Inter- and intra-seasonal variation in transpiration and stem growth in larch forest slope of northern Mongolia

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Introduction

In northern Mongolia, the north-south gradients in moisture and temperature regimes are closely related to the geographical distribution of vegetation. Vegetation type varies from grassland to forest along a south-north gradient, with north-faced forest slopes and south-faced grassland slopes found in the mountainous areas. Increased knowledge of the hydrometeorological interactions between climatic variation and the response of each ecosystem is particularly important in this region. Although the topic of transpiration in forests constitutes one of the major processes being studied, water use by trees of the mountain forest remains poorly clarified in this region.

The objective of the present study is to estimate the intra- and inter- seasonal variation in transpiration from the forest using sap flow measurements. In addition, we made comparison of transpiration with stem growth of trees in this forest.

Observation site and methods

Study site

The study site is larch (*Larix sibirica* Ledeb) forest of north-faced slope in Shijir river basin (47°58' N, 107°25'E, 1646 m a.s.l.), located about 50 km north-east of Ulaanbaatar in Mongolia. Characteristic landscape is found in this area; that is, forest distributes mainly on north-faced slope, while grassland dominates south-faced slope. Ground temperature measurements and tomographic surveys had demonstrated the existence of permafrost with the depth of about 2.5 m of active layer in forest slope, whereas bare of permafrost under the grassland slope (Ishikawa et al. 2003). According to the vegetation measurements in a representative 0.25 ha plot nearby the site, the forest composes mainly larch trees and white birch trees (*betula platyphylla* Sukacz).

Sap flow measurements

Granier (1985, 1987) developed a method of measuring xylem sap flow that gives an accurate and inexpensive estimate of whole-tree transpiration. Iijima et al. (2004) modified the sap flow measurements using cyclic heating system for the larch forest site in Shijir valley. The Granier sensors were installed into fifteen larch trees at Site D and 6 trees at Site O (Fig. 3). Observation was conducted from 6 July to 20 October, 2004 from 13 May to 2 October, 2005, 16 May to 26 September in 2006. Methods of estimating sap flow density and fluxes had been examined based on Iijima et al. (2004). As their results, efficiencies of the seasonal measurements and estimation of sap flow density were confirmed.

Stem growth measurements

Stem radial growth of larch trees along the forest slope was measured using dendroband. Dendrobands were set up at 7 sites along the north-south transect (see Fig. 3). Number of sampling in each site is five and installed at breast height of each trees with 20 to 30 cm DBH. Measurements were made manually once a month during the warm season (from May to October) and once an every 2 month during the cold season (from November to April). At Site D, dendorometers were set at 4 larch trees and measured stem radial growth automatically from May 2005.

Results and discussion

Sap flow flux in each year demonstrates different seasonal variations due to large difference in intra-seasonal hydrometeorological variations (Fig. 1). Although total amount of rainfall during growing season (from May to September) in 2005 (255 mm) was larger than that in 2004 (201 mm) and 2006 (221 mm), rainfall amount was larger in 2004 (126 mm) than that in 2005 (52 mm) during early growing season (from 1 May to 10 July), the rainfall difference well associated with soil moisture storage, that is, lasting wet condition with more than 20 % of soil moisture in 2004, while gradually decreasing up to less than 10 % at late July in 2005. The same gradual decrease in soil moisture occurred in 2006. Consequently, sap flow flux

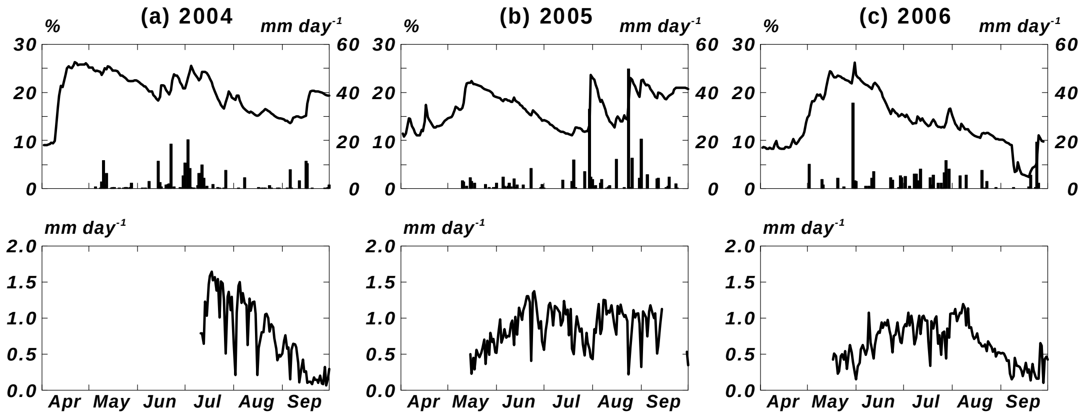

Figure 1. Seasonal variation in rainfall and soil moisture (upper figure), and sap flow flux (transpiration; lower figure), at Site D in (a) 2004, (b) 2005 and (c) 2006. Soil moisture denotes volumetric percentage at 0-20 cm depth

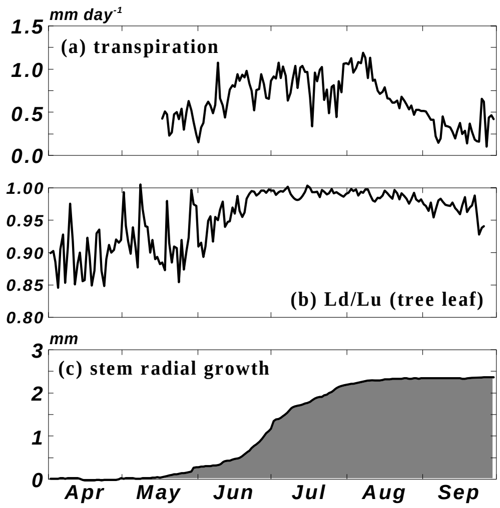

Figure 2. Seasonal variations in (a) transpiration, (b) ratio of downward and upward longwave radiation, and (c) stem radial growth of larch trees at Site D.

in growth mature season (from 10 July to 10 August) was the highest in 2004 (1.18 mm day^{-1}). In contrast, suppressed transpiration was observed in 2005 (0.87 mm day^{-1}) and 2006 (0.90 mm day^{-1}). The interannual difference in sap flow flux exhibits that the rainfall and soil moisture conditions during early growing season until July is effective on transpiration activity in this forest and thus suppression of transpiration occurred in 2005 due to dry period in early growing season.

Sap flow variation strongly associates with tree phenology and stem growth (Fig. 2). According to the ratio of downward and upward longwave radiation, leaf opening of larch trees started in late May and spreading finished at late June. Increase in sap flow flux occurred simultaneously during the leaf opening period. Just after the leaf open, sap flow flux shows maximum value from late June to early August. At that period, continuous stem radial growth was observed.

Stem radial growth of larch trees in the north-south transect in Shijir river basin demonstrates seasonal and interannual variations and topographical difference (Fig. 3). In both years (2005 and 2006), stem radial growth progressed during June through August, which relates the season with the highest sap flow flux (Fig. 2). Gradual and small growth after August continues until October. During cold season after October, trees shrink its stem probably associated with dehydration within xylem to obtain freezing tolerant.

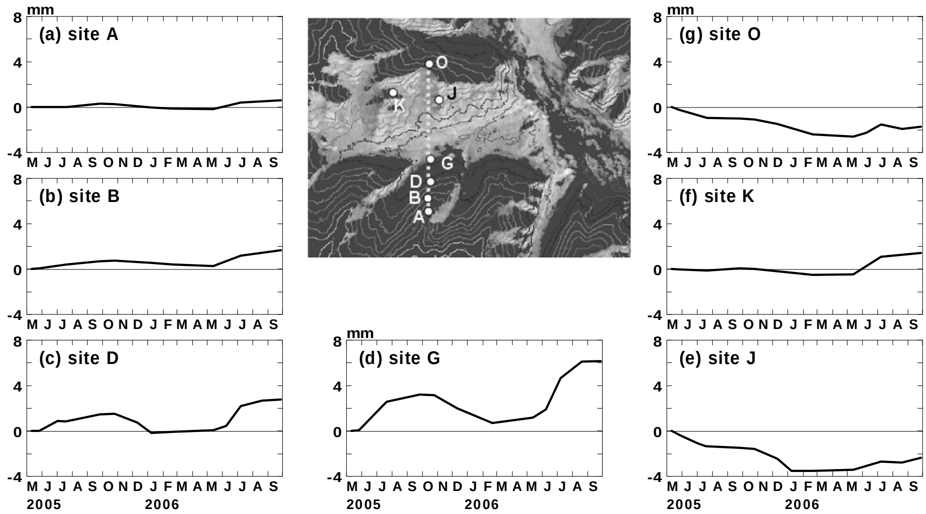

Figure 3. Stem radial growth of larch trees by dendroband measurements along north-south transect

Dark and light areas in topography map (centre) denote forest and grassland, respectively.

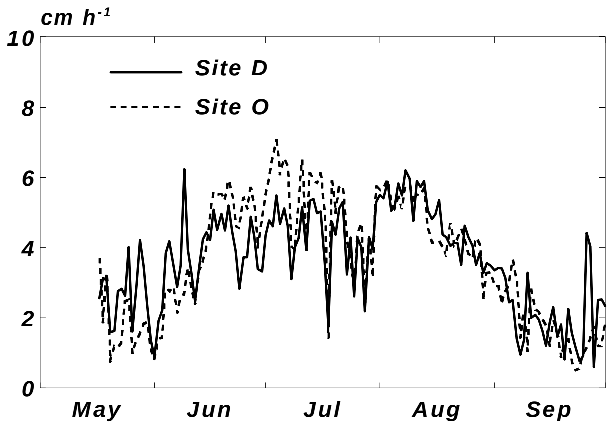

Figure 4. Seasonal variations in daily average of sap flow density at Site D (solid line) and Site O (dotted line). Sap flow densities were averaged 4 (Site D) and 3 (Site O) larch trees with more than 25 cm of DBH

The remarkable difference was found in topographical gradient of stem growth. The largest growth appeared at Site G (valley bottom site of north-faced slope), and gradually decreasing growth amount along with the increase in altitude (Site D, B, and A). On the other hand, there was quite different response of stem growth in south faced slope (Site J, K, and O). Most sites showed shrinking of stem from measurement starting date. Shrinking of stem was apparent in 2005, comparing with in 2006 that is likely due to the difference of hydrometeorological wetness.

On the other hand, there was no significant difference of seasonal variation in sap flow density between at north-faced slope (Site D) and at mountain ridge (Site O) in 2006 (Fig. 4). The topographical difference in stem growth and no difference in sap flow density imply that water use efficiency of larch trees varies topographically likely due to response to different hydrometeorological conditions, such as soil water conditions and incoming radiation. It is still unknown whether suppression of transpiration and tree growth by occurrence of drought year may enhance topographical difference in transpiration. Thus, further quantitative observation is needed to clarify the topographical difference in transpiration and growth relationship in this region.

Conclusion

An estimation of transpiration using xylem sap flow measurements and stem radial growth in a larch forest in Shijir river basin, Mongolia, was conducted in the present study. Summarized insights were as follows;

1. In 2004, sap flow flux (transpiration of each tree) had the largest amounts in 3 years (2004-2006) during mature growth season (early July to August).
2. Interannual difference in sap flow flux was affected due to intra-seasonal hydroclimatic variations, especially amounts of rainfall and soil moisture conditions during early growing season (during June through early July).
3. Increase in sap flow started corresponding to leaf opening period. Stem radial growth tied to period of maximum sap flow flux. Stem growth showed large topographical variation.

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