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The relationship between river runoff and soil moisture content in the Saromabetsu river basin, Hokkaido

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1. Introduction

The importance of macropores as preferential pathways of water, air and chemicals in the soil has been widely recognized (Beven and Germann, 1982; Lin et al., 2005; Jarvis, 2007). Soil moisture is also widely recognized as a key parameter in environmental processes, including meteorology, hydrology, agriculture and climate change. From a hydrologic point of view, soil moisture controls the partitioning of rainfall into runoff and infiltration and therefore has an important effect on the runoff behavior of catchments (Aubert et al., 2003). The Hokkaido island in the subarctic regions experiences both rainfall and snowmelt runoffs every year. The objective of this study is to clarify how infiltrated rainwater or snowmelt water behaves to produce river runoffs by soil moisture monitoring and runoff analyses. In this study, simulations are performed for both rainfall and snowfall runoffs by the tanks model (Sugawara, 1972).

2. Study area and methods

The Saromabetsu river basin in Hokkaido is located at latitude of 43°49 to 44°04N and longitude of 143°04 to 144°00 E (Fig. 1). The river basin has the area of 387.0 km^2 with the maximum elevation of 811 m a.s.l. (mean, 203.3 m a.s.l.) and the mean basin slope angle of 9.73°. The records by the AMeDAS at the Saroma town in 1980 - 2009 show the mean annual precipitation of 789 mm (583mm in summer of May – November and 206mm in winter of December – April) and the annual mean air temperature of 5.3° C (12.4 °C in summer and -4.6 °C in winter). The land cover of the river basin is composed of 73.0 % forest, 26 % agricultural land (mainly, grassland), 1.3 % urban area, and 1.1 % water surface. The basin geology is Cretaceous to Paleogenic marine sedimentary rocks. A continuous river stage recorder (hourly river depth) was installed at site E. A rating curve was established on the basis of successive measurements of discharge and gauge height taken at different stage during 2009. The hourly data of river stage at site E and weather conditions at sites S and H were supplied from the Abashiri District Public Works Management Office, Hokkaido. The river stage was converted to discharge by the established rating curve. Daily evapotranspiration rates were determined by the Penman-Monteith equation. Hourly data of volumetric water content (cm^3/cm^3) were obtained by soil moisture profilers, and *pF* values by tensiometers at forest, grassland and field on the basin slope.

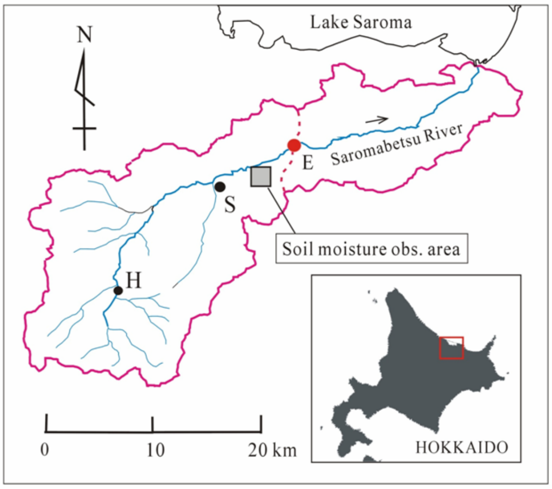

Fig. 1. Location of observation sites in the Saromabetsu river basin, Hokkaido. site E, gauging station of Saromabetsu River; site S, weather station; site H, rainfall station.

3. Result and discussion

Common to rainfall and snowmelt events, the whole layer (especially, 0-20 cm depth) in forest can store rainwater or meltwater a few days after events, and then return to the previous moisture level by gradual drainage. However, in grassland, the drainage after events is very weak except for the surface layer of 0-10 cm depth. Hence, in forest, a heavy rainfall during the gradual drainage could produce more drainage to generate larger river runoffs. At grassland, only the 0-10 cm layer may produce quick flow to the river channel. The tank model (Sugawara, 1972; Yue and Hashino, 2000; Chikita et al., 2007). was applied to the simulation of river runoffs, because many distributed models never gave satisfactory results for snowmelt runoffs. Here, three serial tanks were adopted corresponding to surface runoff, intermediate runoff and baseflow. Hydrographs in the summer of 2008 and the snowmelt season of 2009 were simulated by the tank model. The simulated results are very reasonable to the observed results with R^2 =0.934 and 0.973 and *RMSE*=0.902 and 0.961 m^3/s (Fig. 2 & 3). The surface runoff occupied 41% in 2008 and 34% in 2009 for total runoffs. We calculated total surface runoff and total throughflow at forest and grassland for each event in 2008 summer and 2009 spring (Fig. 5). It is evident that the two variables are close to the 1:1 relationship. The nearly 1:1 relationship between total surface runoff and throughflow indicates that the surface runoff may be produced by unsaturated throughflow in the surface soil layer.

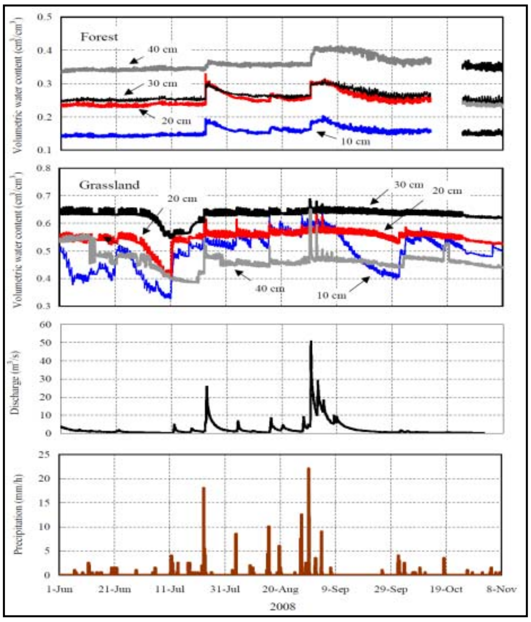

Fig.2. Temporal variations of volumetric water content from profilers at forest & grassland in the summer of 2008

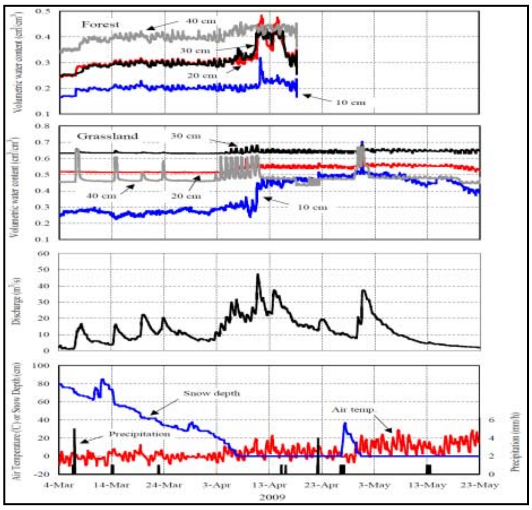

Fig.3. Temporal variations of volumetric water content from profilers at forest & grassland in the snowmelt season of 2009

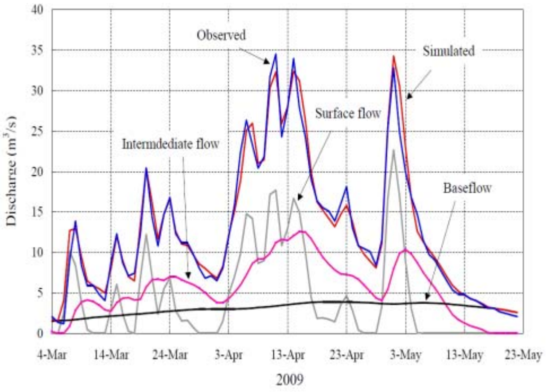

Fig. 4. Comparison between simulated and observed discharges and simulated flow components for snowmelt runoffs.

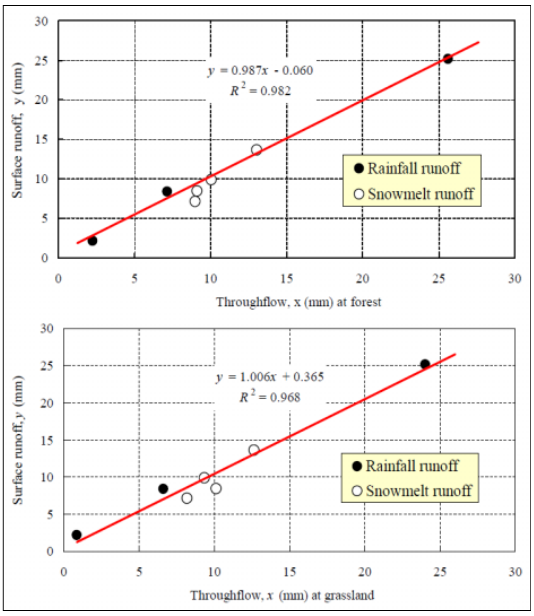

Fig.5. Relationship between total surface runoff and throughflow at forest (upper) and grassland (lower).