

# WATERSHED SCALE CHANGE IN THE CARBON AND WATER CYCLES BY FORESTRY ACTIVITIES IN A COOL-TEMPERATE FOREST IN NORTHERNMOST JAPAN

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## ABSTRACT

To evaluate the deforestation and forestation effects on the carbon and water cycles, micrometeorological and hydrological observations were conducted in a conifer-broadleaf mixed forest in northernmost Japan in the series of these activities. The clear-cutting of trees changed the carbon balance of the ecosystem to the net source in the plant-growing period, although the undergrowth, *Sasa* bamboos, still keeps large biomass after the tree-cutting and the half-hourly flux indicate carbon sequestration in the daytime. Strip-cutting of *Sasa* bamboos and planting of the larch saplings did not cause the distinct change in the emission rate. On the other hand, the evapotranspiration rate recovered to the same level with that in the mixed forest within 2 years after the clear-cutting. We attributed the increase in the evapotranspiration rate partly to the acclimation in the transpiration capacity of *Sasa* bamboos.

## INTRODUCTION

A major source of uncertainty exists in the role of forests at different developmental stages following disturbance when assessing the terrestrial carbon and water cycles. Tree cutting, in particular, causes serious changes in these cycles within a short period. In order to evaluate the deforestation and forestation effects on the carbon and water cycles, trees in an area of 13.7 ha were clear-cut after 1.5 years observation in the mixed forest, then saplings of 2-year old hybrid larch (*Larix gmelinii* × *L. kaempferi*) were planted 8 month after the clear-cutting. In the series of the activities, we conducted flux observation by eddy covariance technique and watershed-scale water balance evaluation using an observation weir. In this paper, the watershed-scale changes in the carbon and water cycles according to these forest activities were discussed.

## SITE DESCRIPTION

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). The dominant tree species were *Quercus crispula*, *Betula ermanii*, *Abies sachalinensis*, *Betula platyphylla* var. *japonica*, 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 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<sup>3</sup> and this cutting removed the woods of 1203 m<sup>3</sup> (ca. 19 tC ha<sup>-1</sup>) from this ecosystem. In October 2003, *Sasa* bamboos (the above ground biomass is 6–12 tC ha<sup>-1</sup>) were strip-cut into 4 m rows (a half of the clear cut area) and ca. 30000 saplings (ca. 0.04 tC ha<sup>-1</sup>) of hybrid larch were planted.

## FIELD OBSERVATION AND DATA CALCULATION

Meteorological and soil sensors were set in August 2001. Closed- & Open-path eddy covariance technique was applied to evaluate the carbon and water fluxes at 32m height. A sonic anemometer and CO<sub>2</sub>/H<sub>2</sub>O fluctuation meters 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. Closed-path flux data were mainly used for the evaluation and the open-path data were for supplemental use. Fluctuation data were sampled at 10 Hz with a digitizing data recorder and the covariances

were calculated every 30 min. After applying the planer fit rotation, the effect of air density fluctuation was corrected. All the raw fluctuation data were checked by a quality control program proposed by Vickers and Mahrt [1997], and Stationarity and Integral turbulence tests [Aubinet, et al., 2000] were applied for the screening of the flux values. Net ecosystem exchange rate (NEE) was determined as the sum of the CO<sub>2</sub> flux and CO<sub>2</sub> storage change in the air column from the forest floor to the flux measurement height. Gap filling of the flux data was applied using the Look up table for H<sub>2</sub>O flux, and using the non-linear regression against photosynthetically active radiation and air temperature for NEE. Meteorological measurements at 32m on a tower included air temperature and relative humidity, net radiation, photosynthetically active radiation, and precipitation. These variables were also monitored on the ground, just above the undergrowth (ca. 2m height). Underground, soil temperature and water content profiles, and soil heat flux were measured at five points. Water table of the stream in the watershed (8 ha) was monitored and the discharge was evaluated using a water table-discharge relationship. The stream water was sampled every 2 weeks and the particulate and dissolved carbon leaching was analyzed using a TOC analyzer. In addition, the litter output through the stream was trapped by nylon nets and collected every month.

## RESULTS AND DISCUSSION

The daily NEE decreased with the increase in the photosynthetically active radiation before the tree cutting and the carbon sequestration rate was 0.4 mol m<sup>-2</sup> day<sup>-1</sup> at its maximum (Fig. 1), however the annual gross primary production nearly balanced with the total ecosystem respiration in the forest and the annual sequestration rate was small (7 mol m<sup>-2</sup>). In addition, ca 10% of the fixed carbon was carried out from the watershed by river water runoff. The clear-cutting of trees further decreased the sequestration capacity of this ecosystem. *Sasa* bamboos have large biomass and the half-hourly NEE was negative (accumulation) in the daytime in its full growing period. However, because of the large respiration rate in the nighttime, the daily NEE kept positive values even in that situation (ca. 0.2 mol m<sup>-2</sup> day<sup>-1</sup>). The emission rate in 2004 was almost the same level with that in 2003, in spite of the strip cutting of *Sasa* bamboos and planting of the larch saplings. Water input to the forested watershed was nearly balanced with the output, and the residual of the balance was little (28 mm). The annual evapotranspiration rate of the forest was 250 mm and was ca. quarter of the stream water runoff. In the plant-growing period in 2003, just after the clear-cutting, the evapotranspiration rate decreased (Fig. 1) and the runoff rate increased. However, in 2004, the evapotranspiration rate recovered to the same level with that of the mixed forest. We attributed the increase in the evapotranspiration rate partly to the acclimation in the transpiration capacity of *Sasa* bamboos. In conclusion, tree cutting changed the carbon balance of the ecosystem to the net source. However, the distinct decrease in the evapotranspiration rate was observed within a year after the logging, and the rate recovered to the same level in the next year.

## REFERENCES

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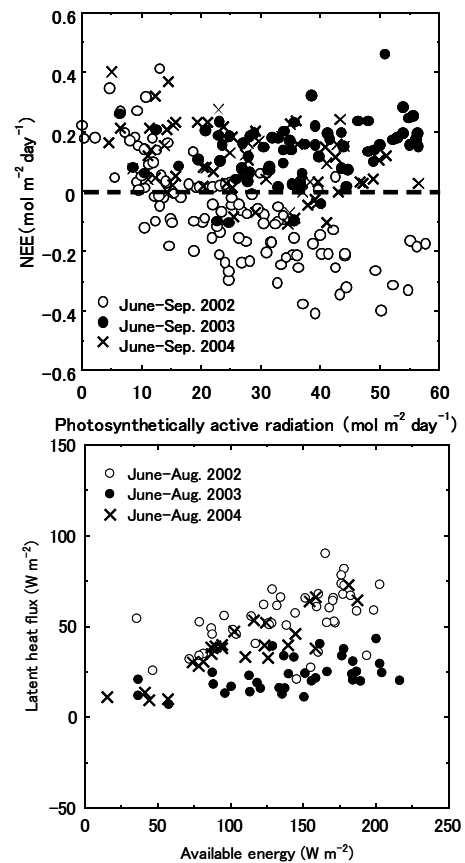


Fig.1. Changes in the NEE and latent heat flux in the plant-growing period caused by the deforestation and forestation.