**Effects of forest fire on the nitrogen cycle in a dry dipterocarp forest, Thailand**

Tetsuya TODA¹, Hiroshi TAKEDA², Naoko TOKUCHI³, Seiichi OHTA⁴, Chongrak WACHARINRAT⁴ and San KAITIPRANEET⁴

¹ Laboratory of Tropical Forest Resources and Environments, Division of Forest Science, Graduate School of Agriculture, Kyoto University, Kyoto 606-8502, Japan
² Laboratory of Forest Ecology, Division of Environmental Science and Technology, Graduate School of Agriculture, Kyoto University, Kyoto 606-8502, Japan
³ Field Science Education and Research center, Kyoto University, Kyoto 606-8502, Japan
⁴ Department of Silviculture, Faculty of Forestry, Kasetsart University, Bangkok 10900, Thailand

* Corresponding author
Tel; +81-75-753-6361, Fax; +81-75-753-6372, E-mail: akinari@kais.kyoto-u.ac.jp

**ABSTRACT**  
The losses of carbon and nitrogen by the forest fire were measured in a dry dipterocarp forest (DDF), northeast Thailand. Seasonal changes in the aboveground biomass of understory grass and their nitrogen concentrations were measured. The aboveground biomass of grass was increased from March to July during the rainy season and reached the peak of 5.8 Mg ha⁻¹ in July. Then, the biomass gradually decreased to 2.5–2.6 Mg ha⁻¹ at the end of rainy season. The nitrogen concentration in grass biomass decreased gradually from 1.7% at the beginning of rainy season to about 1% at the end of rainy season, and dropped markedly to 0.4% at the burning time in January. So about 60% of the peak nitrogen mass (45 Kg ha⁻¹) were lost or retranslocated from the aboveground biomass to belowground. Carbon and nitrogen lost by the forest fire were 2.3 Mg ha⁻¹ and 28 kg ha⁻¹, respectively. The occurrence of forest fire synchronized with the senescent period of grasses, resulting in the minor loss of nitrogen in the forest ecosystem.

**Key words:** Forest fire, Nitrogen, Grass aboveground biomass, Burning loss, Dry dipterocarp forest, Thailand

**INTRODUCTION**

Dry dipterocarp forests (DDF) are biotic or disturbance climax forests in the tropical seasonal forests of Thailand. In these forests, fires occur frequently in the dry season from January to February. By the fire disturbances, organic matters such as litter and grass biomass are ashed and then provide mineral nutrients on the surface soil. So the fire plays an important role in the nutrient cycling of those forests (Ogino et al. 1967; Hirobe et al. 2003; Toda et al. unpublished data).

Ashing provides available form cations but results in the volatilizations of carbon and nitrogen. Nitrogen is an essential nutrient for plant growth. Effects of forest fire on nitrogen loss depend upon the intensity of fire and the plant biomass of above ground (Giardiana et al. 2000; Kauffman et al. 1993, 1995; Zinke et al. 1978; Van Reuler and Janssen, 1993; Mackensen et al. 1996). So frequent events of fire result in the degradation of these seasonal forests and also for the prevention of forest succession into the climatic forests (Vitousek and Howarth, 1991).

But there are rather few studies on the estimation of carbon and nitrogen losses by fire in the DDF of Thailand. In this study, we reported the burning loss of these elements from a DDF forest ecosystem. The effects of forest fire depend upon its intensity and the accumulation of organic matter in the grass and litter layer. Especially, we focused on the effect of burning timing in relation to the organic matter accumulation in the forest floor and growing pattern of aboveground grass biomass.

**MATERIALS AND METHODS**

**Study area**

The study was carried out in the Sakaerat Environmental Research Station (SERS) located in Nakhonrachasima Province, about 180 km northeast of Bangkok, Thailand (lat. 14.30’N, long. 101.56’E). DDF is 12.2 km² and is maintained by human disturbances such as forest fire in every year. Usually, forest fire is occurred in extreme dry
season, around January or February.

The climate type of this area is tropical monsoon (Fig. 1). The annual mean temperature is 22.5 °C, and annual precipitation is 1097 mm. The season is separated in two seasonal terms. From November to March, when monthly rainfall is about or less than 50 mm, is the dry season, while the rest of the year is the rainy season. The details are shown in Toda et al. (in review).

The research stand was selected in DDF. This stand had the latest forest fire in January 2001.

The overstorey vegetation in this stand was dominated by common Thai DDF trees such as *Shorea obtusa* (Dipterocarpaceae), *Xyilia xylocarpa* (Leguminosae-Mimosoideae), *Pterocarpus macrocarpus* (Leguminosae-Papilionoideae). The density of these trees was 444 trees ha⁻¹. The average diameter at breast height (DBH, 1.3 m above the ground) of trees (DBH ≥ 3 cm) and basal area were 17.3 cm and 14.3 m² ha⁻¹, respectively. The understorey layer of this forest is dominated by Poaceae grass, *Arundinaria pusilla*, which densely covered the ground of this forest.

**Monthly grass samplings**

From March 2001 to February 2002, *A. pusilla* was harvested (at ground level) in the randomly chosen 6 quadrates (50 cm × 50 cm square in each), at monthly intervals. Samples were dried at 105 °C for 48 hours and weighted.

**Samplings of fuel in pre-burning and ash in post-burning**

In January 2002, organic matters on the forest floor, which mainly consisted of the tree leaf and grass litter, were collected in each quadrate. In this study, no coarse woody debris was sampled because of the small amounts of large wood debris in the study stand (Toda et al., in review). Immediately after the burning, 6 quadrates were randomly selected in the study stand. In each quadrat, ash was carefully sampled with brushes. All pre- or post-burning samples were also dried at 105 °C for 48 hours and weighted.

**Chemical analysis**

For the analyses of carbon and nitrogen concentration, all dried samples were ground up and then were analyzed by NC analyzer (SUMIGRAPH NC900, SUMIKA chemical Co. Ltd., Japan).

**Estimations of carbon and nitrogen loss**

The ratio of carbon or nitrogen loss by forest fire was calculated as follow: 1−(the stock of carbon or nitrogen in ash after the fire)/(the stock of carbon or nitrogen in surface fuel before the fire). This ratio is an indicator of the fire intensity.

The loss of carbon and nitrogen from the grass ecosystem in DDF were estimated by the following calculation: 1−(the stock of carbon or nitrogen in ash of grass aboveground biomass after the fire)/(the maximum
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RESULTS
Seasonal changes in the aboveground biomass of the understorey grasses and their nitrogen concentrations

Table 1. Seasonal changes in *Arundinaria pusilla* aboveground biomass (Mg ha$^{-1}$) and nitrogen concentration (%). The values in parentheses show standard deviations (n=6).

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mar</td>
<td>Apr</td>
</tr>
<tr>
<td>Aboveground biomass (Mg ha$^{-1}$)</td>
<td>0.5 (0.1)</td>
<td>1.4 (0.0)</td>
</tr>
<tr>
<td>Nitrogen concentration in grass aboveground biomass (%)</td>
<td>1.74 (0.0)</td>
<td>1.62 (0.0)</td>
</tr>
</tbody>
</table>

Fig. 2. Seasonal change in nitrogen accumulation in *Arundinaria pusilla* aboveground biomass (kg ha$^{-1}$). The arrow indicates the occurrence of forest fire. The biomass in February is obtained from the neighbor non burning site. Rainy season: April-October, Dry season: November-March.

stock of carbon or nitrogen in grass aboveground biomass).

Seasonal change in the nitrogen amounts of grass aboveground biomass

Table 2 shows the seasonal changes in the aboveground biomass and nitrogen concentration of grasses. The grass aboveground biomass reached the maximum of 5.8 Mg ha$^{-1}$ in July. Then, the biomass gradually decreased to 2.5–2.6 Mg ha$^{-1}$ at the end of rainy season. In December, the biomass showed a minor increment to 4.7 Mg ha$^{-1}$ and then was stable over the dry season. So this grass showed two flushing periods of shoot production in the growth cycle, i.e. from March to July and in December.

The aboveground biomass grass showed the highest concentrations of nitrogen (1.7 %) at the beginning of the growth. Then, the nitrogen concentrations decreased with the growth of grass during the former half of rainy season (April-June). In the later half of rainy season (August-October), the concentrations were maintained at about 1 %. Nitrogen concentrations dropped to 0.4 % in the middle of the dry season (January-February).

Seasonal change in the nitrogen amounts of grass aboveground biomass

Fig. 2 shows the seasonal change in the nitrogen amounts in the aboveground biomass of grasses. The maximum amount of nitrogen was found in June. Then, the amount decreased, and it was stable after September, excepted in December. The increase of nitrogen in December may be accounted for by the flushing of grass shoots. Just before the fire, the accumulation of nitrogen was less than 20 kg ha$^{-1}$.

Losses of carbon and nitrogen by forest fire

Table 2 shows the distributions of carbon and nitrogen in the grass aboveground biomass, surface fuel biomass,
and ash, respectively, for pre- and post-burning occasions. Before the occurrence of forest fire, the accumulations of carbon and nitrogen in forest floor were 2.4 Mg ha\(^{-1}\) and 29.4 kg ha\(^{-2}\), respectively. By this fire, the losses of carbon and nitrogen were 2.3 Mg ha\(^{-1}\) and 27.6 kg ha\(^{-2}\), respectively and accounted for 96.4 % and 93.9 % of the carbon and nitrogen in the aboveground biomass before the forest fire, respectively. In this forest, the losses of carbon and nitrogen in grass biomass were 70.5 % and 22.2 % of the maximum accumulations of the grass aboveground biomass in July.

**DISCUSSION**

**Burning losses of carbon and nitrogen in DDF**

The losses of carbon and nitrogen depend upon the intensity of fire. The percentages of carbon and nitrogen loss by burning have been reported for the terrestrial ecosystems and range from 30-90 % of total aboveground stock (e.g. Buschbacher et al. 1988; Kaufman et al. 1993, 1995; Giardina et al. 2000; Wan et al. 2001). In this study forest, the losses of carbon (96.4 %) and nitrogen (93.9 %) were high in the comparison of the reported losses.

Kaufman et al. (1993) studied the nutrient losses by burning in Brazilian tropical dry forest and showed that the carbon and nitrogen losses were 73.1-96.1 %, and 79.3-96.1 %, respectively. They concluded that the dryer climate, such as low humidity, led higher losses. In this study, the well burning had also occurred in the severe dry conditions of the no rainfall for two months. This climatic character promoted the high carbon and nitrogen loss rates by the fire in this DDF forest ecosystem.

**Forest fire timing on DDF nitrogen cycle**

In the DDF, the losses of carbon and nitrogen were high because of the effective burning at the dry season. But the losses of carbon and nitrogen from this forest ecosystem were rather small, because of the small accumulation of organic mater in the forest floor and the low nutrient concentrations of grass.

In the DDF, abundances of tree are low, and aboveground biomass is also small. The annual nitrogen return via litterfall is also small and is, 33.4 kg ha\(^{-1}\) (Toda et al., in review). In addition, the rapid litter decomposition (1.3-2.5 year\(^{-1}\) for decay-rate constants) and small amount of litterfall (3.9 Mg ha\(^{-1}\) year\(^{-1}\)) resulted in the low accumulation of surface organic matter at the fire (Takeda & Tian, 2003).

Further, the pioneer grass with fast growth, play an important role to reduce the losses of nutrients from the forest ecosystem. *A. pusilla* is perennial Poaceae plant. This grass starts their major growth at the beginning of rainy season and slow downs in the short dry season. In this study, the occurrence of forest fire synchronized with the senescent period of grasses. The low nitrogen concentrations at the senescent may be accounted for by the retranslocation of nitrogen from the above to below ground biomass. This retranslocation of nitrogen contributed to the preservation of nitrogen in this forest ecosystem. So, the timing of forest fire occurrence reduced the loss of nitrogen by the burning. The burning timing becomes a crucial factor for deciding and maintaining the forest ecosystem of DDF.

Two processes may be recovered the loss of nitrogen in DDF. Tokuchi et al. (2003) studied the input of nitrogen by rainfall and was nearly 10 kg ha\(^{-1}\). Further, biological N, fixation by the Legminosaceae trees (e.g. *P. macrocarpus*, and *X. xylocarpa*) may account for the input of nitrogen. So the two processes may compensate for the nitrogen loss by the fire.

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**Table 2. Changes in biomass, carbon (Mg ha\(^{-1}\)), and nitrogen (kg ha\(^{-1}\)) of surface fuel in pre- and post-burnings. The values in parentheses show standard deviations (n=6).**

<table>
<thead>
<tr>
<th>Fuel biomass (Mg ha(^{-1}))</th>
<th>Carbon (Mg ha(^{-1}))</th>
<th>Nitrogen (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Litter</strong></td>
<td>Pre-burning</td>
<td>Post-burning</td>
</tr>
<tr>
<td>Litter</td>
<td>1.6</td>
<td>0.3</td>
</tr>
<tr>
<td>Grass-aboveground</td>
<td>4.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Ash</td>
<td>0.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Total</td>
<td>5.6</td>
<td>0.9</td>
</tr>
</tbody>
</table>
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REFERENCES


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