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Mini Review on Global Solar Radiation and the Ratio In between Crop Models

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Abstract

The review was conducted at the eight individual sites in Austria and the Czech Republic where measured daily RG values were available as a reference, with seven methods for RG estimation being tested, and ii) for the agricultural areas using daily data from 52 weather stations, with five RG estimation methods. In the latter case the RG values estimated from the hours of sunshine using the angstrom - Prescott formula were used as the standard method because of the lack of measured RG data. At the site level we found that even the use of methods based on hours of sunshine, which showed the lowest bias in RG estimates, led to a significant distortion of the key crop model outputs. When the angstrom-Prescott method was used to estimate RG, for example, deviations greater than 10 per cent in winter wheat and spring barley yields were noted in 5 to 6 per cent of cases. The precision of the yield estimates and other crop model outputs was lower when RG estimates based on the diurnal temperature range and cloud cover were used. The methods for estimating RG from the diurnal temperature range produced a wheat yield bias of more than 25 per cent in 12 to 16 per cent of the seasons. Such uncertainty in the crop model outputs makes the reliability of any seasonal yield forecasts or climate change impact assessments questionable if they are based on this type of data. The spatial assessment of the RG data uncertainty propagation over the winter wheat yields also revealed significant differences within the study area. We found that RG estimates based on diurnal temperature range or its combination with daily total precipitation produced a bias of to 30 per cent in the mean winter wheat grain yields in some regions compared with simulations in which RG values had been estimated using the angstrom -Prescott formula

Keywords: Yield forecasts, Climate change, Crop model

Introduction

In the field of crop yield forecasting [1] or as a climate change impact assessment tool [2-3] in such applications lack of long-term daily weather data and especially data on global solar radiation (RG) has often been a significant challenge, since RG is an indispensable input variable for the majority of these models that simulate crop growth, because photosynthesis itself is primarily driven by solar radiation. Moreover, global solar radiation is a key input variable for methods used at present for potential and actual evapotranspiration estimation, which is an essential part of water balance subroutines in almost all crop models. Other types of mathematical models for crop growth and development apart from the process-oriented methods rely frequently on RG as one of the key independent variables [4] and their outputs might be clearly affected by any RG bias. It has been noted many times [5] that continuous records of global solar radiation measurements are spatially scarce and that the ratio between the number of stations observing daily RG and those measuring temperature and precipitation is highly variable from less than 1:10. The spatial density of weather stations providing complete climatic data sets for crop model inputs is therefore inadequate and the missing RG data have to be substituted. Missing daily radiation data at a given site can either be substituted by data measured at a nearby station, estimated by remote sensing techniques Stochastically generated data may be useful for exploring possible model scenarios for an average theoretical situation using long-term simulations, but they cannot be used for model validation and simulation analysis during a particular period of time [6]. It should also be remembered that the weather generator use would require a time series of observed data (several years at least) in order to set statistical parameters for a particular site. Widespread application of the other two mentioned methods, i.e. linear interpolation and use of neural network analysis in crop growth modeling, is limited for the same reasons as in the weather generator approach and in some cases yield worse results than empirical models [7]. Despite dramatic developments in remote sensing techniques that have made vast databases of RG data available on an unprecedented scale to users, empirical models estimating RG from commonly measured meteorological variables remain an important tool in many agro meteorological applications. Numerous formulas have been made available in previous decades, which might make selection of the most appropriate method for a particular purpose and site. Some of these methods have already been incorporated into crop models as an integral part of the software package, like in case of STICS or SWAP models. Others are developed as standalone applications for use in crop model studies in order to facilitate the preparation of the necessary weather data. All of this poses a problem for some crop model applications (e.g. crop growth monitoring) requiring input parameters to be available in near real time. The second part of the study is thus focused on testing the uncertainty in regional crop model outputs assuming two likely scenarios assuming availability of 1daily extreme temperatures and total precipitation data and 2 only daily extreme temperatures [8-9]. The methods based on cloud cover were not considered in this part of the study as these data were not available in our database for a sufficient number of stations and because with the increasing number of automated weather stations this parameter is not measured. The overall objective was to quantify the uncertainty arising from the use of various RG methods and to compare it with the results found at the local level.

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Result and Discussion

We found that the results varied greatly with the soil type and that the majority of the tested RG methods produced statistically significant differences compared with the control runs. As expected, performed best of all methods and the crop model outputs in most cases did not significantly differ from the simulations based on the observed RG. We found that the differences in crop model outputs caused by the RG were more pronounced in fluvisol [10]. The low sensitivity of sandy chernozem can be explained by the much higher crop water stress on this particular soil that was noted during most of the 97 simulated seasons. As soon as water stress becomes the dominant limiting factor, it suppresses growth processes and decreases the overall effect of differences in RG values [11-13].

Conclusion

Therefore a detailed site analysis of the error propagation was made first using two crop models, namely CERES-Barley and CERES-Wheat. We found that even the method yielding the lowest bias in RG estimates influences a number of key crop model outputs. The precision of the yield estimates and other crop model outputs is lower but still acceptable when estimates based on the diurnal temperature range and cloud cover are used. Methods based on the diurnal temperature range and total precipitation yielded better model estimates than those based on temperature extremes, but there was a systematic bias in the spring barley and winter wheat yields and the considerable increase in seasons with yield departure of more than 25 percent.

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Conflict of Interest

None.

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