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Effect of land-use and land-cover change on nutrients in soil in Bashang area, China

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Abstract: The Bashang area is a water-source area and ecological barrier zone for Beijing and Tianjin. The area is located at 200 km from Beijing and Tianjin and is a typical agriculture-pasture-interlacing zone, in which the eco-environment is vulnerable and hence it is sensitive to environmental change. The area is relatively lagged in social and economic development, where the traditional cultivation mode is predominated in agriculture and animal husbandry, but the disturbance by human activity is relatively small. Therefore, in order to reveal the interrelation between eco-environmental change in the area and environmental change in Beijing and Tianjin area, it is fairly necessary to study the effect of land-use and land-cover change on nutrients in soil in this area. According to the actual situation of changed land use for the limited time period, five series of changed land plots were selected and 4 samples were collected from each series for the study. The samples were collected from different soil-forming levels at the same site in different time. Analysis of the collected samples indicates that in the process of change of land use and land cover, the nutrients in soil, such as organic matter, total N, total P, total K, and available N, P, K, and B, Mo, Mn, Zn, Cu, and Fe, have regularly changed. When the land had changed from grassland and non-irrigated farmland into woodland, and from non-irrigated farmland into irrigated field, the nutrients in soil totally increased. But there exists some exception, i.e. quick-acting N, P, K, and some microelements have appeared to be inconsistent with the mentioned above regularity in some cases.

Keywords: Bashang area; land use change; variation of nutrients

Introduction

The Bashang area is located in Zhangjiakou Municipality of Hebei Province, China(113°50′—118°0′ E and 40°58′—42°42′N), including Zhangbei, Guyuan and Kangbao counties and parts of Shangyi, Fengning, and Weichang counties of Chengde Municipality, with total area of 17371 km^2. It borders on Xilin Gol League and Hunshandake Desert of Inner Mongolia in the north, Hunshan area of Wulanchabu League in the west, and Yanshan Mountains in south, linking with Baxia area of Zhangjiakou and Chengde municipalities, and the extension of Daxingan Range in the east. The area is located on the southern border of Inner Mongolia Plateau, at the middle section of northern China agriculture-pasture-interlacing zone, and is a typical vulnerable eco-environmental zone.

Study on change in land use and vegetation cover becomes a frontier and hot-spot problem in research of global change at present. International Geosphere-Biosphere Program (IGBP) and Human Domain Program(HDP) in Global Environment Change had jointly proposed a research program "Land-use and land-cover change" in 1995. It promoted the study field into a higher stage. An extensive, long-term and integrated research was developed in the North America, Europe, Japan and other countries and regions.

In last years, study on land-use and land-cover change was also developed in China and the study extent and scope were gradually increased(Chen, 1997; Shi, 2001; Turner II, 1994; 1995; Wang, 1998; Yang, 1999).

The land-use and land-cover change has significant effect on environment, e.g. on biodiversity, soil composition and sediment composition, hydrology, chemical property and process of the atmosphere, climate change, ecosystem and so on. Therefore, study on land-use and land-cover change is of great theoretical and practical significance(Guo, 1999; 2000).

The Bashang area is a typical agriculture-pasture-interlacing zone, in which the eco-environment is fairly vulnerable, and hence it is very sensitive to environmental change. The area is located at only 200

Foundation item: The National Nautral Science Foundation of China(No.40072097); * Corresponding author km from Beijing and Tianjin and is a water-source zone and an ecological barrier zone for Beijing and Tianjin. The eco-environmental change in Beijing and Tianjin is directly related to the change in this area. Thus, study on the change in this area is of great significance.

The worse natural conditions made the area developed later and the social and economical developments are more backward. So the area is still poor. The agricultural and pastoral operations are still mainly in the traditional manner. The area was less disturbed by human activities and is favorable for studying the land-use and land-cover change.

The scope of study on land-use and land-cover change is wide. In this paper we study only the effect of land-use and land-cover change on dynamic variation of nutrients in soil in the Bashang area.

1 General situation of land-use and land-cover change in Bashang area

The Bashang area was a nomadic area for long time in history, plantation was small in scale and distributed only sporadically in the area. Agriculture in the area was developed in the period of emperors Kangxi and Yongzheng of Qing Dynasty, earlier in Zhangbei County as a gate to the north of Great Wall, later westward in Kangbao and Shangyi counties, and then gradually extended from the west to the east. With the growing population, grassland reduced and cultivated farmland gradually increased. For example, the population in Zhangbei County was 30 thousand or more people and the reclaimed farmland increased as much as 400 thousand mu (1 mu = 0.066 hm^2, i.e. ha) in the years of emperor Yongzheng, when total population in the whole Bashang area was only 100 thousand or more people and cultivated farmland was 1—2 million mu. By the years of emperor Guangxu, the population in Zhangbei County reached 100 thousand people and cultivated farmland exceeded one million mu. At this time the population in the whole Bashang area was 300 thousand people and cultivated farmland reached 2 million mu. By 1927, the population in Zhangbei County was 300 thousand people and the cultivated farmland exceeded 2 million mu. By 1949, the population in Bashang area reached 460 thousand people, cultivated farmland was 5.5031 million mu, and natural grassland was about 13 million mu. From 1949 to now, with largely growing population and rising live level, especially during 1960s—1970s, when "agriculture gives the first priority to development of food production", extensive land reclamation resulted in gradual reduction of grassland. For example, the grassland was 3.10 million mu in Kangbao County in 1949, including 20 tracts of 10 thousand mu meadows and 25 tracts of 1 thousand mu meadows. However, by 1981, the grassland was only 1.40 million mu in the whole county, reduced by 1.70 million mu against that in 1950s. Only 1.14 million mu of grassland can be used. Few tracts of extensive meadows remained. By the middle-later 1980s, cultivated farmland was 11.0 million mu, and natural grassland was only 4 million or more mu. Moreover, the grassland was significantly degraded. Land cover of the grassland decreased from 90% to less than 35%. The height of grass reduced from 50 cm to around 20 cm. Yield of dry grass decreased from 250—300 kg to 40—50 kg. Capability of livestock-loading reduced from 40—50 sheep unit/hundred mu to 7—8 sheep unit/hundred mu. Meanwhile, grass suitability to livestock reduced and the grass toxicity increased.

During the late 1990s, people in the area were gradually woke up to the destruction of eco-environment by extensive reclamation and great loss caused by it. Recovery of grassland and woodland from reclaimed farmland had begun in local areas. Irrigated farmland was set up and stagger vegetables were planted (Hass, 1994; Statistical Department of Zhangjiakou City, 1999; Zhao, 1997).

In summary, the land-use change in the Bashang area has its strikingly characteristics during 50 or more years. Where grassland changed into cultivated farmland and woodland (artificial woodland of 1.50 million mu was set up in Saihanba area), then cultivated farmland changed into grassland and woodland and nonirrigated farmland changed into irrigated land. This land-use change process resulted in deterioration of eco-environment to some extent, e.g. grassland was degraded and land became sandy. It is essentially a change of nutrients in soil. In this background, study and discussion on the effect of land-use and land-cover change on nutrients in soil is of evident significance. Moreover, the Bashang area is still a poor area in China, in which per capita land is 10 or more mu, few or no chemical fertilizer was applied to the soil. Thus, the obtained data of nutrients in the soil are less disturbed and hence are reliable and reasonable for scientific study.

The main nutrients in the soil in Bashang area were analyzed. They are organic matters, total N, total P, total K, alkaline-hydrolyzed N, active P, active K, and a part of active microelements, such as B, Mn, Mo, Cu, Fe, Zn and so on.

2 Effect of land-use and land-cover change on nutrients in soil

On the basis of the situation of land – use change in the Bashang area, 5 series of changed land plots were selected for the study. They are (a) grassland→nonirrigated farmland; (b) grassland→woodland; (c) nonirrigated farmland→grassland; (d) nonirrigated farmland→woodland: and (e) nonirrigated farmland→irrigated farmland. The data of nutrients in the soil from these 5 series of land plots were analyzed, processed, and plotted in Figs.1—7 and listed in Tables 1—2. The methods for analysis of nutrients in soil were taken from Routine Agrochemical Methods for Analysis of Soils edited by the Agrochemical Profession Commission of the Society of Soil Science of China.

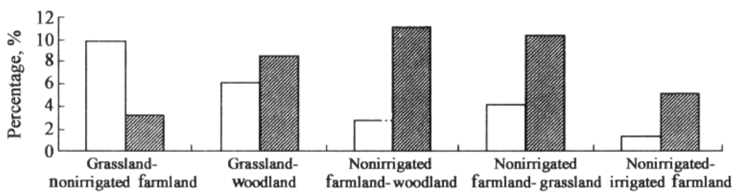

Fig.1 Variation of organic matters in soil

Fig.1 indicates that the variation of organic matters in soil is the most clear in land-use change. When grassland changed into nonirrigated farmland, organic matters in soil decreased from nearly 10% to about 3%, while nonirrigated farmland changed into grassland, organic matters increased from about 3% to 10% or more. The dramatic variation of this set of data reflects that the change of grassland into farmland can lead the fertility of soil to significantly decrease. When grassland changed into woodland, nonirrigated farmland into woodland, and nonirrigated farmland into irrigated farmland, organic matters can much increase. In general, in the land-use change, content of organic matters in soil varies in such a sequence, woodland→grassland→irrigated farmland→nonirrigated farmland.

Fig.2 Variation of total nitrogen in soil

Fig.2 shows the variation of total N from nutrients in land-use change. The variation regularity of total N is basically similar to that of organic maters, only its decreasing amplitude is less in the change of grassland into nonirrigated farmland, but its increasing amplitude is larger in the change of nonirrigated farmland into grassland(from 0.2% to 0.6% or more).

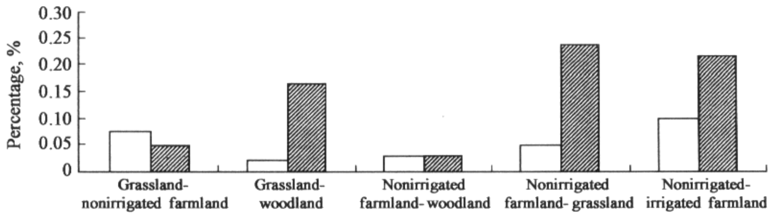

Fig.3 Variation of total phosphorus in soil

Fig.3 shows the variation of total P in soil. The general variation regularity of P is similar to that described above. But when land use changed from nonirrigated farmland into woodland, total P less increased, while nonirrigated farmland changed into irrigated farmland, total P much increased.

Fig.4 shows the variation of total K in soil. Its general regularity is similar to the described above. But in land-use change, content of total K in soil varies in small amplitude. Only when nonirrigared farmland changed into irrigated farmland, it increased significantly.

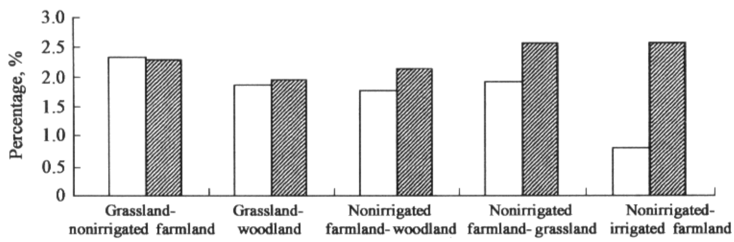

Fig.4 Variation of total potassium in soil

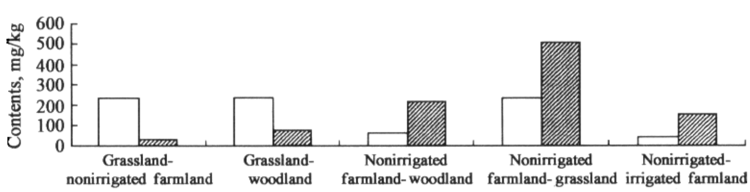

Fig.5 Variation of alkaline-hydrolyzed nitrogen in soil

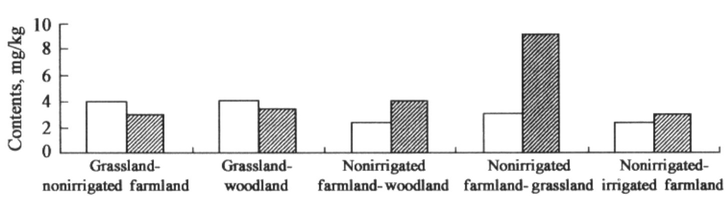

Fig.6 Variation of quick-acting phosphorus in soil

Figs.5—7 show the variations of alkaline-hydrolyzed nitrogen, quick-acting K, and quick-acting P in soil in land-use change. When grassland changed into nonirrigated farmland and nonirrigated farmland into grassland and into irrigated farmland, the alkaline-hydrolyzed N varied significantly. When grassland changed into nonirrigated farmland, it decreased from 233 to 34 mg/kg. While nonirrigated farmland changed into grassland, the alkaline-hydrolyzed N increased from 223 to 512 mg/kg. Only when nonirrigated farmland changed into woodland, it less varied. The variation amplitude of quick-acting P is generally similar to that of alkaline-hydrolyzed N. Only when nonirrigated farmland changed into grassland,

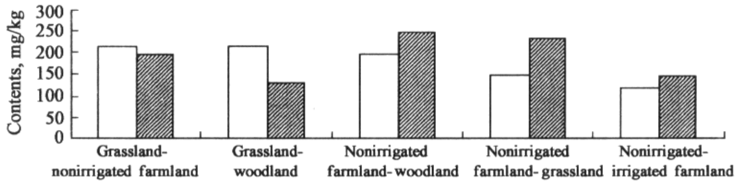

Fig.7 Variation of quick-acting potassium in soil

the quick-acting P in soil increased from 3.1 to 8.2 mg/kg, in larger variation amplitude. Quick-acting K less varied, e.g. when grassland changed into nonirrigated farmland, it decreased from 213 mg/kg to 195 mg/kg.

Six microelements, i.e. B, Mo, Mn, Zn, Cu, and Fe, were selected in the study (Table 1). In land-use and land-cover change, the variation of active constituents of microelements in soil is not regularity to that of N, P, and K, as described above. When grassland changed into nonirrigated farmland, active constituents of Mo, Mn, Zn, Fe, microelements in soil decreased, B, Cu increased but when nonirrigated farmland changed into grassland, they increased in larger amplitude, e.g. Mn increased by 10 times, Cu increased by 15 times, and Fe increased by 14 times. In addition, when nonirrigated farmland changed into irrigated farmland, the increase and decrease of active constituents of 6 microelements are half and half. e.g. Zn increased by 2.4 times, Fe increased by 1.5 times. Mn increased by 1.1 times; B decreased by 1.7 times and Cu decrease by 1.3 times. This may be related to the sufficient water supply to irrigated farmland and various changes of the water regime, in which the physical and chemical processes occur, such as chemical elements are dissolved, migrated, and concentrated with complex regularities.

Table 1 Variation of microelements in soil (in mg/kg)

Type of soil	Microelements					
	B	Mo	Mn	Zn	Cu	Fe
Grassland Ⅰ	0.39	0.10	9.20	0.30	0.52	35.3 0
Nonirrigated farmland	0.57	0.01	8.75	0.292	0.63	10.78
Grassland Ⅱ	–	–	10.90	0.49	0.53	21.78
Woodland	1.22	0.15	1.40	0.56	0.63	20
Nonirrigated farmland Ⅰ	0.50	0.11	4.44	0.149	0.438	5.31
Woodland	–	–	11.90	0.29	0.64	38.60
Nonirrigated farmland Ⅱ	0.37	0.02	2.19	0.12	0.21	5.02
Grassland Ⅲ	0.43	0.13	22.40	1.12	3.22	68
Nonirrigated farmland Ⅲ	0.60	0.10	5.93	0.19	0.89	19.80
Irrigated farmland	0.36	0.10	6.76	0.464	0.69	29.90

Table 2 Comparison of nutrients from non-irrigated farmland in 1980s and 1990s

Time	Organic matter, g/kg	Total nitrogen, g/kg	Quick N, mg/kg	Quick P, mg/kg	Quick K mg/kg	B, mg/kg	Fe, mg/kg	Mn, mg/kg	Cu, mg/kg	Zn, mg/kg
1980s	31.10	1.70	95.63	4.48	132.75	0.53	16.86	5.98	0.72	0.25
1990s	17.30	1.00	159.20	9.97	153.07	0.48	31.57	43.74	0.43	1.57

The described above indicates that in land-use and land-cover change in the Bashang area, the variation of nutrients in soil is regular to certain extent. When grassland changed into nonirrigated farmland, nutrients generally decreased, while nonirrigated farmland changed into grassland, their variation is opposite. When grassland again changed into woodland, nonirrigated farmland changed into woodland and irrigated farmland, the nutrients generally increased. This is a general trend. But there exists some exception, especially alkaline-hydrolyzed N, active P and K, and 6 microelements, their variation sometime did not obey to the described above regularity.

Moreover, contents of nutrients in soil from nonirrigated farmland in different time intervals, in 1980s and 1990s, are listed in Table 2 for comparison. It can be seen in Table 2 that the contents of nutrients in soil generally decreased more in 1990s than in 1980s, in particular, organic matters decreased by nearly 2 times (31.10g/kg in 1980s and 17.30g/kg in 1990s). Total N decreased also by 2 times (1.70g/kg in 1980s and 1.00g/kg in 1990s). It indicates that the traditional cultivation manner has led the fertility in soil to consistently reduce and the land to be degraded as one only acquires from the land and does not conserve the land.

3 Conclusions and suggestions

In the process of land-use change in the Bashang area, the extensive grassland was reclaimed into cultivated farmland. It led nutrients in soil to generally decrease, in particular, organic matters mostly decreased. In contrary, when cultivated farmland changed into grassland, the nutrients in soil increased. In particular, organic matters in soil increased prominently.

When cultivated farmland changed into woodland and into irrigated farmland, or grassland changed into woodland, nutrients in soil increased, otherwise they decreased.

In process of nutrient variation, the variations of active constituents, N, P, and K, and some active microelements are not consistent with the described above regularity, because the variation of these nutrients in soil is very complicated and influenced by many factors, such as soil moisture, temperature, pH value, *E*h value, soil texture, microbial effect, and behaviors of various elements, and so on. Moreover, different cultivation manners can also influence these variations. These problems remain to be further studied(Yuan, 1983).

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