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Forest Fire Impacts to Mongolian Permafrost (Extended Abstract)

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Abstract: In northern Mongolian regions, boreal forest termed as Taiga develops widely and underling permafrost is also distributed. Taiga and Permafrost is in the co-existence relationship as well as Siberian Taiga, where annual precipitation is as low as 200-300 mm per year. The low amount of annual precipitation may not permit to develop the Taiga in general. However underlying permafrost impedes the downward water percolation and maintains some degree of water content in upper soil layers. Once Taiga severely is disturbed by forest fire, then the surface heat budget may loose its balance and permafrost tends to thaw. Thawing of permafrost leads the drying of surface layers associated with salt concentration process. Low water content in surface soil and salinization of soil may result in the interference of regeneration of forest. In 1996, north-eastern Mongolian regions were affected by severe forest fire. Aiming the integration of forest regeneration process, on-the-spot investigation was conducted in Khentey Mountain region. The soil characteristics of burned and unburned area were investigated. Thermal conductivity of soil was obtained. Temperature profiles of soils layers were monitored by means of data loggers. Fire impact to permafrost degradation due to changing thermal regime was indicated by the temperature profiles at various locations. In fired areas, permafrost becomes non-permafrost condition at the south facing slope, but permafrost maintains at the north facing slope.

Relief of Mongolia and Climate

Mongolia is located in east central Asia. On the west, south, and east it borders China and on the north the Russia. The Mongolian territory lies between 42 and 52 north latitude. It covers 1,566 square kilometers, with extreme distances north to south of 1,259 km, and east to west of 2,392 km. While its elevation is 1,580 m above the sea level, the nation has general conformation of a saucer, tipped higher in the northwest and lower in the southeast. Northern part of Mongolia includes considerable forest and mountainous terrain, as well as fertile steppe; therefore both livestock and human population to a large extend, concentrate in the northern third of the country.

Annual precipitation, mainly in the form of summer rain, ranges in different parts of the country from 10 to 400 millimeters. Light snow, combined with extreme cold, results in a considerable belt of permafrost. The temperature range is wide; at Ulaanbaatar, about midway between mountains and desert, average temperature for January is −28°C., and for July 18°C; extremes of temperature are much greater. Fig. 1 shows the air temperature change on an annual average basis from 1940 to 1999 near Boyant Airport at Ulaambaatar. It found warming tendency for air temperature over 60 years, but the effect of global warming could not be considered from these data. Apparently low annual average temperature blow freezing point

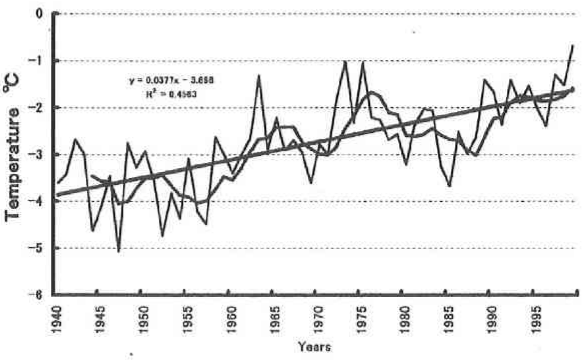

Fig. 1 Air temperature change on an annual basis with 1940 through 1999 in Ulaanbaatar

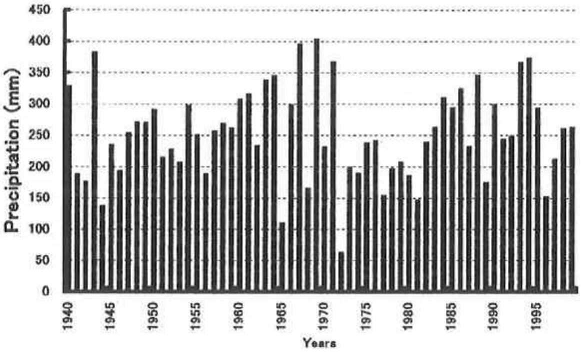

Fig. 2 Total precipitation change on an annual basis with 1940 through 1999 in Ulaanbaataar

proves the possibility of permafrost area. As well as the temperatures, annual precipitation at Ulaanbaatar was shown in Fig. 2. The fluctuation of annual total precipitation was found to be very remarkably wide, hence it is supposed to have strong relation with forest fires and fire fighting work. In Canada, there is a interest report about climate change according to the decreasing of solar energy for January through April (Cutforth 2000). The detail analysis will be waiting for later.

Mongolian permafrost and forest

The high altitude and cold climate are excellent conditions for permafrost conditions. Permafrost area covers about 63 % of the total territory. The continuous permafrost distributes in Hangai, Hentei, Huvsgul, and the Mongol-Altain mountain range. The Mongolian forest covers these area, Hangai and Khenei mountains connecting with Siberia Taiga belts. Coniferous trees, such as the pine and birch are commonest there and the pine forest includes almost larch (*Larix dahurica*). There is a close relationship for distribution map between permafrost and forest cover owing to low temperature, less rainfall and water capillary rise from active layer in permafrost zone such as Siberia taiga (Uemura 1997).

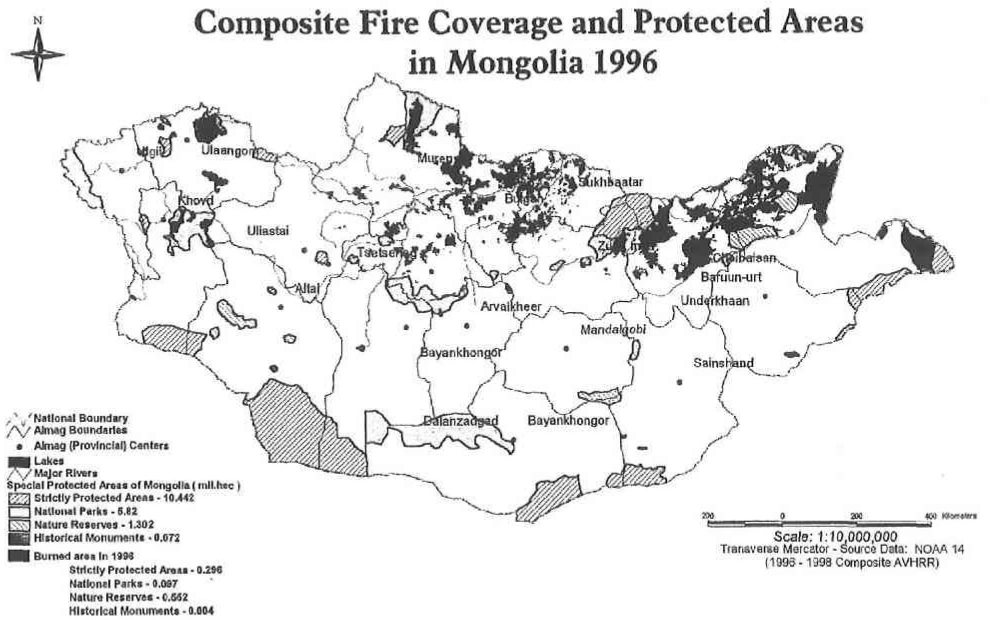

Fig. 3 Composite fire coverage and protected areas in 1996

Forest fires in Mongolia

Among the chief causes of forest fires are careless smoking neglected campfire and lightning (Chandrasekhar 2000). In the case of Mongolia, it is said that the chief causes were due to human activities such as neglected campfire by hunters in the forests. In 1996, the large-scaled forest fires occurred from March to June during four months. The first fires started under the dry condition in the Dornod province on February 23. The strong warm wind in April spread the fires in the forest and prairie toward many provinces. Finally the summer rainfall stopped the forest fires in June and government spokesman pronounced the finishing of the fire fighting on June 17. Then the burned area was estimated about twenty three million hectares approximately. Government of Forestry showed the forest area damaged by fires in Mongolia from 1980 to 1996. This year forest fires was seemed to be serious disaster whatever it experienced in Mongolia. In addition, Fig. 1 shows the distribution of forest areas damaged by fires in 1996. The serious damage due to forest fires could be seen clearly in both Hentein and Huvsgul Mountain ranges and also it occurred remarkably in north territory with permafrost zone.

On-the-spot investigation in Knentey area

We selected the Khentey area far about 240 km from Ulaanbaatar for the field survey spot. Because the spot was classified in the continuous and discontinuous permafrost zone in the Khentey Mountain range. Our investigation was started from July 25 of 1999 and was continued during two weeks. The burned forest was found in the terrace near the Kherlen river, and on the east hillside covered with dense larch trees, soils included with ice, permafrost in ground was found soon. In the forest there were the various typed trees mixed with the perfect burned larch

Table 1. Thermal conductivity and physical properties in the Mongolian fired soils

Plot area	soil depth	Thermal conductivity (W/m・K)	Ignition loss (%)	Moisture (%)	Solid (%)	Aeration (%)
Burned forest (Khentey)	10 cm	0.320	5.2	22.2	45.7	32.1
	20 cm	0.143	2.1	11.4	52.1	36.5
	30 cm	0.258	1.9	12.8	53.3	33.9
	60 cm	0.297	1.5	12.0	58.9	29.1
	90 cm	0.183	1.2	12.7	60.2	27.1
	110 cm	0.195	0.9	10.4	65.8	23.8
Permafrost (Khentey)	10 cm	0.161	3.4	11.9	43.1	45.0
	30 cm	0.153	1.9	12.1	52.6	35.3
	55 cm	0.155	1.3	11.2	57.8	31.0
	75 cm	0.186	1.1	8.0	58.2	33.8
	115 cm	0.159	0.9	7.9	60.8	31.3
	120 cm	0.170	0.9	10.7	64.1	25.2
Prairie (Nalaykh)	40cm	0.149	7.5	11.6	44.1	44.3
	80cm	0.188	7.6	18.3	44.2	37.5
	120cm	0.171	5.4	18.6	48.7	32.7

trees, the burned stem of larch with alive canopy, and only burned foot of larch stem. Because we could not found permafrost in the burned forest, it was supposed that the fire decreased the cover trees, and heat balance was changed. As a result, permafrost had already disappeared in the burned forest. Then on both burned forest with larch and unburned forest with permafrost, soil samples were collected to compare the difference of the thermal conductivity and physical properties of soils. Additionally, the site of prairie was selected for the contrast near Nalaykh city far about 36 km from Ulaanbaatar. On three spots, burned forest, the forest with permafrost and the prairie without trees, soil temperature was measured through the soil profiles by the portable thermometer and several thermistor sensors were installed in the ground and connected with data loggers in order to monitor the temperatures in the soil profile during one year. Table 1 shows the results obtained from three spots to compare the different condition of heat balance and the influence. Consequently, it found that the burned forest had high thermal conductivity on the surface layer. The forest with permafrost showed the considerable lower value in thermal conductivity, so it was guessed that the low thermal conductivity might produce the permafrost condition. As regards with moisture content, the permafrost soil profiles showed lower moisture condition than the burned forest. There were little difference for the ignition loss between the burned and permafrost forest, but the prairie soil was clearly found to have highest values than the forest soil. The analysis on soil temperatures is now continued and soon the results will be shown on the difference of the three spots.

Conclusion

The soil characteristics of burned and unburned area were investigated in Mongolia. Thermal conductivity of surface soil was found to be different between burned and unburned site. Fire impact to permafrost degradation due to changing thermal regime was indicated by the direct temperature profiles at three locations. In fired areas, permafrost becomes non-permafrost condition with few tree-covers, but permafrost would be maintained if the surface covers and density of trees are kept there.

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