Physico-chemical characteristics of soils and their secular changes under different land use in Kherlenbayan-Ulaan

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Introduction

Human activities and climate changes have altered the ecosystem of the rangeland in Mongolian. Recent changes in livestock policies and economic factors have resulted in more intensive land use. It was reported that over grazing and tillage are main causes of vegetation and soil degradation in Mongolia (Bayansgalan et al., 2000). And plant composition change is also one of a problem of a range land production and a grassland ecosystem. Vegetation covering is important for soil conservation, and is mainly controlled by soil water regime in Mongolia (Miyazaki et al., 2003). Soil water characteristics depend on soil structure, especially pore size distribution (Okajima, 1989).

The objective of this study is 1) to revial the secular change of plant composition in protected area, 2) to clarify the difference of physico-chemical characteristics of soils under non-grazing, grazing and cultivation fields of Kherlen Bayaan-Ulaan.

Materials and methods

Study site

Four study sites were established under different land use in KherlenBayan-Ulaan (KBU) (Fig.1). KBU is one of the AWS sites of RAISE project (Sugita 2006).

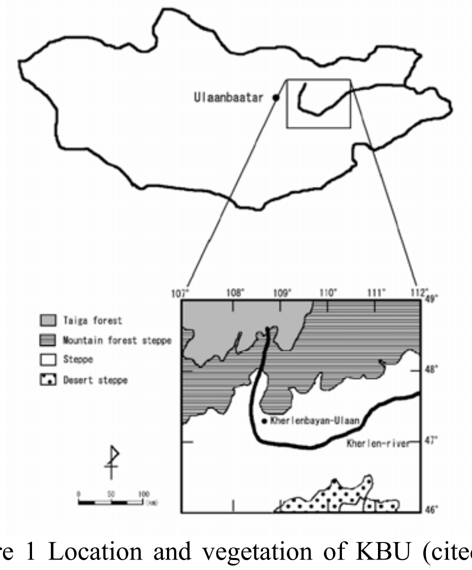

Figure 1 Location and vegetation of KBU (cited from Urano, 2005).

The soils distributed in this area were Haplic Kastanozems or/and Calcic Kastanozems (Asano et al., 2006; Hoshino, 2006). Site 1 is in the protected area from grazing established by RAISE project since July 2002. Site 2 is situated at the out side of protected area and under actual grazing. Site 3 is placed in the abandoned field since 1992. Site 4 is in a crop land.

Vegetation survey

The quadrat method of Suganuma (1978) was used in vegetation survey (n =5, $1m^2$). The extended summed dominance ratio, E-SDR_2 (Yamamoto et al., 1995), was calculated to compare vegetation among communities.

Soil sampling

Quadrats of each site were established after observing soil subsurface layers using soil auger. Bulk soil samples were taken from surface layer for their chemical analysis, and $100cm^3$ core samples were taken for the measurements of physical properties from the depth of 0-5cm. These bulk soil samples were air-dried and sieved to prepare the samples of 2 different sizes; less than 2.0mm and less than 0.5mm. Additionally, $100cm^3$ core samples of 0-5cm depth were taken for the observation of soil micromorphological characteristic of soil thin sections from 5 sampling points in each study site.

Physical measurement and Chemical analyses

The soil samples were subjected to the following physical measurements and chemical analyses (Committee of Soil Environment Analysis, 1997): Three phase ratio, saturated hydraulic conductivity, bulk density, particle size distribution, pH(H_2O), EC, Soil organic carbon and inorganic carbon contents (measured by wet combustion method (Kosaka, et al., 1959, Clark and Ogg, 1942)), Total nitrogen contents, Water soluble cation of Ca^{2+}, Na^+, Mg^{2+}, K^+, Water soluble anions of SO_4^{2-}, Cl^-, PO_4^-, NO_3^-, CEC.

Soil water retention curves and unsaturated hydraulic conductivity of undisturbed core samples were determined with multistep outflow method (Fujimaki and Inoue, 2003) in duplicate at each site.

Micromorphological property and image analysis

Soil thin sections were made as described by

Nagatsuka (1986) and their micromorphology was described according to Bullock (1985) using polarization microscope. Images of thin sections were divided binary image, aggregates and others, then aggregates ratio and voids ratio were calculated.

Results and discussions

Plant compositions of study sites

In site 1 and 2, most dominant species was *Stipa krylovii* at each year. Also, dominant ratio of this increased at site 1 in 2005. On the other hand, the number of species and dominant ratio of other plant species were decreasing. Average plant coverage of site 1 was kept about 60%, while less than 50% at site 2 in 2005 (Table 1 and 2).

Table 1 Result of vegetation survey at sites 1 and 2 in 2003 (Hoshino, 2006).

Site 1 (2003)	Average plant coverage 60%, 20species		
Plant species	ΣC	ΣH(cm)	E-SDR_2
Stipa krylovii	2.60	115	59
Carex sp.	1.00	71	34
Caragana stenophylla	1.08	69	34
Artemisia frigida	1.40	59	30
Artemisia adamsii	1.64	55	29

Site 2 (2003)	Average plant coverage 62%, 10species		
Plant species	ΣC	ΣH(cm)	E-SDR_2
Stipa krylovii	2.60	96	50
Artemisia adamsii	3.28	58	36
Carex sp.	1.64	59	31
Salsola collina	2.32	47	28
Chenopodium aristatum	2.28	39	25

Table 2 Result of vegetation survey at sites 1 and 2 in 2005 (Hoshino, 2006).

Site 1 (2005)	average plant coverage 62%, 10speceis		
Plant species	ΣC	ΣH(cm)	E-SDR_2
Stipa krylovii	13.00	205	100
Cleistogenes squarrosa	5.40	45	32
Caragana stenophylla	1.04	67	20
Carex sp.	1.64	56	20
Lappula redowskii	0.80	41	13

Site 2 (2005)	Average plant coverage 46%, 10species		
Plant species	ΣC	ΣH(cm)	E-SDR_2
Stipa krylovii	6.00	81	43
Carex sp.	7.04	56	41
Cleistogenes squarrosa	5.00	28	26
Caragana stenophylla	0.08	43	11
Allium mongolicum	0.08	28	7

Results of vegetation survey at abandoned field in 2003. Vegetation at abandoned field was extremely different in each year. *Chenopdium aristatum* was dominated in 2003, but scarce vegetation in 2004. And, there were some species in 2005: not only *Chenopdium aristatum* but also *Eragrostis poaeoides* and *Lepidium apetalum* were dominated in 2005. Also, there were not plant residues at soil surface in 2005. On the other hand, at site 4 there were plant residues in 2005. These differences were may be due to non-grazing condition, and also due to the date of survey in 2005, far later period from harvesting, comparing with the survey in 2004. However, these findings indicated that vegetation at these four sites were extremely different in terms of the survey year and season. Vegetation was scarce in sites 3 and 4. Scarce vegetation in site 4 may be partly due to the timing of survey: we surveyed there after harvesting. Vegetation of site 3 indicates that the effect of tillage and subsequent abandonment was still remaining. Although there were plant residues on the surface of this field, which was maybe the species of chenopod as seen from the stem's figure and size.

Soil physico- chemical characteristics at study site

Bulk density of the soils at site 4 was the highest among the four study sites. Also, silt and clay contents of sites 3 and 4 were lower than those of sites 1 and 2 (Table 3). These small contents of clay might bring lower CEC at sites 3 and 4 (Table 5). And, total dry weight of gravel at site 4 was the highest among four study sites. And, the soil at site 3 was more sandy than those of sites 1 and 2 (Table 4).

Table 3 Physical properties of the soil samples (Hoshino, 2006).

Site	Solid (%)	Liquid (%)	Air (%)	Bulk density ($Mg\ m^{-3}$)	Macropore / capillary pore	Saturated hydraulic conductivity ($cm\ s^{-1}$)	Dry weight of gravel ($g\ dL^{-1}$)
1	47.1	23.4	29.8	1.27b	0.19ab	3.4×10^{-3} a	39.70b
2	47.1	21.0	32.0	1.22b	0.22a	4.5×10^{-3} a	29.63b
3	45.7	21.6	32.4	1.21b	0.18b	3.0×10^{-3} a	38.35bc
4	52.6	15.6	32.2	1.42a	0.23a	3.9×10^{-3} a	63.12a

Values are means of 16 replicates. Means with different letters within a variable indicate significant differences at $P < 0.05$ by *student t*-test class.

Table 4 Particle size distribution and soil texture of the soil samples (Hoshino, 2006).

Site	Clay(%)	Silt(%)	Fine sand(%)	Coarse sand(%)	Soil texture
1	9.1	23.3	11.6	56.0	SL
2	14.2	20.4	14.6	50.8	SL
3	9.5	5.6	32.2	52.7	LS
4	3.7	8.9	26.8	60.6	LS

SL : Sandy Loam, LS : Loamy Sand

Table 5 Some chemical properties of the soil samples (Hoshino, 2006).

Site	EC ($dS\ m^{-1}$)	pH(H_2O)	Total-C (%)	Total-N (%)	CEC ($cmol(+)kg^{-1}$)	Weight of roots ($g\ dL^{-1}$)
1	0.24b	5.31c	2.18b	0.22b	10.11a	3.21b
2	0.18c	5.68b	2.57a	0.27a	10.05a	4.83a
3	0.41a	5.45bc	1.81c	0.17c	8.27a	2.32ab
4	0.14d	6.16a	1.03d	0.12d	6.36b	0.69c

Values of EC, pH, Total-C, Total-N and weight of roots are means of 16 replicates. Values of CEC is means of three replicate. Means with different letters within a variable indicate significant differences at $P < 0.05$ by *student t*-test class.

Hydraulic properties of the soils at sites 1 and 2 were comparable. However, available water become larger in the order of site 2>site 1>site 3>site 4 (Fig.2). Volumetric water content at 0cm of pressure head of site 4 was the smallest among four study sites. Accordingly, pore size of 10-5-10-7m of the soils at sites 1 and 2 were larger than that of the soils at sites 3 and 4 (Fig. 3). These facts indicated that sites 1 and 2 have pore size diversity than sites 3 and 4. So, sites 1 and 2 have more suitable environment of pore size distributions to plant growth.

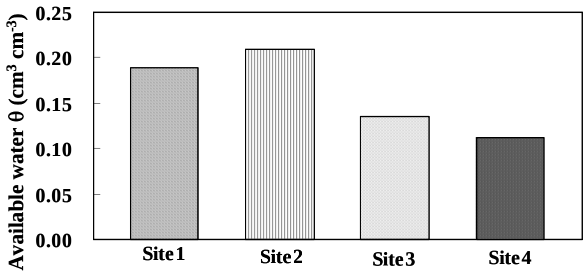

Figure 2 Available water of the soil samples (Hoshino, 2006).

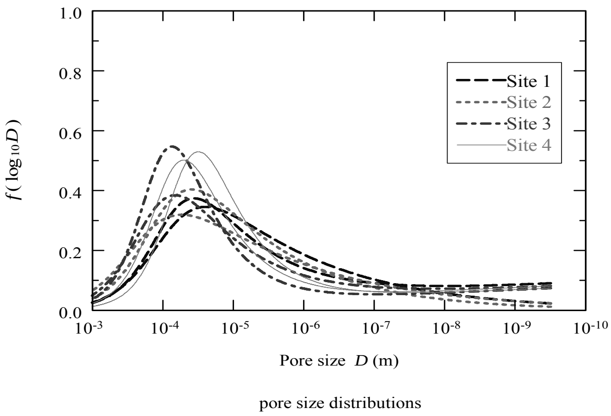

Figure 3 Pore size distributions of the soil samples (Hoshino, 2006).

Table 6 Relative percentage of pore size distributions of the soils at each study site (Hoshino, 2006).

	Porosity(%)					
	1000μm<	100-1000μm	10-100μm	1-10μm	0.1-1μm	0.1μm>
Site1	6.5	17.4	11.9	6.6	4.2	5.9
Site2	9.8	18.1	11.9	6.3	3.3	3.9
Site3	12.4	20.0	7.9	4.1	3.6	5.8
Site4	5.6	18.6	7.9	3.2	2.6	4.5

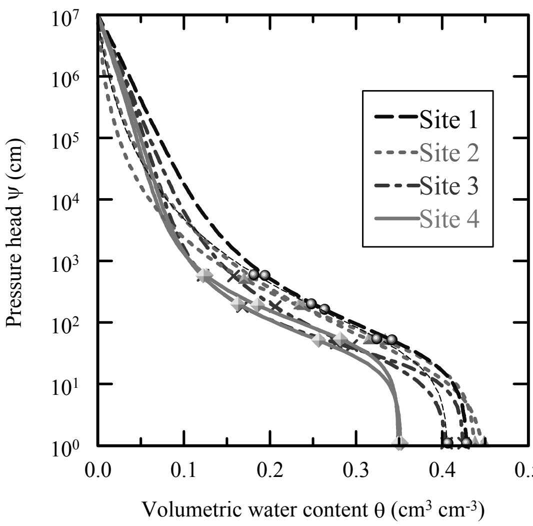

Figure 4 Water retention curves of the soil samples (Hoshino, 2006).

Moreover, there was a relationship between available water of soils and soil organic matter contents (Fig 2 and 4), suggesting that hydraulic properties of soils is also influenced by soil organic matter contents through the formation of variable aggregates and pores of soil microstructure. The highest value of Total-C and Total-N contents for the soils at site 2 was probably due to the supply of waste of livestock's (Kumada, 1981). On the other hand, there was a negative correlation between Total-C, Total-N and weight of roots 42 and bulk density of the soils. The highest value of EC at site 3 was probably due to the residual effects of fertilizer application and irrigation.

Micromorphological characteristics of soils at study site

From observations of soil thin sections obtained from sites 1, 2 and 3, there were a lot of fine materials in the upper part and many coarse materials in the lower part. On the other hand, the pattern of upper part and lower part of the sample from site 4 was relatively uniform, and many coarse materials were observed in whole section. Tillage would enhance the uniformity.

From descriptions of soil this section (Table 6), the ratio of fine materials was larger in the sample from sites 1 and 2 than that from sites 3 and 4. There were intergrain macro-aggregate structure and granular structure in the samples from sites 1, 2 and 3. There was only compact grain structure at site 4. Also, each granular was connected each other in the sample from site 2. On the other hand, each granular existed as single granule in the sample from site 4. From descriptions of soil this section, grain size was smaller in the samples from sites 1 and 2 than those from sites 3 and 4. Each aggregates was linked together in the sample from site 1. On the other hand, a few aggregations linked together in the sample from site 3. There were only thin aggregations around the gravel in the sample from site 4. Since voids size of 1-100μm at sites 1 and 2 was higher than other sites according to the result of void size distributions this might be caused by the prevailing microstructure size.

Table 6 Description of soil this section of each study site (Hoshino, 2006).

	Site 1	Site 2	Site 3	Site 4
c/f 10μm	4:6	3:7	8:2	8:2
microstructure	Integrain macro-aggregate structure Granular structure			Compact grain structure
Aggregate size (μm)	30-80	30-80	50-200	50
Voids size (μm)	30-50	20-100	20-80	80
Mineral materials (%)	9	9	18	52
Aggregate (%)	51	64	64	29
Voids (%)	40	27	18	19

Sites 1 and 2, keeping grassland vegetation, have developed microstructure of soils. While, at sites 3 and 4, poor vegetation and tillage might have resulted in the small contents of aggregate. Soil micro structure at site 3 was improved, by comparing with that of site 4. Also, vegetation was improved by exclusion of grazing pressure at Site 1. However, soil morphological properties of site 1 were not clearly different from Site 2.

Conclusions

In this study, it was clarified that the plant compositions, physico-chemical properties and micromorphological characteristics of different land use sites in KBU. The differences in these characteristics were discussed between site 1 and site 2 where grassland vegetation was maintained, and also between site 3 and site 4 where tillage was executed from1962-1992 and at still present, respectively.

In Fig. 4, the factors of controlling various soil properties were summarized for each site. Vegetation of KBU has the intimate relation with available water of soils. Since available water was controlled by soil microstructure and its size, especially site 3 and 4. Soil microstructure and its size of these sites were controlled by the ratio of aggregates.

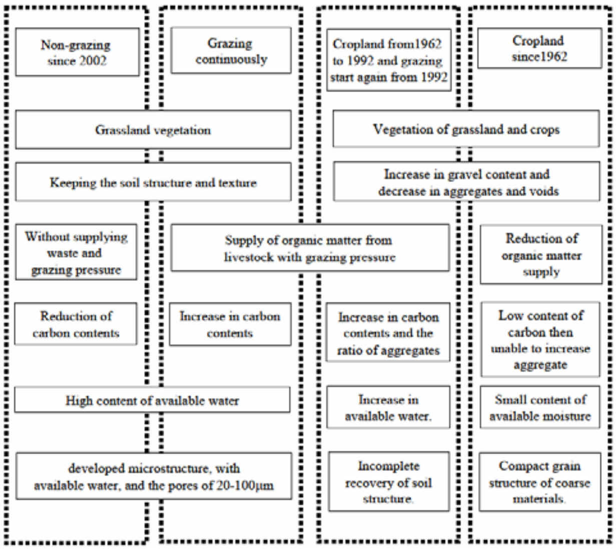

Figure 4 Factors controlling various soil properties at the four study site (Hoshino, 2006).

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