The groundwater and soil moisture response to rainfall at two hillslopes with different geological underlying and soil characteristics

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Introduction

Understanding the process of rainfall-runoff response in steep hillslopes and headwater catchments has improved greatly since the fundamental research of Hursh (1936). More newly researches in Japan coming from Kosugi et al. (2008), and others Japanese researches (Katsuyama et al., 2005; Onda et al., 2001; Uchida et al., 2003), showed the greatly importance the role of bedrock groundwater in central Japan.

However, the runoff generation processes in humid tropical forests are different from the ones in temperate regions. Soils in humid tropical forests are usually rich in clay content, deeply weathered, and have a soil depth for several meters (Verheye, 2009). This paper analyzed both groundwater and tensiometer data in the two hillslopes with different underlaying geological structures and soil properties. The objectives of this paper are (1) How the groundwater react to the rainfall? (2) How do the bedrock level and soil characteristics influence the groundwater fluctuation at the hillslope scale?

Data and Methodology

The study hillslopes are located in the Batanghari River basin (42,690 km2) in Jambi Province, Sumatra Island, Indonesia (Fig. 1(a)). This study focusses on two hillslopes with different geological structure land covers (Fig. 1(b) and (c)): a forested hillslope in Sekancing township (SK) and a 15-years-old palm plantation in Pulau Raman township (PR).

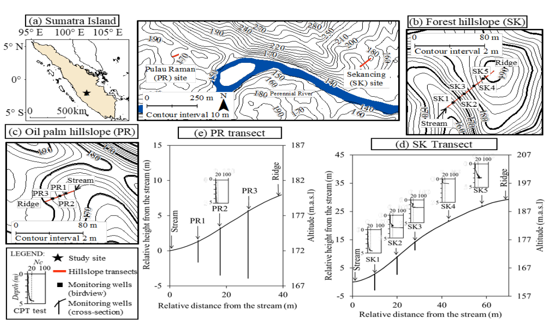

Fig.1 (a) Sumatra Island, (b) Location of the studied forest hillslope, (c) Location of the studied oil palm hillslope, (d) Cross-sectional views of the transect on forest hillslope, (e) Cross-sectional views of transect on oil palm hillslope.

The monitoring period presented here is from December 2019 to December 2020. The GW level was recorded every 10 minutes from the three observation boreholes (named SK1, SK2, and SK3) installed along the SK hillslope and PR hillslope (named PR1, PR2, and PR3) (Fig.1(d) and (e)). The pressure head was measured with tensiometers (Uizin) installed at 30, 60 and 90 cm. For simulating the GW responses of some scenarios, the RRI (Rainfall Runoff Inundation) model was employed.

Results

First, we investigated the vertical propagation of rainfall pulse based on the groundwater (GW) and tensiometric responses in SK and PR. We found that the dynamic changes of groundwater in SK and PR. Through this figure we can observed that the groundwater fluctuates more dynamically in SK and has smoother pattern in PR (Fig.2).

The RRI (Rainfall Runoff Inundation) model was employed to replicate the observed variation of groundwater fluctuation and analyzed the differences

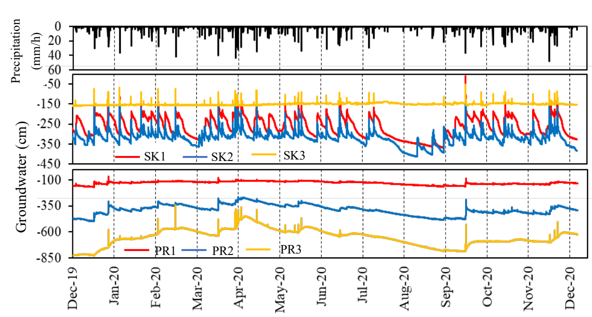

Fig.2 Groundwater level from observation data.

of GW response by switching some parameters of SK to PR and vice versa. Those parameters are hydraulic conductivity (Ks), soil water retention curve (SWRC), and depth of soil. By this way, we examined the contribution each parameter to the GW table.

The resulted showed that by changing the Ks in SK to the one obtained from PR which is nearly the half from the original, the groundwater was shallower and smaller in magnitude than control. SWRC of SK1 and PR3 has no significant differences in values. Therefore, by switching the parameter, we did not find the significant difference responses of the groundwater.

Through changing the soil depth in SK1 to be 8m, GW pattern was reached 7.5m and less in fluctuation. Distinctively, the GW of this case did not have spiky pattern as control, Ks, and SWRC cases had have. Finally, the last simulation was switching the soil depth of PR from 8m to 4m. The model showed the GW to be shallower and less fluctuated.

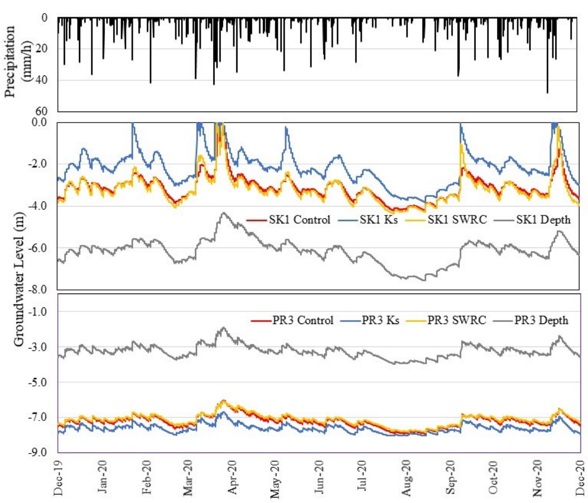

Fig.3 Groundwater level of some scenarios by RRI model.

Discussion and Conclusion

There were significant differences in the groundwater dynamics between the two adjacent hillslopes. However, these differences may not be directly related to the difference in land cover but likely due to difference in the soil depth and hillslope gradient as well as the antecedent soil moisture.

The RRI model successfully confirmed that observation founding. The hydraulic conductivity (Ks) and soil depth were parameters that made the GW pattern was change in both SK and PR hillslopes. Moreover, in SK1 switch depth case, the GW did not have spiky pattern as others have had. It seems the spiky was affected by the positioning itself, characteristics of hillslope, and lateral flow from the upstream.

One of the important findings in this study is that in the humid tropic region that have thick soil layers, the geological structure such as soil depth and hydraulic conductivity have an important role in the dynamic response of the groundwater.

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