Seasonal Patterns of Evapotranspiration in a Forested Headwater Catchment Affected by 50% Strip Thinning: Application of Short-time Period Water Budget Method

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INTRODUCTION

Evapotranspiration (ET) is one of key hydrological processes for examine water losses in a forest catchment. In general, changes in forest stand conditions by forest management (e.g., clear-cutting and thinning) alter the amount of ET from forests (Bosch and Hewlett 1982; Sun et al. 2008). Forest thinning is one of the common treatments to improve and change stand structure and thus altered ET processes of the forests (Zhang et al. 2001). Various methods such as catchment water balance method, soil water budget and eddy covariance have been applied for estimating total ET and/or parts of ET including interception, transpiration and soil evaporation in forested areas (Wilson et al. 2001). Hence, changes in ET after forest thinning (or management) was typically measured by based on flux tower (Dore et al. 2010) and stand scale sap flow measurement (Breda et al. 1995; Lagergren et al. 2008). These studies were difficult for extrapolating toward catchment scale processes for the effects of forest management. To overcome the problems, we applied short-time period water budget (SPWB; Linsley et al., 1958; Suzuki, 1985) method for estimating changes in ET after 50% strip thinning in a headwater catchment. SPWB also has advantages for estimating seasonal changes of ET using precipitation and discharge.

METHOD

This study was conducted in a headwater catchment (catchment K2) covered by Japanese cedar and cypress plantation in Tochigi Prefecture, Japan (139°36´E 36°22´N, 90-290 m above sea level). The area of catchment K2 is 17.1 ha and the slope ranges from 20° to 45°. 50% of the stems within an area of 10.9 ha was removed by strip thinning from July to December, 2011. Runoff was measured with the combination of box-type V-notch weir and Parshall flume at the output of catchment K2. Water level was measured by using water level logger (TruTrack WT-HR 1000) at 10-min intervals. Rainfall was measured by using a HOBO tipping-bucket rain gauge (RG3; Onset Computer Corporation) with 5-min interval located in an open area in catchment K2. Rainfall and runoff data from August, 2010 to December, 2012 was used in this study, which was separated to pre-thinning (from August, 2010 to July, 2011) and post-thinning (from January to December, 2012) periods.

We therefore summarized the rainfall and runoff data with daily values for analysis of SPWB method. SPWB method (Linsley et al., 1958; Suzuki, 1985) is based on short-period (8 to 100 days) of equal precipitation and discharge volumes. We assumed bedrock percolation and soil water storage were constant throughout the analysis in the calculation.

RESULTS AND DISCUSSION

Total rainfall during pre- and post- thinning period were 1367.2 and 1295.2 mm, respectively, whereas the 20-years mean annual rainfall recorded in the closest station (Sano AMeDAS) was 1259.3 mm. Monthly rainfall shows seasonal fluctuation with most of the rainfall occurred from May to October and numbers of typhoons observed in 2011 (**Fig. 1a**). Observed total runoff during pre- and post-thinning were 389.8 and 423.3 mm, respectively. The runoff-rainfall ratio of pre-and post-thinning period were 28.5 and 32.7%, respectively. Higher monthly runoff generally occurred from May to October in this area because of a rainy season from May to July and a typhoon season from August to October. Monthly runoff ranged from 7.6 to 172.0 mm with a mean of 32.5 mm in pre-thinning period and from 4.1 to 126.6 mm with a mean of 35.3 mm in post-thinning period, respectively (**Fig. 1b**).

Based on SPWB method, estimated annual ET during pre- and post-thinning period were 977.4 and 871.9 mm, respectively. This result showed that ET decreased 105.5 mm due to 50% strip thinning. Seasonal pattern of ET estimated by SPWB method also agreed to the estimated values by plot scale observation by Sap flow, interception loss, and forest floor ET (969.2 mm by SPWB method and 979.8 mm by Sun et al. 2017 from November, 2010 to October, 2011; 766.0mm by SPWB method and 780.1 mm by Sun from November, 2011 to October, 2012). Hence, field measurement by Sun et al. 2017 tended to be higher than SPWB in winter months of both pre- and post- thinning periods. During winter period, because only few rainfall felt and resulted in less runoff variation, ET calculated by SPWB method was low. On the other hand, tree transpiration and forest floor evaporation continuously used soil water during this period and therefore has higher ET than that calculated by SPWB method.

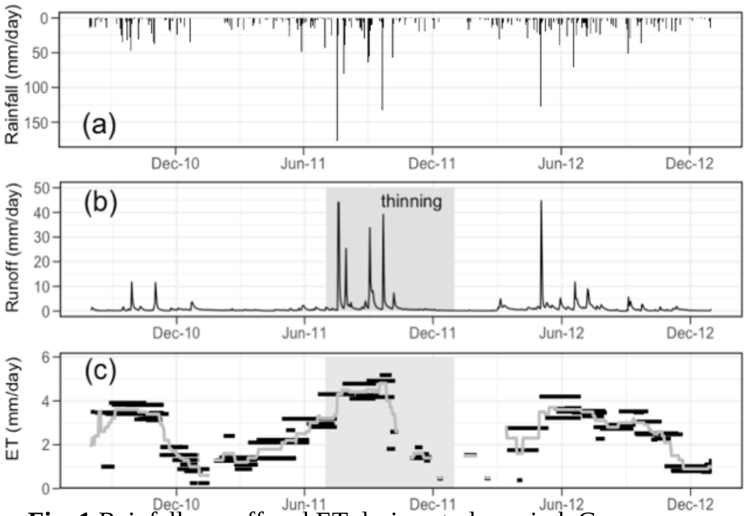

Fig. 1 Rainfall, runoff and ET during study period. Grey zone represented the thinning period.

CONCLUSIONS

Our results of comparing SPWB method with field measurement suggest that SPWB method can effectively account for the total amount of interception loss, transpiration and soil evaporation throughout a year, although seasonal or monthly rainfall patterns can affect the ET estimates by SPWB method. On the other hand, SPWB method did not include the changes of soil water content and groundwater level, which could cause the differences of ET estimates between SPWB method and catchment water balance method.

Keywords: evapotranspiration, headwater catchment, short-term water balance, strip thinning