Spatio-temporal streamflow generation under changing environment in a small forested headwater catchment

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論文題名　：Spatio-temporal streamflow generation under changing environment in a small forested headwater catchment
（環境変動下における源頭部森林小流域の時空間流出形成機構）

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論　文　内　容　の　要　旨

Headwaters contribute a substantial part of the flow in river networks. Clarification of the streamflow generation mechanism in headwater catchments is of great importance to water resource management. There have been many studies on streamflow generation mechanisms at the hillslope and catchment scales. However, there have been few studies focused on seasonality of the water yield and streamflow generation mechanisms.

Streamflow generation in headwater catchments can be altered by forest thinning by affecting evapotranspiration, soil infiltration capacity, and surface and subsurface flow paths. As the area of abandoned or non-managed plantation forest has increased in Japan, forest thinning which basically aimed to increase tree growth has emerged as a forest management tool to prevent environmental problems such as erosion and floods. However, findings regarding changes in event flow characteristics after thinning have been inconsistent, and the effect of forest management on streamflow generation mechanism in abandoned Japanese plantation forests should be clarified.

The overall objective of this study is to understand the spatio-temporal streamflow generation mechanisms in forested headwater catchment and address the implication of forest management on streamflow generation mechanism. The objective is further divided into two objectives: understand the relationship between the spatial distribution of water yield and the streamflow generation mechanism; understand the effects of thinning on rainfall-runoff characteristics. This research was conducted at Yayama Experimental Forest, a steep 2.98-ha headwater catchment covered with 46-year-old Cypress and Cedar tree plantation in western Japan.

The first objective is to understand the relationship between the spatial distribution of water yield and the streamflow generation mechanism. The spatio-temporal variation of streamflow generation processes in YEC was examined. The time when baseflow of the upstream section exceeded that of downstream coincided with the time when the riparian groundwater switched from downwelling to upwelling. This suggested that upwelling of the riparian groundwater increased considerably in the upstream section during the wet period, resulting a shift in the relative size of baseflow between the upstream and downstream sections. The timing of fluctuations among hillslope soil moisture, hillslope groundwater and streamflow revealed that the hillslope contributed to storm flow, but this contribution was limited to the wet period. Overall, these results suggested that streamflow generation has strong spatial variations, even in small, steep headwater catchments.

The second objective is to understand the effects of thinning on rainfall-runoff characteristics.

The changes in rainfall-runoff characteristics were examined in the year prior to and after intensive thinning of 50% in number in YEC. The magnitude of event peak flow, event quick flow, event water yield and event response time did not change after thinning. Because 70% of events had multiple flow peaks, the relationships between each flow peak and the rainfall just prior to that peak were also analyzed. The increase in accumulated quick flow, flow rise and flow drop was significant after thinning. The flow drop during the falling limb of each flow peak increased and led to a lower initial flow in the subsequent peak resulting in no increase in peak size. The flow peak in events with over 30 mm rainfall amount and over 2 mm/h average rainfall intensity showed significant increase in flow peak, flow rise, flow drop, and accumulated quickflow which suggested that the catchment exhibited more shallow flow paths during large rainfall amounts after thinning. No changes were revealed in event based analysis, but the changes in flow peaks were detected, which suggested the importance of examining all flow peaks when investigating the rainfall-runoff characteristics.

Overall, the spatial variation of streamflow generation in small steep headwater catchments is closely related to hillslope groundwater and subsurface flow dynamics, and during early post-thinning years, the YEC exhibited more shallow flow paths during large rainfall events after thinning, which may induce flood risk and soil erosion.