J. Agric. Meteorol. (農業気象) 60 (5): 1025-1028, 2005

Deforestation Effects on the Micrometeorology in a Cool-temperate Forest in Northernmost Japan

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Abstract

Evaluation of the tree cutting effect on the environment is crucial for wise use of woods considering environmental and biological conservation. In order to evaluate the tree cutting effects on the heat and water environments, a micrometeorological observation was conducted in a conifer-broadleaf mixed forest in northernmost Japan before and after the tree cutting, and the change was discussed. The tree cutting increased the solar radiation on the ground surface and the soil heat flux during the snow free period. However, the ratio of the soil heat flux to solar radiation was still small even after the tree cutting and most of the values were < 5%. Accordingly, there was little difference in the soil temperature between before and after the cutting. Dense undergrowth of *Sasa* bamboos control the increase of the radiation on the ground surface and soil temperature in this ecosystem, and this may act as an obstacle to tree regeneration. On the other hand, the ceasing of transpiration by trees suppressed the decrease of soil water after the tree cutting. The change of the soil water may lead to the change of the water balance in this watershed.

Key words: Evapotranspiration, *Sasa*, Soil temperature, Soil water content, Tree cutting

1. Introduction

A major source of uncertainty exists in the role of forests at different developmental stages following disturbance when assessing the terrestrial carbon, energy and water cycles (Geider *et al.*, 2001). Tree cutting, in particular, causes serious changes not only in these cycles, but also in the biodiversity within a short period. Thus, for wise use of woods, considering environmental and biological conservation, evaluation of the tree-cutting effect on the environment is crucial in the series of the entire forest dynamics (Kowalski *et al.*, 2003).

In order to evaluate the tree cutting effects on the heat and water environments, the monitoring of the micrometeorology was conducted in a conifer-broadleaf mixed forest in northernmost Japan. After 1.5 years observation in the forest, trees in an area of 13.7 ha were clear-cut, continuing the observation. In this paper, the micrometeorology between before and after the tree cutting was compared, and the effect of the tree cutting was discussed.

2. Materials and Methods

2.1 Site description and tree cutting

The study site was located on a flat terrace in the Teshio Experimental Forest, Hokkaido University (45°03'N, 142°06'E, 66 m asl) (Fig. 1). The soil is Gleyic Cambisols and has a surface organic horizon of ca. 10 cm thick. The dominant tree species were

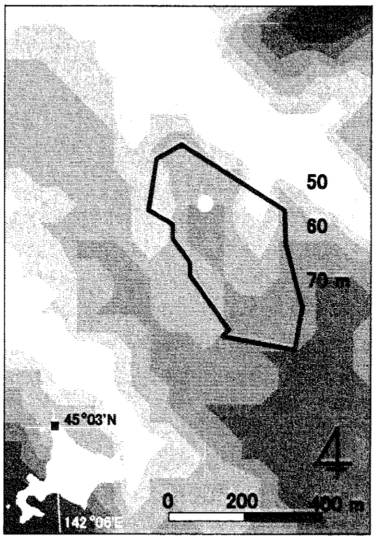

Fig. 1. Study site. Circle indicates observation tower and enclosure means clear-cut area.

Accepted on December 6, 2004

Quercus crispula, *Betula ermanii*, *Abies sachalinensis*, *Betula platyphylla* var. *japonica*, *Picea jezoensis*, and *Acer mono*, and evergreen dwarf bamboos (*Sasa senanensis* and *Sasa kurilensis*) formed dense undergrowth on the forest floor. Maximum and mean heights of the tree canopy were ca. 24 and 20 m, respectively. The basal area of canopy trees was 22 m^2 ha^{-1} and the leaf area index of canopy trees and *Sasa* bamboos was 3 and 4.5, respectively at its maximum value.

During January to March 2003, trees in the area of 13.7 ha were clear-cut. Preliminary research revealed that the total biomass volume of trees in this area was 2193 m^3 (Koike *et al.*, 2001) and this cutting removed the woods of 1203 m^3 (ca. 19 tC ha^{-1}) from this ecosystem, while the *Sasa* bamboos (the above ground biomass is 6–12 tC ha^{-1}) were kept intact.

2.2 Field observation and data calculation

Meteorological and soil sensors were set in August 2001. Open-path eddy covariance technique was applied to evaluate sensible and latent heat fluxes at 32m height. A sonic anemometer (DA600-3TV, Kaijo, Japan), and a CO_2/H_2O fluctuation meter (OP2, DDG, USA) were used for the evaluation. After the tree cutting, another set including the same instruments was placed above the *Sasa* canopy at 4.6m height. Fluctuation data were sampled at 10 Hz with a digitizing data recorder (DRM3, TEAC, Japan). The sampling started every 30 minutes with a duration time of 1640 s. After applying the planer fit rotation (Wilczak *et al.*, 2001), covariance values were corrected according to the sensor span and separation (Kaimal *et al.*, 1972; Moore, 1986), then WPL correction (Webb *et al.*, 1980) was applied.

Meteorological measurements at 32m on a tower included air temperature and relative humidity (HMP45D, Vaisala, Finland), wind speed and direction (DA600-3TV, KAIJO, Japan), downward solar radiation (CM-21F, Kipp & Zonen, The Netherlands), long-wave radiation (PIR, The Eppley Laboratory, Inc., USA), net radiation (CNR-1, Kipp & Zonen, The Netherlands), photosynthetic photon flux density (LI-190SZ, Li-Cor, USA), and precipitation (CYG-52202, RM Young, USA). Air temperature, relative humidity, wind speed, net radiation, photosynthetic photon flux density were also monitored on the ground, just above the undergrowth (ca. 2m height). The data from the sensors above the *Sasa* canopy were used for describing the understory condition before the tree cutting, but after the cutting, the data were used for representing the canopy surface condition. Underground, soil temperature and water content profiles, and soil heat flux were measured by platinum resistance thermometers (C-PTWP, Climatec, Inc., Japan), time domain reflectometry sensors (CS615, Campbell Scientific Inc., USA), and heat flow transducers (HFT-1.1, REBS, USA), respectively, at five points.

Sensor signals were sampled every 5s and stored as half-hour means (CR23X, Campbell Scientific Inc., USA), but the daily averages were used for the following comparison. The average data of the five points were used as the underground data. The daily decrease rate of soil water content between 0 and 60 cm deep was calculated using the soil water content profile, measured at 5, 10, 30, and 60 cm deep.

3. Results and Discussion

Daily average air temperatures at a height of 32m ranged from −13.3°C in winter to 22.8°C in summer 2002, and ranged from −13.8°C in winter to 20.6°C in summer 2003, and a distinct change by the tree cutting was not observed. The clear-cutting increased the vegetation surface albedo (ratio of reflected to downward solar radiation) both in the snow-free and snow-covered periods. In the snow-covered period, *Sasa* bamboos were under the snowpack and the opened snow surface increased the albedo up to 0.8, although the albedo in the snow-free period was less than 0.15 even after the tree cutting (Fig. 2). Because of the lack of the tree canopy, solar radiation on the ground surface and the soil heat flux increased during the snow-free period after the tree cutting. However, the ratio of the soil heat flux to the solar radiation was still small even after the clear-cut (most of the values were < 5%) and there was little difference in the soil temperature between before and after the cutting which we attributed to shading by *Sasa* bamboos (Fig. 3).

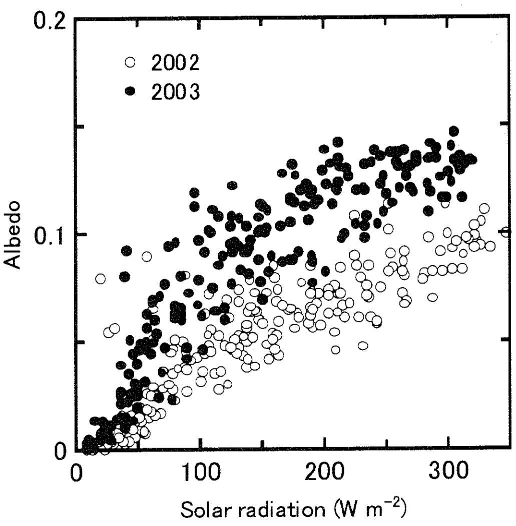

Fig. 2. Change of the albedo in snow-free period caused by the tree cutting.

In spite of the slight change in the soil heat environment, the cutting caused significant increase in the soil water content (Fig. 4). Before the cutting, the soil water content at 5cm deep decreased to 26% during May to June and in September, when the

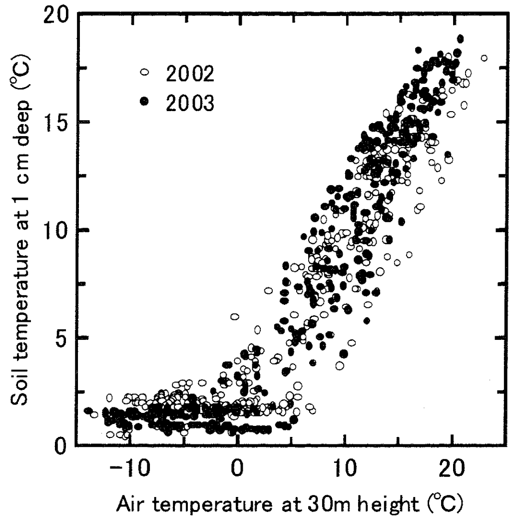

Fig. 3. Change of the soil temperature caused by the tree cutting.

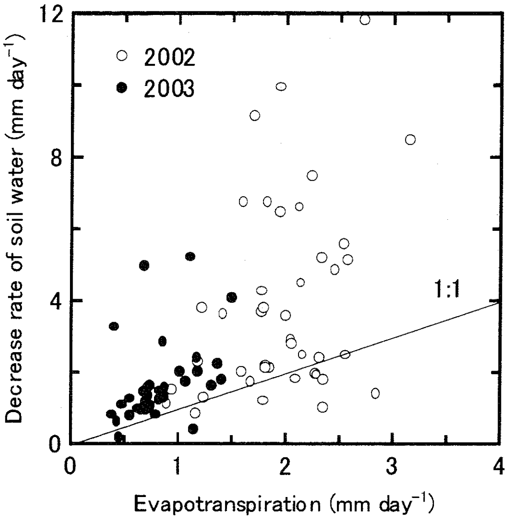

Fig. 5. Relationship between the evapotranspiration rate and the decrease rate of soil water

amount of the precipitation was small. However, after the cutting, the water content kept higher values (>35%), although the amount of precipitation during the snow-free period was smaller than that before the tree cutting (786 and 641 mm in 2002 and 2003, respectively).

The relationship between the evapotranspiration rate by the eddy covariance method and the decrease rate of soil water content is shown in Fig. 5. This figure shows that the decrease of the soil water decrease rate was caused by the ceasing of the transpiration by trees. After the tree cutting, the decrease rate of soil water increased with the increase in the evapotranspiration rate. The values in Fig. 5 can be plotted around a 1:1 line in this period, but the decrease rate was slightly higher than the evapotranspiration rate. The relationship after the tree cutting suggested that evapapotranspiration was the main cause of the soil water decrease, but other outputs, e.g. water discharge to the stream, also occurred. On the other hand, before the tree cutting, the decrease rate was much larger than the evapotranspiration rate especially at high rates of evapotranspiration, and the value was up to 12 mm day^{-1}. With trees, the heterogeneity of the soil environment increases by the distribution of tree roots. In addition, a part of the water absorbed by tree roots is stored in tree bodies and the decreased soil water does not relate to the transpiration directly. Accordingly, a scattered relationship would appear before the tree cutting. On the other hand, because *Sasa* bamboos distribute homogeneously and the above-ground biomass decreased after the tree cutting, the relationship can be recognized more clearly than that before the tree cutting.

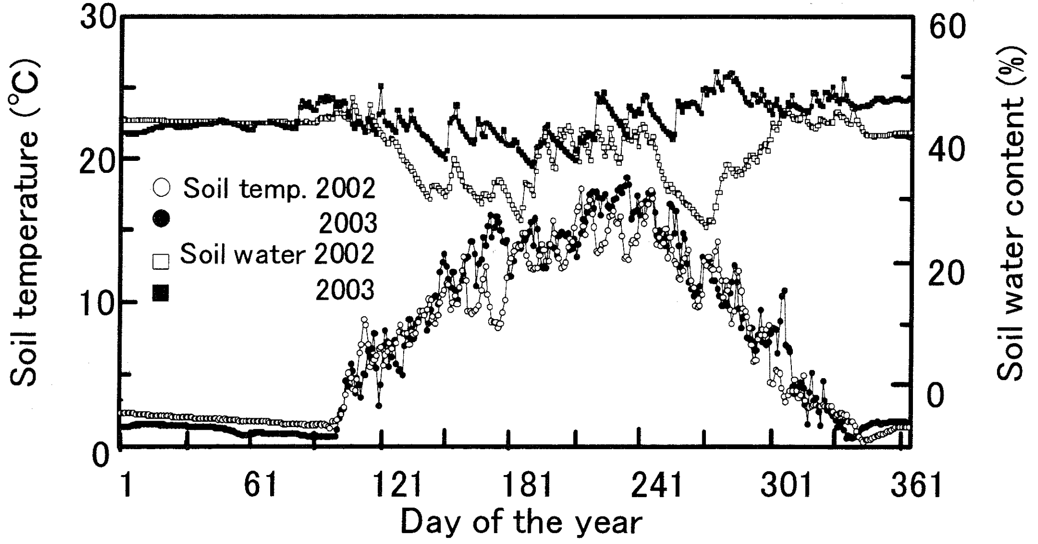

Fig. 4. Changes of the soil temperature (1cm deep) and soil water content (5cm deep) caused by the tree cutting

In conclusion, this tree cutting did not cause large changes in the soil heat environment because the large biomass of understory vegetation, i.e. *Sasa* bamboos, exists after the cutting and shades the solar radiation. However, the ceasing of the transpiration by trees suppressed the decrease of soil water throughout the plant-growing period. The change of the soil water may lead to the change of the water balance in this watershed.

Acknowledgements

This research was made by the collaboration of Hokkaido University, National Institute for Environmental Studies, JP, and Hokkaido Electric Power Co., Inc., JP, through the project "CC-LaG experiment," and was made possible by support from M. Takada (Hokkaido Institute of Environmental Sciences) and the staff of the Teshio Experimental Forest.

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