam, 2000; Mcalister, 1998; Braimoh, 2004; Lal, 1996; Shepherd, 2000, Chen, 2001; Williams, 1993; Lichon, 1993). Karst has been regarded as a fragile environment by environmental scientists. Because of its low capacity, a karst system is difficult to restore if once disturbed (Yuan, 1988; 1993). Changes in hydrological balances are not unique to karst region, but karst regions are more sensitive than others (LeGrand, 1984). Recent studies on effects of land use changes on soil properties showed important physical and chemical modifications of soil in karst region. The conversion of natural forest to other forms of land can provoke soil erosion (Williams, 1993), lead to a reduction in soil organic content (Lichon, 1993; Chen, 2001), total N, total P (Chen, 2001), lose soil quantity (Lichon, 1993), and even modify the soil structure (Lichon, 1993) in karst region.

Karst occupies about 33% or 344×10^4 km^2 of the land area in China, which is located mainly in Southwest China. Because of population pressure and economic devolvement, land use changed significantly, leading to remarkable modification of soil properties in karst region of Southwest China.

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In the present study we analyzed the land use changes from 1982 to 2003, and assessed the effects of land use changes on pH value, organic matter, total N, total P, total K, available N, available P and available K in soil of Xiaojiang watershed in Yunnan Province, Southwest China.

2 The study area

The Xiaojiang watershed located in Yunnan Province, Southwest China covers an area of about 1034 km^2. It extends 24°12'-24°45'N and 103°32'-104°00'E with an elevation of about 1900 m. It has a subtropical plateau monsoon climate with mean annual precipitation of 1000 mm and mean air temperature of 15.2 °C. The watershed is mainly underlain by Triassic system with carbonate rocks of 617 km^2 or about 60%. The soil mainly consists of red soil in Xiaojiang watershed, which covers 730 km^2 or 71%. The population was 22.7×10^4, of which 20×10^4 was in rural area in 2003. The gross domestic product (GDP) was 3.34×10^8 yuan, of which agriculture gross domestic product was 2.27×10^8 yuan in 2003. So Xiaojiang watershed is a typical karst agricultural region.

3 Materials and methods

3.1 Land use data and analysis

To facilitate the operation between series of spatial data, the land use category in Xiaojiang watershed is limited to 6 classes, i.e., forestland, cultivated land, unused land, orchard land, water body and construction land.

Land use data in 1982 (scale 1:50,000) was obtained from aerial photo of 1982 by interpreting, and verified and rectified through field survey.

Land use data in 2003 (scale 1:50,000) was obtained from Land-sat TM digital image in 2003 by supervised classifications, and checked by field survey.

The analysis of land use change was completed by geographical information system software (Arcgis and Professional MapInfo).

3.2 Soil sampling and analysis

Sixty-two soil samples were collected, of which 19 from cultivated land converted from forestland, and 12 from cultivated land converted from unused land, and 13 reforested land, and 7 orchard land converted from cultivated land, and 11 unused land (rocky desertified land) converted from cultivated land (Figure 1). Soil samples collected from 0-20 cm depth were air-dried and passed through a 2 mm sieve, and subsequently analyzed in the laboratory for pH (1:2.5 $CaCl_2$), organic matter (Walkley-Black), total N (Kjeldahl), total P (colorimetry), total K (flame emission spectroscopy), available N (diffused), available P (Bray-P) and available K (NH_4-acetate). Slope data of sampling points was derived from a digital elevation model constructed from 10 m vertical interval contour lines of the study area.

3.3 Statistical analysis

All data summary and statistical analysis were calculated using SPSS computer procedures. Paired samples t-test of soil properties indices proved the significance test.

4 Results and discussion

4.1 Land use change

Through spatial overlay analyzing two-period land use maps, which was supported by geographical information system, the land use change matrix was obtained (Table 1).

As shown in Table 1, the land use changed significantly in Xiaojiang watershed in the past 20 years. The percentages of land use for each type were 19.63 cultivated land, 27.84 forestland, 0.02 orchard land, 1.89 construction land, 0.72 water body and 49.9 unused land in 1982, respectively, but they were converted into 46.5, 27.47, 0.15, 3.24, 0.77 and 22.77 in 2003, respectively.

The total land converted covered an area of 610.12 km^2 in Xiaojiang watershed during the past 20 years. The main land use type changes were from unused land into cultivated land and forestland, and from forestland into cultivated land. So the cultivated land increased by 268.5 km^2 or 132.7%, but unused

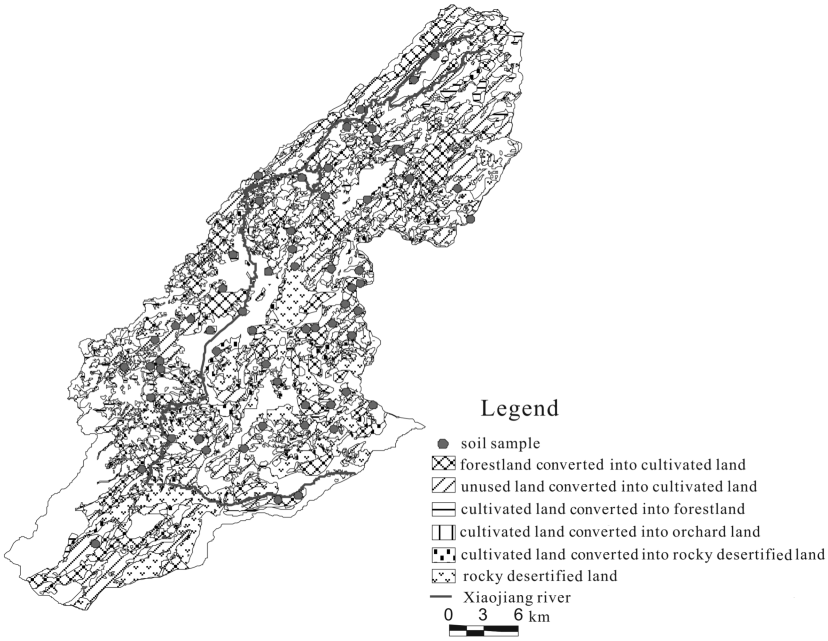

Figure 1 Distribution of soil sampling sites

Table 1 The land use change matrix in Xiaojiang watershed from 1982 to 2003 (km^2)

Land use category	Cultivated land	Forestland	Orchard land	Construction land	Water body	Unused land	1982 total percentage (%)
Cultivated land	123.1	37.19	0.44	5.63	1.7	34.94	203 (19.63%)
Forestland	134.29	114.67	0.39	2.99	1.65	33.91	287.9 (27.84%)
Orchard land	0.12	0	0	0	0	0.1	0.22 (0.02%)
Construction land	0	0	0	19.5	0	0	19.5 (1.89%)
Water body	3.99	1.14	0.13	0.08	1.05	0.99	7.38 (0.72%)
Unused land	210	131	0.54	5.3	3.6	165.56	516 (49.9%)
2003 total	471.5	284	1.5	33.5	8	235.5	1034
Percentage (%)	(45.6%)	(27.47%)	(0.15%)	(3.24%)	(0.77%)	(22.77%)	(100%)

land decreased by 280.5 km^2 or 54.36% during the last 20 years.

When analyzing the relationship between the total cultivated land area and the total population annually during the 20 years by SPSS software, we can obtained a conic equation on the annual total cultivated land area and the annual total population, that is:

$$y = 1034.12 - 130.07x + 4.7328x^2 \qquad R^2 = 0.988$$

where y is the total cultivated land per year, and x is the total population per year.

Also, when the correlation between the cultivated land area and gross domestic product, and agriculture gross domestic product per year were analyzed in Xiaojiang watershed during the last 20 years, the correlation coefficients were 0.782 and 0.855 at $p < 0.01$, respectively.

With the increase of the food demand due to the rapid growth of population, the demand for cultivated land increased significantly which resulted in the conversions of forestland and unused land into cultivated land in the karst region with a low productivity and environmental capacity, and because the cultivated land is the main economic sources in the karst agricultural region, the development of survival economy brings about the increase in cultivated land. So it was clarified that the rapid growth of population and the economic development were the direct factors leading to cultivated land increase in Xiaojiang watershed during the past 20 years.

The deterioration of environment due to excessive assart is badly endangering the ecosystem safety of the Pearl River drainage basin. With the implementation of the project of protecting the ecosystem of the Pearl River drainage basin, the cultivated land and unused land were converted into forestland from the mid-1990s in Xiaojiang watershed. So the ecosystem protection is an important driving force of forestland change in Xiaojiang watershed during the past 20 years.

4.2 Soil properties change

Table 2 reveals that soil properties have modified in the past 20 years following the land use change, and Table 3 indicates that those tested indices of soil properties have modified significantly (except available P).

As shown in Table 2, soil pH value increased by 0.43, but the coefficients of variation (CV) of soil pH value show a declining trend. Pared samples t-test indicates that the soil pH value has modified significantly in the past 20 years. The variation of soil pH value has relation to the conversions of forestland and unused land into cultivated land. With the forest clearance, the eluviation of soil will be depressed due to the decline of soil moisture, and the content of CO_2 and the concentration of H^+ in soil will decline, and the soil pH value will increase.

Table 2 Statistical characteristics of soil properties indices of the corresponding sampling sites in 1982 and 2003 (N = 62)

	Mean	Standard deviation	CV (%)	Minimum	Maximum
1982					
pH	6.30	0.62	9.8	4.99	7.70
Organic matter/g kg^{-1}	38.02	20.19	53.1	13.40	124.80
Total N/g kg^{-1}	1.86	1.12	60.3	0.42	7.37
Available N/mg kg^{-1}	144.42	83.40	57.8	40.4	509.90
Total P/g kg^{-1}	1.63	1.23	75.6	0.57	7.79
Available P/mg kg^{-1}	11.795	8.32	70.6	1.35	43.10
Total K/g kg^{-1}	10.94	7.10	64.9	4.00	37.37
Available K/mg kg^{-1}	84.69	38.10	44.9	20.99	182.60
2003					
pH	6.73	0.66	9.7	5.63	7.97
Organic matter/g kg^{-1}	25.76	13.27	51.5	1.90	65.40
Total N/g kg^{-1}	1.44	0.75	52.1	0.19	3.80
Available N/mg kg^{-1}	113.43	61.90	46.1	25.24	308.30
Total P/g kg^{-1}	1.01	0.47	46.5	0.30	2.22
Available P/mg kg^{-1}	10.85	11.74	113.21	0.96	61.36
Total K/g kg^{-1}	12.6	7.93	62.9	4.10	43.60
Available K/mg kg^{-1}	119.42	48.48	40.6	59.04	390.00

Table 3 Pared samples t-test of soil properties indices of corresponding sampling sites in 2003 and 1982

	Mean	t	df	Sig (2-tailed)	Significant
pH	0.43	10.202	61	0.000	**
Organic matter	-12.26	-4.717	61	0.000	**
Total N	-0.42	-3.292	61	0.002	**
Available N	-30.99	-2.917	61	0.005	**
Total P	-0.62	-4.011	61	0.000	**
Available P	-1.14	-0.748	61	0.457	NS
Total K	1.66	6.154	61	0.000	**
Available K	34.73	6.579	61	0.000	**

Significant at 0.05 level. ** Significant at 0.01 level. NS, not significant.

In the past 20 years, the content of soil organic matter decreased by 12.26 g kg^{-1} or 32.5%, and the coefficients of variation (CV) of soil organic matter shows a declining trend, and pared samples t-test indicates that the content of soil organic matter has modified significantly. Because of the enrichment of Ca and Mg in limestone soil, the content of soil organic matter is more than that in nonkarst soil (Cao, 2003). The content of soil organic matter decreased significantly, for which the plant residue decreased significantly in soil, and soil erosion was easily triggered because limestone soils are typically shallow and because the open joint systems facilitate the washing underground of soil material following the forest clearance (Williams, 1993). The soil organic matter has a higher CV because the content of soil organic matter in the limestone soil is more than that in sandstone soil. But the variation of soil organic matter CV has relation to the decrease of the content of soil organic matter in the limestone soil.

Because the soil organic matter is the sources of soil total N and total P and the enrichment of Ca and Mg in limestone soil, the contents of soil total N and total P in limestone soil are more than those in sandstone soil. Because the content of soil organic matter decreased with the land use changes, the contents of soil total N and total P decreased accordingly. Also, the CV of soil total N and total P decreased due to the decrease of the contents of soil total N and total P.

The content of soil total K increased by 1.66 g kg^{-1} in the past 20 years, and the CV of soil total K shows a decreasing trend, and pared samples t-test indicates the content of soil total K has modified significantly. The K mineral still exists in soil, although the soil organic matter decreases with soil erosion, and the K fixation increases with the increase of soil pH value (Zhao, 2002).

Because the soil organic matter is the major sources of N and P, the variation of the contents of soil available N and available P are influenced by the content of soil organic matter and the use of fertilizer.

4.2.1 The soil properties modified following forestland conversion into cultivated land As shown in Table 4, the soil properties modified significantly (except total K) after forestland was converted into cultivated land. The soil pH value, the contents of total K and available K increased by 0.39, 0.59 g kg^{-1} and 41.81 mg kg^{-1}, respectively, but the contents of soil organic matter, total N, total P, available N and available P decreased by 24.21 g kg^{-1}, 0.77 g kg^{-1}, 1.36 g kg^{-1}, 86.33 mg kg^{-1} and 6.8 mg kg^{-1}, respectively, after forestland conversion into cultivated land in the past 20 years.

The soil pH value increases due to forest clearance, which brings about a decline in the content of CO_2 and the concentration of H^+.

With the forest clearance and the crop residues taking out, the plant residues preserved in soil declined significantly and soil erosion was easily triggered. The soil organic matter in cultivated land is decomposed faster than that in forestland due to the act of cultivating, which may consequently lead to a significant reduction in the soil organic matter.

With a decline in the soil organic matter and reduced use of N and P fertilizers following forestland conversion into cultivated land, the total N, total P, available N and available P showed a declining trend.

But with the increase of soil pH value, the content of soil total K increased due to the increasing of K fixation (Zhao, 2002). Variation in soil available K is influenced by the use of potash fertilizer.

The variation of the soil properties, following forestland conversion into cultivated land, is different because of differences in geological background. The contents of soil organic matter, total N, total P, available N and available P decreased by 34.25 g kg^{-1}, 1.17 g kg^{-1}, 2.24 g kg^{-1}, 118.23 mg kg^{-1} and 9.86 mg kg^{-1}, respectively, after forestland was converted into cultivated land in the carbonate stone; but those indices decreased by 11.05 g kg^{-1}, 0.45 g kg^{-1}, 1.25 g kg^{-1}, 51.59 mg kg^{-1} and 4.76 mg kg^{-1}, respectively, after forestland was converted into cultivated land in the sandstone. The soil pH increased by 0.41 in the carbonate stone, but that increased by 0.21 in the sandstone, after forestland was converted into cultivated land. Those variations of the soil properties in different strata indicated that the soil developed from carbonate stone is more fragile than the soil developed from sandstone.

4.2.2 The soil properties modified following unused land conversion into cultivated land As shown in Table 5, after unused land was converted into cultivated land, the soil properties modified significantly (except total K and available N). The soil pH value, the content of total K, available N, available P and available K increased by 0.3, 1.3 g kg^{-1}, 1.74 mg kg^{-1}, 2.17 mg kg^{-1} and 25.38 mg kg^{-1}, respectively, but the contents of soil organic matter, total N and total P decreased by 9.45 g kg^{-1}, 0.11 g kg^{-1} and 0.65 g kg^{-1}, respectively, after unused land conversion into cultivated land in the past 20 years.

Variation of soil properties following unused land conversion into cultivated land follows the same pattern as forestland converted into cultivated land. But the variation extent of soil properties tested indices in unused land conversion into cultivated land is lower than that in forestland conversion into cultivated land. This can be explained by the fact that unused land converted into cultivated land is on the lower slopes with better soil management, whereas forestland converted into cultivated land on the higher slopes with poor soil management.

Table 4 The variation of soil properties following forestland conversion into cultivated land

Stratum	Slope	Sample quantity	Sampling time	pH	Organic matter g kg^{-1}	Available N mg kg^{-1}	Available K mg kg^{-1}	Available P mg kg^{-1}	Total N g kg^{-1}	Total K g kg^{-1}	Total P g kg^{-1}
Carbonate stone	15.5	9	1982	6.16	71.46	282.3	105.32	19.11	3.50	10.92	3.33
			2003	6.57	37.21	164.07	99.15	9.25	2.33	10.94	1.09
			Variation value	+0.41	-34.25	-118.23	-6.17	-9.86	-1.17	+0.02	-2.24
			Variation percentage %	+6.66	-47.93	-41.88	-5.86	-51.60	-33.43	+0.18	-67.27
Quaternary	11.9	5	1982	6.78	44.64	167.00	95.74	19.24	1.62	6.18	1.33
			2003	7.27	25.34	103.36	173.78	14.78	1.13	6.30	0.97
			Variation value	+0.49	-19.3	-63.64	+78.04	-4.46	-0.49	+0.12	-0.36
			Variation percentage %	+7.23	-43.23	-38.11	+81.51	-23.18	-30.25	+1.94	-27.07
Sandstone	15.8	5	1982	5.94	31.46	127.07	89.03	13.28	1.7	19.88	2.10
			2003	6.15	20.41	75.48	188.8	8.52	1.25	21.18	0.85
			Variation value	+0.21	-11.05	-51.59	+99.77	-4.76	-0.45	+1.3	-1.25
			Variation percentage %	+3.54	-35.12	-40.60	+112.06	-35.84	-26.47	+6.54	-59.52
Average	14.6	19	1982	6.26	53.87	211.11	98.51	17.61	2.48	11.83	2.35
			2003	6.65	29.66	124.78	140.32	10.81	1.71	12.42	0.99
			Variation value	+0.39	-24.21	-86.33	+41.81	-6.80	-0.77	+0.59	-1.36
			Variation percentage %	+6.23	-44.94	-40.89	+42.44	-38.61	-31.05	+4.99	-57.87
Significant*				**	**	*	*	**	**	NS	**

* Significant at 0.05 level. ** Significant at 0.01 level. NS, not significant

Table 5 The variation of soil properties following unused land conversion into cultivated land

Stratum	Slope	Sample quantity	Sampling time	pH	Organic matter g kg^{-1}	Available N mg kg^{-1}	Available K mg kg^{-1}	Available P mg kg^{-1}	Total N g kg^{-1}	Total K g kg^{-1}	Total P g kg^{-1}
Carbonate stone	10.7	7	1982	6.50	33.70	113.92	106.48	7.45	1.34	11.16	1.29
			2003	6.81	21.80	115.08	127.86	12.51	1.20	11.20	0.68
			Variation value	+0.31	-11.90	+1.16	+21.38	+5.06	-0.14	+0.04	-0.61
			Variation percentage %	+4.77	-35.31	+1.02	+20.08	+67.92	-10.45	+0.36	-47.29
Sandstone	18.1	5	1982	6.35	32.78	127.28	79.64	12.18	1.54	13.86	1.46
			2003	6.59	26.74	129.87	114.22	10.30	1.45	16.90	0.86
			Variation value	+0.24	-6.04	+2.59	+34.58	-1.88	-0.09	+3.04	-0.60
			Variation percentage %	+3.78	-18.43	+2.03	+43.42	-15.44	-5.84	+21.93	-41.10
Average	13.8	12	1982	6.40	33.32	119.48	95.30	10.25	1.42	12.28	1.36
			2003	6.70	23.87	121.22	120.68	12.42	1.31	13.58	0.71
			Variation value	+0.30	-9.45	+1.74	+25.38	+2.17	-0.11	+1.30	-0.65
			Variation percentage %	+4.69	-28.36	+1.45	+26.63	+21.18	-7.75	+10.59	-44.85
Significant*				**	*	NS	*	*	**	NS	*

* Significant at 0.05 level. ** Significant at 0.01 level. NS, not significant.

Also, the variation of the soil properties, following unused land conversion into cultivated land, is different because of differences in geological background. The contents of soil organic matter, total N and total P decreased by 11.9 g kg^{-1}, 0.14 g kg^{-1} and 0.68 g kg^{-1}, respectively, after unused land was converted into cultivated land in the carbonate stone; but those indices decreased by 6.04 g kg^{-1}, 0.409 g kg^{-1} and 0.60 g kg^{-1}, respectively, after unused land was converted into cultivated land in the sandstone. The soil pH increased by 0.31 in the carbonate stone, but that increased by 0.24 in the sandstone, after unused land conversion into cultivated land. Those variations of the soil properties in different strata indicated that the soil developed from carbonate stone is more fragile than the soil developed from sandstone.

4.2.3 The soil properties modified following reforestation As shown in Table 6, after reforestation, the soil properties modified, but the variation is not significant (except soil pH value). The soil pH value, the contents of total K and available K increased by 0.3, 2.65 g kg^{-1}, and 9.83 mg kg^{-1}, respectively, but the contents of soil organic matter, total N, total P, available N and available P decreased by 2.8 g kg^{-1}, 0.18 g kg^{-1} and 0.34 g kg^{-1}, 10.65 mg kg^{-1} and 2.83 mg kg^{-1}, respectively, after reforestation.

This can be explained by the fact that reforestation soil is the higher slopes with poor soil management and a short period of time. Because the land is almost bared which leads to soil erosion due to a short-time reforestation and the use of fertilizer decreased, the contents of soil organic matter, total N, total P, available N and available P decreased, but the soil pH value increased. With the increase of soil pH value, the content of soil total K increased.

Table 6 The variation of soil properties following cultivated land conversion into forestland

Stratum	Slope	Sample quantity	Sampling time	pH	Organic matter g kg^{-1}	Available N mg kg^{-1}	Available K mg kg^{-1}	Available P mg kg^{-1}	Total N g kg^{-1}	Total K g kg^{-1}	Total P g kg^{-1}
Carbonate stone	20.7	9	1982	6.05	35.71	142.22	84.05	12.03	2.02	10.06	1.66
			2003	6.45	32.58	133.25	88.34	8.86	1.74	11.09	1.25
			Variation value	+0.4	-3.13	-8.97	+4.29	-3.17	-0.28	+1.03	-0.41
			Variation Percentage %	+6.61	-8.77	-6.31	+5.10	-26.35	-13.86	+10.24	-24.70
Sandstone	16.1	4	1982	6.20	27.48	95.20	58.54	6.33	1.55	11.75	1.73
			2003	6.36	24.85	84.83	80.83	5.56	1.55	14.78	1.53
			Variation value	+0.16	-2.63	-10.37	+32.29	-0.77	0	+3.03	-0.20
			Variation percentage %	+2.58	-9.57	-10.89	+55.19	-12.16	0	+25.79	-11.56
Average	19.3	13	1982	6.10	33.00	127.76	76.20	10.35	1.88	10.58	1.68
			2003	6.40	30.20	117.11	86.03	7.52	1.70	13.23	1.34
			Variation value	+0.30	-2.80	-10.65	+9.83	-2.83	-0.18	+2.65	-0.34
			Variation Percentage %	+4.92	-8.48	-8.34	+12.90	-27.34	-9.57	+25.05	-20.24
Significant*				*	NS	NS	NS	NS	NS	NS	NS

* Significant at 0.05 level. ** Significant at 0.01 level. NS, not significant.

4.2.4 The soil properties modified following cultivated land conversion into orchard land As shown in Table 7, after cultivated land conversion into orchard land, the soil properties modified insignificantly. The soil pH value decreased by 0.16, but the contents of organic matter, total N, total P, total K, available N, available P and available K increased by 17.54 g kg^{-1}, 0.8 g kg^{-1}, 0.77 g kg^{-1}, 1.53 g kg^{-1}, 88.8 mg kg^{-1}, 23.51 mg kg^{-1} and 122.9 mg kg^{-1}, respectively.

With cultivated land conversion into orchard land, soil properties modified due to the fact that the land cover has been changed and the farmers can obtain more income from orchard land than from cultivated land which leads to increased use of fertilizer and improved land management.

Soil pH value declined due to the fact that soil environment was more humid and soil eluviation was stronger, and that the content of CO_2 and the concentration of H^+ in soil increased because land was covered by dry branches and fallen leaves, and that farmers used more fertilizer, especially more organic fertilizer after cultivated land conversion into orchard land.

Soil organic matter increased significantly because of substantial increase in plant residues preserved in soil and more fertilizer, especially more organic fertilizer applied after cultivated land conversion into orchard land.

Table 7 The soil properties change following cultivated land conversion into orchard

Stratum	Slope	Sample quantity	Sampling time	pH	Organic matter g kg^{-1}	Available N mg kg^{-1}	Available K mg kg^{-1}	Available P mg kg^{-1}	Total N g kg^{-1}	Total K g kg^{-1}	Total P g kg^{-1}
Carbonate stone	6	7	1982	6.68	18.70	73.28	72.47	4.74	1.00	13.47	0.83
			2003	6.52	36.24	162.08	195.37	28.25	1.80	15.00	1.60
			Variation value	-0.16	+17.54	+88.8	+122.9	+23.51	+0.80	+1.53	+0.77
			Variation percentage %	-2.40	+93.80	+121.20	+169.59	+495.99	+80.00	+11.36	+92.77
	Significant*			**	**	**	**	**	**	**	**

* Significant at 0.05 level. ** Significant at 0.01 level. NS, not significant.

With application of more fertilizer and increase in soil organic matter, the contents of soil total N, total P, total K, available N, available P and available K increased significantly after land conversion.

4.2.5 The soil properties modified following cultivated land conversion into unused land (rocky desertified land) As shown in Table 8, after cultivated land conversion into unused land, the soil properties modified insignificantly. The soil pH value, the contents of total K and available K increased by 0.7, 2.74 g kg^{-1} and 12.23 mg kg^{-1}, respectively, but the contents of soil organic matter, total N, total P, available N and available P decreased by 24.73 g kg^{-1}, 1.01 g kg^{-1}, 0.54 g kg^{-1}, 68.29 mg kg^{-1} and 7.51 mg kg^{-1}, respectively, after 20 years land conversion. And the soil thickness declined insignificantly, most of the soil thickness is less than 10 cm.

Table 8 The soil properties change following cultivated land conversion into unused land

Stratum	Slope	Sample quantity	Sampling time	pH	Organic matter g kg^{-1}	Available N mg kg^{-1}	Available K mg kg^{-1}	Available P mg kg^{-1}	Total N g kg^{-1}	Total K g kg^{-1}	Total P g kg^{-1}
Carbonate stone	17.6	11	1982	6.50	33.92	119.57	70.36	9.62	1.74	6.41	1.19
			2003	7.20	9.19	51.28	82.59	2.11	0.73	9.15	0.65
			Variation value	+0.70	-24.73	-68.29	+12.23	-7.51	-1.01	+2.74	-0.54
			Variation percentage %	+10.77	-72.91	-57.11	+17.38	-78.07	-58.05	+42.75	-45.38
		Significant*		**	**	**	*	**	**	*	**

* Significant at 0.05 level. ** Significant at 0.01 level. NS, not significant.

The fragility of soils on the higher slopes and poor soil management led to intense soil erosion and loss of soil nutrients, the continuous cultivation caused soil nutrients depletion and removal of soils, hence the cultivated land finally developed into rocky desertified land.

Soil pH value increased significantly as a result of soil desiccation on the uncovered land and loss of soil nutrients, which leads to enrichment of Ca and Mg in soil, and the decline in the content of CO_2 and the concentration of H^+ in soil.

The contents of soil organic matter, total N, total P, available N and available P decreased significantly due to intense soil erosion and lower input in fertilizer.

But with the increase of soil pH value, the content of soil total K increased.

5 Summary and conclusions

This study reveals that the rapid growth of population and the economic development lead to land use changes, which lead to remarkable modifications in soil properties in karst region, Southwest China.

Because of modifying land-cover and management measures of soil, land use changes can cause significant modifications in soil properties. After forestland and unused land were converted into cultivated land, soil properties modified significantly which showed an increasing trend in soil pH value and total K, but a declining trend in the contents of soil organic matter, total N and total P. While cultivated land was converted into orchard land, soil pH value showed a declining trend, but the contents of soil organic matter, total N, total P and total K increased significantly. After land conversion, the contents of soil organic matter, total N, total P, available N, and available P declined significantly, but soil pH value and total K showed an increasing trend.

Also, with the change in land use and management measures of soil, the modifications in soil properties which developed from carbonate stone were more sensitive than those in the soil developed from sandstone.

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