Types of forest fire and biomass decreasing patterns in northern Mongolian forests

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Abstract

Northern Mongolian Forests are frequently affected by wild fires. In this research, we investigate the biomass decrease after fire by measuring the biomass of primitive forest. First, we made a relational expression of D^2H and stem weight using stem analysis and soft X-ray densitometry. Second, we measure the DBH, H and other tree characteristics in different primitive forest. Finally, we estimated the forest biomass. On one hand, we assume 4 types of forest fires: light, middle, heavy and post-harvest fire and we simulate the decrease of biomass after fire. In case of a middle grade fire, stand structure will be maintained with temporary biomass decreasing because regeneration and seedling growth will be induced. In case of light fire, regeneration and seedling growth will be restricted and biomass will increase because of the growth of dominant trees. In case of heavy fire and post-harvest fire, biomass will significantly decrease and regeneration will be continued over a long period.

Keywords: Northern Mongolia, *Larix sibirica*, Forest fire, Biomass, Regeneration

1. Introduction

There is a vast larch (*Larix sibirica*) forest area in Khovsgol region, northern Mongolia (Crisp et. al, 2004). In this area wild fires are common phenomena (Hayasaka, 2011; Akojima and Honda, 2002). Loss of forest resources is recognized as a major issue for the Mongolian economy (Dorjsuren, 2008). There is no report about decreasing forest biomass and few reports about regeneration and encroachment in transition zone between forest and grass land. It is necessary to understand the effect of different fire types on forest biomass, CO_2 emission after fire and regeneration of forest. In this research, we estimate the biomass decrease after fire by measuring the biomass of primitive forest.

2. Methodologies

We use some innovative technology in this study. We made a relational expression of D^2H and stem weight using stem analysis and soft X-ray densitometry combination technique. On one hand, we set 4 types of forest fire: light, middle, heavy grade and post-harvest and simulate the biomass decrease after fire. Next, we measured the light condition of forest floor which could support and seedling growth after the regeneration and we estimate the changing the stand structures.

Site locations: The study region extends from 50°57'24''N to 51°26'48''N and from 99°11'37''E to 99°44'07''E and at 1,550m.a.s.l. as shown in Figure 1. Mean annual temperature is -7.1 degree reported in Renichinhumbe. Site location and investigation plot size are shown in Table 1.

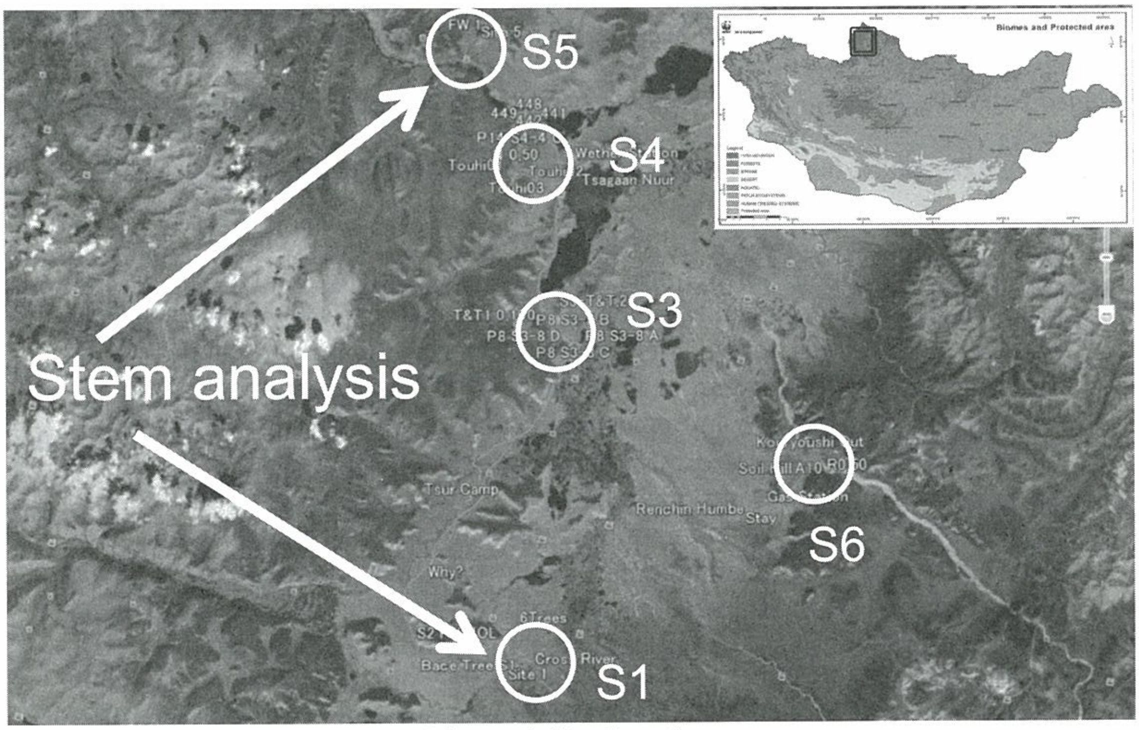


Figure 1 Site location

Note: Aerial photograph is from Google earth, wide area Mongolian map from "Quoted from "Chimed-Ochir B., Hertzman T., Batsaikhan N., Batbold D., Sanjmyatav D., Onon Yo. and Munkhchuluun B. (2010) Filling the Gaps to Protect the Biodiversity of Mongolia. WWF Mongolia Programme Office, August 2010"

Table 1 Site Location

Site No.	Forest type	Size	Location	Altitude
S1 (ET)	Mixed forest	20m×25m	50°57'24''N, 99°24'16''E	1556
S3-1 (LS)	Larch forest	10m×100m	51°14'38''N, 99°21'31''E	1699
S3-2 (IS)	Larch forest	10m×50m	51°14'37''N, 99°21'29''E	1697
S4 (HM)	Mixed forest	10m×50m	51°20'55''N, 99°17'12''E	1797
S5-1 (BF)	Larch forest	10m×50m	51°26'50''N, 99°11'36''E	1654
S5-2 (AF)	Larch forest	10m×50m	51°26'48''N, 99°11'37''E	1654
S6-1 (AK)	Mixed forest	5m×40m	51°09'22''N, 99°43'44''E	1633
S6-2 (RH)	Spruce forest	5m×50m	51°09'22''N, 99°44'07''E	1639

Tree cruise: We measured the DBH, H and other tree forms in several primitive forest. Measurement item are stand position of X, Y, Z axis, tree species, tree height, diameter breast height, crown height and four direction of crown width.

Stem analysis: Various methods of stem analysis have been proposed for estimating the wood volume of individual trees (Wenger, 1984; Osumi, 1987). Generally, the stem volume is calculated as a sum of the volumes of treetop, stem butt and a series of log segments between them (Figure 2). In this study, the volume of each log is calculated by the cone trapezoid shape (Eq. 1).

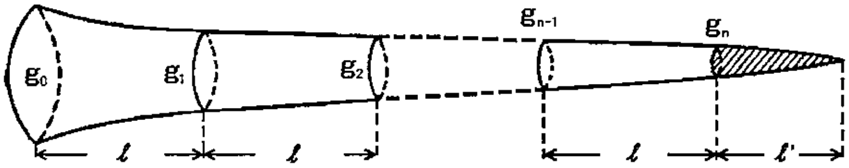


Figure 2 Method of averaged cross-sectional area

$$V = \frac{L}{3}\left(S_{base} + S_{top} + \sqrt{S_{base} \cdot S_{top}}\right) \qquad \text{Eq. 1}$$

Where, V = volume of log,
L = length of log
S_{base} = cross section area of the basal end of log
S_{top} = cross section area of the apical end of log

Tree disk samples for the stem analysis were collected form Site 1 and 5. In this study, we use the stem density analyzing method (Nobori et al., 2004) which was constructed as a system for analyzing the weight growth of stems using the data obtained by soft X-ray densitometry (Parker et al., 1980) and morphological stem analysis. X-ray photographs were taken in the Institute of Wood Technology, Akita prefectural University. Annual volume increase was calculated as the difference between volumes in two successive years. The weight of each log was calculated by multiplying the volume by the mean of the volume densities of wood disks taken from the upper and basal ends of each log. Annual increase in weight and total wood weight were also obtained from these data.

Light condition of forest floor: There are typical swamp-forest transition zones in Darhad valley, west of the Khovsgol Lake. Most typical forest species are larch and spruce (*Picea obobata*) and relative dominance of larch is high. In case of sandbanks and riparian forests, mixed larch and spruce forest are observed. There are few young larch seedlings over 1.3m height in a 100-120m area. However, there are many spruce seedlings. In this site, we estimate the light demand of larch seedling growth. The plot size was set to 4 meter width and 130 meter length. In this transect, tree position, tree size and light conditions at 1.0m height were measured (Figure 3).

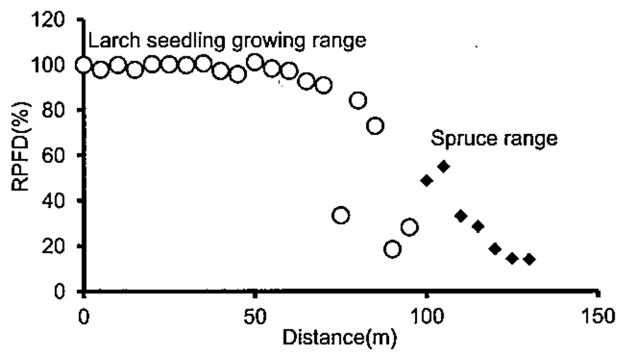
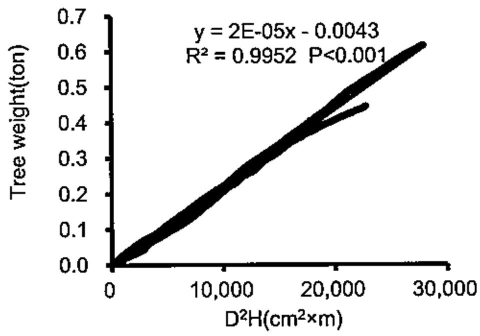


Figure 3 Light condition of S1

3. Results

Stem weight formula: The results of stem weight calculating equations of larch and spruce are shown in Figure 4. At same stem size, larch was heavier than spruce. D^2H of 20,000 was 0.45 ton for larch and 0.35 ton for spruce. Here, we use the root and branch ratio for Japanese Larch (48%) and Spruce (82%) value.



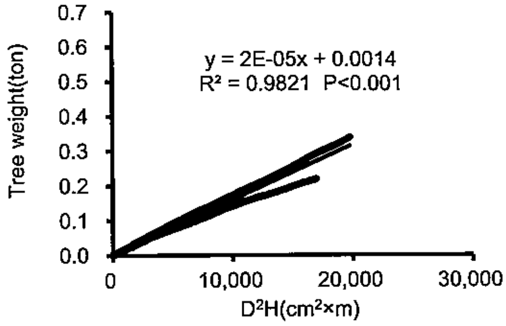


Figure 4 Simplified equation of tree weight of Larch and Spruce

Table 2 Biomass summary

Site	Forest type	N/ha*1	Total weight (ton)	Regeneration
S1-B (IS)	Mixed forest	380	94.5	many
S3-1 (LS)	Larch forest	800	276.2	little
S3-2 (IS)	Larch forest	820	433.7	few
S4 (HM)	Mixed forest	1,180	202.2	many
S5-1	Larch forest	1,060	337.9	few
S5-2	Larch forest	660	558.2	few
S6-1 (RH)	Spruce forest	1,120	180.5	many
S6-2 (AP)	Mixed forest	1,550	379.6	little

Note *1 Tree size over 6cm DBH.

Forest Biomass summary: Forest biomass summary is shown in Table 2. In this table, total weight included branch and roots. Tree numbers ranged from 380/ha to 1,550/ha. Total weight ranged from 94.5ton/ha to 558.2ton/ha. By the way, typical biomass of Taiga was 200ton/ha in average. However, we found the over twice biomass forest in these area.

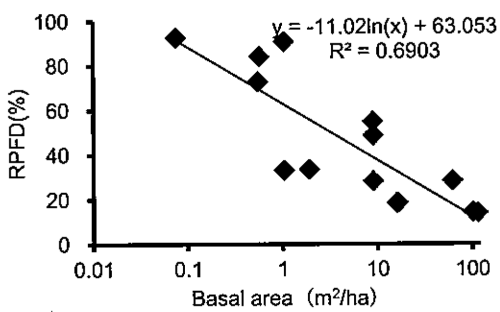


Figure 5 Relationship between Basal area and RPFD

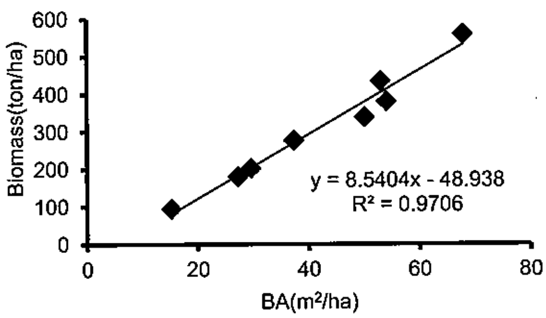


Figure 6 Relationship between BA and Biomass

Light demand for Larch regeneration: Relative photon flux density (RPFD) was investigated at 1m height. RPFD is lower than 30% inside the high forest. Larch cannot grow under 20 % RPFD level. The relationships between basal area and RPFD are shown in fig. 5. Relative photon flux density (RPFD) under 20 % was basal area over 49.4 m^2/ha. Basal area 49.4(m^2/ha) corresponded to Biomass 373.1ton/ha (Figure 6).

Relative growth of DBH and Tree height: Relative growth curves of S5-1 and S5-2 are shown in Figure 7. S5-1 and S5-2 is adjacent to grasslands, but there are no small trees less than 10m in S5-2. What happened in S5-2? We are presuming that low intensity fire happened at this forest in past times.

Limit of Larch regeneration: Larch regeneration will not happen at biomass over 373.1(ton/ha) (Table 3).

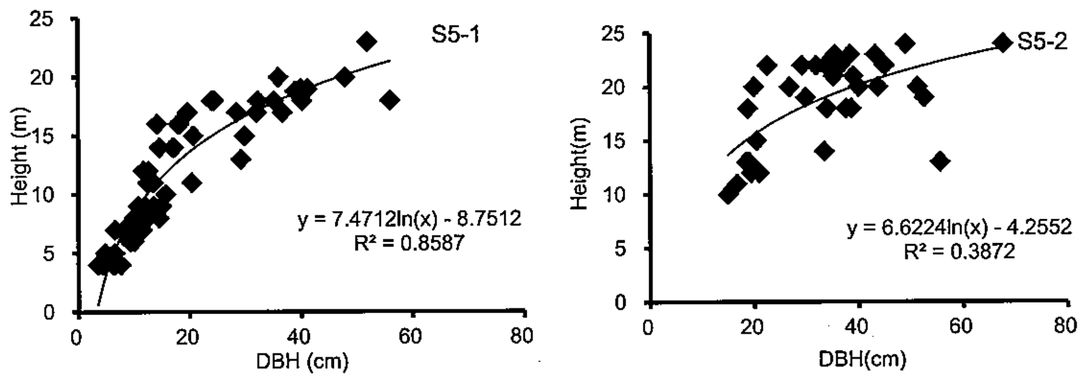


Figure 7 Relative growth curves of S5-1 and S5-2

Table 3 Limit of Larch regeneration

Species	Site (note)	Number (N/ha)	Biomass (ton/ha)	Basal area (m²/ha)	Possibility of regeneration
Mixed forest	S1-B (inside)	380	94.5	15.22	
Spruce forest	S6 (Renchin Humbe)	1,120	180.5	27.24	*Positive*
Mixed forest	S4 (holly mountain)	1,180	202.2	29.57	
Larch forest	S3TT1 (road side)	800	276.2	37.31	
Larch forest	S5-1	1,060	337.9	50.04	*Boundary*
Mixed forest	S6 (Ak plot)	1,550	379.6	54.04	
Larch forest	S3TT2	820	433.7	52.94	*Negative*
Larch forest	S5-2	660	558.2	67.85	

4 Discussions and Conclusion

In case of slightly low fire severity, understory vegetation and seedlings will be burnt. Few C will be loss as CO_2 emission. Many branch and leaf still remain making regeneration more difficult. There is no competition between young and adult trees. In case of heavy fire severity, all branch and leaves are burnt and C will be loss by CO_2 emission. But many stem and root will still remain after long years. Charcoal will be stored in the ground not corroding away in the soil. After the fire event, carbon will be accumulated on the soil. Regeneration will become positive after few years, when seeds are supplied by nearby forests. After large scale fires happen, regeneration will be more restricted. In case of moderate fire severity, understory vegetation and seedling will be burnt and some trees will remain. Regeneration will become positive after seeds are supplied from the remaining trees. Light conditions will guarantee seedling growth. It seems that moderate fires preserve the stand structure. In case of post-harvest fire, all branch and leaves are left on the ground. After few years ago, left branches will dried out. When wild fires take place after harvested forest, almost all carbon will be lost as CO_2 emission. Charcoal in the surface of the ground will be burnt. Soil condition will become poor in. After large scale fires take place, regeneration will be continuously negative condition for a long period.

Acknowledgement
This study was supported by the United Graduate School of Agricultural Sciences, Iwate University Dean fund the JSPS Scientific Research fund (Grant number 22405022).

Literature cited

Akojima, I. and Honda, Y. (2002) Wild fire of Mongolia in 1996. Quarterly Journal of Geography, 54: 111-116.

Chimed-Ochir B., Hertzman T., Batsaikhan N., Batbold D., Sanjmyatav D., Onon Yo. and Munkhchuluun B. (2010) Filling the Gaps to Protect the Biodiversity of Mongolia. WWF Mongolia Programme Office, August 2010"

Crisp, N., Dick, J. and Mullins, M. (2004) Mongolia forestry sector review. 144pp, The World Bank. Victoria, B.C.

Dorjsuren, E. (2008) Trends in forest ownership, forest resources tenure and institutional arrangements: Are they contributing to better forest management and poverty reduction? A case study from Mongolia. 27pp, FAO, Mongolia.

Hayasaka, H. (2011) Recent Vegetation Fire Incidence in Russia. Global Environmental Research, 15: 95-103.

Nobori, Y., Sato, K., Onodera, H., Noda, M. and Katoh, T. (2004) Development of stem density analyzing system combined X-ray densitometry and stem analysis. Journal of Forest Planning, 10(2): 47-51.

Osumi, S., (1987): Lecture Text of Forest Measurement (In Japanese). 286pp, Yokendo, Tokyo.

Parker, M. L., Bruce, R. D. and Joza, L. A., (1980): Xray densitometry of wood at the W.F.P.L., Western forest products laboratory technical report No.10.

Wenger, K. F., (1984): Forestry Handbook. 1335pp. John Wiley & Sons. New York.