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Controls on the likelihood and development time of soil moisture shortage during drought in Southwestern Germany

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Droughts, such as the recent event of 2018 that hit many regions of Europe, have a large impact on environment and society. These droughts are often characterized and studied as slowly developing creeping phenomena. However, a root zone soil moisture shortage potentially affecting plant growth and agricultural production can develop rather quickly, e.g., under dry conditions that favor high evapotranspiration or in shallow root zones with a low available soil water content. In this study, we investigate which variables (climate and soil properties) exert a control on the likelihood and development time of simulated soil moisture shortage during drought across Baden-Württemberg (Southwestern Germany). First, the TRAIN model was used to simulate root zone soil moisture for a 1 km resolution grid over Baden-Württemberg. For major drought years (e.g., 2003 & 2018), soil moisture time series of each agricultural grid cell across the region were characterized according to 1) whether or not a soil moisture shortage was reached that year (here, defined as a level <30% of the available soil water content), and 2) the time it took to drop from field capacity to a soil moisture shortage. Finally, (logistic) regression analyses were applied to identify the dominant controls on the likelihood and development time of soil moisture shortage. Results show that the majority of the agricultural grid cells across the study region reach soil moisture shortage in major drought years such as 2018. The development time of soil moisture shortage varied substantially. The dominant control on the likelihood and development time of soil moisture shortage was found to be the available water content of the root zone, i.e. a higher likelihood and faster development for shallow root zones with a low available water content. The evapotranspiration- and precipitation- rate alone during the development of soil moisture shortage were only weakly related to the development time. However, these meteorological variables are of added explanatory value for the development time when considered in combination with the available water content of the soil. Overall, these results give insight in the variability and controls on the likelihood and development time of root zone soil moisture shortage during drought, which is important information for monitoring and early warning of the soil moisture drought hazard.