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論文の内容の要約

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学位論文名	**Evaluating the effects of forest thinning on runoff generation in forested watersheds: Field monitoring and process-based modeling approaches** 山地流域における森林間伐が水流出に及ぼす影響の評価： 現地観測および流出モデルによる解析

【論文の内容の要約】

（分量の制限はありません。課題設定、方法論、実験・解析、結論・考察など、当該論文の全体がわかる形で作成のこと）

Forest thinning is an important part of the silvicultural treatment, in which selected trees were removed within an entire forest stand with random or following by strip. Forest thinning is currently recommended for producing timber, water resources management, and ecosystem maintenance in forested headwater catchments in Japan. In particular, 50% of forest thinning is currently recommended instead of low intensity thinning, because of the effectiveness of timber production. Hence, most of the previous studies focused on thinning with 30 to 35% of stem removal. Moreover, in most of the previous studies for the investigation of runoff responses by thinning, a catchment was assumed as a black-box. Changes in specific runoff components were not examined in such black-box systems. Therefore, mechanisms for changes in hydrological processes due to forest thinning and associated management practices (i.e., forest road, and skid trail) are not examined. In addition, recent studies showed that dominant hydrological processes depended on the observation scales from hillslope, headwaters to their downstream. Therefore I examined the effects of forest thinning on internal hydrological processes in hillslope, headwaters, and downstream catchments using both field observation and modeling approaches.

To examine the effects of forest thinning on runoff generation at the plot and catchment scales, I conducted field observation in headwater catchments draining Japanese cypress (*Chamaecyparis obtusa*) and cedar (*Cryptomeria japonica*) forests at Mie and Tochigi prefectures. At the Mie site, 58% of the stems in the treated headwater catchment M5 (0.4ha) were removed by random thinning, while the control catchment M4 (0.2ha) was untreated. Overland flow from hillslope plots (8 x 25 mm) and stream runoff from catchments outlets were monitored. At the Tochigi site, I conducted field observation in the nested catchments from 3 ha to 17 ha. 50% of the stems was removed by strip thinning in the catchment K2 (treatment catchment), while the catchment K3 was remained untreated as a control.

Results in Mie site showed that differences of runoff responses in plot and catchment scales. Monitoring at surface plots showed that increases in overland flow associated with the increases in net-precipitation. Vegetation ground cover and soil physical properties did not significantly change due to thinning. In zero-order basin scale, the paired-catchment analysis revealed that annual catchment runoff increased 241 mm after the thinning. Increases in runoff responses after thinning were associated with increases in net-precipitation, and soil water availability, and decreases in evapotranspiration. Moreover, delayed runoff increased significantly, while quick runoff and peak flow followed similar patterns in the pre- and post-thinning periods. Flow duration also increased from 57% in the pre-thinning period to 73% after the thinning. These results associated with changes in the availability of soil water and evapotranspiration.

Results of Tochigi site revealed different runoff responses in the first- to third-order catchments. Increase in annual catchment runoff was 667 mm in 17 ha third-order catchment of K2-1, while the increase of runoff in 10 ha second-order catchment of K2-2 was 227 mm. Increased annual runoff amounts from 4 to 5 ha of the first-order catchments of K2-3 and K2-4 were 287 to 406 mm, respectively. Both quick (including peak flow) and delayed flows increased significantly in the third- and second-order catchments, while only delayed flow increased in the two first-order catchments. Because the amount of base flow in K2-1 was 2 to 3 times greater than that of K2-2 plus K2-3, bedrock groundwater inflow occurred on the channel from K2-2 to K2-1. The groundwater inflows affected the increases of delayed runoff and base flow components after thinning. On the other hand, monitoring locations with greater contribution of skid trail runoff of K2-2 had greater increases in the quick flow component.

For testing observation data using model condition, I applied Soil and Water Assessment Tool (SWAT) in Mie site for examining changes in runoff components under modeled and observed conditions. Modeling results showed that surface and subsurface interaction with respect to groundwater inflow affected the order of magnitude of treatment effects. Modeling results also showed that changes in base flow components strongly related to changes in soil water availability related to net-precipitation and evapotranspiration. Such modeling approaches can be applied for testing the various scenarios of thinning operations for changes in hydrological processes.

The findings of this study suggested that forest management by forest thinning is essential for water resources management in forested areas. This study showed the contributions of overland flow, road and skid trail runoffs, and bedrock groundwater flow for changes in runoff after the thinning. Increased annual runoffs with 227 to 667 mm after thinning were within the ranged of treatment effects of the previous studies. Increased runoff was specifically occurred during base flow period rather than storm period when soil surface disturbance was minimized. For the management practices, careful site preparation by forest operators and skid trail installations is necessary. Such practical guides of forest management should be developed for sustainable forest management, timber production, and water resource management in the steep terrain of headwater catchments.