Bull. Sugadaira Montane Res. Cen. No. 9, 55-68 pp. (1988)
(Sugadaira Montane Research Center, University of Tsukuba)

Study of the Soil Properties of the Grassland in Baiinxile, Xilinhot, Inner Mongolia

TAKEHIKO TAKAHASHI[1], CHEN ZUOZHONG[2], HUANG YAQIN[3]

*[1] *Lab. of Soil Sci., Fac. of Agriculture, Kobe University, 1 Rokkodai, Nada, Kobe 657, Japan*

*[2] *Institute of Botany, Academia Sinica, 141 Xizhimenwai Street, Beijing, China*

*[3] *Scientific Research Institute of Environmental Protection of the Inner Mongolia Autonomus Region, No.5 Building, West street, New City, Huhehot, Inner Mongolia, China*

Synopsis

We had an opportunity to research the soil of the grassland (steppe and meadow) in Baiinxile, Xilinhot, Inner Mongolia in 1987.

The research area is located at the Xilin River basin which is the principal part of the Inner Mongolia grassland. We have 5 Plots for soil survey by excavating pits. The soil survey Plots were the same as the vegetation and the soil animal survey Plots. Plot 1 is heavey grazing land, Plot 2 is meadow-light graging land, Plot 3 is grazing land, Plot 4 is meadow land, and Plot 5 is *Populus* afforestation land. The soils of each Plot are chestnut soil (Plot 1, 2, 3), chernozem (Plot 4) and grey forest soil (Plot 5). In spite of that the soil texture of the grassland is SL-L, the soils in absorbing root sphere (0-50cm horizon) are compact with poor developed soil structure. But on the contrary, it seems to control to strongly dry the soil. And so, it seems that the utilization form of the grassland and the soil physical properties are closely related.

Key words: Inner Mongolia, grassland, afforestation land, soil physical and chemical property, utilization form of land

Introduction

We intend to summarize our research on the soil of the grassland in Baiinxile, Xilinhot, Inner Mongolia (Fig.1), where we had an opportunity to research in 1987.

This research was supported by scientific research fund (overseas scientific research) from the Ministry of Education. The subject for research is "Studies on biological pro-

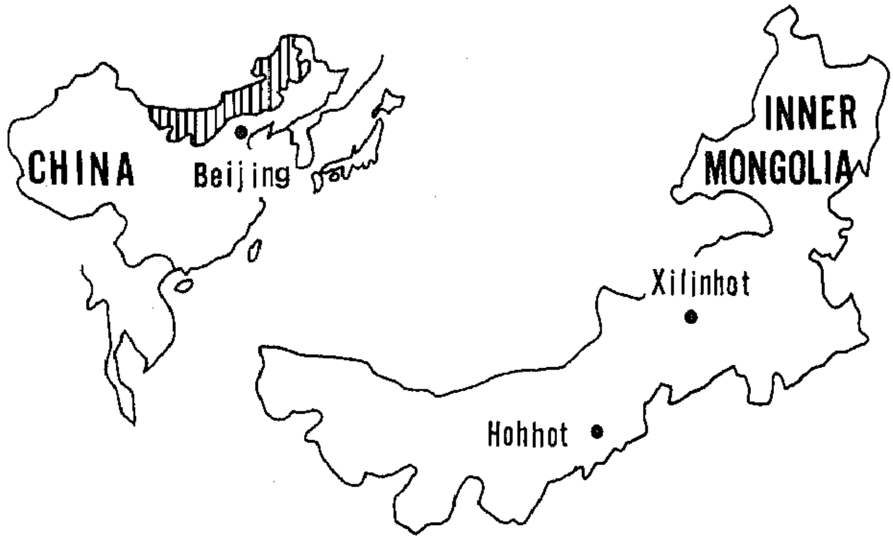

Fig. 1. Location of the Inner Mongolia Autonomous Region, China.

duction and environmental conservation of grassland in Inner Mongolia."

The soil properties of the grassland in Baiinxile have been researched by many researchers, among whom the study of LI (1985, 1988) and WANG and CAI (1988) were especially excellent. But research data on the soil physical properties of the grassland are insufficient, and there still remains a wide unexplored domain. The present research aims at obtaining more fundamental knowledge of the physical properties of soil in absorbing root sphere (0–50cm horizon soil) (TAKAHASHI et al, 1983).

In preparing this presentation, we got considerable help of our colleagues, other members of research committee, Mr. JIANG S., Dr. I. HAYASHI, Dr. T. NAKAMURA, Dr. M. TERADA and Dr. K. SUZUKI, and had many discussion with them. Their contribution to this paper are great and we take pleasure in acknowledging the important part played by them.

And we should like to express our grateful thanks to Mr. LIAN HAO, Director of Construction and Environmental Protection Bureau of Inner Mongolia, the government of the Inner Mongolia Autonomous Region, the Scientific Research Institute of Environmental Protection, Inner Mongolia Autonomous Region, Department of Biology, Inner Mongolia University, Institute of Botany, Academia Sinica and Inner Mongolia Grassland Ecosystem Research Station, Academia Sinica and the persons concerned in those institutions who extended us their kind assistance.

Research Area

The research area is located at the Xilin River basin which is the principal part of the Inner Mongolia grassland and 1000–1500m above sea level (WANG and CAI, 1988).

Many of the research Plots were situated within a livestock farm of Baiinxilie, Xilinhot city. The annual average temperature is $-0.4°C$ and the annual precipitation is 350mm with fluctuation of 180–500mm, among them 60–80% concentrates from June to August (WANG and CAI, 1988).

The soil types of this area include grey forest soil, chernozem, chestnut soil, meadow soil, bog soil, saline soil and woodland sand soil. The sonalsoil is chestnut soil. Chestnut soil is an alkaline soil, low in organic matter (less than 4%), poor in fertility and marked in calcic horizon (WANG and CAI, 1988).

Most of the grassland in Baiinxile are formed by steppes and meadows. The steppes in Baiinxile are dominated by *Artemisia* spp comm., *Stipa* spp–*Aneurolepidium chinese* comm. and *Aneurolepidium chinese–Stipa* spp comm. etc. There are *Stipa grandis*, *Stipa krylovii* and *Stipa bicalensis* in *Stipa* spp–*Aneurolepidium chinese* comm., and those *Stipa* spp dominant respectively in each suitable environment for growth and development.

We have 5 Plots for soil survey by excavating pits. Table 1 shows the locality of the surveyed Plots and Fig.2 shows the map of the soil surveyed area and Plots. Fig.3 shows the map of the soil of Xilin river basin which is our surveyed area for reference.

Table 1. Lacality of the surveyed plots.

Plot No.	Lacality
1	Wunchuntulu
2	Iho-ura (Survey plot of *Stipa grandis* grassland of Grassland Ecosystem Research Station)
3	Iho-ura (Survey plot of *Aneurolepidium chinese*. grassland of Grassland Ecosystem Research Station)
4	Gason-ura
5	Zhukestai-nur (*Populus davidiana* afforestation)

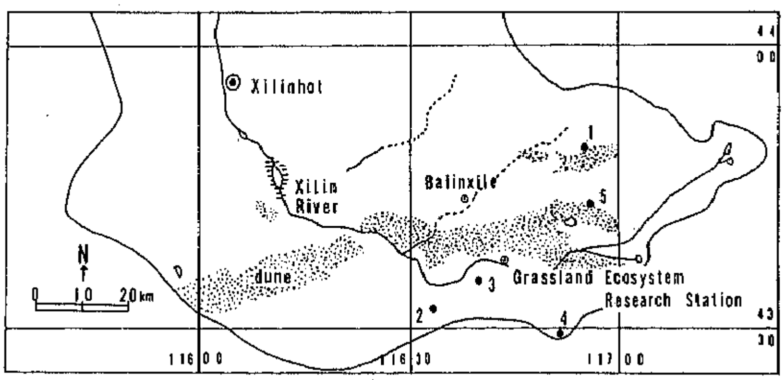

Fig. 2. Map of the soil surveyed area (the Xilin River basin).
The numbers in the figure show the surveyed plot number.

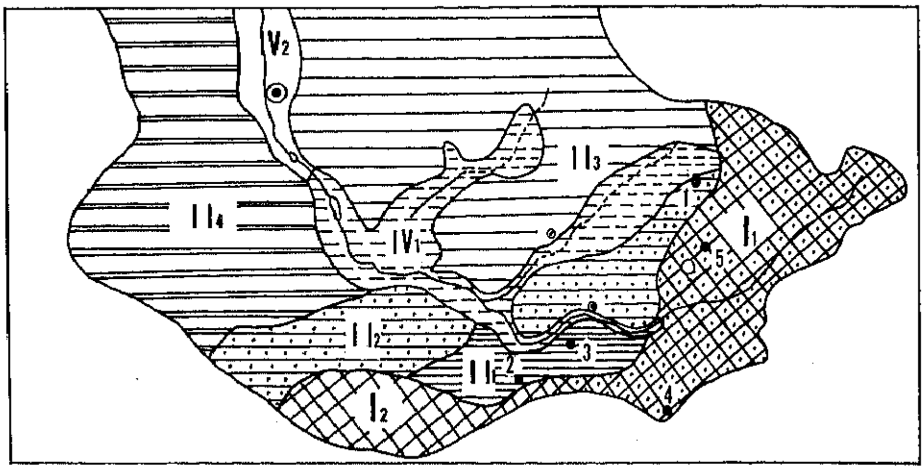

Fig. 3. Map of the soil of the Xilin River basin (WANG and CAI, 1988).
I_1, Eastern part chernozems. I_2, Western part carbonate-chernozems. II_1, Southern part dark chestnut soils. II_2, Chestnut sandy soils or sandy chestnut soils. II_3, Eastern thick layer-dark chestnut soils. II_4, Western sandy chestnut soils. IV_1, Upper and middle stream of Xilin River-meadow soils or bog soils. IV_2, Middle and down stream of Xilin River-salinized meadow soils.

Methods

The field work for this research was carried out in summer in 1987. The soil survey Plots were the same as the vegetation and the soil animal survey Plots.

The field survey of soil morphology and soil sampling were made by method of FORESTRY EXPERIMENT STATION (1955). Soil compactness of each soil was measured by YAMANAKA style hardness tester. Soil sampling was made per each horizon and we measured the soil physical and chemical properties for each horizon soil.

For the soil physical properties, we carried out the experiment to measure the three phase of soil, water holding capacity (maximum capillary water capacity), minimum air capacity, volume weight and soil hardness. The method of measurement used in these experiments was 100 ml-type soil actual-volumenometric method and HASEGAWA style cone penetrometric method. For the soil chemical properties, we carried out the experiment to measure the pH, T-C, NH_3-N, NO_3-N, available P_2O_5 and exchangeable Ca, Mg, K, Mn, Al of air dried soil by using the simplified soil nutrient tester.

Result and Discussion

The summary of the soil research Plots is indicated on Table 2. Plot 1, 2, 3 are steppe, Plot 4 is meadow, and Plot 5 is *Populus* afforestation land. Plot 1, 2, 3, 4 are the grassland with gentle slope made up of *Aneurolepidium chinese* class, *Potentilla tanacetifo-*

Table 2. Outline of soil survey plots.

Plot. No.	Date	Altitude (m)	Slope exposition	Slope inclination (°)	Geology or Soil material	Topography	Soil type	Land use	Vegetation *
1	1987 7.29	1300	S25E	2	diluvium	gentle slope middle part	Sandy dark chestnut soils	heavy grazing land	*Aneurolepidium chinese* Class *Potentilla tanacetifolia-Koeleria cristata* order/ alliance *Stipa krylovii-Festuca dahurica* association
2	1987 7.31	1200	S12E	2	diluvium	gentle slope middle part	Dark chestnut soils	meadow-light grazing land	*Stipa grandis-Artemisia commutata* association *Anemarrhena asphodeoides* subassociation
3	1987 7.25	1200	N89E	3.5	aeolian sandy soil residual soil	gentle slope middle part	Ortho chestnut soils	grazing land	*Stipa grandis-Artemisia commutata* association Typical subassociation
4	1987 7.28	1400	S62E	3	lava	gentle slope middle part	Ortho chernozems	meadow	*Stipa baicalensis-Carex pediformis* association
5	1987 8. 3	1350	N22E	30	dune	steep slope middle part	Sandy dark gray forest soils	afforestation land	*Populus davidiana* afforestation

* NAKAMURA.T. et al, 1989

lia-Koeleria cristata order / alliance(NAKAMURA et al, 1989).

Plot 1 is heavy grazing land made up of *Stipa krylovii-Festuca dahurica* ass., Plot 2 is meadow-light grazing land made up of *Stipa grandis-Artemisia commutata* ass., Plot 3 is grazing land made up of *Stipa grandis-Artemisia commutata* ass., Plot 4 is meadow land made up of *Stipa baicalensis-Carex pediformis* ass.(NAKAMURA et al, 1989).

The soils of each Plot are as follows; Plot 1: sandy dark chestnut soil, Plot 2: dark chestnut soil, Plot 3: ortho chesnut soil, Plot 4: ortho chernozem, Plot 5: sandy dark grey forest soil.

The Table 3 indicates the soil morphology. The all Plot soils are yellow brown-brown soil with hue of 10YR and the soil horizon are divided into 4-8 layers. The soils of Plot 1, 2, 3, 4 on grassland are less gravel. The soil texture is SL-L, but the soil has a massible structure, high soil compactness and less porosity. About the soil of Plot 5 on afforestation land, the soil texture is S-SL, but it is contrast to the grassland soil that the soil has granular structure in upper layer, and lower soil compactness. Also the grassland soils of Plot 1, 2, 3, 4 have less sedimentation of litter and less accumulation of humus. By contrast, the afforestation land soil of Plot 5 is rich. In the horizon under second layer of Plot 2, 3, 4 we found spot of $CaCO_3$.

Table 4 indicates three phase, water holding capacity, minimum air capacity and volume weight of the soil. Fig.4 indicates the vertical distribution of physical properties of them.

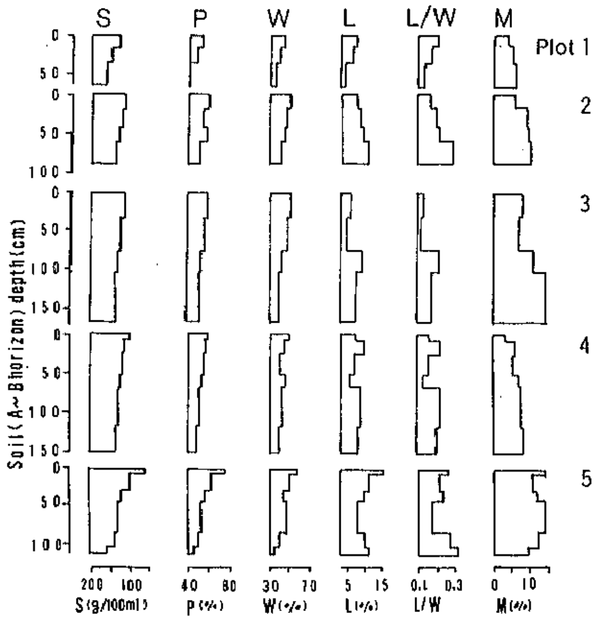

Fig. 4. Vertical distribution of physical properties of soil.
S: Volume weight (g/100ml). P: Porosity (%). W: Water holding capacity (%). L: Minimum air capacity (%). M: Water content of natural soil.

Table 3. Soil morphology.

Plot. No.	Horizon	Depth (cm)	Soil color	Humus*1	Gravel*2	Soil*3 texture	Soil*4 Structure	Soil*5 pore	Soil Compactness (mm)	Soil*6 Moisture	Plant root quantity*7 (Large, Middle, Fine)	Litter deposition (cm)
1	A	0~14	10YR3/3 dark brown	++	G, s~m, +	SL~(L)	Gr, vf~f	s, +	24~27	−	−, −, ++	L layer :0.5
	B	14~34	10YR4/4 brown	+	G, s~m, +	SL~(L)	Ma	s, +	24~30	−	−, −, ++	F :±
	BC	34~68	10YR6/6 bright yellowish brown	±	G, s~l, +	SL	Ma	s, +	22~28	−	−, −, +	H :0.5
	C	68~(110)	2.5Y 6/6 bright yellowish brown	±	G, s~l, +	SL	Ma	s, +	13~22	(±)	−, −, +	
2+1	A	0~18	10YR4/3 dull yellowish brown	+	G, s, ±	(Sl)~L	Gr, vf	s, +	22~26	−	−, −, ++	L layer :±
	B_1	18~42	10YR5/3 dull yellowish brown	+	G, s, ±	(Sl)~L	Ma	s, +	32~36	−	−, −, +	F :±
	B_2	42~60	10YR4/4 brown	+	G, s, ±	(Sl)~L	Ma	s, +	19~24	−	−, −, +	H :±
	BC	60~87	10YR6/4 dull yellow orange	±	G, s~l, +	(Sl)~L	Ma	s, +	24~27	−	−, −, ±	
	C	87~(110)	10YR6/6 bright yellowish brown	±	−	SL	Ma	s, +	19~24	−	−, −, ±	
3+2	A	0~30	10YR3/4 bark brown	+	G, s, ±	(SL)~L	Ma	s, +	22~27	−	−, −, +++	L layer :±
	B_1	30~73	10YR3/4 dark brown	+	G, s, ±	(SL)~L	Ma	s, +	20~24	−	−, −, ++	F :±
	B_2	73~100	10YR4/4 brown	+	G, s, ±	(SL)~L	Ma	s, +	18~22	(±)	−, −, +	H :±
	BC	100~166	10YR4/6 brown 10YR5/8 yellowish brown	± ±	G, s, ±	(SL)~L	Ma	s, +	22~24	(±)	−, −, +	
	C	166~(180)	10YR6/6 bright yellowish brown	±	G, s, ±	(SL)~L	Ma	s, +	16~17	(±)	−, −, ±	
4+3	A_0−(A_1)	0~3	10YR3/2 brownish black	++	−	(SL)~L	Gr, f	s, ++	±	−	−, ++, +++	L layer :±
	A_2	3~22	10YR3/4 dark brown	+	−	(SL)~L	Ma	s, +	20~25	−	−, ++, +++	F :±
	A_3	22~47	10YR4/3 dull yellowish brown	+	−	SL~(L)	Ma	s, +	26~32	−	−, ±, ++	H :±
	AB	47~68	10YR5/3 dull yellowish brown	+	−	SL~(L)	Ma	s, +	27~29	−	−, ±, +	
	B	68~114	10YR6/4 dull yellow orange	±	−	SL~(L)	Ma	s, +	26~29	−	−, −, +	
	BC	114~150	10YR6/4 dull yellow orange	±	−	SL−(L)	Ma	s, +	20~24	±	−, ±, +	
	C	150~(180)	10YR6/4 dull yellow orange	±	−	SL−(L)	Ma	s, +	17~22	±	−, −, ±	
5	A_0−A_{11}	0~5	10YR2/2 brownish black	+++	−	SL	Gr,vf~f	s~m, ++	3~9	−	−, ±, ++	L layer :4
	A_{12}	5~29	10YR2/2 brownish black	+++	−	S~SL	Gr,vf	s, +	9~18	−	−, ±, ++	F :4
	A_{21}	29~40	10YR2/3 brownish black	++	−	S~(SL)	Gr,vf	s, +	5~18	(±)	−, ±, +	H :4
	A_{22}	40~79	10YR2/2 brownish black	+++	−	S~SL	Ma	s, +	12~19	±	−, ±, +	
	B_1	79~98	10YR2/2 brownish black	+++	−	S~SL	Ma	s, +	8~12	±	−, ±, +	
	B_2	98~107	10YR3/3 dark brown	++	−	S	Ma	s, +	7~15	±	−, −, +	
	BC	107~130	10YR4/6 brown	±	−	S	Ma	s, +	3~5	(±)	−, −, ±	
	C	130~(155)	10YR6/4 dull yellow orange	±	−	S	Ma	s, +	4~6	(±)	−, −, ±	

*1 +++ very rich ++ rich + common ± poor

*2 G: Gravel
l large m middle S small (−non)

*3 S: Sand SL: Sandy loam L: Loam

*4 Gr: Granular structure Ma: Massive structure
f fine vf very fine

*5 m middle s small
++ common + few

*6 ± slightly wet − dry

*7 +++ very abundant ++ abundant + common ± few − non

+1 Large amounts of $CaCO_3$ Plots are present in 2nd~4th layers.

+2 Large amounts of $CaCO_3$ Plots and dead roots are present in 2nd~5th layers.

+3 Large amounts of $CaCO_3$ plots and dead roots are present in 2nd~7th layers.

Table 4. Physical properties of soil.*1, 2

Plot No.	Horizon	Depth (cm)	Air ratio Av (%)	*3 Water ratio Mv (%)	Solid ratio Sv (%)	Porosity P (%)	Degree of water saturation H(%)	Volume weight S (g/100ml)	Specific gravity d	Water content by wet soil Mm(%)	Water content by weight Mo(%)	Water holding*4 capacity V % W(%)	W%	Minimum air capacity L(%)	L/W
	A	0～ 14	46.4	4.2	49.4	50.6	8.3	129.3	2.62	3.1	3.2	43.0	33.3	7.6	0.18
1	B	14～ 34	41.9	5.3	52.8	47.2	11.2	144.9	2.74	3.5	3.7	40.6	28.0	6.6	0.16
	BC	34～ 68	33.7	5.9	60.4	39.6	14.9	162.9	2.70	3.5	3.6	34.9	21.4	4.7	0.13
	C	68～(110)	28.8	9.6	61.6	38.4	25.0	174.6	2.83	5.2	5.5	30.2	17.3	8.2	0.27
	A	0～ 18	51.9	6.0	42.1	57.9	10.4	115.3	2.74	4.9	5.2	50.7	44.0	7.2	0.15
	B_1	18～ 42	46.4	9.3	44.3	55.7	16.7	121.4	2.74	7.1	7.7	47.0	38.7	8.7	0.19
2	B_2	42～ 60	47.0	9.4	43.6	56.4	16.7	123.7	2.84	7.1	7.6	46.9	37.9	9.5	0.20
	BC	60～ 87	41.1	9.8	49.1	50.9	19.3	137.0	2.79	6.7	7.2	40.1	29.3	10.8	0.27
	C	87～(110)	30.0	7.1	62.9	37.1	19.1	169.3	2.69	4.0	4.2	31.8	18.8	5.3	0.17
	A	0～ 30	38.8	7.8	43.4	56.6	13.8	113.8	2.62	6.4	6.9	50.5	44.4	6.1	0.12
	B_1	30～ 73	37.3	7.2	45.5	54.5	13.2	118.5	2.60	5.7	6.1	49.1	41.4	5.4	0.11
3	B_2	73～100	42.0	11.3	46.7	53.3	21.2	120.8	2.59	8.6	9.4	43.9	36.3	9.4	0.21
	BC	100～166	34.4	14.8	50.8	49.2	30.0	133.2	2.62	10.0	11.1	41.9	31.5	7.3	0.17
	C	166～(180)	34.8	16.1	49.1	50.9	31.6	126.0	2.57	11.3	12.8	46.1	36.6	4.8	0.10
	A_0－(A_1)*5	0～ 3	53.2	3.2	43.6	56.4	5.7	100.6	2.31	3.1	3.2	48.8	48.5	7.6	0.16
	A_2	3～ 22	49.1	6.2	44.7	55.3	11.2	108.1	2.42	5.4	5.7	45.6	42.2	9.7	0.21
4	A_3	22～ 47	48.5	6.0	45.5	54.5	11.0	112.5	2.47	5.1	5.3	47.4	42.1	7.1	0.15
	AB	47～ 68	45.4	7.4	47.2	52.8	14.0	120.0	2.54	5.8	6.2	46.8	39.0	6.0	0.13
	B	68～114	44.2	7.7	48.1	51.9	14.8	125.5	2.61	5.8	6.1	43.3	34.5	8.6	0.20
	BC	114～150	39.9	8.4	51.7	48.3	17.4	135.0	2.61	5.9	6.2	40.6	30.1	7.7	0.19
	C	150～(180)													
	A_0－A_{11}	0～ 5	62.9	13.9	23.2	76.8	18.1	52.0	2.24	21.0	26.7	61.5	118.3	15.3	0.25
	A_{12}	5～ 29	51.6	10.6	37.8	62.2	17.0	95.9	2.54	10.0	11.1	51.3	53.5	10.9	0.21
	A_{21}	29～ 40	43.9	11.6	44.5	55.5	20.9	117.7	2.64	9.0	9.9	45.6	38.7	9.9	0.22
5	A_{22}	40～ 79	40.0	14.0	46.0	54.0	25.9	120.1	2.61	10.4	11.6	46.1	38.4	7.9	0.17
	B_1	79～ 98	38.2	12.5	49.3	50.7	24.7	130.8	2.65	8.7	9.6	40.2	30.7	10.5	0.26
	B_2	98～107	35.9	9.3	54.8	45.2	20.6	144.7	2.64	6.0	6.4	34.4	23.8	10.8	0.31
	BC	107～130	36.7	4.4	58.9	41.1	10.7	154.8	2.63	2.8	2.8	27.1	17.5	14.0	0.52
	C	130～(155)	38.0	2.0	60.0	40.0	5.0	159.8	2.66	1.2	1.3	29.3	18.3	10.7	0.37

*1 Data measured by 100ml-type soil actual-volumenometric method.
*2 On unair-natural soil.
*3 Water content of natural soil.
*4 Maximum capillary-water capacity.
*5 Data of 0～5cm horizon soil.

The thickness of the A horizon and A-BC horizon are as follows; Plot 1: 14cm, 68cm, Plot 2: 18cm, 87cm, Plot 3: 30cm, 166cm, Plot 4: 47cm, 150cm, Plot 5: 79cm, 130cm. About the grassland soil, the development and differentiation of soil horizon is almost propotionate to utilization form and vegetation type of grassland.

As for all Plots, air ratio, porosity and water holding capacity gradually gecrease from surface to lower horizon and soil volume weight gradually increases. Compared with the afforestation land soil, grassland soil has less than 10% low water ratio and water content by wet soil. But it is distinctive that minimum air capacity is under 10%, minimum air capacity / water holding capacity ratio is less than 0.2, water ratio and water content by wet soil increase gradually from surface horizon to lower horizon. This is a necessary characteristic of the soil for large perennial grass to continue to grow and develop under dry condition.

Table 5 indicates three phase, water holding capacity, minimum air capacity and soil volume weight of the soil in absorbing root sphere (0-50cm horizon soil). And Fig.5 indicates these physical properties to make easy to compare each Plot soil.

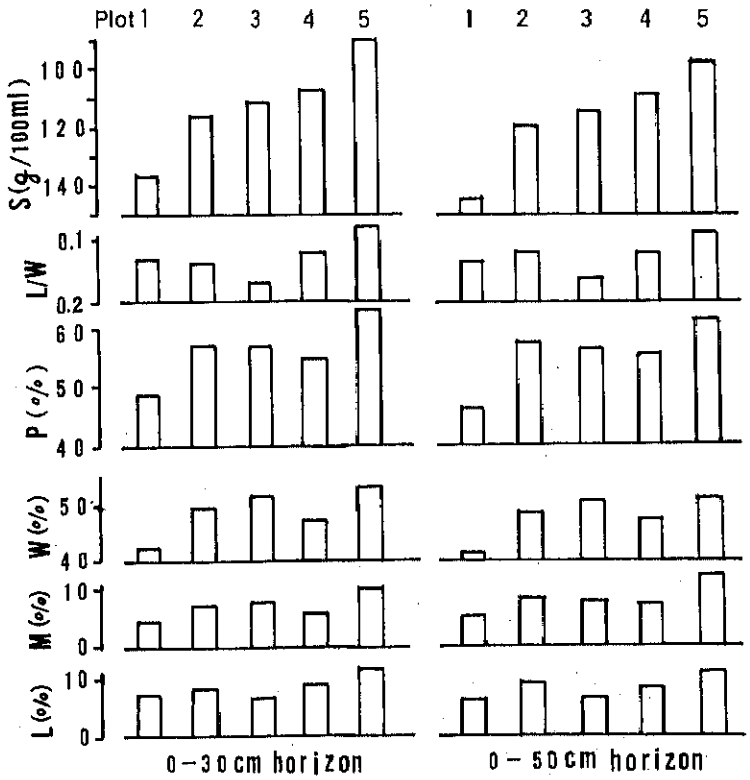

Fig. 5. Physical properties of soil in absorbing root sphere (0~50cm horizon soil).
S: Volume weight (g/100ml). P: Porosity (%). W: Water holding capacity (%). L: Minimum air capacity (%). M: Water content of natural soil.

Table 5. Physical properties of soil in absorbing root sphere (0~50cm horizon soil).*1, 2

Depth (cm)	Plot No.	Air ratio Av (%)	Water*3 ratio Mv (%)	Solid ratio Sv (%)	Porosity P (%)	Degree of water Saturation H(%)	Volume weight S (g/100ml)	Specific gravity d	Water content by wet soil Mm(%)	Water content by weight Mo(%)	Water holding*4 capacity V% W(%)	Water holding*4 capacity W%	Minimum air capacity L(%)	L/W
	1	40.5	5.2	54.3	45.7	11.4	146.3	2.69	3.4	3.6	39.4	26.9	6.3	0.16
	2	48.5	8.1	43.4	56.6	14.3	119.6	2.76	6.3	6.7	48.3	40.4	8.3	0.17
0~50	3	48.2	7.6	44.2	55.8	13.6	115.7	2.61	6.2	6.6	49.9	43.1	5.9	0.12
	4	48.8	6.0	45.2	54.8	10.9	110.6	2.45	5.1	5.4	46.8	42.3	8.0	0.17
	5	48.7	11.8	39.5	60.5	19.5	101.1	2.56	10.5	11.7	50.0	49.5	10.5	0.21
	1	43.9	4.8	51.3	48.7	9.9	137.6	2.68	3.4	3.5	41.7	30.3	7.0	0.17
	2	49.7	7.3	43.0	57.0	12.8	117.7	2.74	5.8	6.2	49.2	41.8	7.8	0.16
0~30	3	48.8	7.8	43.4	56.6	13.8	113.8	2.62	6.4	6.9	50.5	44.4	6.1	0.12
	4	49.4	5.8	44.8	55.2	10.5	108.5	2.42	5.1	5.3	46.4	42.8	8.8	0.19
	5	52.2	11.2	35.6	64.4	17.4	89.3	2.51	11.1	12.5	52.8	59.1	11.6	0.22
	1	35.3	5.8	58.9	41.1	14.1	159.3	2.70	3.5	3.6	36.0	22.6	5.1	0.14
	2	46.7	9.3	44.0	56.0	16.7	122.3	2.78	7.1	7.6	47.0	38.4	9.0	0.19
30~50	3	47.3	7.2	45.5	54.5	13.2	118.5	2.60	5.7	6.1	49.1	41.1	5.4	0.11
	4	48.0	6.2	45.8	54.2	11.4	113.6	2.48	5.2	5.5	47.3	41.6	6.9	0.15
	5	42.0	12.8	45.2	54.8	23.4	118.9	2.63	9.7	10.8	45.9	38.6	8.9	0.19

*1 Data measured by 100ml-type soil actual-volumenometric method.
*2 On unair-dry natural soil.
*3 Water content of natural soil.
*4 Maximum capillary-water capacity.

In the case of the grassland soil of Plot 1, 2, 3, 4, both 0-30cm and 0-50cm horizon soils are almost porosity$<$60%, water holding capacity$<$50%, minimum air capacity $<$ 10%, and minimum air capacity / water holding capacity ratio$<$0.2 and volume weight$>$110g/ 100ml, and compact soil with poor developed soil structure. But, on the contrary, it seems to control to strongly dry the soil. And so, it indicates that even water ratio (water content by natural soil) and water content by wet soil are$<$10%, large perennial grass grows and develops under dry condition.

Compared with the grassland soil, the afforestation land soil of Plot 5 has good physical properties, and it indicates the characteristic of the forest soil which is well-balanced with water and air holding under the dry condition.

We compared physical properties of the soils of Plot 1, 2, 3, 4 from Fig.5. The heavy grazing land soil of Plot 1 is quite poor as follows; volume weight of 0-50cm horizon soil$>$140g/100ml, porosity$<$50%, water holding capacity$<$40%, water content by natural soil $\leqq$ 5%, and it shows characteristically the degeneration of "plant community-soil system" by heavy grazing. About the grazing land soil of Plot 3, in spite of becoming a little worse by being made compact with pasturage, the growth and development of vegetation which can maintain a moderate pasturage is being maintained, because of having a comparably high water holding capacity, a low minimum air capacity, and a low minimum air capacity / water holding capacity ratio. The light grazing land-meadow soil of Plot 2 and meadow soil of Plot 4 indicate that by stabilization of "plant community-soil system", they maintain the structure comparably well-balanced with the supply of water and air, and the utilization form of the land. And the soil physical properties are closely related.

Fig.6 indicates the vertical distribution of the hardness of the 0-60cm depth soil by cone penetrometer. The grazing land soil of Plot 1, 3 are hard compared with the light grazing land-meadow soil and the meadow soil of Plot 2, 4, especially the tendency is strongly recognized in the upper horizon. It can be said that it reflects the compactness of soil by grazig. The afforestation land soil of Plot 5 is quite soft. At Plot 1, 2, 3 hard soils exsist in the part of 20-40cm depth. It seems to indicate that this is closely related with the integration of $CaCO_3$ and also steppe, which is almost in the same state to heavy grazing land, was being continued in the past.

Table 6 indicates the soil chemical properties. The grassland soil of Plot 1, 2, 3, 4 are neutral to alkaline soil reflecting the integration of exchangeable Ca and Mg. On the contrary, the afforestation land soil of Plot 5 is acid soil by the integration of humus. These research Plots are generally poor in the integration of NH_3-N, NO_3-N, available P_2O_5, and exchangeable K. And it can be said that in point of soil nutrient the Plots are poor.

Conclusion

We had an oppotunity to research the soil of the grassland (steppe and meadow) in

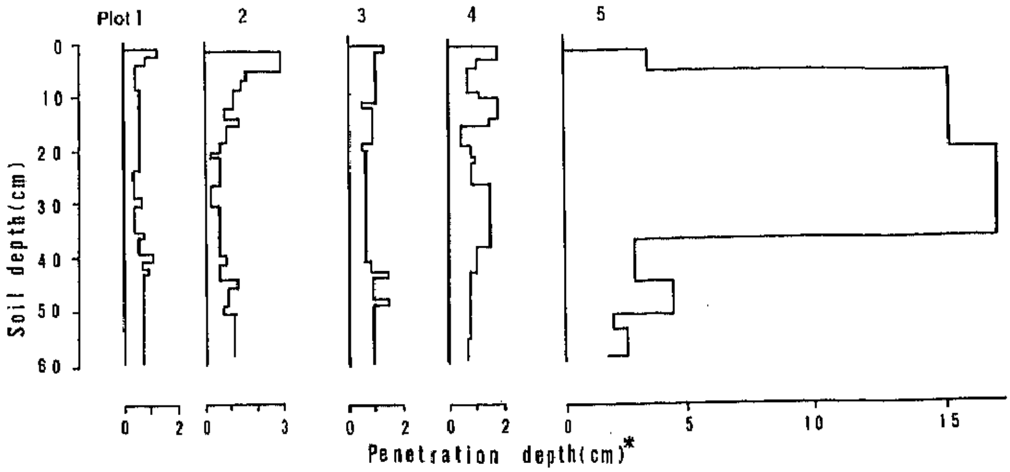

Fig. 6. Result of penetration test of soil by cone penetrometer.
* penetration depth per one blow of hammer.

Baiinxile, Xilinhot, Inner Mongolia in 1987. We have 5 Plots for soil survey by excavating pits.

1) Plot 1, 2, 3 are steppe, Plot 4 is meadow, and Plot 5 is *Popurus* afforestation land.

2) Plot 1, 2, 3, 4 are the grassland with gentle slope made up of *Aneurolepidium chinese* class, *Potentilla tanacetifolia-Koeleria cristata* order / alliance.

3) Plot 1 is heavey grazing land made up of *Stipa krylovii-Festuca dahurica* ass., Plot 2 is meadow-light grazing land made up of *Stipa grandis-Artemisia commutata* ass., Plot 3 is grazing land made up of *Stipa grandis-Artemisia commutata* ass., Plot 4 is meadow land made up of *Stipa baicalensis-Carex pediformis* ass..

4) The soils of each Plot are as follows; Plot 1: sandy dark chestnut soil, Plot 2: dark chestnut soil, Plot 3: ortho chesnut soil, Plot 4: ortho chernozem, Plot 5: sandy dark grey forest soil.

5) The soils of all Plots are yellow brown-brown soil with hue of 10YR.

6) The soil texture of the grassland is SL-L, but the soil has a massive structure, high soil compactness and less porosity.

7) We found remarkable spots of $CaCO_3$ in the horizons under second layer of Plot 2, 3, 4.

8) The thickness of the A horizon and A-BC horizon are as follows; Plot 1: 14cm, 68cm, Plot 2: 18cm, 87cm, Plot 3: 30cm, 166cm, Plot 4: 47cm, 150cm, Plot 5: 79cm, 130cm.

about the grassland soil, the development and differentiation of soil horizon is almost propotionate to utilization form and vegetation type of grassland.

9) The physical properties of the soils in absorbing root sphere (0-30cm, 0-50cm

Table 6. Chemical properties of soil.*1, 2

Plot No.	Horizon	Depth (cm)	pH (H_2O)	NH_3-N (mg/kg)	NO_3-N (mg/kg)	Available P_2O_5 (mg/kg)	Exchange-able Ca (%)	Exchange-able Mg (mg/kg)	Exchange-able K (mg/kg)	Exchange-able Mn (mg/kg)	Exchange-able Al (mg/kg)
	A	0~ 14	6.8	5~10	±	5	0.20	270	10	0.5	<25
1	B	14~ 34	9.0	5~10	±	±	0.09	200	10	0.1	<25
	BC	34~ 68	9.5≦	5~10	±	±	0.04	200	10	±	<25
	C	68~(110)	9.5≦	5~10	±	2	0.04	160	10	±	<25
	A	0~ 18	6.4	15	±	3	0.15	160	25	0.2	<25
	B_1	18~ 42	9.5≦	5~10	±	±	0.20	160	50	0.5	<25
2	B_2	42~ 60	9.5<	5~10	±	±	0.09	270	50	0.1	<25
	BC	60~ 87	9.5<	5~10	±	±	0.09	200	50	0.3	<25
	C	87~(110)	9.5<	5~10	±	±	0.09	270	25	±	<25
	A	0~ 30	6.4	5~10	1	±	0.15	270	10	0.5	<25
	B_1	30~ 73	9.5<	5~10	1	±	0.04	400	10	±	<25
3	B_2	73~100	9.5<	5~10	1	±	0.15	320	25	±	<25
	BC	100~166	7.2	15	1	5	0.20	320	25	0.5	<25
	C	166~(180)	8.0	5~10	1	±	0.04	320	10	±	<25
	A_0–(A_1)	0~ 3	6.8	25	±	±	0.25	200	200	0.1	<25
	A_2	3~ 22	7.2	15	±	±	0.15	180	25	0.1	<25
	A_3	22~ 47	9.0~9.5	25	±	±	0.25	200	25	±	≦25
4	AB	47~ 68	9.0~9.5	25	2.5	±	0.25	200	25	0.1	<25
	B	68~114	8.0	20	1	±	0.20	200	25	0.1	≦25
	BC	114~150	7.6	15	30	±	0.15	270	10	0.1	≦25
	C	150~(180)									
	A_0–A_{11}	0~ 5	5.4	10	±	12.5	0.15	200	50	±	<25
	A_{12}	5~ 29	5.4	5~10	±	12.5	0.09	270	25	±	<25
	A_{21}	29~ 40	5.6	5~10	±	7.5	0.09	270	10	0.5	<25
5	A_{22}	40~ 79	5.4	5~10	±	7.5	0.04	270	10	0.2	<25
	B_1	79~ 98	5.4	5~10	±	5	0.15	270	35	±	<25
	B_2	98~107	5.4	5~10	±	2	0.04	160	10	±	<25
	BC	107~130	5.4	5~10	±	2	0.02	130	25	±	<25
	C	130~(155)	5.2	5~10	±	2	0.02	130	25	±	50

*1 Data measured by rapid test (used soil diagnosis set).

*2 On air-dry fine soil.

horizon) of the grassland are almost as follows; volume weight > 110g/100ml, porosity < 60%, water holding capacity < 50%, minimum air capacity < 10% and minimum air capacity / water holding capacity ratio < 0.2. So, the soils are compact with poor developed soil structure.

10) But on the contrary, it seems to control to strongly dry the soil. And so, it indicates that large perennial grass grows and develops under dry condition.

11) Compared with the grassland soil, the afforestation land soil has good physical properties, and it indicates the characteristic of the forest soil which is well-balanced with water and air holding under the dry condition.

12) At the steppe of Plot 1; 2, 3 hard soils exist in the part of 20-40cm depth. It seems to indicate that this is closely related with the integration of $CaCO_3$ and also steppe, which is almost in the same state to heavy grazing land, was being continued in the past.

13) The grassland soils are neutral to alkaline soil reflecting the integration of exchangeable Ca and Mg. On the contrary the afforestation land soil is acid soil by the integration humus.

14) It seems that the utilization form of the grassland and the soil physical properties are closely related.

References

FORESTRY EXPERIMENT STATION 1955. Textbook of survey method for the national forestland. Ministry of forestland.: p.6-12. (in Japanese)

LI S. 1985. Pleliminary studies on moisture regime and its relationship with plant biomass in grassland. Research on grassland ecosystem No.1. Science press.: p.195-202. (in Chinese with English summary)

LI S. 1988. The growth of plants at grassland and the water condition in the chestnut soil. Research on grassland ecosystem No.2. Science press.: p.10-19. (in Chinese with English summary)

NAKAMURA T., GONG Y. and JIANG S. 1989. A preliminary study on the classification of steppe vegetation using Braun-Blanquet's method in some areas of Xilin River basin in Inner Mongolia. Bull. Sugadaira Montane Res. Cen.. **9**: 9-17. (in English)

TAKAHASHI T., NISHIMURA H., NISHIDA M., ICHIKAWA S., KITAMOTO Y. and KAYAMA R. 1983. Correlation between the vegetation succession and the physical and chemical properties of the soil in absorbing root sphere (0-50cm horizon soil) of *Pinus densiflora* forest in the granite area of Mt. Rokko district. Japanese J. of Soil Sci. and Plant Nutrition. **54**: 124-130. (in Japanese with English summary)

WANG J. and CAI Y. 1988. Studies on genesis, types and characteristics of the soils of the Xilin river basin. Research on grassland ecosystem No.3. Science press.: p.23-83. (in Chinese with English summary)