Uncertainty in the Global Solar Radiation Data, its Propagation in Crop Models and Consequences for the Spatial Analysis

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DETAILS AVAILABLE: www.ufa.cas.cz/dub/crop/crop.htm

INTRODUCTION

*The effect of uncertainty in estimated **global solar radiation (R_G)** data on the dynamic crop model outputs has not been fully researched. It has been often reasoned in literature that the overall effect of a biases in R_G data will cancel each other over the growing season and thus could be neglected owing to uncertainties in other parameters. This claim is based on an assumption that the biases are normally distributed with a mean of zero. However as some authors noted the error in the R_G data are unlikely to cancel as simply because of non-linearity in the crop model response and also because the mean biases of the substitute R_G data are frequently different from zero. Most of the studies dealing with the crop model sensitivity to the R_G evaluated only the effect of the constant deviation in the R_G values during the growing season. The purpose of this study was to explore uncertainties in the crop model outputs introduced by methods for R_G estimates and provide potential users of these methods with detailed knowledge of the behavior of each equation under specific circumstances In the same time the study was intended as an indirect evaluation of R_G method performance via application in the crop models over the area of Central Europe north of Alps.*

AIMS

- *To assess the crop model outputs sensitivity to seven widely used methods of R_G estimation using detailed crop models CERES-Barley & CERES-Wheat at 8 sites with high quality weather data;*
- *To evaluate the R_G error propagation in the spatialized yield estimates using WOFOST crop model;*
- *To estimate effect of R_G uncertainty over regional yield estimates*

EXPERIMENTAL DATA-*site specific analysis*

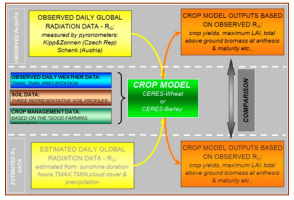
EXPERIMENTAL DATA:

STATION	ALTITUDE (m)	Annual mean temp. (°C)	Annual precip (mm)	Number of years with data
Grounden	426	9.9	1261	12
Graz	340	10.8	822	12
Gross-Enzersdorf	153	10.7	548	8
Hradec Králové	285	8.5	612	17
Kocelovice	519	7.5	591	15
Kuchařovice	354	8.5	484	16
Langenlois	210	10.1	473	8
Ostrava-Poruba	242	8.3	721	11

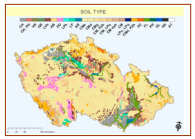
CERES model settings:
3 soil types (light, medium, heavy
crops (winter wheat, spring barley)

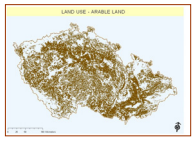
Reference method: *measured R_G values*

Examined methods for estimating R_G	***/ inputs***
Angström-Prescott	*/ sunshine duration hours*
Klabzuba et al.	*/ sunshine duration hours*
Suppit and van Kappel	*/ cloud cover, TMAX & TMIN*
Thornton and Running	*/ TMAX, TMIN & Precipitation*
Winslow et al.	*/ TMAX, TMIN & Precipitation*
Donatelli and Campbell	*/ TMAX & TMIN*
Hargreaves et al.	*/ TMAX & TMIN*



EXPERIMENTAL DATA-*spatial analysis*

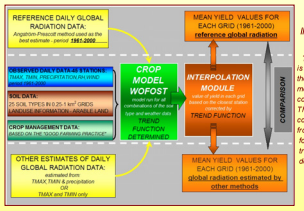




Reference method: *Angström-Prescott – the best possible estimate (R_G data in the Czech Republic measured data only at 11 sites!!)*

Examined methods for estimating R_G	***/ inputs***
Thornton and Running	*/ TMAX, TMIN & Precipitation*
Winslow et al.	*/ TMAX, TMIN & Precipitation*
Donatelli and Campbell	*/ TMAX & TMIN*
Hargreaves et al.	*/ TMAX & TMIN*

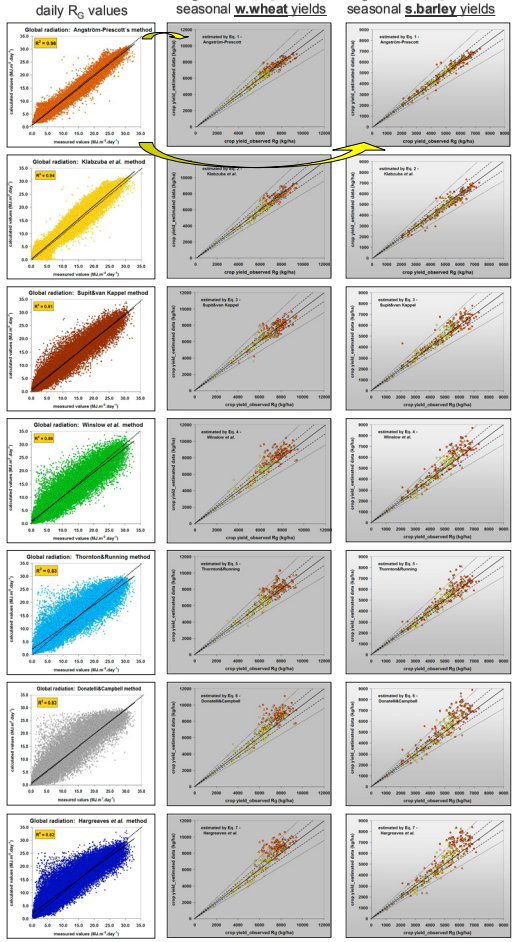
WOFOST model settings:
25 soil types (soil physics based on 1074 soil pits)
winter wheat – parameters based on detailed calibration (10 stations)

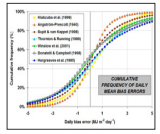


INTERPOLATION MODULE
The interpolation module is used to derive trend of the model parameter (e.g. mean yield) based on the coordinates and altitude. The trend is then used to correct model parameter from the nearest station for each grid. Separates trend equations are derived for each soil type.

RESULTS-*site specific analysis*

measured vs. estimated daily R_G values | R_G error propagation in seasonal **w.wheat** yields | R_G error propagation in seasonal **s.barley** yields





● Chernozem ◆ Sandy Chernozem
▲ Fluvisol — line 1:1
- - deviation +/-10% ···· deviation +/- 25%

METHOD RANKING:

MEASURED vs. ESTIMATED R_G	*ERROR PROPAGATION IN THE: winter wheat yields*	*ERROR PROPAGATION IN THE: spring barley yields*	*R_G PREDICTORS*
1) Angström-Prescott	*1) Angström-Prescott*	*1) Angström-Prescott*	*sunshine duration*
2) Klabzuba et al.	*2) Klabzuba et al.*	*2) Klabzuba et al.*	*sunshine duration*
3) Suppit&van Kappel	*3) Suppit&van Kappel*	*3) Suppit&van Kappel*	*TMAX, TMIN, cloudiness*
4) Winslow et al.	*4) Thorton&Running*	*4) Thorton&Running*	*TMAX, TMIN, rainfall*
5) Thorton&Running	*5) Winslow et al.*	*5) Winslow et al.*	*TMAX, TMIN, rainfall*
6) Donatelli&Campbell	*6) Donatelli&Campbell*	*6) Donatelli&Campbell*	*TMAX, TMIN*
7) Hargreaves et al.	*7) Hargreaves et al.*	*7) Hargreaves et al.*	*TMAX, TMIN*

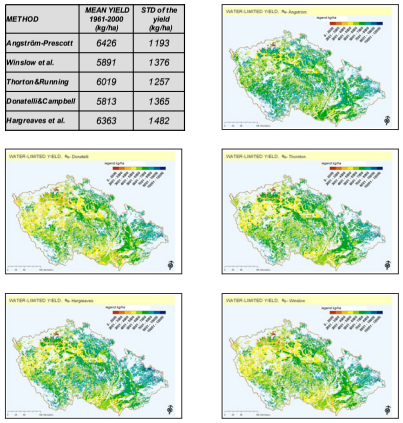
No calibration of the methods was attempted and all empirical coefficients were derived from previously published studies.

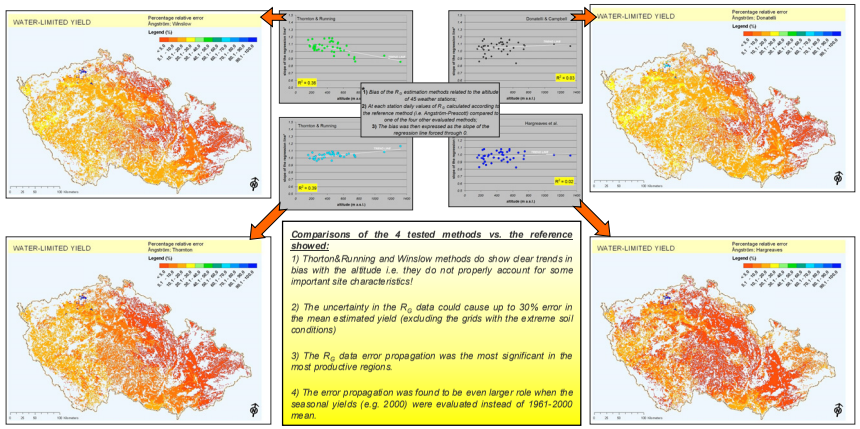
RESULTS-*spatial analysis*

- *The spatial analysis was based on the comparison of 4 methods used for the daily R_G data estimates with results of the Angström-Prescott method considered as the reference method.*
- *The overall mean yield (as average of all arable soil grids) calculated with the Angström-Prescott R_G data was 6426 kg/ha, which corresponds well with the statistical data of winter wheat yields (Czech statistical office: 1990-2000).*
- *Most of the arable soil has the water-limited production potential within 4-8 tons/ha. The lowest yielding patches are concentrated into the soil polygons with rather extreme soil conditions (usually used for fodder production).*
- *WOFOST model in general overestimates the importance of the water stress over other important environmental qualities and consequently it indicates unrealistically high yields at altitudes above 500 m.*
- *There is significant difference between mean yields simulated with R_G data derived by other methods. Surprisingly the least reliable method in the site analysis i.e. Hargreaves et al. showed the closest match to the reference method!!!*

Ranking of the methods according to spatial analysis results:
1) Hargreaves et al., 2) Thornton&Running; 3)Donatelli & Campbell; 4) Winslow et al.

METHOD	*MEAN YIELD 1961-2000 (kg/ha)*	*STD of the yield (kg/ha)*
Angström-Prescott	*6426*	*1193*
Winslow et al.	*5891*	*1376*
Thorton&Running	*6019*	*1257*
Donatelli&Campbell	*5813*	*1365*
Hargreaves et al.	*6363*	*1482*





Comparisons of the 4 tested methods vs. the reference showed:

1) Thorton&Running and Winslow methods do show clear trends in bias with the altitude i.e. they do not properly account for some important site characteristics!

2) The uncertainty in the R_G data could cause up to 30% error in the mean estimated yield (excluding the grids with the extreme soil conditions)

3) The R_G data error propagation was the most significant in the most productive regions.

4) The error propagation was found to be even larger role when the seasonal yields (e.g. 2000) were evaluated instead of 1961-2000 mean.

CONCLUSIONS

- *The best out of the tested R_G estimation methods for site specific crop modelling are those based on the sunshine duration hours. The least reliable methods are those based on the diurnal temperature range only.*
- *Even the most precise methods of R_G estimate considered in our study do lead to the significantly different crop model outputs than those obtained with the R_G observed data.*
- *The final results of the error propagation are in some cases extremely difficult to predict due to varying influence of other parameters (e.g. other weather variables, soil properties or crop management).*
- *The best performing methods for estimating R_G at the individual sites do not necessarily perform satisfactorily in the spatialized studies – ESPECIALLY IF ANY SPATIALLY DEPENDEND TRENDS IN THE METHOD BIAS DO EXIST.*
- *Due to the existence of the trend in biases of Thornton&Running and Winslow et al. methods, the crop model outputs based on these data showed much poorer results than the estimates based on Donatelli&Campbell and Hargreaves et al. methods.*
- *Errors in the long-term mean yield predictions arising from imperfect R_G data could be substantial and can be higher than 30% under specific circumstances. The possible effect of R_G error propagation is even higher when seasonal yields are considered.* (All conclusions are valid for the tested WOFOST model at the conditions of the Czech Republic).
- ***Neither of the tested methods of R_G estimate could be considered fully suitable for spatial assessment of crop yield under the conditions of the Central Europe!***