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Soil nutrient changes due to land use changes in Northern China: a case study in Zunhua County, Hebei Province

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Abstract. Since the 1980s, land use in rural areas of China has changed greatly as the result of political initiatives. These changes have caused soil nutrient changes which are examined in this paper for Zunhua County, northern China from 1980 to 1999. The areas of farmland, grassland, and paddy decreased greatly and were replaced by increases in forest and residential land. The soils under forest in 1999 transformed from farmland in 1980 increased in organic matter by 21%, total nitrogen by 18%, available nitrogen by 65%, available phosphorus by 17% and available potassium by 17%. Similarly, in the area which was converted from farmland in 1980 to grassland in 1999, soil organic matter, total nitrogen, available nitrogen, available phosphorus, and available potassium increased by 38%, 37%, 71%, 2% and 28%, respectively. Changes from farmland to forest and grassland not only changed land cover but also improved soil fertility and probably reduced soil nutrient losses.

Keywords: Land use, change, nutrients, nitrogen, phosphorus, potassium, soil fertility, Northern China

INTRODUCTION

Land use is the result of interactions between physical factors and human activities. Land use change may influence many natural phenomena and ecological processes, including soil nutrient and soil water change (Fu *et al.* 1999, 2000), water runoff and soil erosion (Burel *et al.* 1993), biodiversity and biogeochemical cycles (Freemark *et al.* 1986; Correll *et al.* 1992). Land use changes can result in land degradation, such as water and soil loss and land desertification. It can also control water and soil loss, land desertification, and improve soil quality (Fu *et al.* 1994; Islam *et al.* 2000). Since the late 1970s, the new land policy 'Household Responsibility System' was implemented in the Chinese countryside, which has advanced China's agriculture and led to great changes in land-use structure (Chen *et al.* 2001). Land use change has resulted in some changes in soil nutrients. This paper took Zunhua county, a typical agricultural area in northern China as a case study to analyse the relationship between land use changes and soil nutrient changes. The objectives were:

(1) to identify land-use change within two typical periods of 1980 and 1999;
(2) to examine soil nutrient changes between 1980 and 1999; and
(3) to analyse the relationships between land use changes and soil nutrient changes.

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MATERIAL AND METHODS

Study area

Zunhua County is located between longitudes 117°34′ and 118°14′ east and latitudes 39°55′ and 40°22′ north. The county covers an area of 1520 km^2 consisting of alluvial and diluvial plains (36%) surrounded by hills (64%) (Figure 1).

Land-use change detection

The MSS (Multiple Spectrum Scanner) and TM (Thematic Mapper) remote sensing image data were used for the land use maps of the study area in 1980 and 1999. Six land-use types, farmland, grassland, paddy field, residential land, water and unutilized land were identified on the images. The ILWIS (ILWIS, 1998) GIS (Geographical Information System) software was used for land use area change analysis and transition matrix analysis between land use types from 1980 to 1999 (Heusdan 1983; Aaviksoo 1993; Fu *et al.* 1994).

Soil sampling and analyses

Soil nutrient data in 1980 were obtained from the Second National Soil Survey (Soil Survey Office of Hebei Province, 1990). With reference to the sample location in 1980, soil samples (0–20 cm) were collected from 297 sites in November 1999. The sample number for farmland, forest, grassland, and paddy field was 213, 65, 24, 5, respectively.

For each site, three samples were collected and their average value used to represent the sampling site. The distance between the three samples was about 20 m; for each sample; five cores points from a 1 × 1m grid were bulked.

Total nitrogen was determined by the semi-micro Kjeldahl method. Available nitrogen was determined by the Cornfield method (alkaline hydrolysable nitrogen). Available potassium and available phosphorus were extracted with 3% $(NH_4)_2CO_3$ solution. The filtered solution was measured by ICP-AES. Organic matter was determined by the $K_2Cr_2O_7$ titration method (Editorial Committee, 1996).

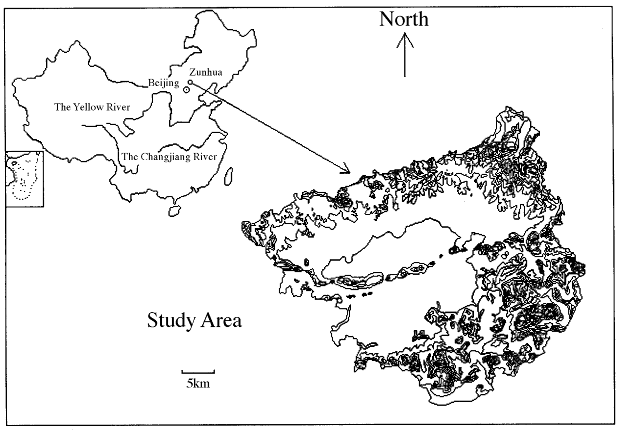

Figure 1. The location of Zunhua County in China.

RESULTS AND DISCUSSION

Land use changes

Land use change (Table 1) from 1980 to 1999 showed:

(1) the area of farmland, grassland and paddy field decreased by 40–50%;

(2) the areas of forest, residential land, and water fields increased by over 60%; and

Table 1. Area changes of land use types from 1980 to 1999. 1% = 15.3km^2.

Land use type	Area (%)	
	1980	1999
Farmland	58.5	35.8
Forest	14.8	42.6
Grassland	21	11.5
Paddy field	1.4	0.8
Residential land	1.4	8.4
Water	0.4	0.9
Unutilized land	2.5	0

Table 2. Transition matrix of land use types from 1980 to 1999 (transition probabilities in %).

Land use type	1999							
1980	Farmland	Forest	Grassland	Paddy field	Residential land	Water	1980 (km^2)	1999 (km^2)
Farmland	50.1	28.9	9.6	0.7	10.1	0.6	892.5	545.4
Forest	8.4	78.8	10.9	–	1.1	0.8	226.8	650.2
Grassland	12.6	63.9	20.2	–	2.3	1	312.9	175.5
Paddy field	66.6	0.6	–	18.1	14.7	–	21.9	11.3
Residential land	8.5	0.2	–	–	91.3	–	21.4	125.0
Water	15.7	34.3	2.8	–	0.4	46.8	5.9	13.6
Unutilized land	59.3	31.3	1.9	0.9	6.6	–	39.6	–

Table 3. The mean soil nutrients (0–20 cm) in different land use types in 1999 and (1980).

	Organic Matter (%)	Total N (%)	Available N (mg kg^{-1})	Available P (mg kg^{-1})	Available K (mg kg^{-1})
Farmland	1.38^{c} (1.17)	0.087^{c} (0.070)	94.9^{c} (67.3)	26.2^{c} (18.2)	88.8^{c} (72.8)
Forest	1.63 (1.38)	0.089^{a} (0.079)	113.5^{c} (76.9)	26.0 (23.7)	111 (106)
Grassland	1.46^{c} (1.05)	0.090^{c} (0.068)	102.2^{c} (57.6)	23.9 (20.9)	107^{a} (79)
Paddy field	1.47 (1.3)	0.069 (0.075)	95.64^{b} (68.25)	19.6 (23.2)	78.7 (86.7)

*Significant at 5% level of probability **Significant at 1% level of probability ***Significant at 0.1% level of probability

Table 4. Soil nutrient changes (0–20 cm) from 1980 to 1999 in sample sites.

1980 - 1999	Sample size	Organic Matter (%)	Total N (%)	Available N (mg kg^{-1})	Available P (mg kg^{-1})	Available K (mg kg^{-1})
Farmland-Forest	35	$1.15–1.39^{**}$	$0.076–0.090^{**}$	$72.8–120.2^{***}$	21.7 – 25.4	$98.8–115.8^{**}$
Farmland-Grassland	21	$1.05–1.45^{***}$	$0.067–0.092^{***}$	$60.1–102.8^{***}$	24.4 – 24.9	$86.4–110.8^{*}$
Grassland-Forest	14	$1.06–2.28^{*}$	$0.07–0.091^{*}$	$58.3–123.3^{***}$	20.7 – 26.5	$78.2–106.4^{*}$

* Significant at 5% level of probability ** Significant at 1% level of probability *** Significant at 0.1% level of probability

(3) unutilized land had been transformed to farmland, forest; and residential land.

The results of a transition matrix (Table 2) reflected the area increase or decline of each land use type. Between 1980 and 1999, 29%, 10%, and 10% of cultivated farmland were converted to forest, residential land and grassland respectively. About 64% of grassland was transformed to forest. About 59% of unutilized land was transformed to grassland, and 31% was transformed to forest.

At the end of 1978, it was decided nationally to change the communes and again distribute land use rights to individual farmers. This is called the 'Household Responsibility System' (the second land reform). The introduction of this system in China started in 1979 and was completed in 1984. In the study area, this system was introduced in 1981. In the study area there was extensive woodland cover before 1958 and this dropped to a minimum in 1958 due to the 'Great Leap Forward'. In the early 1960s, it rose again by community activities after the establishment of communes, however, during the late 1960s and 1970s, it declined again due to wood harvesting during the 'cultural revolution'. After the second land reform in 1981 the woodland area increased greatly due to the land policy change. During the commune period, all the trees belonged to the community and nobody took care of them. In many cases, the local farmers were reluctant to report the occurrence of woodland destruction since it would not benefit them. After the second land reform, most of the trees were assigned to farmers and a new policy, 'who plants, owns' was adopted. To plant new trees in sparse wild grassland was encouraged and much of the sloping farmland was converted to forest.

Soil nutrient changes

Table 3 gives the mean soil nutrients in different land use types in 1980 and 1999. The nutrient status of farmland in 1999 increased significantly ($P < 0.1\%$) compared to 1980. The increase in organic matter content was because of an increase in straw incorporation. The differences in organic matter content for forest between 1980 and 1999 were not statistically significant. Except for available P, all soil nutrient levels for grassland improved significantly between 1980 and 1999. Soil nutrient changes could be related to changes from grassland to forest and from farmland to forest and grassland. The introduction of forest and grassland may have reduced the loss of soil nutrients by erosion and leaching.

Land use changes and soil nutrient changes

The changes from farmland to forest and grassland produced great soil nutrient changes (Table 4). In the areas transformed from farmland in 1980 to forest in 1999, organic matter, total nitrogen, available nitrogen, available phosphorus, available potassium in the soil surface had increased by 21%, 18%, 65%, 17%, 17%, respectively. In the areas transformed from farmland to grassland, organic matter, total nitrogen, available nitrogen, available phosphorus, available potassium in the soil surface had increased by 38%, 37%, 71%, 2%, 28%, respectively. These changes will have modified the soil structure and controlled water and soil loss and land desertification.

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