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Process-based crop water availability and the role of soil hydraulic properties in crop water use efficiency

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The need for improvements in the water use efficiency by agricultural ecosystems requires a holistic assessment of the hydraulic functioning of cropped soils, taking into consideration the most relevant interactions and feedbacks that control the soil water budget. Despite that, crop available water is most commonly calculated using a static value of pressure head for field capacity and wilting point. This conflicts with the physics of water movement in the soil-plant-atmosphere system. To advance on the issue of available water, we implemented a mechanistic approach to isolate the effects of soil hydraulic properties (K-Theta-h) of layered soils on water balance components and land and water productivity, adopting comprehensive scenarios of soil water availability and requirements. Agro-hydrological simulations were performed using the SWAP model integrated with the WOFOST crop growth module. The simulated scenarios included the rainfed crop growth of maize and soybean in three climate zones, evaluating the present-day climate scenario as well as two future scenarios, a wetter and a and drier one, totalling 108 scenarios simulated for 30 years each. Simulations were performed for six soils for which (K-Theta-h) relationships were obtained by inverse modelling of evaporation experiments for the full range of soil water contents commonly found in the domain of crop available water. The determined soil hydraulic parameters could be employed to calculate crop available water using the traditional method based on fixed pressure heads for field capacity and wilting point, as well as by a multi-layer process-based approach of crop water availability. The process-based approach allows incorporating important system characteristics (atmospheric demand and crop properties) and soil hydraulic properties in a transparent way, contrarily to the traditional method. The agro-hydrological simulations showed that the hydraulic response of soils is determined by climate zones and crop water requirements. While land productivities increased under the wetter climate scenario, water productivity was consistently reduced by both future climate scenarios.