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# Carbon Emissions from Forest Fires on Scots Pine Logging Sites in the Angara Region of Central Siberia

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## Introduction

Wildfire and forest harvesting are the two major disturbances in the Russian boreal zone. Currently, 10 to 15 (and up to 20) million ha per year burn annually in Russia (e.g. Soja *et al.* 2004). Wildfires are projected to increase in both frequency and severity as climate changes. Both legal and illegal logging are also increasing rapidly in many forest areas of Siberia (Vandergert and Newell 2003). Non-recovered logged sites total about a million hectares in Siberia. These logged areas appear highly susceptible to fire due to a combination of high fuel loads and accessibility for human-caused ignition). Changing patterns of timber harvesting increase landscape complexity and can be expected to increase the emissions and ecosystem damage from wildfires, inhibit recovery of natural ecosystems, and exacerbate impacts of wildland fire on changing climate and on air quality. The Angara region is the major forest harvesting zone in the Krasnoyarsk Region of Siberia (Fig.1) and most fires here occur on logging sites. Every year about 30 thousand hectares are logged in the Angara region (Fig.2). Scots pine and larch logging site fuels become readily ignitable earlier than under forest canopy. Therefore, fire spreading from logging sites to surrounding forest is a common situation in this region. Furthermore, living ground vegetation present on logging sites fails to reduce fire intensity and rate of spread. As a result, the risk of high-severity fire remains high throughout the snow-free period. Large amounts of conifer tree branches, tops, and fallen deciduous tree parts are left on logged forest sites. This logging slash contributes greatly to site fire hazard in spring and summer; it constitutes, in combination with cured grass, a readily ignitable loosely packed fuel layer (Fig.3).

This study focuses on estimating fire impact on fuel consumption and carbon emission in Scots pine (*Pinus sylvestris)* forests of the Angara region in central Siberia.

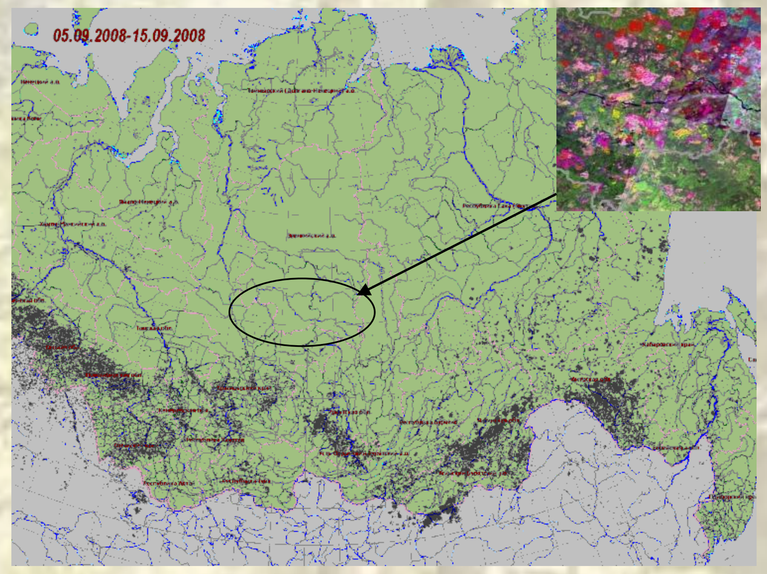


**Fig.1.** Region of study

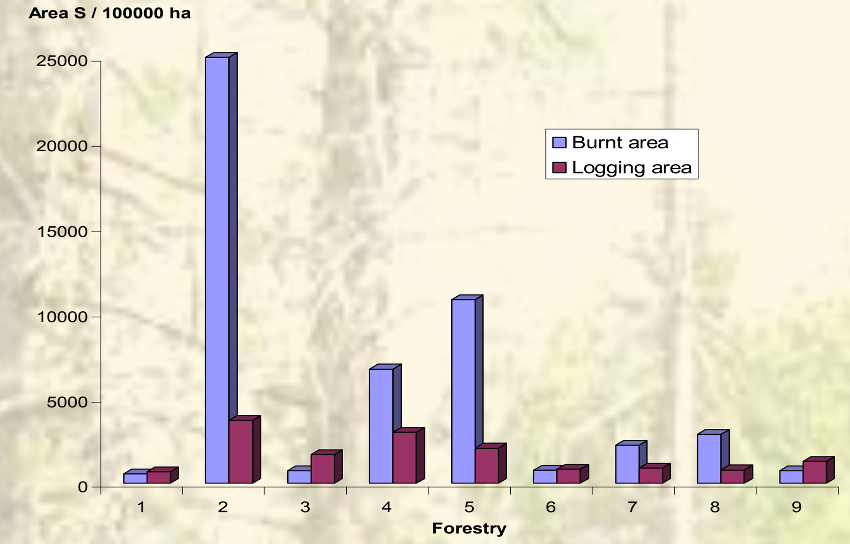


**Fig.2.** Burned and logged area in forestry of Angara region (for 2008 year)

**Fig.3.** Increase of fire severity in places with high fuel load left after cutting

## Results

Logged blocks accounted up to 90% of the total logging site area, 8-10% of the area was skid trails, and up to 2% was loading area. Fuel loading varied from 55 to 80t/ha across the logging sites, except for loading areas. Although the zones near skid trails did not cover much area, fuel accumulation exceeded100 t/ha in some of them. The presence of these zones of heavy fuel loads complicate forest fire suppression and containment.

Logging slash contributed 2/3 of the total fuel loading. Logging slash amounts this high complicate wildfire control and increase its cost. Duff load appeared to be 50% lower on and near skidding trails than in logging blocks. This might be attributed to partial fuel removal due to skidding operations. However, the loading of needles and small tree branches (up to 7 cm in diameter) on and along skid trails was almost 5 times that in logging blocks. High fine fuel loads are responsible for generally high fire hazard of this area.

Species composition of grasses and herbs did not change after cutting, but cover increased up to 75% due to *Calamagrostis epigeios* and *C. Arundinacea.* Mosses decreased in vigor, on logged sites but their biomass did not change significantly. Post-fire projected cover and biomass of the grass and herb layer decreased both on logged and unlogged sites. Mosses were dead completely on logged/burned sites.

Logged sites have higher fire hazard than forest sites because untreated logging slash dries out much more rapidly than understory fuels. This results in higher fuel consumption on logged sites than on unlogged sites. Dead down woody fuels up to 1.0 cm in diameter are consumed almost completely on both logged and unlogged areas, while the percent of branches 1.1-7.0 cm in diameter tends to increase (Fig.12,13).

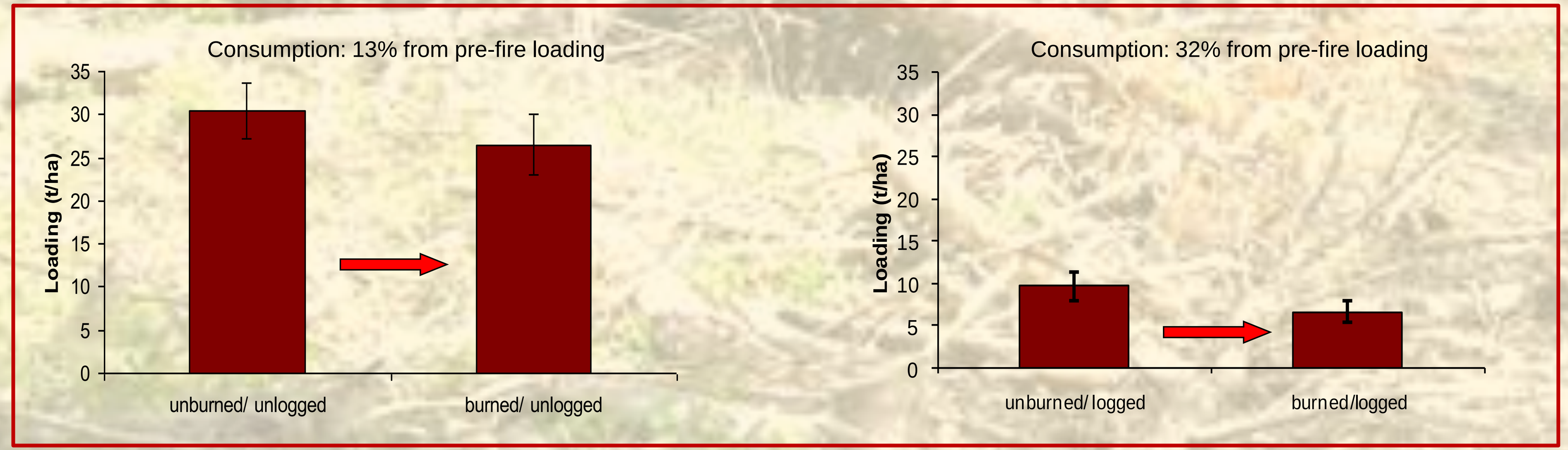


**Fig.12.** Ground fuel consumption due to fire on unlogged (a) and logged (b) units

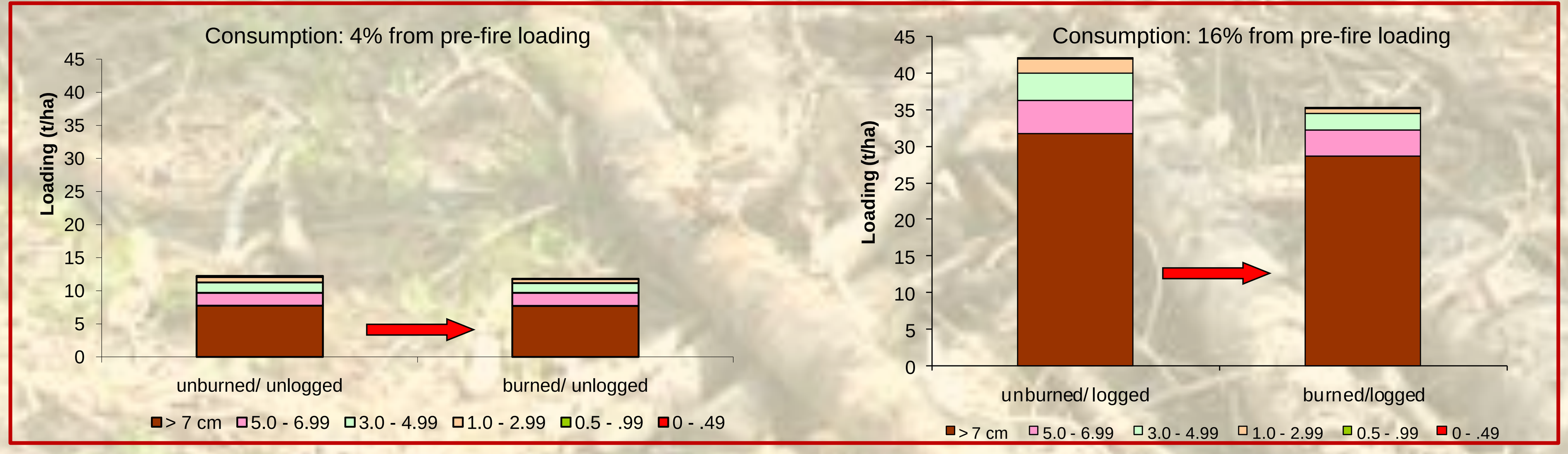


**Fig.13.** Down woody fuel consumption due to fire at unlogged (a) and logged (b) units

## Materials and Methods

Fire impacts on the overstory trees, subcanopy woody layer, and ground vegetation biomass were estimated on 14 logged and unlogged sites of Scots pine (*Pinus sylvestris*) and larch (*Larix sibirica*) in the Lower Angara Region of Siberia in 2009-2010 as part of the NASA-funded NEESPI project "The Influence of Changing Forestry Practices on the Effects of Wildfire and on Interactions Between Fire and Changing Climate in Central Siberia". On each area investigations were carried out on four types of sites: 1. logged/unburned; 2. logged/burned; 3. unlogged/unburned; and 4. unlogged/burned (Fig. 4-7).

**Fig.4.** Logged / unburned unit

**Fig.5.** Logged / burned unit

**Fig.6.** Unlogged / unburned unit

**Fig.7.** Unlogged / burned unit

At each unit, we established nine 5-m triangular sampling plots (Fig.8). In each plot we estimated percent cover of the surface vegetation and percent projected ground cover for each different type of ground fuel (moss, lichen, grass, and litter). We measured dead and down woody fuels using a line intercept method adapted from Van Wagner (1968). Ground fuels (e.g., feather moss, lichens, litter, forest floor), were sampled in three 20 x 25-cm subplots within the each triangle (Fig.9,10). Understory shrubs and sprout clumps taller than 1.3m were measured within the triangle area and biomass regressions were developed. Tree density and size were measured in 9 m radius (254.5 m$^2$ ) circular plots at the center of the triangle. Diameter at breast height for each tree was measured (Fig.11). If the area had been harvested, stump diameter at 20-cm above ground level were measured. Carbon emission from fires on both logged and unlogged burned sites were estimated based on calculated fuel consumption. We measured soil respiration at each site using a 1 liter PVC chamber placed on to surface of the ground cover. Transient $CO_2$ was measured with a model LI-800 $CO_2$ analyzer.

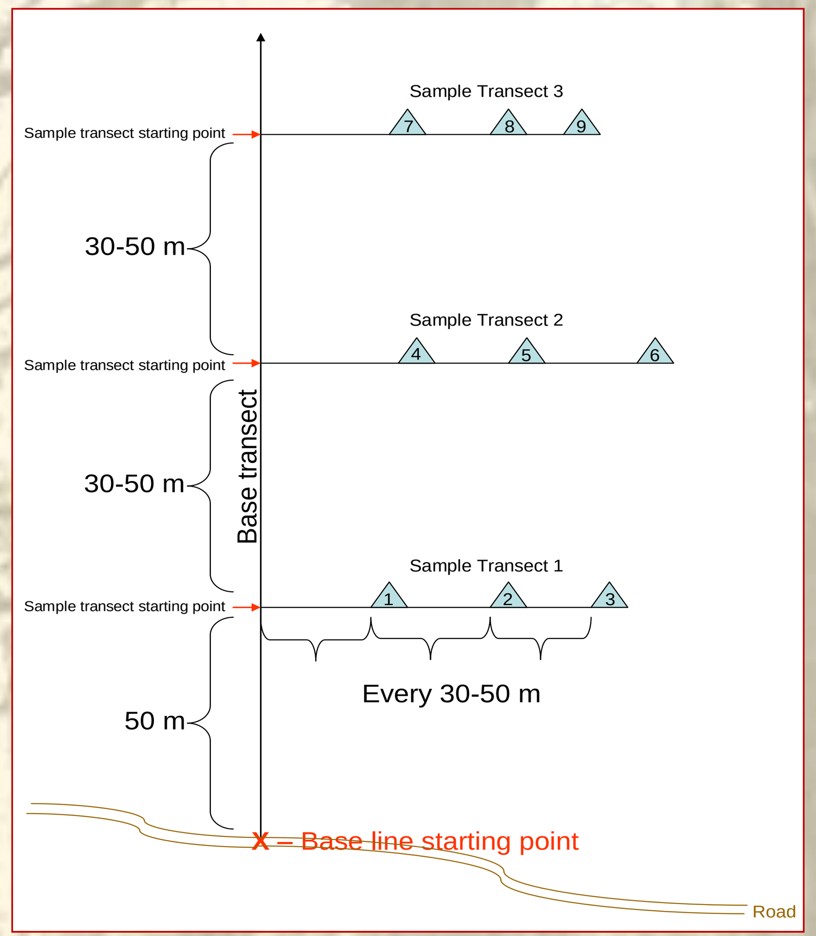


**Fig.8.** The basic sampling layout, showing base transect, sample transect, and sample triangle locations used to characterize one unit.

**Fig.9.** Sampling of ground fuels on logged / unburned area

**Fig.10.** Sampling of ground fuels on logged/burned area

**Fig.11.** Tree inventory on unlogged area

Fuel consumption was typically less in spring fires than during summer fires. According to literature data summer stable experimental fires were found to consume more fuels (44% and 48% in logging blocks and along skidding trails, respectively). Fire burned across about 90% of the total logging area and consumed 60% of <2.5-Post-burning fuel loading was found to be at the lowest level sufficient for fire spread (200-300 g/m$^2$). Fire reduce logging site fire hazard cm-diameter and 26-46% of moderate- and large-diameter logging slash elements (Valendik et al. 2000).

Soil respiration on logged areas was half that in pine forest. Respiration from ground cover on logged/burned areas was 50% less than at logged/unburned area while it is 3 times lower comparing unlogged/burned and unlogged/unburned areas. Soil respiration from mineral soil is 20-45% higher than from ground cover (Fig.14).

Above-ground carbon stocks are higher on unlogged than on logged sites. However, both live and dead surface fuel loads are much higher on logged sites, where logging slash is left onsite. As a result fuel consumption and carbon emission from fires on logged sites appeared to be twice that on unlogged sites burned as surface fire. In Angara region average area burned is about 80 x 10$^3$ ha. Up to 70% of all wildfires begin on logging sites followed by spreading to adjacent forest and is about 10-20% from total area burned. Thus, carbon emissions are estimated to be 48-100 Mt/ha. Soil respiration decreased on both site types (burned and logged) after fires. This reduction may partially offset fire-produced carbon emissions.

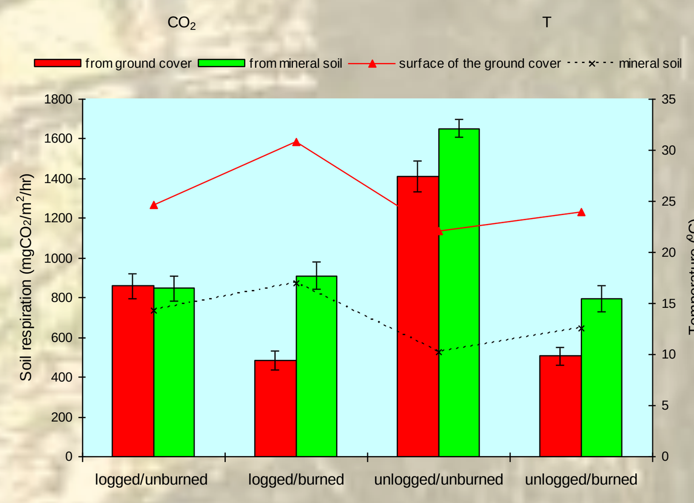


**Fig.14** Post-fire changes in soil respiration at logged and unlogged sites of Scots pine forests

## Conclusions

Fires occurring on logged areas were typically of higher severity than those in unlogged forests, but the specific effects of fire and logging varied widely among forest types and as a result of weather patterns during and prior to the fire. Carbon emissions due to fire were higher on logged areas compared to undisturbed sites. Post-fire soil respiration decreases found for both site types partially offset carbon losses. Carbon emissions from fire and post-fire ecosystem damage on logged sites are expected to increase under changing climate conditions and as a result of anticipated increases in future forest harvesting in Siberia.

## Citations


Soja A.J., Sukhinin A.I. , Cahoon Jr. D.R., Shugart H.H. and Stackhouse Jr. P.W. 2004 AVHRR-derived fire frequency, distribution and area burned in Siberia *International Journal of Remote Sensing* **25** (10), doi:10.1080/01431160310001609725

Vandergert, P., and J. Newell. 2003. Illegal logging in the Russian Far East and Siberia. *International Forestry Review* **5**(3) 303-306.

Valendik E.N., Vekshin V.N., Vershovets S.V., Zabelin A.I., Ivanova G.A., Kisilyashov E.K. 2000 Prescribed burning at logged area in dark-coniferous forests. Novosibirsk. Publishing SB RAS. p. 209

Van Wagner C.E. 1968 The line intersect method in forest fuel sampling. *Forest Science* **1** 20–26.


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