Effects of forest thinning on plot and catchment runoff responses in Japanese headwater basins

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1. Introduction

Forest thinning is an important part of the silvicultural treatments which is the preferred harvesting method in water producing watersheds. Thinning is the only currently used practice to maximize productivity of water by potential increasing water availability (Dung et al., 2010). However, effects of thinning on runoff responses in the previous studies were not consistent. A few studies showed increases of runoff, whereas other results showed decreases or no effect. Most of the previous studies originated only in the catchment scale, whereas the changes in net precipitation and infiltration after thinning occur in hillslope scales. *For examining the effects of forest thinning on hydrological process, we evaluated; (1) Overland flow runoff response in hillslope scale and (2) Storm and base flow runoff response in catchment scale after thinning.*

2. Study site

This study was conducted in two small catchments (0.19ha: catchment M4 and 0.35ha: catchment M5) in Mie Prefecture (34°21′ N, 136°25′ E), south-central Japan (Fig. 1a). The catchment area of M5 was covered by Japanese cypress with 3500 stems/ha in pre-thinning. Mean annual precipitation and air temperature was 2000 mm and 14°C, respectively. Dominant hillslope gradient ranges from 35^0 to 45^0. The soil depth ranged from 0.6 to 1.8 m. Bedrock is consisted by Cambisols.

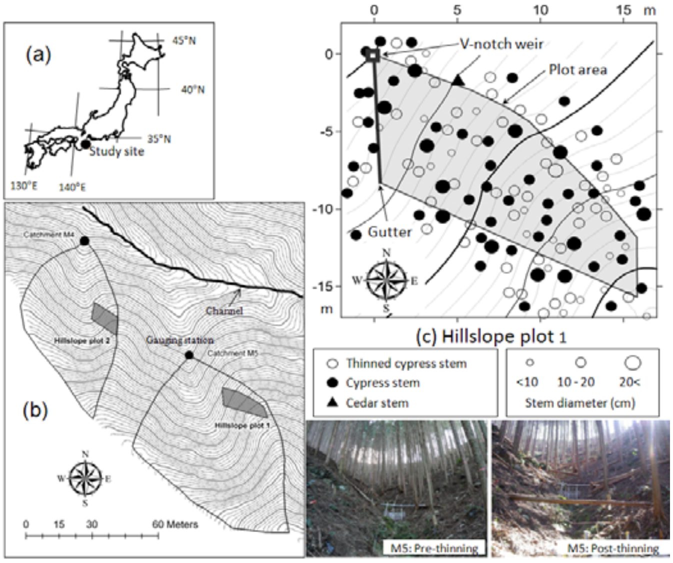

Figure 1. (a) Location of study site; (b) location and topography of study catchments and hillslope plots; (c) Treatment characteristics of hillslope plot 1 and catchment M5

3. Method

We established hillslope plots within two small catchments for monitoring overland flow generation and catchment runoff. Catchment M5 (including hillslope plot 1) was a treatment catchment in which 58.3% of stems (corresponding to 43.2% of basal area) were removed, whereas the catchment M4 (including hillslope plot 2) remained untreated as a control (Fig. 1b and 1c). Overland flow generation and catchment runoff were monitored over 2 years pre- and 2 year post-thinning periods. Estimation of quick and delayed runoff using hydrograph separation analysis adopted from Hewlett and Hibbert (1967).To examine the effect of forest thinning on monthly runoff responses, we applied statistical analysis for paired catchment data. We established a pre-logging calibration equation between catchments M5 and M4 using Generalized Linear Model (GLM). Then we predicted post-thinning runoff using the calibration model. Finally, we conducted t-test for value of residuals (observed – predicted values). The statistical analysis was conducted using *R* package

4. Results and discussion

Catchment and hillslope runoff from M5 and M4 were significantly correlated when developing the calibration equations (Fig.2). Significant differences appeared in total monthly catchment runoff and delayed runoff between the pre-thinning and post-thinning periods. Treatment effects were consistently positive in both catchment and plot runoff in the post-thinning period (Fig. 2). However, no significant differences appeared in the monthly quick runoff of catchment M5 and monthly overland flow from hillslope plot 1.

Paired-catchment analysis of monthly data also revealed significant increases in catchment runoff, but hillslope plot runoff did not change significantly. Estimated increase in mean annual runoff was 240.7 mm of the post-thinning period. This increase of runoff was mostly associated with the increase of the delayed runoff.

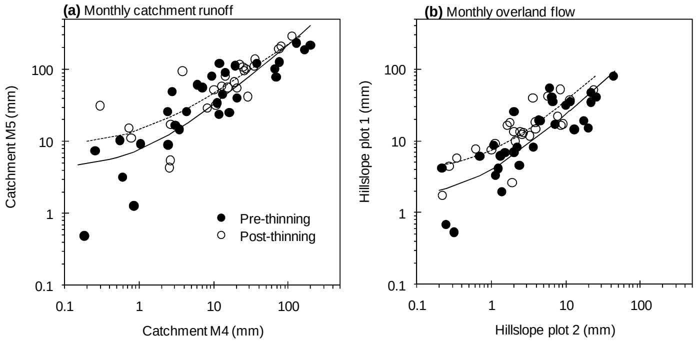

Figure 2. (a) Monthly runoff from treated catchment M5 and control catchment M4; and (b) monthly hillslope plot runoff from treated plot 1 and control plot 2.

The duration and magnitude of daily precipitation were similar during pre- and post-thinning periods (Fig. 3a). Mean daily catchment runoff during the pre-thinning period was 1.8 mm for M5 and 1.1 mm for M4. During the post-thinning period, mean daily runoff from M5 increased to 3.1 mm, but remained relatively constant from M4 (mean: 0.9mm) (Fig. 3b). Mean overland was similar between pre- and post-thinning periods in hillslope plots 1 and 2 in M5 and M4 (Fig. 3c). At M5, mean daily quick runoff during the pre- and post-thinning periods was 0.9 and 0.7 mm, respectively, while mean daily delayed runoff during the pre- and post-thinning periods was 0.9 and 2.4 mm, respectively.

Mean daily flow duration of the ephemeral channel in catchment M5 was 207 days (58.6% of the year) during the pre-thinning period. The duration of catchment runoff in M5 was 287 days (78.6% of the year) in the first year of the post-thinning period and 249 days (68.2% of the year) in the second year of the post-thinning period. In M4, the duration of runoff in the ephemeral channel ranged from 130–202 days (35.6–55.3% of 365 days) during the first and second years of the post-thinning period. Changes in daily flow duration between the first and second year after thinning suggested that canopy closer after thinning and increased evapotranspiration may occur from the first to second year.

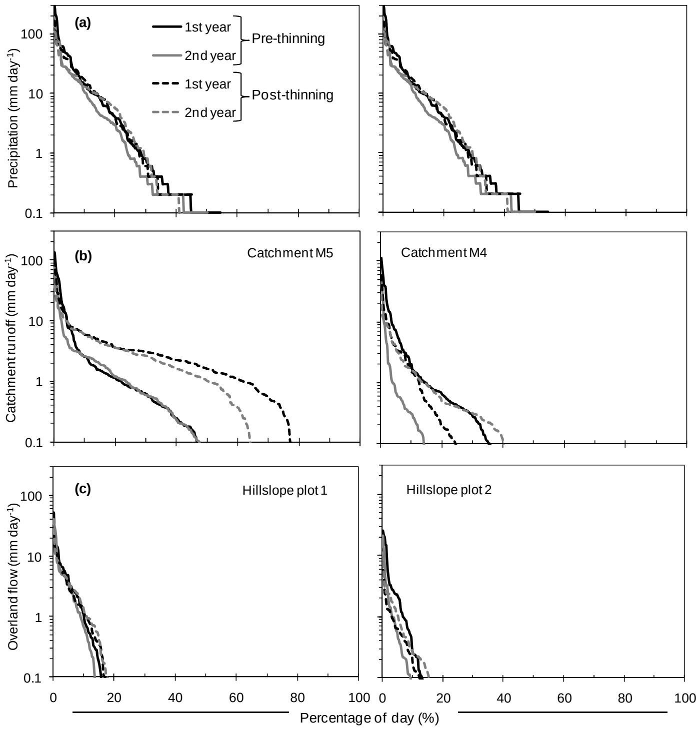

Figure 3. Percentage of days of (a) precipitation; (b) catchment runoff responses; and (c) overland flow responses during the two years pre- and two year post-thinning periods.

5. Conclusion

Based on our field observations and analysis, we concluded the following issues for effect of thinning on runoff generation: (1) Forest thinning increased annual runoff by 240.7 mm; (2) Forest thinning increased flow duration of an ephemeral channel from 56.7–73.3%; (3) Increases in plot runoff were not significant and did not directly contribute to the increases in catchment runoff, and (4) Increases in runoff response were associated with increases in base flow components, which were related to changes in net precipitation, soil water availability, and evapotranspiration.

References

Dung BX, Miyata S, and Gomi T., 2010. Effect of forest thinning on overland flow generation on hillslopes covered by Japanese cypress. *Ecohydrology*. Doi: 10.1002/eco.135

Hewlett JD, Hibbert AR. 1967. Factors affecting the response of small watersheds to precipitation in humid areas, in: *Sopper, W.E., Lull, H.W. (Eds.), Intl. Symp*. For. Hydrol. Pergamon, New York, pp. 275-290.