A simulation of larch forest dynamics associated with fire in northern Mongolia

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Abstract

Forest decrease due to wildfires is a serious problem in northern Mongolia. When considering this problem, we need to understand the change of biomass according to the magnitude of forest fires and the time that it will take for the forest to recover its original biomass. The aim of this research is to estimate the change of biomass in relation to the type of fire scale and time of forest recovery. The tree cruise and the stem analysis was taken to parameterized the actual condition of forest biomass. The forest biomass was estimated by combining the stem analysis and soft X-ray densitometry. We estimated the decrease of biomass after occurrence of wildfire by using Yield-Number curve. According to these simulations forest subjected to light fire intensity type which will take 25 years to recover its original biomass. Forest subjected to middle fire intensity type will take 123 years recover its original biomass, and the heavy fire intensity type will recover its original biomass often more than 170 years.

Keywords: Biomass; Forest dynamics; Larch forest; Tree ring analysis; Yield-Number curve

1. Introduction

The natural forest in Northern Mongolia is very important forest for carbon sinks. We must save these forests. But forest decrease due to wildfires is a serious problem in northern Mongolia. When considering this problem, we need to understand the change of biomass according to the forest fire scales and to understand the time that will take for the forest to recover its original biomass. Therefore, the aim of this research is to estimate the change of biomass according to the forest fire scale and the time for forest recovery after wildfires.

2. Methods

We used a combination of several analysis techniques in this study (Taki et al., 2012). First, we made a relational expression of D^2H and stem weight using stem analysis and soft X-ray densitometry combination technique. Second, we conducted a tree cruise in primitive forest, measuring the DBH, tree height, number of trees and additional forest information. Third, we estimate the forest biomass using the data from the tree cruise with the relational expression of D^2H and stem weight. On one hand, we assume 3 types of forest fires in the case of low layer, all layer and after harvest. In the case of all layer fire and after harvest will thinkable that the disappear all of biomass. Therefore, we assume 3 magnitudes of forest fire (light, middle, heavy) in the case of low layer fire. Finally, we simulated the decrease of biomass after the occurrence of 3 types scale forest fire. We used Yield-Number curve of Yield-Density diagram for the simulation (Kikuzawa, 1983). The Yield-Density diagram is one of the forest density management methods.

2.1 Site locations

The study region was between 50°57'24''N - 51°26'48''N and 99°11'37''E - 99°44'07''E and at 1,550m.a.s.l (Figure 1). Mean annual temperature is -7.1°C reported in Renichinhumbe hear site S6. Site location and investigation plot size are shown in Table 1.

2.2 Tree cruise

We measured the DBH, tree height (H) and other tree characteristics in the some types of primitive forest. Measurement items are located at a given X, Y, Z-axis within the stand, at a given X, Y, Z-axis within the stand, tree species, tree height (H), diameter breast height (DBH), crown height and four direction of crown width.

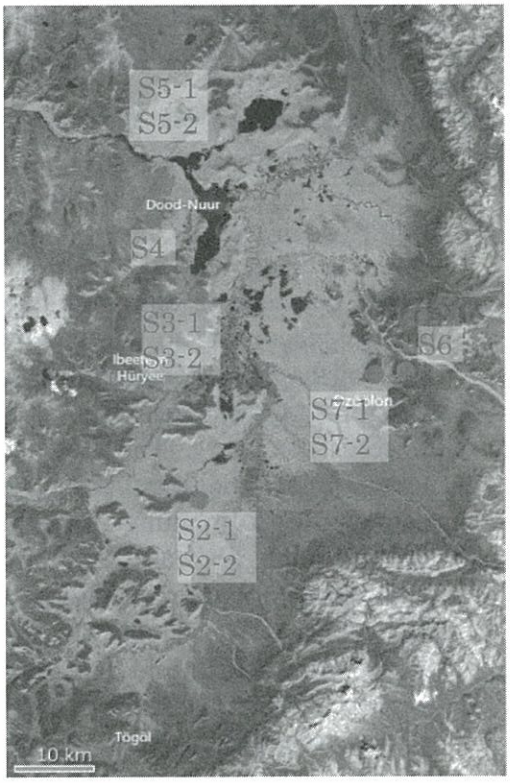

Figure 1 Study area

Table 1 Site Location

Site No.	Plot size	Location	Number of trees (N/ha)
S2-1	5m×85m	50°58'54"N, 99°22'09"E	1294
S2-2	5m×80m	50°58'54"N, 99°22'09"E	1550
S3-1	10m×100m	51°14'34"N, 99°21'25"E	890
S3-2	10m×50m	51°14'34"N, 99°21'25"E	880
S4	10m×50m	51°20'56"N, 99°17'13"E	1120
S5-1	10m×50m	51°26'49"N, 99°11'36"E	1740
S5-2	10m×50m	51°26'49"N, 99°11'36"E	840
S6	5m×50m	51°09'24"N, 99°44'05"E	1650
S7-1	10m×50m	51°08'32"N, 99°41'52"E	680
S7-2	10m×50m	51°08'32"N, 99°41'52"E	900

2.3 Stem analysis and weight growth formula

Tree disk samples for stem analysis were collected at Site 5. In this study, we use the stem density analysis method (Nobori et al., 2004, Taki et al., 2012) which was constructed for analyzing the weight growth of stems using the data obtained by soft X-ray densitometry (Parker et al., 1970, Polge H, 1970). X-ray photographs were taken after Institute of Wood Technology, Akita prefectural University.

After Soft X-ray photographing, we analyzed tree rings by using Win DENDRO (WinDENDRO Density 2009b, Regent Instruments, Inc). The flowchart of tree ring analysis is shown on Figure 2.

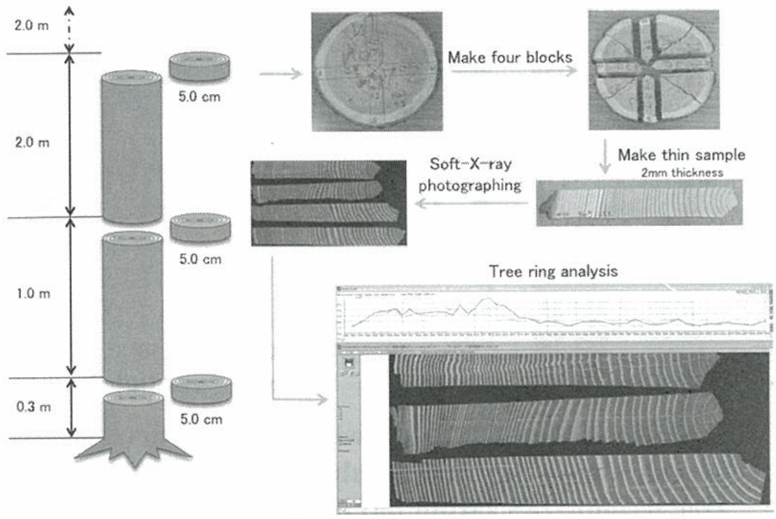

Figure 2 the flowchart of tree ring analysis

Yearly volume increase was calculated as the difference between the volumes of two successive years. The weight of each log was calculated by multiplying the volume by the mean volume densities of wood discs took from the upper and basal ends of each log. Yearly increases in weight and total wood weight were also obtained from these data.

Formula 1 is weight growth formula. This formula means a relationship between D^2H and total tree weight of each ring (Figure 3). In this study, we used this formula for calculating each tree weight from tree cruise data.

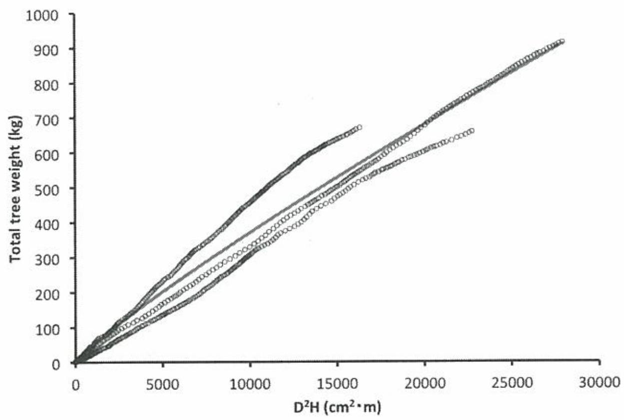

Figure 3 Relationship between D^2H and total tree weight

$$W = 0.1147 \cdot (1 + D^2H)^{0.8770} \quad (r = 0.974,\ p < 0.001) \qquad \text{Formula 1}$$

W= Total tree weight (kg)

$D^2H = DBH^2 \cdot$ Tree height

2.4 Calculating of the Yield-Number curve

Yield means total tree weight (ton/ha) and Number means number of trees (N/ha). One Yield-Number curve (Y-N curve) means one forest. At first, tree cruise data were lined up from big DBH class to small DBH class. Second, The number of trees and the tree weight were sum in order from big DBH class to small DBH class. At last, the cumulative values were plotted on the double logarithmic graph from big DBH class to small DBH class (Figure 4). Then, these plotted points were approximated by formula 2.

DBH class (cm)	Total number of trees (N/ha)	Total tree weight (ton/ha)
34	20	6.93
28	60	19.99
26	100	32.08
24	160	48.61
22	340	89.17
20	620	134.06
18	920	167.44
16	1180	188.86
14	1780	222.85
12	2080	234.84
10	2300	242.24
8	2400	245.28

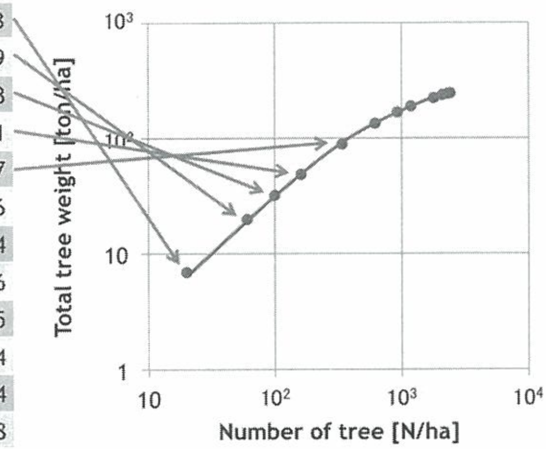

Figure 4 Method for drawing the Y-N curve

Note: The left side table shows the total number of trees=2400(N/ha) and the total tree weight=245.28(ton/ha) in this sample forest

$$1/Y = B/N + A \qquad \text{Formula 2}$$

Y = Yield (Total tree weight (ton/ha))

N = Number (Number of trees (N/ha))

A and B are coefficients.

3. Results and discussions

We estimated the time for forest recovery after wildfires for site S5-1. Figure 5 shows the change of forest structures by fire intensity and the simulation of the Y-N curve moving. Table 2 shows the change of biomass and basal area before and after the wildfires.

The assumption in the simulation of the light fire intensity type, will be that individuals of height 9m or less were all burned. This type will take 25 years to recover its original biomass. The assumption in the simulation of the middle fire intensity type will be that individuals of height 15m or less were all burned. This type will take 123 years to recover to its original biomass. The assumption in the simulation of the heavy fire intensity type will be that individuals of DBH 30cm or less were all burned. This type will not recover to original biomass or more than 170 years.

The number of trees was 1740 per hectare in the S5-1 original forest. Total tree weight was 463.9 ton/ha in original forest. After burnt, total tree weight will decrease to 396.4 ton/ha (under 9m tree height), 335.3 ton/ha (under 15m tree height) and 280.9 ton/ha (under 30cm DBH). The 9m and 15m tree height will recover to its original biomass (463.9 ton/ha) in 25 to 123 years.

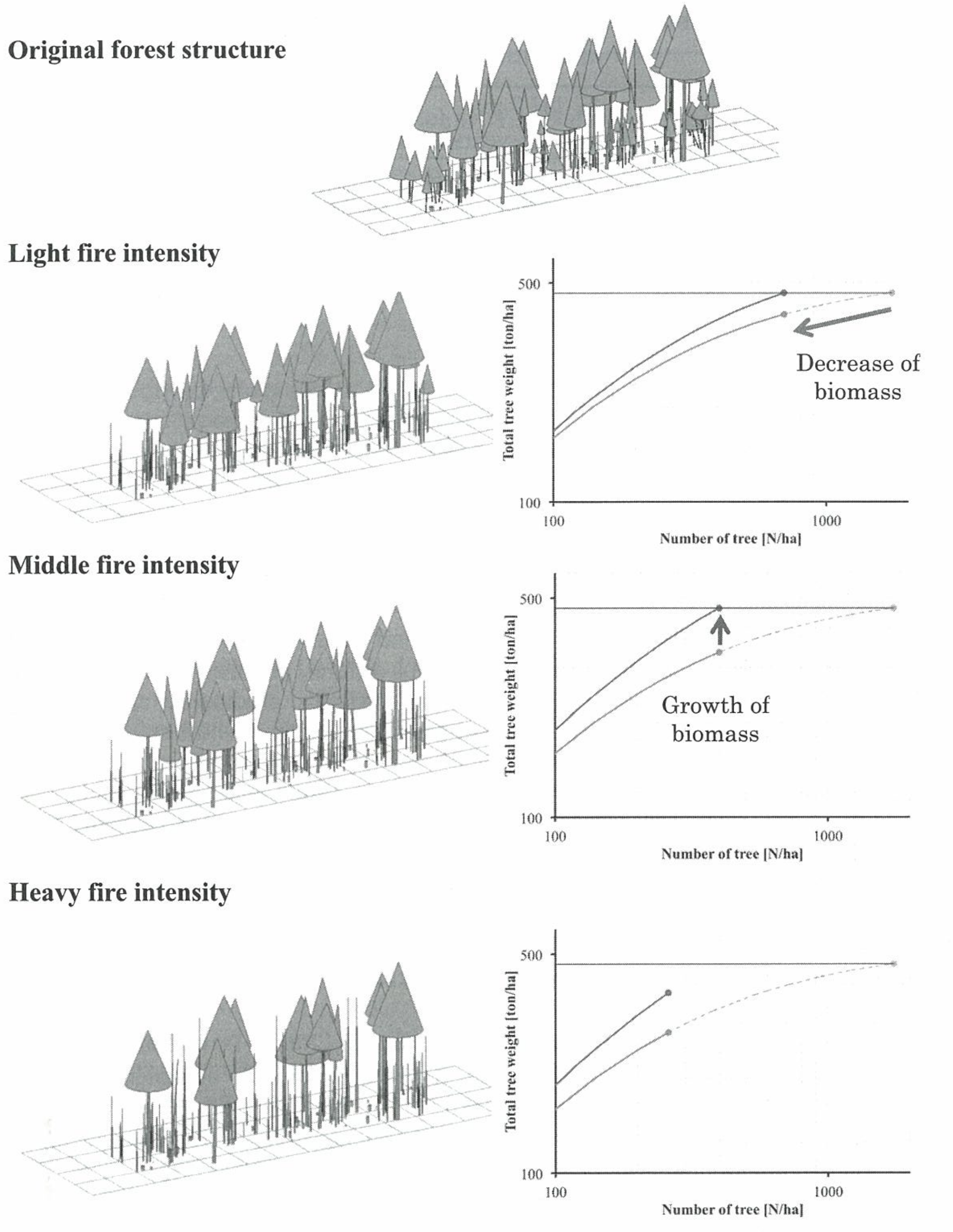

Figure 5 Change of the forest structure by fire intensity, and simulation of the Y-N curve.

Note: The dotted line means original forest biomass. The red line means forest biomass after wildfire. The blue line means forest biomass after simulation.

Table 2 Change of biomass and basal area

	S5-1						
	Origin	≦TH 9 m		≦TH 15 m		＜DBH 30 cm	
		Burnt	25 years	Burnt	123 years	Burnt	170years
Number of tree N/ha	1740	700		400		260	
Total tree weight ton/ha	463.9	396.4	463.9	335.3	463.9	280.9	375.7
Basal area m^2/1.3m height	55.2	47.8	54.3	38.3	53.5	34.0	44.1

4. Conclusion

Forests subjected to heavy fire intensity will need long time for recovery. Completely burnt forests will be very difficult to recover. There is a risk of desertification and deforestation in northern Mongolia region. Measures that to protect the carbon sinks and biomass resources. The introduction of concepts and techniques of forest management are required in order to understand the current status of forest and their future growth. In addition, the introduction and development of seedlings production and planting technology will be required in order to recover forests affected by wildfires.

Acknowledgements

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