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Effects of grassland degradation on chestnut soil properties in Bashang Plateau, China

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Abstract: The repeated effects of vulnerable habitat and unreasonable human activities on the Bashang Plateau of China led the chestnut soil to degrade. It expresses in reducing soil CEC, decreasing nutrient content, decomposing organic complexes, and reducing humus in loose, steady and tight bond forms, respectively. The percentage of three forms are 21%—34%, 44%—55% and 5%—6.2%, respectively.

Key words: Bashang Plateau; chestnut soil; organic and inorganic complexes; humus bond form

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Introduction

Chestnut soil on the Bashang Plateau is one of the soils in zonal distribution. The degradation of the chestnut soil resulted from the environmental vulnerability in the region and unreasonable human activities. It is also an important indication for eco-environmental evolution in ted region. Study on some aspects of the soil degradation could provide relevant theoretical basis for mitigation and even prevention its further degradation. At present few researchers paid their attention on and studied the problem having its practical implications and the works concerning this problem in the region is also scarce. The authors have studied sand grain size and amount in the soil, coverage of surface plant, soil fertility and replacement amount, organic and inorganic complex, humic substance in the soil in combination with its morphology. The result obtained is of significance either in theoretical aspect or in taking corresponding control measures.

1 Analytical methods

The methods used in this study are as follows: total soil nitrogen: semi-micro Kjeldahl procedures; total soil phosphorus: digestion H_2SO_4-$HClO_4$-Mo-Sb-Sc colorimetry; total soil potassium: NaOH-fusion method; soil CEC: natrium acetate method; available soil Fe, Mn, Cu, Zn: DTPA immersion-extraction-atomic absorption spectrophotometer; soil complex: according to reference(Xiong, 1982); bond form of humus in soil: according to reference (Xiong, 1982).

2 Physiographical conditions

Bashang is a general name for the North Hebei Plateau, including Guyuan, Zhangbei and Kangbao counties and parts of Shangyi, Fenning and Weichang counties. It covers an area of 17687 km^2. The region is located in the Inner Mongolia Plateau-Yanshan Mountains region-North China Plain transition zone, in a conjunction zone between monsoon and continental climates, between dry and semi-dry climates, and between agricultural and pasture regions, geomorphically it is characterized by lava platform and erosional plateau relief. The region is divided into western part, cold-warm semi-dry steppe zone, and eastern part, cold-warm semi-humid forest-steppe zone by Shandianhe River. In the western part, the annual average temperature is 2.2℃, precipitation is 374 mm, and the evaporation is 1831 mm. The evaporation/precipitation ratio is 4.9. Heavy wind is 59.1 days on average. Annual sunshine time is 2928.1h. Cumulative temperature ≤10℃ is 1935.9℃, dryness 1.28, and frost-free period 100.8 days. The natural vegetation type is dry steppe. In the eastern part, average temperature is 0.6℃, annual average precipitation 433 mm, average evaporation 1578 mm. The evaporation/precipitation ratio 3.74, annual average wind 54 days, annual sunshine time 2775 h. In total, cumulative temperature ≤10℃ is 1591.0℃, dryness 0.8, and frost-free period 76 days. The natural vegetation is forest steppe. The dry-cold windy habitat conditions and steppe vegetation make chestnut soil occupy a dominant position in Bashang region.

3 Distribution of chestnut soil

Chestnut soil on the Bashang Plateau can be divided into 6 subtypes, such as dark chestnut soil, and so on. It is distributed in an area of 1274400 km^2 in total, which is account for 70% of the whole region. Dark chestnut soil is mainly distributed in mountain areas, valleys, and piedmont zones on the Bashang Plateau margin at 1500—1900m elevation. The soil-parents are alluvium-slopewash, loessic and proluvial materials on granite, gneiss, syenite, metamorphic rocks, rheolite, granite-porphyry, and basalt. Chestnut soil is mainly distributed in the mountain zones and hill areas along the plateau margin at elevation of 1350—1750m. The soil-forming matrix is aluvial-slopewash materials, Quaternary loess and Quaternary alluvial proluvial sediments on gneiss, granite, rheolite, rheolitic tuff, basalt, andesite, syenite, schist, slate, shale, sandstone, quartzite, and dolomite rock series. Meadow chestnut soil in mainly distributed on Xiashitang and Eryintang beaches of river banks on the plateau, and in broad valleys hills at elevation of 1300—1450m. The soil-forming matrix is fluvial-alluvial sediments. Salt-affected chestnut soil is mainly distributed on Eryintang Beach, river banks, around swamp and in conjunction zone between Eryintang and Xiashitang beaches on the Bashang Plateau at elevation of 1250—1450m. The soil-forming matrix is proluvial sediments. Alkalized chestnut soil is mainly distributed on Eryintang Beach on the Bashang Plateau at elevation of 1300—1450m. The soil-forming matrix is alluvial. Castanozem-like soil is distributed on slope exposed to the sun and their tops in mountainous and gentle hill zones along the plateau margin at elevation of 1500—1750. The soil-forming matrix is alluvial and slopewash materials on granite, gneiss, granite-porphyry, rheolite, basalt, andesite, diorite, diabase, quartzite, quartz sandstone, sandy gravels, limestone, and dolomite. The distribution area of the six subtypes of chestnut soil is listed in Table 1.

Table 1 Distribution area of six subtypes of chestnut soil

Soil name	Area, 10^4 hm^2
Dark chestnut soil	14.02
Chestnut soil	72.92
Meadow chestnut soil	5.08
Salinized chestnut soil	11.75
Alkalized chestnut soil	5.13
Castanozem-like soil	18.54

4 Degradation of chestnut soil on the Bashang Plateau

4.1 Nutrient content in undegraded chestnut soil

Soil samples were collected from 0—20 cm surface layers of different subtypes of the chestnut soil in ted region. The samples of every subtypes were collected from 20—30 sites. Nutrient contents in these different subtypes of chestnut soil are listed in Table 2 and Table 3.

It can be seen in Table 2 and Table 3 that in the habitat under the dry, cold climate condition and in the shorter growth season, the process of organic matter accumulation is longer than that of its decomposition in chestnut soil in the region. Thus, organic matter content in the soil is higher, in the range of 19.4—49.1 g/kg. The main nutrients in the soil are total nitrogen 0.82—2.55 g/kg, total P_2O_5 0.55%—1.45%, and total K_2O 15.4—28.5 g/kg. The higher content of total potassium is related with the matrix, from which chestnut soil formed. The contents of organic matter, nitrogen, phosphorus, and potassium, in some subtypes of chestnut soil on the Bashang Plateau indicate that the potential nutrients in the soil are relatively high, reaching moderate to higher level. The contents are relatively low, especially Zn and Mo, which is high soil pH. The contents of macro- and micro-elements show that moisture is the most important for chestnut soil to provide its nutrients for crop growth and high yield. Under the precondition of appropriate moisture, rational application of fertilizer can make the chestnut soil area gain high crop yields.

Table 2 Nutrient contents in different subtypes of chestnut soil(g/kg)

Soil name	Organic matter	Total nitrogen	Total P_2O_5	Total K_2O
Dark chestnut soil	49.1	2.55	1.45	15.4
Chestnut soil	23.3	1.40	0.52	24.3
Meadow chestnut soil	19.4	1.07	0.92	25.9
Salinized chestnut soil	39.0	7.39	0.97	23.0
Castanozem-like soil	24.1	0.82	0.55	28.5

Table 3 Available micronutrient contents in different subtypes of chestnut soil(mg/kg)

Soil name	Fe	Mn	Zn	Cu	Mo
Dark chestnut soil	21.70	6.65	0.58	0.54	0.06
Chestnut soil	9.14	6.78	0.50	0.63	0.05
Meadow chestnut soil	6.81	4.00	0.21	0.55	0.05
Salinized chestnut soil	6.61	4.95	0.289	0.65	0.06
Castanozem-like soil	7.04	5.89	0.22	0.60	0.04

4.2 Degradation of chestnut soil

It reflects mainly in relatively increasing amount of sand grains in the soil, decreasing biomass covering the ground surface, and soil fertility. According to study results by Zhu Zhenda, the dissertation of chestnut soil on the Bashang Plateau increases at an annual rate of 4.66% for 12 years, during 1975—1987. The dissertation of soil was 2612.8 km^2 during 1970s, accounting for 14.21% of the total area, and reached 4514.52 km^2 during 1980s, 24.55% of the total area, which is 72.28% higher than that in 1970s, the fertility of the degraded soil reduces, and biomass in the grassland decreases, and animal carrying-capacity reduces. For this reason, we have studied the causes of the soil degradation. The area selected for the study is a grassland with different degree of soil degradation. The grassland was mainly overpastured, resulted in decreasing biomass and edible grass species and soil on the grassland is exposed. According to biomass and covering degree, three degradation cases were rated, light, moderate, and heavy degradation. These were studied comparatively for the soil subtypes.

4.2.1 Soil with lowering capability to retain fertility and decreasing nutrients

The capability of soil to retain fertility and nutrients is an important indicator of the soil quality. The soil degradation is often reflected in this aspect. Here the CEC and partial nutrient contents in the soils are listed in Table 4.

It can be seen in Table 4 that soil CEC decreases largely. The overpasture led to reducing vegetation cover to different degree and to bare soil. Moreover, the dry climate, rare rainfall and heavy wind led the soil deflation, bonded soil grains were blown off and coarse grains are kept on. Thus the soil CEC largely decreased. The CEC of moderately and heavily degraded soils have decreased 16.7% and 31.3% in compared with that of lightly degraded soil. The nutrients in soil have also decreased with deflation and decreasing bonded soil grains. In comparison with slightly degraded soil, total phosphorus lost 15.5% and 30.0% and total potash lost 5.3% and 13.4%, respectively. The reducing soil replacement and decreasing nutrient amount are the main indicators for soil degradation and are directly related with the loss of complexes bonded by organic and inorganic colloids in soil. For this reason, we have determined organic and inorganic complexes in soil of different degradation degrees.

Table 4 Replacement amount and partial nutrient contents in top soil

Degradation degree	Organic matter		Total nitrogen		Total P_2O_5		Total K_2O		CEC	
	Content, g/kg	Decrease, %	Content, g/kg	Decrease, %	Content, g/kg	Decrease, %	Content g/kg	Decrease, %	Content g/kg	Decrease, %
Light	24.3	0.0	0.31	0.0	0.29	0.0	20.80	0.0	8.47	0.0
Moderate	20.9	13.9	1.16	11.5	1.09	15.5	19.70	5.3	7.05	16.7
Heavy	18.8	22.6	0.92	29.8	0.90	30.0	18.01	13.4	5.82	31.3

4.2.2 Organic and inorganic complexes in soil with different degradation degree

Organic matter in soil is mostly in the form of humus and bonded with minerals and less unbounded in free state. The organic and inorganic complexes are the material basis for forming good aggregate and are relatively active in soil. The existence of the complexes makes the soil to be in suitable state and to provide good condition for crop growth. The biomass in grassland can directly determine the formation of organic colloid. As a pasture, the biomass will decrease and hence affect the formation of organic and inorganic complexes in the soil. Soils of different degradation degree have different amount of organic colloid, which is also different bond forms with inorganic colloid. Here the organic and inorganic complexes are expressed as the complexes in original soil and listed in Table 5.

Table 5 Complexes in soil of different degradation degree

Degradation degree	Organic carbon in soil		Original soil complex	
	Content, g/kg	Decrease, %	Content, g/kg	Decrease, %
Light	21.8	0.0	53.4	0.0
Moderate	18.4	15.6	49.4	7.5
Heavy	16.2	25.7	46.5	12.9

The data in Table 5 indicate that three types of different degraded soils have relatively low complexes, less than 53%. The complexes in soils reduces gradually with the soil degradation degree increasing. In comparison with that in light degraded soil, the complexes in moderately and heavily degraded soils reduced 7.5% and 12.9%, respectively. Content of organic carbon in the soils also decreases with the soil degradation, 15.6% in moderately degraded soil and 25.7% in heavily degraded soil. It indicates that the complexes in original soil and organic matter in the soil decrease with the soil degradation. Different degradation of soils results in different amount of biomass on the ground. The heavier the degradation degree, the less the biomass, the less the organic matter from above and underground plant materials, and correspondingly, the less the formed organic colloid, the less the organic-inorganic complexes. Meanwhile, organic colloid in original soil will be aged, dissolved, and loses its bonding capability due to the exposure of soil at the dry climate and high temperature. Then, the soil complex will reduce. Therefore, to reserve the biomass on grassland and to ensure a certain vegetation cover on soil can provide an important environmental condition for preventing soil from degradation.

4.2.3 Bond forms of humus in different degraded soils

Entering in soil, some of organic matter is decomposed by micro-organism and formed humus, which is bonded again with minerals into complex. Part of the organic matter was not bonded to minerals and remains in the soil. Both these parts of organic mater, bonded and unbounded to minerals were studied by Fu(Fu, 1983), who have separated them with gravity fluid with density

2.0. Part of organic matter bonded to minerals is more than 2.0 and called heavy group, and that unbounded to minerals is less than 2.0 and called light group. Bond of humus to minerals is in loose, steady, and tight bond forms. For the heavy group, the content of humus in the three different forms in the differently degraded soils are shown in Table 6.

Table 6 Bond forms of humus in differently degraded soils

Degradation degree	Organic carbon in soil of heavy group		Loose bond form		Steady bond form		Tight bond form	
	Content, g/kg	Decrease, %	Content, g/kg	Decrease, %	Content, g/kg	Decrease, %	Content, g/kg	Decrease, %
Light	10.0	0.0	6.89	0.0	1.37	0.0	12.34	0.0
Moderate	9.41	5.9	5.42	21.3	0.76	44.5	11.72	5.0
Heavy	8.90	11.0	4.52	34.4	0.61	55.5	11.57	6.2

It can be seen in Table 6 that in the process of soil degradation, humus in the loose and steady bond forms are more lost 21%—34% and 44%—55%, respectively. But humus in tight bond form is less lost, only 5%—6%. Because the organic matter remaining in soil has formed organic colloid and is bonded to minerals into humus in loose bond form, thus it decreases less than that in steady bond form, but humus in tight bond form is more strong and less lost. Humus in moderately degraded soil decreases less than that in lightly degraded soil by 5%—44% and humus in heavily degraded soil decreases less than that in lightly degraded soil by 6%—55%. The trend of decreasing humus in three bond forms is coincident with that of organic carbon in soil of heavy group. This is due to the decreasing biomass in soil, reducing vegetation cover, and decreasing organic matter entering into the soil and organic colloid formed from it.

4.3 Causes for degradation of chestnut soil and countermeasures for its prevention

The chestnut soil is developed in the habitat areas of North Hebei Bashang Plateau under the dry, cold and windy conditions. Moreover, human activities, such as confusion in land reclamation, pasture, overpasture, overdeforestation, and preference for application of chemical fertilizer have additional effect, which led to decreasing biomass, reducing vegetation, blowoff of silty and clay soils, and hence loss of balance between silty, sandy, and clay soils. The soils became sandy, organic complex decreases, and soil chemical and physical properties deteriorate. Therefore, it is very important and urgent to perform scientific management of grasslands, ordering development of pasturage, and mitigation of eco-environment deterioration.

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