

Delimiting the validity domain of a crop model with uncertainty analysis: the case of a vineyard model with a run-off module

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Introduction

Many crop models, for instance APSIM, Aquacrop, CropSyst, DSSAT, EPIC, use a run-off module based on the “curve number (CN) method” as described in the USDA National Engineering Handbook. This method is easy to integrate into daily-time step crop models but lacks precision as it only considers daily rainfall intensity and empirically adapts the rainfall run-off ratio to soil surface conditions (Young and Carleton, 2006). This lack of precision can be a major concern when simulating crops having a significant bare soil proportion (as vineyards or orchards) under stormy rainfall regimes, as in Mediterranean climate. This uncertainty source may also be present with future climatic conditions characterized by more frequent stormy rainfall events. In this work, we introduce a simple method to detect when the uncertainty coming from the CN method propagates significantly in a model output. This procedure is applied to a vineyard crop model and allows the identification of model parameter values leading to high (or low) uncertainty.

Materials and Methods

Our case study is a vineyard water balance model (Gaudin et al., 2010) used for estimating the dynamics of vineyards water stress. The model performs a water balance with a single tipping bucket approach and includes a CN run-off module. The main model output is the fraction of transpirable soil water (FTSW), which is deduced from the soil humidity using the total transpirable soil water parameter (TTSW). Our procedure to detect the uncertainty is based on the random variable interpretation of the CN parameter, which states that only the range of the CN parameter, [CNI, CNIII], is reliable and that for each separate rainfall event, the correct CN value is a random variable within this range. This hypothesis has been used in (Young and Carleton, 2006) to build a run-off stochastic model. Our approach consists in extracting the reliable range of CN values in order to build the uncertainty range on the model output. This method only needs two simulations: one with CN=CNI, one with CN=CNIII (both for all rainfall events). The method requires that the model is monotonic with respect to the CN values, which is verified with the vineyard model. We also performed a numerical experiment on a climatic sequence of 42 years (Montpellier, France) in order to analyze the response of the FTSW uncertainty when soil parameters (TTSW and CN) vary. For each 42-year long simulation, we counted how many years the uncertainty in FTSW, measured with the mean uncertainty over the vineyard season (april-october),

is greater than a threshold (we took 0.2, which is the order of magnitude of this vineyard model error (Roux et al, 2014)).

Results and Discussion

The propagation of uncertainty using our procedure can be seen on the right side of Figure 1. The uncertainty propagates differently depending on the parameter setting and has a complex dynamic structure. However, the detection of uncertainty in the parameter space using the long climatic sequence reveals that the region with low CN (high infiltration) and low TTSW (small water stock) has a low occurrence of uncertainty (point B), while the region with high CN (low infiltration) and high TTSW (big water stock) appears very sensitive to run-off uncertainty (point A). The run-off uncertainty model, as every model, has some limits, such as the empirical determination of CN_I and CN_{III} from the central CN value, but the strong tendency shown in the parameter space can be used to apply the model more safely. These results apply mainly when using the model on pluri-annual climatic sequences. They should be completed by uncertainty evaluations when the water stock at vineyard budburst is known.

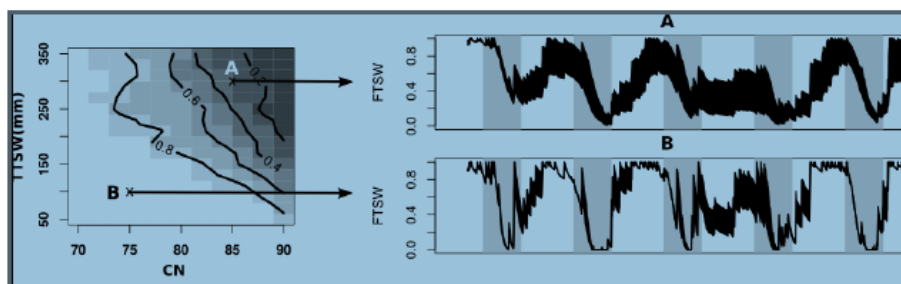


Figure 1. illustration of the propagated uncertainty in the parameter space (parameter CN and TTSW) on the left with two examples on the right side of detailed uncertainty curves plotted over the first 5 years. Gray levels on the left part represent the reliability index of the model output, with low reliability for darker areas.

Conclusions

We have proposed a method to detect the uncertainty associated with the use of the curve number method in crop models. The method allows detecting situations where the uncertainty level may be high. This information may be useful for model users and model developers for instance to guide model improvement in coherence with model use.

References

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