LAND USE EFFECTS ON SOIL PROPERTIES IN A HILLY AREA, NORTHERN CHINA

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Abstract

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The rational use of land in the hilly areas of China has become an urgent task for the Chinese government. This study was undertaken to evaluate the effects of different land uses on soil bulk density and soil nutrients in the hilly areas of Zunhua, northern China. Samples were collected from the surface soil (0-20 cm) of pine forest, grassland, chestnut forest, and farmland that had been cultivated for 6 months and for over 3 years, respectively. The results indicated that deforestation and cultivation increased soil bulk density and decreased most soil nutrients. Compared to pine forest, the bulk density value of grassland, 6 months cultivated land, chestnut forest and 3 years cultivated land increased by 13.3%, 14.2%, 27.5%, and 39.7%, respectively. Soil nutrients except available N and P showed significant differences among different land uses. Compared to pine forest, soil nutrient contents except total P in chestnut forest and 3 years cultivated soils decreased significantly. Chestnut forest decreased soil organic matter (SOM) by 60.7%, total N by 35.6%, total K by 21.3%, and available K by 57%; while 3 years cultivated soils decreased SOM by 62.9%, total N by 52.6%, total K by 31%, and available K by 60%. The deterioration indices showed that a severe degradation occurred to 3 years cultivated land and to chestnut forest. Cultivation on steeper slopes (> 20°) should be prohibited. Because the soils in chestnut forest did not deteriorate as severely as slope farmland, and because chestnut forest can produce more economic benefits, it can be selected to be a rational land use in the hilly area of Zunhua County. However, soils under chestnut forest will severely deteriorate unless appropriate soil and water conservation practices are used.

Key words: land use, soil nutrients, bulk density, hilly area, northern China

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Introduction

Land use change may influence many natural phenomena and ecological processes (Turner, 1989), including biodiversity (Wilson, 1988), water runoff and erosion (Burel et al., 1993; Fu et al., 1994), and also soil conditions (Buschbacher et al., 1988; Fu et al., 1999). Rational land use can improve soil structure and increase soil resistance to environmental change (Fu et al., 2000, 2001). Irrational land use change may result in soil compaction, poor soil aeration, loss of soil fertility, nutrient imbalance, reduction in soil organic matter content and soil biodiversity, loss of the available water capacity, water imbalance, and diminish soil quality (Lal et al., 1999), increase soil erosion (Warkentin, 1995) and decrease environmental quality including loss in biodiversity (Crist et al., 2000).

Land use, which denotes the human employment of the land (Turner, Meyer, 1994), has a close relationship to soil nutrients. Land use change may result in the change of vegetation cover (Turner, Meyer, 1991), surface albedo (Gornitz, 1985; Henderson-Sellers, Wilson, 1983), plant residues (Dalal, Mayer, 1986), and soil microorganisms (Kennedy, Papendick, 1995). Land use changes are also associated with the changes of soil management practices (Halvorson et al., 2000). These changes will inevitably cause the redistribution of nutrients in soil systems. Many researchers have reported the effects of land use change, especially deforestation on soil properties in tropical areas (Hajabbasi et al., 1997; Solomon et al., 2000). Generally, agricultural practices in forest areas can leave the land more susceptible to soil degradation including lower hydraulic conductivity, higher soil bulk density and lower organic matter level. There are the studies in China, most previous studies were focused on the problems of severe soil erosion in loess plateau of northern China and reclamation of red soil area in southern China. For example, Fu et al. (1999) reported that land use structure types of slope farmland-grassland-forest and terrace-grassland-forest from hill bottom to top had a better capacity to maintain the soil nutrients in the hilly area of the Loess Plateau. Wang et al. (2001) also indicated that in the loess plateau of northern China, significant differences in soil organic matter, including total nitrogen and available nitrogen exist among different land uses. And woodland, shrub land and grassland had higher levels of nitrogen and available nitrogen compared to fallow land and crop land in this area. In red earth hilly areas of southern China, some studies reported that great differences exist in organic carbon storage for different land use systems. In examples, organic carbon storage was found to be lower in farmland and artificial grassland systems and higher in forest systems (Li, Yuan, 2001).

Zunhua County in Hebei province is a typical agriculture County in northern China with regard to economy, population structure, land use etc. Land use has undergone great changes in the past 20 years. Large areas of sloping farmland have been converted to forests since the 1980's due to policy drive. As a result, soil status had generally improved (Fu et al., 2001; Guo et al., 2001). However, some irrational land uses, such as deforestation and cultivation on steeper land still exist, and severely hampers the sustainable use of land. Therefore, the objective of this study is (1) to evaluate the effects of land use on soil nutrients and bulk density, (2) evaluate soil deterioration of different land uses and (3) make some suggestions for rational land use in the hilly areas of northern China.

The 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 plains (36%) and surrounded by hilly land (64%). The elevation of the plain ranges from 20 to 80 m, and 90% of the hilly land is less than 300 m in elevation. In addition, a discontinuous mountain that is 2-3 km wide and 200 m high runs from west to east across the central part of the County. Seasonal rivers such as river Lihe and river Linhe flow from NE to SW and converge to form the Yuqiao reservoir. The area has a continental climate. The mean annual temperature is 10.1°C and the mean annual rainfall is about 804 mm. Main crops in this area include wheat (*Triticum aestivum* L.), corn (*Zea mays* L.), rice (*Oryza sativa* L.) and peanuts (*Arachis hypogaea* L.). The soils are characterized by Haplic Luvisols and Ustic Cambisols.

Material and methods

Soil sampling and laboratory analysis

Three typical land use types, pine forest (*Pinus tabulaeformis*), chestnut forest (*Castanea mollissima*), and lands cultivated for more than 3 years (cultivated 3 year) were selected in the hilly area of Zunhua County for investigation in August 2000. The lands cultivated for six months (cultivated 6 month) that were converted from pine forest and grassland, and where the pine trees were deforested nearly one year ago were also investigated. Corn (*Zea mays* L.) was grown in the cultivated fields. Soil samples (0-20 cm) were collected: nine sites are samples in pine forest, chestnut forest, land cultivated for six months and three years, and five sites are samples in grassland. For each site, three samples were collected and their average value used to represent the site. The distance between the three samples was about 20 m; for each sample, 5 core points from a 1×1 m grid were bulked. All samples were taken from similar topography location. The characteristics of the soil sampling sites are shown in Table 1. The examined soil data included soil bulk density, soil organic matter (SOM), total nitrogen (TN), total phosphorus (TP), total potassium (TK), available nitrogen (AN), available phosphorus (AP) and available potassium (AK). The soil samples were air-dried and sieved (< 2 mm) prior to chemical analysis.

Table 1. The description of sampling sites

Land use types	Sample size	Soil taxonomy	Texture	Height[m]	Slope aspect	Slope position	Slope gradient
Pine forest	9	Haplic Luvisols	Loam	195	North	Top-middle	22°~28°
Grassland	5	Haplic Luvisols	Loam	144	North-east	Top	22°~27°
Chestnut	9	Haplic Luvisols	Loam	153	North-east	Top-middle	22°~25°
Cultivated 6 month	9	Haplic Luvisols	Loam	184	West-north	Middle	23°~26°
Cultivated 3 year	9	Haplic Luvisols	Sandy-loam	138	North-east	Middle	21°~25°

Table 2. Means comparison of soil bulk density, soil nutrients, soil organic matter and total nitrogen pools among different land uses

Land use	Bulk density [g/cm^3]	OM [g/kg]	TN [g/kg]	TP [mg/kg]	TK [%]	AN [mg/kg]	AP [mg/kg]	AK [mg/kg]	OM pool [kg.hm^{-1}]	TN pool [kg.hm^{-1}]
Pine	0.98±0.077a^z	32.6±7.5a	1.33±0.026a	492.99±56.67a	1.88±0.18a	119.71±37.2	6.35±1.55	202.13±26.4a	634.7±151.9a	25.8±4.99ab
Grassland	1.11±0.06b	28.8±2.9a	1.35±0.22a	457.14±150.8a	1.50±0.32b	113.94±29.0	6.89±1.77	152.10±46.4a	638.9±63.8a	29.8±29.9a
Chestnut	1.25±0.086c	12.8±5.74b	0.87±0.033b	654.57±150.64b	1.48±0.17b	139.24±107.3	6.07±2.41	86.58±37.1b	317.5±147.6b	21.8±8.8bc
Cultivated 6 month	1.12±0.093b	29.8±4.75a	1.25±0.25a	493.01±82.2a	1.72±0.32b	188.56±31.6	6.73±2.6	158.87±68.52a	667.4±132.4a	27.9±6.6ab
Cultivated 3 year	1.37±0.038d	12.1±3.78b	0.64±0.096b	574.6±88.2ab	1.29±0.3c	123.02±62.6	4.66±1.68	81.04±34.7b	329.6±101.4b	17.6±2.75c
LSD^y	C	C	C	A	B	NS	NS	C	C	A

z- means in a column with the same letter are not significantly different at $p < 0.05$

y+ a- significant at 5% level of probability, b- significant at 1% level of probability, c- significant at 0.1% level of probability

The bulk density was determined by the ring method. The soil with ring (100 cm^3) was hot-dried at the temperature of 105 °C until the weight had no change, then calculated the bulk density value. Soil total N was determined by the semi-micro Kjeldahl method. Soil samples were digested with concentrate sulphuric acid catalyzed by K_2SO_4-$CuSO_4$-Se, then nitrogen in solution was determined by the Kjeldahl method. Total P was determined colorimetrically after wet digestion with H_2SO_4 + $HClO_4$, phosphate-P in solution was determined colorimetrically by the formation of the blue-phosphomolybdate complex following reduction with ascorbic acid. Total K was determined by the flame photometer method. Available nitrogen was determined by a micro-diffusion technique after alkaline hydrolysis. Available K and available P were extracted with 3% $(NH_4)_2CO_3$ solution. After filtering, the filtering solution was measured by ICP-AES. Organic matter was determined by the oil bath-$K_2Cr_2O_7$ titration method (Editorial Committee, 1996).

Statistics

Statistical analysis of the data was carried out by one-way analysis of variance (ANOVA) using the software SPSS (1993). If the main effects were significant at $p < 0.05$, a post hoc separation of means was done by univariate LSD test.

Results

Land use effects on soil bulk density

There was a significant difference (at the 0.1% level of probability) for bulk density values among the five land uses. The surface soil (0-20 cm) of the pine forest had the lowest bulk density value, and the 3-years-cultivated land had the highest bulk density values. The grassland soils had about the same bulk density as the 6 months cultivated soils (Table 2). The bulk density in chestnut soil was higher than grassland soil and 6 months cultivated soil.

Land use effects on soil nutrients

The SOM content in surface soil (0-20 cm) from different land use types decreased in the order of: pine > cultiv. 6 month > grassland > chestnut > cultiv. 3 year (Table 2). The highest value of SOM in surface soil was pine forest and the lowest value of SOM was farmland cultivated for over 3 years. The difference of SOM among pine, cultivated 6 months and grassland was not statistically significant. The SOM in chestnut forest soils and 3 years cultivated soils decreased significantly.

Different land use types showed statistically significant differences in their total N contents (Table 2). Grassland and pine forest were the richest in total N, followed by 6 months cultivated land, then chestnut forest and finally 3 years cultivated land. As with organic matter, there were no significant differences of total N contents among cultivated 6 month, pine forest and grassland soils. Total N contents in chestnut soils and over 3 years cultivated soils also decreased significantly.

The total P values in pine forest, grassland and cultivated 6 month soils were lower significantly than in chestnut forest and cultivated 3 year soils (Table 2). Total P contents in grassland soils were the lowest. There were not significant differences of total P between pine forest, grassland and cultivated 6 month soils.

Cultivated 6 months soils seemed to have a higher available N value. Grassland and pine forest had lower values. For available P, grassland and cultivated 3 years soils had respectively the highest and the lowest value. There were no significant differences of available N and available P contents among the five land uses.

The total K values of the pine forest, grassland, chestnut forest, cultivated 6 months and cultivated 3 years soils varied significantly from 1.29% to 1.88% (Table 2). The grassland soils had about the same total K as the chestnut forest. Soils under farmland cultivated for about 6 months had a slightly higher total K value, however, the differences between farmland cultivated for about 6 months, grassland and chestnut forest were not statistically significant. Compared to pine forest, the total K value was lower in these three soils, but higher than that of farmland soils cultivated for over 3 years. Trends in average available K content follow the order of: pine forest (202.13 mg/kg) > cultivated 6 month (158.87 mg/kg) > grassland (152.10 mg/kg) > chestnut forest (86.58 mg/kg) > cultivated over 3 year (81.04 mg/kg). The differences between these average values are statistically significant. As with SOM and total N, there were also no significant differences of available K contents among cultivated 6 month, pine forest and grassland soils.

Deterioration evaluation of different land uses

The soil deterioration index was applied to evaluate the soil deterioration degree in different land uses. The soil deterioration index (Adejuwon, Ekanade, 1988; Islam, Weil, 2000) was computed on the assumption that the status of individual soil properties under grassland, cultivated 6 month, chestnut forest, cultivated 3 year were once the same as that of soils under pine forest prior to conversion. The difference between mean values of individual soil properties under grassland, cultivated 6 month, chestnut, cultivated 3 year compared to base line values of soil properties under pine forest was computed and expressed as a percentage of the mean value of individual properties. These percent changes were then averaged across all soil properties to compute the soil deterioration index.

$$DI = \frac{[(p_1 - p_1')/p_1' + (p_2 - p_2')/p_2' + \cdots + (p_n - p_n')/p_n'] \times 100\%}{n},$$

where *DI* is soil deterioration, $p_1, p_2, \ldots p_n$ are the value of soil property 1, property 2, property 3....property *n* of standard land use, $p_1, p_2, \ldots p_n$ are the value of soil property 1, property 2, property 3....property *n* of other land uses; *n* is the number of selected soil properties. The soil deterioration index can be positive or negative. Positive value means land quality improved and negative value means land quality decreased. Values of available N and P were not included in this calculation because they showed no significant differences between the five land use types. Because higher soil bulk density often indicates a degraded land (Lowery et al., 1995), the opposite difference between mean values of bulk density was used in calculating the deterioration index.

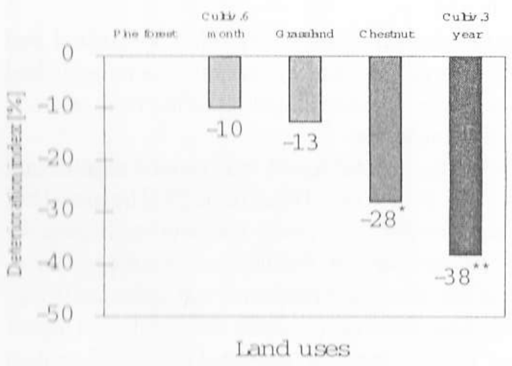

Fig. 1. The deterioration index of different land uses (* significant at 5% level of probability, ** significant at 1% level of probability compared to pine forest).

Figure 1 showed the deterioration index for the five land uses and their means compared to pine forest land. Cultivated 3 years land had the greatest deterioration index of –38%, indicating that this land experienced the most severe degradation. Chestnut forest also had a lower deterioration index of –28%, so the degradation was also severe. In contrast, the deterioration indices for soils under cultivation 6 months and grassland had no significant differences when compared to pine forest, showing that no significant deterioration had occurred under these two land use types. These soil deterioration indices show clearly that significant deterioration occurs in soil quality when pine forest systems are converted for agriculture without the use of appropriate soil and water conservation practices.

Land use effects on soil organic matter pools and total nitrogen pools

Soil organic matter and total N pools were computed by multiplying their contents with dry weight of 100x0.2 m thick surface soil layer bulk density and depth (0-20 cm). The results are listed in Table 2. Cultivated 6 months land had a higher organic matter pool value, however,

the differences among pine forest, grassland, cultivated 6 months land were not statistically significant. The SOM pool values of chestnut forest and cultivated 3 year land were 317.5 kg/hm^2 and 329.6 kg/hm^2, respectively. The soil organic matter pool value in chestnut and cultivated 3 year land were significantly lower than in pine forest, grassland, and cultivated 6 month land.

The total nitrogen pool of grassland was the highest, however, there were no significant differences among the means of total nitrogen of pine forest, grassland, and cultivated 6 month land. Compared to grassland, the total nitrogen pool value of chestnut forest and cultivated 3 year land had a significant decrease.

Effects of land uses and topographical factors on soil bulk density and soil nutrients

General Linear Model (GLM) was applied to determine the percentage of variance of soil bulk density and soil nutrients to land use and topographical factors (Table 3). Dependent variables were soil bulk density, organic matter, total nitrogen, total phosphorus, total potassium, available nitrogen, available phosphorus, and available potassium, respectively. Independent variables were land use, slope position, slope aspect, height, and slope gradient, respectively. Land use, slope position, and slope aspect were used as classification variables. Height and slope gradient were used as continuous variables. The ordinal variables used in the regression equation were land use, slope position, slope aspect, height, and slope gradient. From Table 3, land use explained 92.60% of total variance of bulk density and the statistical test was significant ($p < 0.001$). Land

Table 3. Statistical significance *p* and percentage of variance explained for linear models relating soil bulk density and soil nutrients to land use and topographical factors

Variance source	Bulk density	*p*	OM	*p*	TN	*p*	TP	*p*	TK	*p*	AN	*p*	AP	*p*	AK	*p*
Sum of squares	0.635	0.000	26.483	0.000	2.642E-02	0.012	3.613E+05	0.000	2.024	0.033	3.699E+04	0.707	52.99	0.441	8.495E+04	0.015
Land use	0.588 (92.60%)	0.000	25.375 (95.82%)	0.000	2.324E-02 (88.03%)	0.000	1.541E+05 (42.69%)	0.001	1.443 (71.29%)	0.004	2.973E+04 (80.35%)	0.174	16.97 (32.02%)	0.424	7.229E+04 (85.05%)	0.001
Slope position	1.212E-02 (1.91%)	0.738	0.474 (1.79%)	0.862	1.129E-03 (4.28%)	0.811	1.748E+05 (48.42%)	0.000	0.347 (17.14%)	0.311	3.403E+03 (9.20%)	0.934	7.632 (14.40%)	0.767	7.589E+03 (8.93%)	0.548
Slope aspect	7.808E-03 (1.23%)	0.271	0.172 (0.65%)	0.504	1.667E-03 (6.31%)	0.142	1.463E+04 (4.05%)	0.107	0.105 (5.19%)	0.228	1.447E+03 (3.91%)	0.564	17.545 (33.11%)	0.053	3.887E+03 (4.57%)	0.219
Height	4.985E-05 (0.01%)	0.929	0.280 (1.06%)	0.395	1.922E-04 (0.73%)	0.610	1.012E+04 (2.80%)	0.176	7.224E-02 (3.57%)	0.315	1.765E+03 (4.77%)	0.524	2.117 (4.00%)	0.485	491.1 (0.58%)	0.657
Slope gradient	2.692E-02 (4.24%)	0.135	0.183 (0.69%)	0.784	1.965E-04 (0.74%)	0.873	7691 (2.13%)	0.486	5.665E-02 (2.80%)	0.665	6.454E+02 (1.74%)	0.927	8.732 (16.48%)	0.370	689.1 (0.81%)	0.868

use also explained 95.82% of variance in organic matter, 88.03% in total nitrogen, 42.69% in total phosphorus, 71.29% in total potassium, and 85.05% in available potassium. There was no significant difference in available nitrogen and available phosphorus and the results were the same as the above. The results showed that land use could explain most of variance of soil bulk density and for most soil nutrients we examined. Part variance of soil total phosphorus and available phosphorus can be explained by slope position and slope aspect. In fact, our study mainly focused on the effect of land use on soil bulk density and soil nutrients. We have controlled the topographical conditions when we were taking samples, that is, selected the relatively same topographical position. The results indicated that the control of topography was successful.

Discussions

Effects of land use on soil bulk density and soil nutrients

Deforestation followed by cultivation resulted in a reduction of vegetation cover, an increased soil aeration, a decline in soil structural properties and thus increased bulk density (Hajabbasi et al., 1997). This process could be enhanced by the use of machinery either for deforestation or cultivation (Lal, 1987). The multi-comparison of bulk density showed that land uses could be classified into 4 groups (Table 2): pine forest, grassland and 6 months cultivated land, chestnut forest and 3 years cultivated land. These results indicated increasing the intensity of cultivation could increase the soil bulk density (Kachanoski, Carter, 1999; Bowman et al., 1990; Hill, 1990). Compared to pine forest, the bulk density value of grassland, cultivated 6 month, chestnut forest and cultivated 3 year increased 13.3%, 14.2%, 27.5%, 39.7%, respectively. The similar bulk density of grassland and 6 months cultivated soils was possibly due to the grassland compaction by the hooves of the sheep and goats (Girma, 1998).

SOM and total N in chestnut forest and 3 year cultivated soils decreased significantly (Table 2). Compared to pine forest, the reduction percentage of SOM and total N were 60.7% and 35.6% in chestnut forest soils, and 62.9% and 52.6% in farmland soils cultivated for 3 years, respectively. The lower levels of SOM and total N in chestnut and 3 years cultivated soils may be attributed to a reduced input of plant residues and greater carbon losses by aggregate disruption and increased aeration by tillage (Burle et al., 1997; Dalal, Mayer, 1986; Brown, Lugo, 1990). Some inappropriate land management practices in this area also enhanced the decline of SOM and total N level. For example, the weed in chestnut forest is usually removed by using herbicide so that chestnuts dropped onto the ground could be easily collected during the harvest time. Collection of corn stalk and burning at the fields is also a common practice. These practices caused a higher soil disturbance and less biomass carbon returned to the land (Christensen, 1992).

It is observed that the organic matter content of soils under cultivation for over 3 years is much lower than that of the pine forest soils (Table 2). However, there were no significant differences of SOM contents between pine forest soils and 6 months cultivated soils, in

which the SOM value (2.98%) was even a little higher than that (2.88%) of grassland soils. Some researchers have reported that the C level dropped sharply during the first years following initial cultivation when native forest was converted to agricultural production (Davidson, Ackerman, 1993; Mann, 1986). Woods and Schuman (1988) reported that after only one year of cultivation, declines of total organic C (14%), mineralized C (62%), total organic N (18%), and mineralized N (51%) occurred. However, the results in our study showed that no significant changes occurred for SOM in soil that had been cultivated for six months. One possible reason is that the cultivation time is too short to cause an obvious change of SOM. In addition, the great reduction of SOM probably occurred after harvesting the corn, which will take out much C from soils.

Total P had higher values in chestnut forest and 3 years cultivated farmland. That may be partly due to the input of a certain amount of fertilizer P in chestnut forest and cultivated 3 years land. However, the effect of fertilizer on soil nutrients in hilly area in Zunhua County was very limited. The use of fertilizer depends on the farmer's affluence. Most farmers are poor and little fertilizer is used in hilly agricultural lands. Organic fertilizers are also not much used. And when there is no use of chemical fertilizers or pesticides, the total P contents of the soils do not always decrease with cultivation and some forest soils have lower P contents than the cultivated areas (Saikh et al., 1998). Available N and P may be more easily affected by natural environmental factors. The larger deviation between samples in each land use type caused no significant differences between different land uses. Total K contents have a close relationship with soil parent materials. The high total K value in pine forest soils indicated that the soils experienced little disturbance, while intensive cultivation caused lowest total K contents in cultivated 3 years soils. Soil organic matter can absorb much positive ion, such as K^+, so the changes of available K among different land uses were similar with SOM.

Effects of land use on soil organic matter pool and total nitrogen pool

The values of organic matter (OM) and TN pools in chestnut forest and 3 years cultivated soils decreased significantly, but there is no significant difference among pine forest, grassland and cultivated 6 months farmland. Thus, C and N storage in soils in agricultural ecosystem is lower than soils in forest ecosystem.

Implications for environmental management

How to use land rationally in hilly areas and preserve and improve soil quality has become an urgent task for the Chinese government. The hilly areas of Zunhua County are representative similar areas in northern China. Our research results show that the 6 months cultivated slope farmland has not undergone significant soil degradation in comparison to pine forest. The most severe soil degradation occurred to over 3 years of cultivation. The damage to soil by cultivation of steeper slopes (>20°) is the most severe and the speed of deterioration was fast. Hence, cultivation on steeper slopes (>20°) is a severe threat to the maintenance and improvement of soil quality and it is recommended that cultivation on such slopes should be prohibited.

In pine forest soil organic matter is great and bulk density was lower and it is the best choice to reduce soil nutrients and water loss. However, it is impractical to plant pine forest throughout the hilly areas because it can not bring enough economic benefits to ensure people's livelihood. The soil deterioration under chestnut forest was not as severe and the forest can generate more economic benefits. In addition, the speed of chestnut soil deterioration was much slower than on sloping farmland. Hence, the development of chestnut forests can be a rational land use in the hilly area of Zunhua County. However, the development of chestnut forests must be accompanied by appropriate soil and water conservation practices. The soils of chestnut forests will deteriorate greatly unless appropriate soil and water conservation practices are used.

It should also be noted that although soils under grassland and 6 months cultivated farmland had not experienced significant degradation (Fig. 1), their bulk density values had increased significantly, compared to pine forest (Table 2). As soil compaction had increased, consequently the ability to conserve soil nutrients and hold water was compromised, possibly damaging the soil's microbiogical activities. The soil was prone to degradation after a short period of time.

In general, the development of horticulture such as chestnut forest in the hilly areas of northern China is a recommended land use to ensure environmental security and economic profit. However, the pine forests in many hilly areas were deforested in order to develop chestnut plants and the process had caused severe soil degradation and soil nutrient loss. It is therefore necessary to develop soil and water conservation practices in chestnut forest, especially biological conservation practices. Also, conservation of pine forest and shrubs improves the ability of soils to resist environmental changes and increases the landscape heterogeneity as well as being an effective supplemental land use to the chestnut forest.

Conclusions

Deforestation and cultivation resulted in an increase of soil bulk density and a decrease of soil nutrients. Compared to pine forest, the bulk density of grassland, land cultivated 6 months, chestnut forest and land cultivated 3 years increased by 13.3%, 14.3%, 27.5%, and 39.8%, respectively. The differences of all soil nutrients, except for available N and P, were statistically significant between different land use types. Soil nutrient contents in chestnut and 3 years cultivated soils decreased significantly except for total P, which had a significant increase. Compared to pine forest, chestnut forest SOM decreased by 60.7%, total N by 34.6%, total K by 21.3%, and available K by 57%; while 3-years cultivated soils SOM decreased by 62.9%, total N by 51.9%, total K by 31.4%, available K by 59.9%. Soil cultivated for approximately 6 months showed no significant deterioration compared to pine forest, however, the most severe degradation occurred in the land cultivated for 3 years. Chestnut forest also experienced severe degradation. Cultivation on steeper slopes (> 20°)

in hilly areas is obviously a severe threat to maintenance and improvement of soil quality and should be prohibited. Replacing pine forest by chestnut forest is not sustainable land use, although this method might be generated. The soils under chestnut will severely deteriorate unless appropriate soil and water conversation practices are used.

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Guo X., Fu B., Chen L., Ma K., Li J.: **Vplyv využitia pôdy na pôdne vlastnosti v horskej oblasti Severnej Číny.**

Ako racionálne využiť pôdu v horskej oblasti Číny sa stalo nalichavou úlohou čínskej vlády. V tejto štúdii hodnotíme vplyvy rôznych typov využitia pôdy na sypnú hmotnosť pôdy a pôdne živiny na pahorkatine Zunhua v severnej Číne. Vzorky sme odoberali z povrchu zeme (0-20 cm) v borovicovom lese, na lúke, v gaštanovom lese a na farme, ktoré sme kultivovali 6 mesiacov a viacej ako 3 roky. Výsledky naznačovali, že odlesnenie a kultivácia zvyšovala sypnú hmotnosť pôdy, ako aj pôdne živiny. Prirovnajúc k borovicovému lesu, sypná hmotnosť pôdy na lúke 6 mesiacov kultivovanej pôdy, gaštanového lesa a 3 roky kultivovanej pôdy sa zvýšila o 13.3%, 14.2%, 27.5% a 39.7%. Pôdne živiny okrem N a P poukázali na značné rozdiely na rôznych pôdnych typoch. Pri porovnaní s borovicovým lesom obsah pôdnych živín okrem celkového P v gaštanovom lese a 3 roky kutivovanej pôdy sa značne znížila. V gaštanovom lese pôdna organická hmota (SOM) sa znížila o 60.7%, celkový N o 35.6%, celkový K o 21.3% a aktívne K o 60%. Indexy zhoršovania poukázali na to, že vážna degradácia sa objavila na pôde kultivovanej 3 roky a v gaštanovom lese. Kultivácia na strmejších svahoch (> 20 °) by sa mala zakázať. Keďže pôda v gaštanovom lese sa nezhoršila do takej miery ako svahovitá poľnohospodárska pôda a keďže gaštanový les môže produkovať vyšší ekonomický zisk, môže sa stať vybratým typom racionálneho využívania zeme v horskej oblasti Zunhua. Pôdy v gaštanovom lese budú však vážne ohrozené, ak sa nepoužije vhodná ochrana pôdy a vody.