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SENSITIVITY ANALYSIS OF AQUACROP EVAPOTRANSPIRATION TO WEATHER STATION DISTANCE

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ABSTRACT

Water balance calculation is essential for reliable agricultural management, and the actual evapotranspiration (ET) is the most complicated balance term to estimate. In agriculture, the most common method used is based on Penman-Monteith reference evaporation is determined from weather conditions for an unstressed grass cover, further multiplied by crop specific and soil water availability coefficients to obtain the actual evapotranspiration. This approach is also used in the AquaCrop model. This model has proven to be accurate when all weather data are locally available. However, in many cases, weather data can't be collected on the site due to the limited number of stations and the vast region covered by each of them. Instead, data are often collected at many kilometers from the study site. The question we want to study is: how does evapotranspiration accuracy evolves with respect to weather station distance? A winter wheat plot in Lonzée (Belgium) was studied during the 2014-2015 agricultural seasons. Actual evapotranspiration was simulated with AquaCrop thanks to the weather data collected at 3 different distances from the study site: on the site (data collected by a fluxnet station), 20 km, 50 km and 70km from the site. The non-on-site weather data were derived from spatially interpolated 10 km grid data. These results were then compared to the fluxnet station evapotranspiration measurements to assess the impact of the weather station distance. Substantial differences, which were found between the four cases, evoking the importance of assimilating satellite derived ET products (e.g. MSG) into AquaCrop.

Keywords: *agrometeorology, evapotranspiration, AquaCrop, weather data.*

INTRODUCTION

Agriculture production relies greatly on the timing and volume of water fluxes across the soil, plant and atmosphere domains. These fluxes are strongly related to the spatio-temporal patterns of evapotranspiration (ET). Therefore, evapotranspiration estimation is crucial for efficient agricultural production

monitoring and water resources management. For example, it allows the detection of early drought and the estimation of crop yield (Penman 1948;Allen et al. 1998). But evapotranspiration is the most difficult term to estimate. In agriculture, the method described by FAO (Allen et al. 1998) is the most commonly used: the Penman-Monteith method (Monteith 1965) is applied to an unstressed grass cover, and multiplied by two coefficients to reflect the specific behavior of the particular crop and soil water availability. Based on this model, the FAO developed a software named AquaCrop (Steduto et al. 2012).
If accurate weather variables, crop-specific coefficients and soil conditions needed are not available, this method can lead to errors up to 20% of the actual value (Paço et al. 2006). This inaccuracy leads agricultural managers (particularly in irrigated area) to use large safety factors. The consequences can be large: a waste of up to hundreds of millions of m³ of water per year in big irrigated perimeters in arid regions experiencing food insecurity. (www.FAO.org 2016)
Indeed, in most cases, crop evapotranspiration is calculated with weather data from the nearest weather station that can be situated at several kilometers from the crop. In this study, we want to explore on a test case the evolution of the evapotranspiration accuracy with the distance of the data source used as forcing.

MATERIALS AND METHODS

To achieve the targets set, we predict ET through the combination of models (AquaCrop and B-CGMS weather data), and control the results with in-situ measurements (Fluxnet tower)

Fluxnet station:

FLUXNET is a network of micrometeorological tower sites. The flux tower sites provide local weather data and use eddy covariance methods to measure the exchanges of carbon dioxide (CO_2), water vapor, and energy between terrestrial ecosystems and the atmosphere.
Indeed, ET fluxes can be retrieve directly from water vapor measurement or calculated by energy budget from the heat flux measurement (www.fluxnet.ornl.gov 2016). For this work, we calculated ET from energy budget. It is important to note that the lack in energy balance closure with the eddy covariance technique may lead to an uncertainty on fluxes measurement around 20% (Wilson et al. 2002).

AquaCrop model:

AquaCrop is a model developed by FAO to increase water efficiency practices in agricultural production (Raes et al. 2012).
Indeed, AquaCrop simulates the yield of herbaceous crop as a function of water crop consumption. Therefore yield is calculated as a function of evapotranspiration. The estimation of evapotranspiration is based on the Penman-Monteith equation (Monteith 1965). According to this model, the reference evapotranspiration (ET0) is calculated from four daily weather variables: net radiation, air temperature, wind speed and relative humidity.
ETo is multiplied by two coefficients to adapt the standard result to the reality. The first coefficient reflects the specificity of each crop (phenology, canopy cover,

rooting depth, crop transpiration, soil evaporation, biomass production, and harvestable yield). The second coefficient is used to reflect the soil water availability in the root zone. This coefficient is calculated from a water balance that keeps track of incoming and outgoing water fluxes at the boundaries of the root zone. That includes the processes of run-off, infiltration, redistribution (or drainage), deep percolation, capillarity rise, uptake and transpiration (Raes et al. 2012).

B-CGMS weather grid (Belgian Crop Growth Monitoring System):

Off-site weather data were provided by the B-CGMS weather grid. This grid is based on daily meteorological data from a hundred weather stations covering Belgium which were spatially interpolated at the grid level 10km x 10km., http://b-cgms.cra.wallonie.be).

This study was conducted over a winter wheat crop plot in Lonzee (Belgium) during the agricultural season 2014-2015. This plot is equipped with a Fluxnet station which records both weather and fluxes measurement. (www.fluxnet.ornl.gov 2016, http://fluxnet.ornl.gov/site/49)

For this work, we wanted to address operational conditions of ET calculation. Therefore, crop and soil input were set up with default parameters values proposed by AquaCrop (on Irrigation and Drainage paper No 56).

Frist, we compared ET measurement from Fluxnet station and ET calculated with AquaCrop thanks to Fluxnet tower weather data. The objective of this initial step is to control if AquaCrop leads to reliable ET values.

Secondly, we used the B-CGMS weather grid to envisage weather conditions in several distances around the crop. We calculated ET with AquaCrop thanks to grid weather data. As can be seen in Figure 1, we selected daily weather data at 3 different distances from the site (20km, 50km, 70km) for 8 geographical directions from the crop (North, North-East, East, South-East, South, South-West, West, North-West) to determine if the distance between the weather station (where weather data are collected) and the crop has an impact on AquaCrop ET accuracy.

And finally, we explored the impact of the weather data source on the crop ET accuracy.

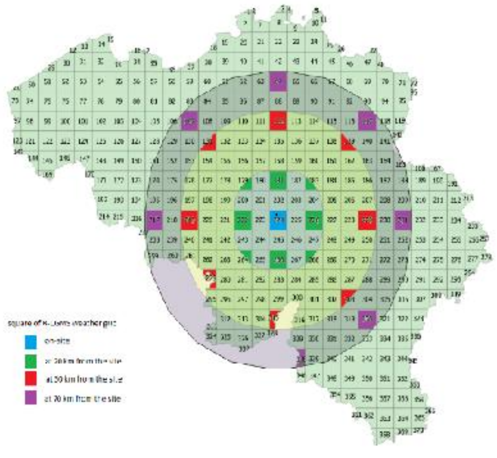

Figure 1: B-CGMS weather grid and squares used in AquaCrop

RESULTS AND DISCUSSION

We first compared ET measurement and AquaCrop ET calculation using weather data collected on the crop site). Figure 2 shows the good agreement between AquaCrop ET and ET measurement during the agricultural season. This is also confirmed by the scatter plot presented at Figure 3. We observe that the regression line (red) has a good R^2, and is close to the the ideal 1-1 line (blue).

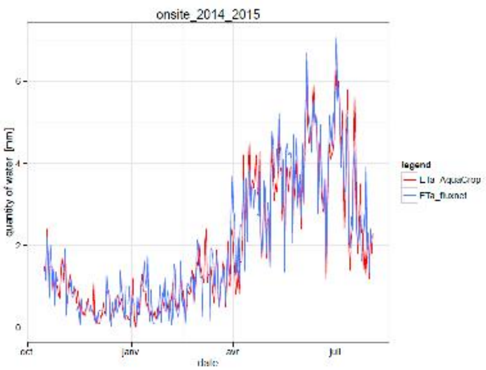

Figure 2: Evolution of ET measured by Fluxnet (blue) and calculated with AquaCrop (red) during the agricultural season 2014-2015 at Lonzée (BE).

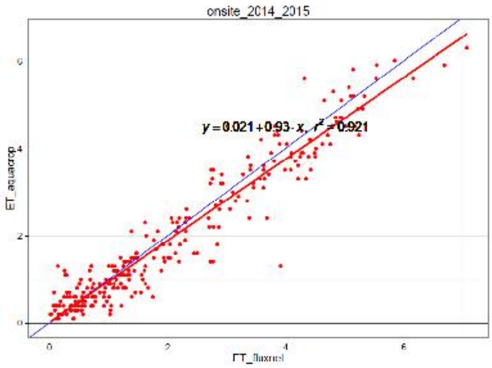

Figure 3: Relation between the Fluxnet measurement and AquaCrop calculation.

The ET model presents a bias of 0.1 mm/day and a root mean square error of 0.5 mm/day. This uncertainty is usually considered as acceptable for agriculture purposes.

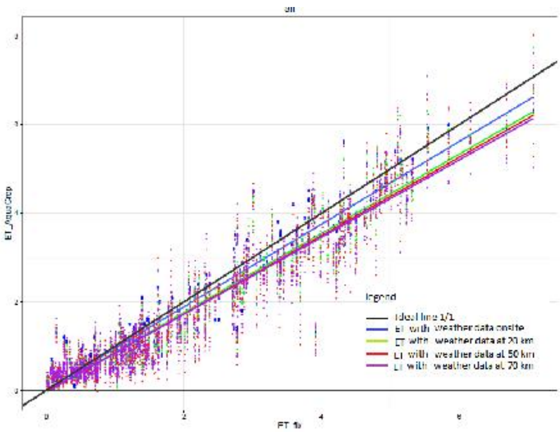

Figure 4: Comparison between ET measured with Fluxnet tower and ET calculated thanks AquaCrop with weather data from different distances from the crop site

To evaluate the impact of weather source distance on the AquaCrop ET accuracy, we compared the ET calculated with AquaCrop for the 8 grid points at 20km, 50km and 70km. The figure 4 shows that ET underestimation increases with the distance of the data source. But the gap between the ET with on-site weather data and distance of 20 km is the most important.The evolution of the bias and RMSE as a function of the distance (Table 1) confirms the visual interpretation of Figure 4.

Table 1. Used Fluxnet station for ET validation. Bias and RMS of AquaCrop ET calculation for each distance between weather data collection and crop site

	Bias (mm/day)	RMSE (mm/day)
On site	- 0.12	0.45
20km	- 0.25	0.50
50km	- 0.28	0.55
70km	-0.29	0.59

The third part of the study consists in the analysis of the direction impact.

The figure 5 presents the comparison of the root mean square error (RMSE) between the 8 directions around the plot as a function of distance.

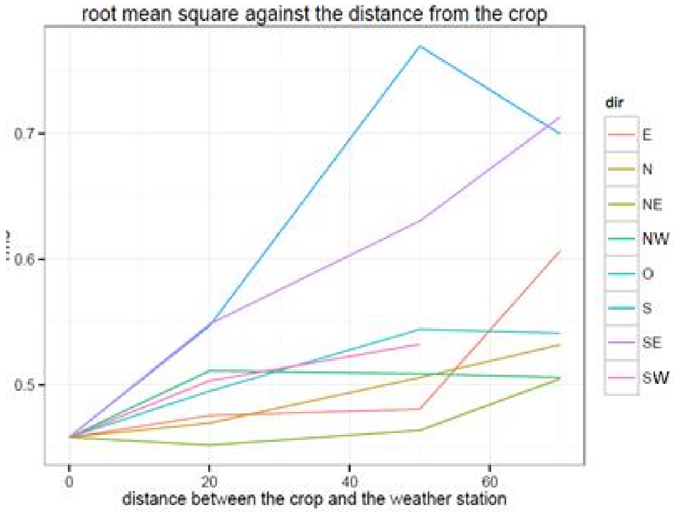

Figure 5: Root mean square errors for 8 directions in function of the distance between crop site and weather data collection site

For most of the directions, the errors increase smoothly from the on-site situation. The largest increase of the error occurs in the S and SE directions which correspond to the most hilly part of Belgium. In such conditions, the highest discrepancies between local weather data and remote interpolated forcing can be expected and have the highest impact on the AquaCrop results.

CONCLUSION

The purpose of this work is the accuracy assessment of ET calculation with AquaCrop when the weather data are collected out of the site. We use as reference in-situ ET measurement from a Fluxnet station available on the site. Weather data

are obtained from the B-CGMS grid. To mimic the operational conditions, AquaCrop is used with standard parameterizations for crop and soil.
We conclude that 1) AquaCrop provides accurate results in Lonzée during the 2014-2015 agricultural season; 2) the accuracy of ET calculated by AquaCrop with weather data collected at distance from the site can make ET results less reliable. The results become less accurate with increasing distance of data source used as forcing. The detailed results are site specific and they depend substantially on the chance to have the same weather conditions in the crop site and in the data collection place. The rainfall is probably the most influencing factor, being largely dependent on the topography. Those results are especially meaningful taking into account the scarcity of dense weather observation networks in most parts of the world. We anticipate an increasing sensitivity of AquaCrop with factors such heterogeneous site environment, changing climate conditions, unavailable weather data in the vicinity of the considered site or input data with poor quality.

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