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Validation and sensitivity analyses of a soil temperature and moisture model under pedoclimatic conditions of southern Quebec (Canada)

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Soil moisture and temperature conditions play an important role in plant growth and development. Modelling soil moisture and temperature could allow predicting yield and outbreaks of pest insects, diseases, asphyxia, and drought risks. In this study, the Soil Temperature and Moisture Model (STM^2), developed by USDA, was used to generate soil moisture and temperature predictions at different depths: 15, 30, 45, and 60 cm for moisture and 10 cm for temperature. This model has two kinds of inputs: 1) soil properties (soil texture and organic matter content) and 2) daily weather data (total rainfall, minimum and maximum air temperatures). During the 2008 and 2010 growing seasons (mid-May to mid-October), soil moisture and temperature measurements were obtained from three pedoclimatic stations equipped with EC-10 soil moisture probes and HOBO soil temperature probes. Those measurements have been used as references to validate the STM^2 predictions. These pedoclimatic stations were located in three corn fields of southern Quebec (Canada) representing the soil surface texture diversity observed in this agricultural area: loamy sand (LS), sandy loam (SL) and silty clay (SiC). For each pedoclimatic station, a soil profile was sampled and analyzed to measure soil texture (coarse fragments ($>$2 mm), sand, silt and clay percentages), organic matter content, bulk density, saturated hydraulic conductivity (Ksat), soil moisture content at different tensions (permanent wilting point at 1500 kPa, field capacity at 33 kPa, and saturation at 0 kPa). Weather data were collected at Environment Canada weather stations located in the vicinity of corn fields. Relative sensitivity analyses were conducted on the STM^2 pedotransfer functions (PTF) in order to determine which soil properties has the greatest impact on soil moisture and temperature predictions. The model performance was evaluated using the modelling index d and two error measurements (RMSE = Root Mean Square Error and Bias) computed for the global growing season and at three corn growth periods: 1) seeding to emergence, 2) emergence to flowering and 3) flowering to senescence. The global performance of soil temperature predictions was better than soil moisture predictions. The estimation quality decreases with increasing depth and is higher during the first and third growth periods. Daily predictions were better than hourly predictions for soil moisture but they were mostly the same for soil temperature. Good performances were observed for LS and SiC. The model performance was slightly lower for the SL soil. The PTF used in the STM^2 were mostly satisfactory. However, the PTF used for estimating Ksat showed lower performance. Nevertheless, the STM^2 sensitivity analyses revealed that Ksat plays a marginal role in soil moisture and temperature predictions. In fact, the STM^2 is more sensitive to bulk density. The PTF sensitivity analyses demonstrated that permanent wilting point was more affected by clay percentage, field capacity by clay and sand percentages, saturated hydraulic conductivity by clay and silt percentages, and bulk density by organic matter and clay percentages. Therefore, this preliminary study shows that the STM^2 model could be used in combination with soil and climatic data sets for reliably predicting soil moisture and temperature variations in southern Quebec (Canada).