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Seasonal controls of soil water content spatial pattern in a steep forested catchment: A modeling approach

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Characterizing soil volumetric water content (VWC) dynamics at different soil depth plays a key role in hydrological modeling and is essential for effective catchment management. However, our understanding of how critical zone structure (topography and soil) and rainfall affect VWC dynamics is limited. Therefore, the objective of this study was to investigate the effects of the hillslope structure and rainfall on VWC dynamics in a steep forested, zero-order catchment. VWC was measured from soil surface to soil-bedrock interface at five soil layers (0-8, 8-40, 40-70, 70-110, and 110-160 cm) for a complete water year, and covering various landscapes such as an ephemeral stream, riparian, and different hillslope positions. A total of 13 environmental indices, including eight DEM-derived terrain attributes and five soil attributes, were used to investigate the relationships between soil-terrain attributes and VWC. An all-possible-subsets regression model was adopted to construct the soil water content prediction model (SWPM). A geophysical method (ground penetrating radar, GPR) was used to investigate the soil depth to assist in the establishment of SWPM. The results demonstrate that the all-possible-subsets regression model performed well for predicting VWC. Additionally, the strength of the relationships between soil-terrain attributes and VWC could be different through time. For instance, the relationships between the topographic wetness index (TWI) and VWC were all significant ($P<0.05$) from August to October, whereas the correlation between TWI and VWC was not significant ($P\geq0.05$) at approximately 25% of measurement days from November to February. The results also show that the high correlation between terrain-related attributes and VWC usually occurs in the measurement days with high catchment storage state, whereas the high correlation between soil-related attributes and VWC more often occurs in the measurement days with low catchment storage state. Therefore, the control factors of VWC spatial organization vary from humid (controlled by topographic redistribution of water) to arid (controlled by vertical processes such as evapotranspiration) seasons.