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Plot-scale study of surface runoff on well-covered forest floors under different canopy species

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ABSTRACT

To investigate the effects of vegetation canopy on surface runoff, four runoff plots (2 m × 1 m in size) were established under different types of forest canopies (S1: sawtooth oak and Japanese larch; S2: Chinese cork oak; S3: shrub; and S4: Korean pine) on a mountain slope in central Korea. Rainfall, throughfall, and surface runoff were measured from July 2007 to October 2009. During the observation period, there was no storm event with a rainfall intensity that exceeded the average value for infiltration rates at the runoff plots. Each plot showed differences in surface runoff generation (S1 > S2 ≒ S3 > S4). The plots with broad-leaf litter layers had higher maximum water storage capacities than the plot with a needle-leaf litter layer. These results imply that the water storage capacity and the leaf shape of the litter layer affected surface runoff generation. Moreover, under dry conditions (<20 mm of API_7), the rainfall threshold for all plots, except S4, required for surface runoff generation decreased and surface runoff from all plots increased slightly compared with relatively wet conditions (>20 mm of API_7). Storm runoff coefficients at all plots decreased drastically as the value of API_7 increased. This suggests that the lowering of the rainfall threshold for surface runoff generation and the resulting increase in surface runoff might be related to the development of hydrophobic conditions on the soil surface caused by dry conditions. Therefore, in addition to leaf shape and water storage capacity of the litter layer, the soil water condition also can be an important factor in plot-scale evaluations of surface runoff generation from a slope well covered with litter layer.

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1. Introduction

Studying stormflow generation and its hydrological flow pathways is important for understanding not only the hydrologic cycle and water resources in a forested area but also for developing land management practices related to the evaluation of soil erosion and the transportation of nutrients and contaminants (Sidle et al., 2007). Hortonian overland flow occurs rarely on forested hillslopes covered with a deep organic layer in the temperate region (Sidle et al., 2007); however, some studies have reported shallow preferential flow in the organic horizon perched on the mineral soil surface (e.g., McDonnell et al., 1991; Sidle et al., 1995; Noguchi et al., 1999; Kim et al., 2005; Sidle et al., 2007; Gomi et al., 2008). Sidle et al. (2007) termed this shallow preferential flow "biomat flow"; the term refers to stormwater movement through a near-surface layer on hillslopes; i.e., a type of lateral, preferential flow. At the catchment or hillslope scale, the amount of biomat flow and its effect on overland flow generation may be insignificant. However, biomat flow provides a buffer against Hortonian overland flow, promotes periodic deep percolation (Abraham et al., 1994; Sidle et al., 2007), and is significantly related to water routing and erosion implications (Sidle et al., 2007).

Although biomat flow in runoff plots may persist for only a short distance, less than 0.5 m (Noguchi et al., 1999; Sidle et al., 2001), it may affect surface runoff. Therefore, the flow pattern within the litter layer could be an important factor in surface runoff generation. The litter interception storage capacity increases with rainfall intensity (Sato et al., 2004; Guevara-Escobarl et al., 2007). Sato et al. (2004) also suggested that not only the litter mass but also the rainfall condition and leaf shape are important in evaluating the moisture dynamics in the litter layer. Their results showed that the broad-leaf litter of *Lithocarpus edulis* intercepted more rainwater than did the needle-leaf litter of

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Cryptomeria japonica, and rainwater moved laterally in the litter layer of *L. edulis*, whereas it moved directly down (vertically) in the litter layer of *C. japonica*. In addition, Guevara-Escobarl et al. (2007) suggested that the litter layer-soil matrix interface had little effect on drainage and storage. The hydrologic process of floor interception is similar to that of canopy interception (Putuhena and Cordery, 1996); therefore, it is possible that the water storage capacity and leaf shape of the litter layer could affect the amount and flow pattern of biomat flow.

Many studies have reported that a dry summer or drought can lead to the development of hydrophobic surface characteristics on the surface soil (e.g., Burch et al., 1989; Buttle and Turcotte, 1999; Doerr et al., 2000; Miyata et al., 2007; Gomi et al., 2008). The development of hydrophobic conditions on the surface soil affects the infiltration rate (Burch et al., 1989; Doerr et al., 2000) and can affect the occurrence of overland flow (Buttle and Turcotte, 1999; Miyata et al., 2007; Gomi et al., 2008). Furthermore, soil moisture is one of the most important factors affecting soil water repellency (Doerr et al., 2000). Although surface runoff generally can be produced to a greater extent under nearly/fully saturated soil conditions than under dry soil conditions, some previous studies have reported that surface runoff may be higher when soil moisture is relatively low (e.g., Buttle and Turcotte, 1999; Miyata et al., 2007; Gomi et al., 2008) than when it is relatively high (e.g., Sidle et al., 1995; Kim et al., 2005). The effects of soil moisture conditions on surface runoff generation are complicated and not yet fully understood (Doerr et al., 2000).

Research examining overland flow generation on forested hillslopes in temperate regions is still lacking. In particular, studies of the effects of slope conditions, such as a deep litter layer, are few. We hypothesized that surface runoff that included Hortonian overland flow and biomat flow would be generated on forested hillslopes covered with a deep litter layer. We also supposed that the litter layer under different vegetation communities may have different leaf shapes and various water storage capacities, and that these different characteristics affect surface runoff generation. In addition, we speculated that soil surface hydrophobicity caused by dry conditions can affect surface runoff generation. To examine these theories, we installed surface runoff plots on forested hillslopes under different vegetation types and measured the surface runoff.

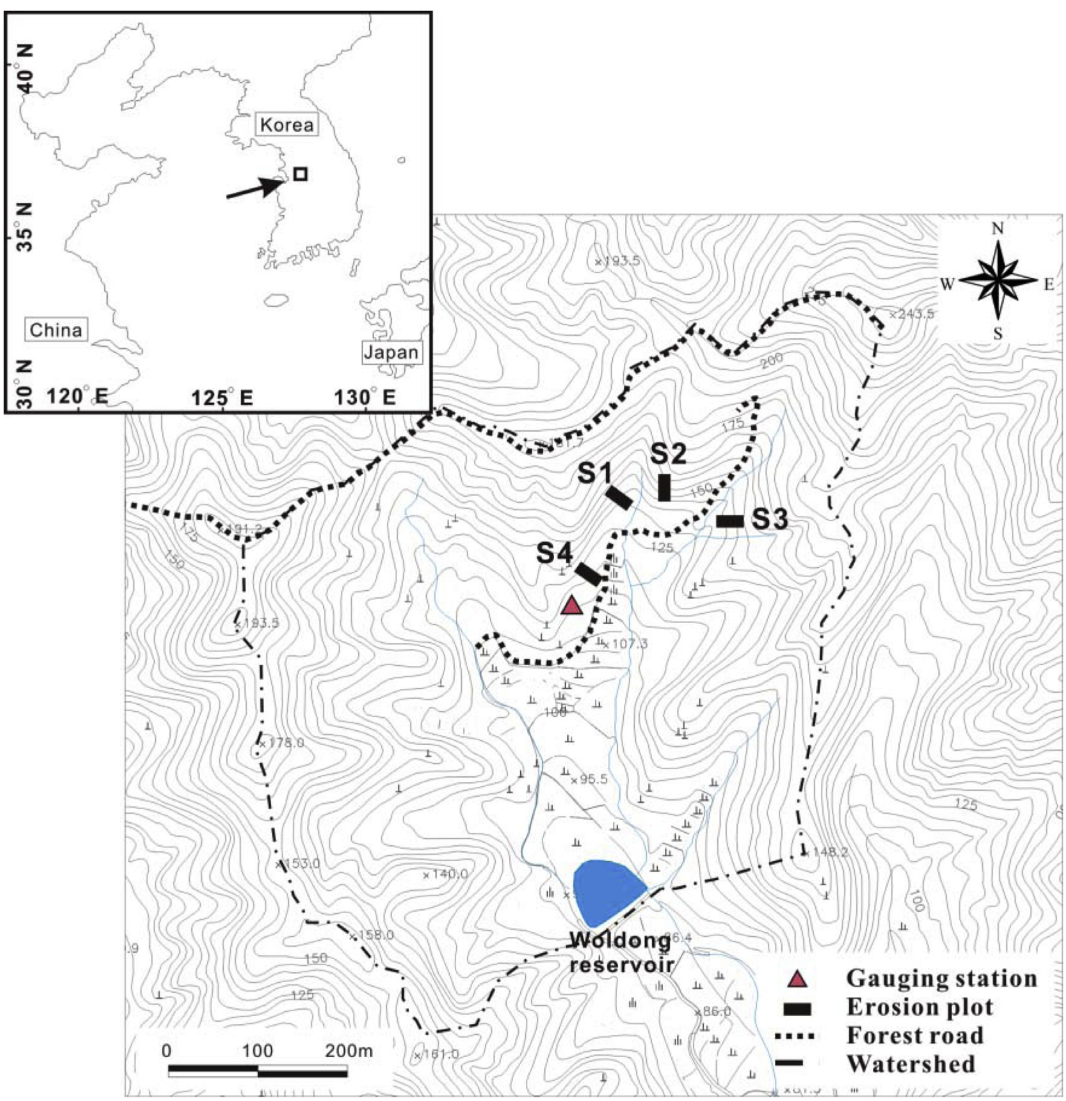

Fig. 1. Locations of the study area and runoff plots.

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