Assessing the Uncertainty when Using a Model to Compare Irrigation Strategies

Daniel Wallach, Nathalie Keussayan, François Brun,*
Bernard Lacroix, and Jacques-Eric Bergez

ABSTRACT

A major use of crop models is to evaluate management strategies. An important question is how accurate models are for such evaluations. The purpose of this study was to determine how to use a combined crop and decision model to evaluate irrigation strategies for corn (maize, Zea mays L.) and to estimate the uncertainty in the criteria used for evaluation. The uncertainty estimation has three steps. First, the sources of uncertainty are identified. We considered uncertainty in the model parameters and model residual error. Second, the uncertainty in each source is quantified. We used a Bayesian approach to obtain a posterior distribution of the model parameters and variances of residual error. Finally, the uncertainties are propagated through to the quantities of interest. In this case, we included calculations for observed quantities—these posterior predictive checks allowed us to verify that our uncertainty estimates were reliable—and predictions of the criteria used to evaluate the irrigation strategies. We considered several criteria including multiyear average yield and interannual yield variability. The uncertainty in average yield was quite small (standard deviation of about 0.2 Mg/ha). This is due to the fact that much of the error in yield prediction cancels out when looking at average yield. Three major conclusions are that this model can be a powerful tool for evaluating irrigation strategies, that prediction of average yield can have much less uncertainty than prediction of yearly yield, and that it is essential to verify the reliability of uncertainty estimates using data.

A n important objective in crop modeling is to use models to evaluate and compare management strategies (Boote et al., 1996, 2010; Stephens and Middleton, 2002; Bergez et al., 2010). Experimental comparisons are, of course, essential but are necessarily limited to a relatively small number of locations, years, and management practices. Models make it possible to generalize the experimental results to new conditions and also to compare strategies other than those tested experimentally. The specific aspect of crop management of interest in this study was irrigation management. Several studies have used models to explore the consequences of different irrigation strategies (Baumhardt et al., 2009; Garcia-Vila et al., 2009). Bergez et al. (2001) proposed a simulation tool specifically adapted for evaluating irrigation strategies. The power of crop models as a generalization tool comes, however, with an important drawback: the model is only an approximation of reality and so there is uncertainty in the results calculated using a model. An essential question then is the extent of this uncertainty and, as a result, the usefulness of a model for determining management strategy. Evett and Tolk (2009) specifically posed the question of whether crop models are sufficiently accurate to aid in deciding irrigation practices.

The common procedure for dealing with model error is to first do a general evaluation of the model, which involves comparing the model calculations with experimental data. If the model is deemed sufficiently accurate, it is then used to evaluate various management strategies (for example, Garcia-Vila et al., 2009). Common criteria for comparing calculated and observed values are the mean square error (MSE) and modeling efficiency (EF). This approach is not fully satisfactory. First of all, it furnishes an estimate of the quality of the model averaged across the population represented by the data. When we use a model to evaluate strategies, however, we want the quality of predictions for those specific strategies. Second, it would be more informative to have a full probability distribution of uncertainty for each calculated quantity rather than an average error. Third, we may be interested in various criteria for evaluating a strategy other than the criteria related to the quality of prediction year by year. For example, an important criterion for judging irrigation strategies could be yield averaged across years, so we would want to evaluate the uncertainty in predicting that criterion.

This suggests that it would be useful to do a detailed uncertainty analysis. In such a study, the sources of uncertainty are identified and quantified, and then how those uncertainties translate into uncertainties in the predictions of interest is evaluated (de Rocquigny et al., 2008). The result is an indicator of uncertainty (for example, a probability distribution) for each specific prediction.

The purpose of this study was to develop a methodology for applying uncertainty analysis to a comparison of irrigation strategies for corn. We illustrate using a crop model coupled with algorithms that translate irrigation strategies into...