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Carbon Emissions from Forest Fires in Great Xing'an Mountains from 1980 to 2005

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Abstract. A combination of federal inventory data and ground-based approach was used to compute the amount of carbon released by forest fires in Great Xing'an Mountains from 1980 to 2005. Base on the field survey data and allometric equations, biomass of 32 separate carbon pools in 8 forest types were estimated. Combustion factors were then calculated from these survey data. An improved estimation method was used and then got the total pyrogenic carbon emissions. About 12061232.48 t carbon was released by forest fires during 1980-2005.

Keywords: Forest fire; combustion factor; carbon emission

Forest fire represents a significant source of gases and aerosol particles to the atmosphere. Elevated concentrations of these emissions have been observed in connection with forest fires in various regions of the world[1-8]. Some kinds of these gases contribute to the greenhouse effect and large amounts of particles released by forest fire influence the radiative properties of the atmosphere. So feedbacks of fire have the potential to affect regional and global climate by modifying atmospheric chemistry and the radiation budget.

Most studies of fire emissions use the approach of Seiler and Crutzen[9],where pyrogenic emissions are measured as the result of four factors: area burned, fuel density (biomass per unit area),combustion factor(fraction of biomass consumed by fire),and emission factor(mass of a given chemical species released per mass of fuel consumed). Cahoon et al. used an improved satellite-based area measurement to estimate trace gas emissions from 1987 fires in northern Eurasia[10]. Conard and Ivanova emphasized the importance of surface fires and fire severity in Russia and based on fire return intervals to estimated both direct and indirect emissions of carbon from Russia [11]. Hao and Ward estimated methane emissions from fires in the boreal forest region are 0.9 TgC yr-1 [12]. Kasischke et al. varied fuel consumption estimatesin five different land cover types to estimate carbon released from fire in 1990 and 1991 in Alaska[13].

Some researches about forest fire carbon emissions of the Great Xing'an Mountains have been published. But most previous studies focus on the emissions of surface and aboveground biomass. But in Great

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Xing'an Mountains, the emissions from burning of soil organic matter (moderately to highly decomposed organic material) occupy a large part of the emission inventory. Accurate estimating of the emissions requires considering burning of aboveground vegetation as well as a shallow layer of litter (dead foliage and twigs lying on the ground surface) and a deeper layer of soil organic matter. In this paper, we build on and extend the results of former studies. A combination of fire statistical data and supplementary ground measurements afforded the estimation of the amount of carbon released by forest fire from 1980 through 2005. Hope this research can provides basic data for Great Xing'an Mountains forest fires carbon balance and acid rain and other disasters phenomenon research

1. Method

1.1. ***Study*** *area.*

Great Xing'an Mountains located in northeastern China (50º10´-53º33´N, 121º12´-127º00´E) and covers approximately 8.35×106 hm2. The region has a typical continental climate, with long, cold winters and short, cool summers. The mean annual temperature is-2.8℃ and total annual precipitation is 746 mm. Elevation varies gradually from approximately 300 to 700 m. This region is the most serious forest fire hazards of China and the burned area is thelargest.

The dominant forest types in the region are Rhododendron simsii-Larixgmelinii, Ledum palustre-Larixgmelinii, Grass-Larixgmelinii, Rhododendron simsii-Pinus sylvestrisvar.mongolica, Betula platyphylla-Larixgmelinii, Betula platyphylla-Rhododendron simsii, Quercusmongolica-Lespediza bicolor, Quercusmongolica-Betula platyphylla.

Emissions estimates Total carbon emission from forest fire(C) can be estimated after Seiler and Crutzen [1980] as:

$$C=AB\,f_c\beta, \qquad (1)$$

where A is the total area burned(hm2),B is the biomass density(t/ hm2), fc is the fraction of the biomass that is carbon, and β is combustion factor(the fraction of biomass consumed during burning).

Fires in the Daxing'an Mountains differ from those in temperate and tropical forests because of the burning of soil organic matters. And as discussed before, the estimation should include considerations of the forest types, fire severity and oil organic matter consumption. To account for these, the equation (1) is modified to:

$$C=A[B_Tf_{cT}\beta_T+ B_Uf_{cU}\beta_U+ B_Lf_{cL}\beta_L +C_S\beta_S],$$

where the T, U, L, and S subscripts refer to the tree, understory, litter, and soil components of biomass, respectively. Carbon fraction of biomass is 0.5. The combustion factor (tree, understory, and litter) during a fire is estimated in accordance with levels of fire severity.

1.2. Area burned

Area burned is a primary factor when estimating forest fire emissions. We used historical forest fires data combined with GIS to get the burned area of different forest types during 1980-2005(tab.1). The largest is Ledum palustre-Larixgmelinii and then Betula platyphylla-Larixgmelinii, Betula platyphylla-Rhododendron simsii, Quercusmongolica-Betula platyphylla, Rhododendron simsii-Pinus sylvestrisvar.mongolica, Grass-Larixgmelinii, Rhododendron simsii-Larixgmelinii.

Tab. 1 Burned area of different forest type in different fire severi hm^2

Forest type	Fire severity			
	Low	Moderate	High	Total
A	1080.86	1463.00	5214.00	7757.86
B	205.30	600.00	259000.00	259805.30
C	448.43	403.00	11636.00	12487.43
D	4.20	0.00	20938.00	20942.20
E	1971.76	4455.30	248500.00	254927.10
F	648.14	1455.00	251312.70	253415.80
G	397.57	1327.70	141383.00	143108.30
H	609.07	1187.00	46233.00	48029.07

A: Rhododendron simsii-Larixgmelinii;B: Ledum palustre-Larixgmelinii; C: Grass-Larixgmelinii; D: Rhododendron simsii-Pinus sylvestrisvar.mongolica; E: Betula platyphylla-Larixgmelinii; F: Betula platyphylla-Rhododendron simsii; G: Quercusmongolica-Lespediza bicolor; H: Quercusmongolica-Betula platyphylla. The same below.

1.1. Fuel load

Fuel load for each forest type was computed using field survey data and a combination of allometric equations appropriate for species. We chosen the representative forest types and set three 20×20m standard fields unaffected by fire in each type. Tree biomass was estimated with species- and site-specific allometric equations relating stem diameter to volume and species-specific wood density values [14]. All the shrubs and small hardwoods were harvested and weighted to determine the biomass of understory. Three 1×1m spots were sated in each standard field and collected the grass, twigs, fallen leaves and the top 10cm soil organic matter.

1.2. Combustion factor

The combustion factors of trees are calculated from measurements of char-
ring and ocular estimated loss of foliage and branches. The combustion factorsof understory and litter were calculated from ground-based survey of burned and unburned field. The combustion factors of soil layer were the result of comparison of top 10cm soil of burned and unburned field.

2. Result and discussion

2.1. Area burned

The area burned of forest types and fire severities was shown in Table 1. ANOVA results show that although difference among burned area of different types was large, but the impact of forest types on the area is not obvious. The total area burned was 1000473.06 hm2 and average was 38479.73 hm2 for each year.

2.2. Fuel load

he biomass of different parts and forest types was shown in table 2. In all forest types the proportion of tree biomass is the highest, followed by the layer of soil organic matter, litter and understory. The biggest biomass of tree was Betula platyphylla-Larixgmelinii and the smallest was Quercusmongolica-Lespediza bicolor. The biggest biomass of understory was Grass-Larix gmelinii and the smallest was Betula platyphylla-Rhododendron simsii. The biggest biomass of litter was Rhododendron simsii-Larixgmelinii and the smallest was Quercusmongolica-Lespediza bicolor. The biggest biomass of soil was Rhododendron simsii-Larixgmelinii and the smallest was Ledum palustre-Larixgmelinii..

Tab. 2 Biomass of Tree, Understory, Litter and Soil in different forest type t/hm2

	A	B	C	D	E	F	G	H
Tree	62.09	58.06	68.35	64.96	73.48	66.12	52.82	60.48
Understory	0.62	1.9	3.27	0.59	0.45	0.22	0.64	1.4
Litter	9.44	6.52	5.82	5.65	6.12	7.7	5.49	6.79
Soil	20.36	4.52	6.03	11.42	20.09	18.66	10.01	18.51

2.3. Combustion factors

The combustion factors estimated for each carbon pool and burn severity class are shown in Table 3. Aboveground biomass that burned is mostly leaves, small twigs and branches. Trees distributed more biomass to boles as they grow, so shrubs have a higher fraction of biomass available for burning than trees. Surface fire was prevailing in this region, so litter layer surfer more consumption.

Soil organic matter is an important carbon pool of boreal forest region. Amiro et al. indicate that their study may underestimate the role of organic soils burning[15]. We added the contribution from soil organic matter burning to the fuel consumption in Table 3.

2.4. Carbon emission

Direct carbon emissions estimates are reported by forest type and burned severity in Table 4. the total amount of carbon emission was 12061232.48 t in 1980-2005 and average 482449.3 for each year. Betula platyphylla-Rhododendron simsii and Betula platyphylla-Larixgmelini contributed the most part of carbon emission and respectively was 29.5% and 12%. And then is Ledum palustre-Larixgmelinii, Quercusmongolica-Lespediza bicolor, Quercusmongolica-Betula platyphylla, Rhododendron simsii-Pinus sylvestrisvar.mongolica, Grass-Larixgmelinii, Rhododendron simsii-Larixgmelinii.

Tab. 3 Combustion factors of each pools in different fire severity

Forest type		Fire severity			Forest type		Fire severity		
		Low	Moderate	High			Low	Moderate	High
A	Tree	0.06	0.12	0.30	E	Tree	0.04	0.10	0.25
	Under story	0.21	0.50	0.70		Under story	0.23	0.52	0.75
	Litter	0.50	0.75	1.00		Litter	0.45	0.78	0.90
	Soil	0.04	0.08	0.10		Soil	0.06	0.09	0.12
B	Tree	0.05	0.08	0.24	F	Tree	0.03	0.12	0.30
	Under story	0.15	0.32	0.65		Under story	0.19	0.47	0.69

	Litter	0.45	0.60	0.60		Litter	0.40	0.75	0.82
	Soil	0.05	0.08	0.09		Soil	0.04	0.07	0.10
C	Tree	0.09	0.15	0.38	G	Tree	0.02	0.11	0.26
	Under story	0.25	0.55	0.70		Under story	0.26	0.56	0.70
	Litter	0.50	0.63	0.86		Litter	0.40	0.82	0.90
	Soil	0.04	0.08	0.15		Soil	0.06	0.09	0.13
D	Tree	0.07	0.14	0.45	H	Tree	0.06	0.15	0.28
	Under story	0.18	0.34	0.54		Under story	0.22	0.46	0.67
	Litter	0.31	0.56	0.90		Litter	0.52	0.80	0.95
	Soil	0.05	0.07	0.11		Soil	0.04	0.07	0.11

Tab. 4 Carbon emission from Tree, Understory, Litter and Soil in different forest types t/hm^2

Forest type	Fire severity			
	Low	Moderate	High	Total
A	5074.638	12047.51	79609.96	96732.11
B	651.6222	2857.92	2523722	2527231
C	1423.317	1919.57	113382.3	116725.2
D	14.64939	0	375751.3	375765.9
E	6903.23	31551.77	3308318	3346773
F	1896.393	10999.07	3539463	3552358
G	798.9964	7681.608	1443768	1452248
H	1644.55	8706.942	583046.7	593398.2

Conclusion

In this study we examined carbon emissions from Great Xing'an Mountains forest fires from 1980 to 2005, when about 1000473 hm2 of forest burned. The amount of 12061232.48 t was released by forest fires .Clearly carbon emissions from forest fires are an important part of any forest carbon budget. This region was predicted to experience some of the largest temperature increases from climate change, and the forest hold one of the largest pool of carbon. More attention should be payed to the role of forest fires in regulating the forest carbon budget.

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