Sunflowers crop management using satellite images

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ABSTRACT

- The decision making tools for crop management (water, nitrogen, yield prediction) are available using crops observations and agronomic models. New technology using satellite images could now improve the management of the crop at the field scale.
- 4 satellite images were taken at budding stage, beginning and end of anthesis, and 20 days later. A calibration of signals was conducted during two years (2009 and 2010) on a production area of sunflower in France (West area). This work aims to validate the estimation of leaf area, leaf area index and leaf area duration through satellite images. According to the sensors on board able to get signal from red edge bands, we tried also to obtain calibrations in relation with the status of nitrogen nutrition of crops. The study was conducted on 25 sunflower fields spread on the west region of France.
- From these calibrations, and using knowledge of decision rules on the crop management and/or crop physiology, three applications were tested. The first one deal with irrigation management according to the level of leaf area reached by the crop prior to anthesis, the other one estimate the yield potential of the plot by measuring the decrease of leaf area between the end of flowering and early maturity. Using two satellite images, we could calculate at the field level the leaf area duration post-flowering well correlated with the final yield. Concerning the nitrogen status, it is possible to estimate the index of nitrogen nutrition (value between the optimum N concentration and the observed one), itself related to the amount of nitrogen absorbed by the crop early (before 12 leaves stages). According to the yield goal and taking into account the nitrogen already absorbed, an advice for N fertilizer could be delivered and applied on the canopy before budding.
- From the two years of experiment, signals calibration to estimate leaf area criteria at the field scale had been validated. Using the satellite images, decision making tools could be set up to predict crop management as irrigation or yield potential according to leaf area duration after anthesis. Correlations between satellite signal and fields datas for nitrogen estimation (leaf content and nitrogen absorption) are still to be improve.
- *Access to spatial information map the heterogeneity of sunflower fields and allow delivering advices to farmers according to this heterogeneity. An automatic chain for the treatment of satellite images using the calibration set up is in progress. Sharing it in a large geographic area will make the concept economically accessible to farmers.

Keywords : Sunflower; Water Nitrogen management; remote sensing

INTRODUCTION

Access to satellite imagery becomes easier in recent years. Their application for crop management increase: 15% of the area of rapeseed and wheat produced in France are subject to a council for nitrogen fertilizer from the images of biomass and nitrogen absorbed estimated by satellite just pervious re-growth. In addition, these new tools provide access to spatial variability, mapped and used directly for extension services. The performances of embedded sensors are now well calibrated for measures of vegetation indices. Agronomic models are then used to define the requirement for crop nitrogen (Emeriau et al., 2002), according with the yield goal. Nevertheless, direct access for data's on the nitrogen absorption either the nitrogen or chlorophyll cover is rarely available. The technology available today on the RapidEye satellite constellation (www.rapideye.net) offers this possibility. In the case of sunflower crops, attempts to develop these new technologies are still under progress.

The most immediate applications of the measurement of leaf area could be for irrigation advices. CETIOM develops a rule for sunflower irrigation management, based on the level of leaf area index at the beginning of flowering (Merrien and Grandin, 1990, Champolivier et al., 2011). This measurement to the plot is so far difficult to implement, allometric methods are laborious, indirect measurements of radiation intercepted are suitable (e.g. Licor technology), but the equipments still not widely available and the conditions of its use rather strict. Other estimations (visual...) does not seem appropriate. The use of satellite imagery is well adapted to estimate of a vegetation index, well correlated to the leaf area or the leaf area index (including population density).

The second application, based also on the measurement of leaf area, deal with yield prediction in experimental conditions as well as in the field. The decline in leaf area between the end of flowering and physiological maturity is in relation with the crop yields. This relationship, which implements the concept of LAD (leaf area duration) is measured by the variation in leaf area between two snapshots: one at the end of flowering, the second about a month later (Merrien et al., 1981, Champolivier, 2000).

The last application is probably more innovative : in-board technology on the constellation of five satellites used for our study, five lengths waves cover the blue (440-510 nm),the green (520-590 nm), the red (630-685 nm), the near infrared (760-850 nm), but also the red-edge (690-730 nm). This last one could be used for estimation of leaf chlorophyll content, correlated with nitrogen content. Thus, it's possible to estimate the chlorophyll content of leaves, well correlated with canopy nitrogen content. From the vegetation index, we can easily estimate biomass and therefore, combined with the nitrogen content, we estimate the amount of nitrogen absorbed. The decision rule implemented in this case is the one developed by the tool CETIOM Héliotest (Reau et al., 2001). From the data collected (nitrogen content of leaves) and optimal values defined by the dilution curve (Debaeke et al., 2011), we can calculate an index of N nutrition (NNI, ratio between the nitrogen content of canopy and optimum nitrogen content). This index measured at "12 leaves stage" (CETIOM's scale) is well correlated with the level of soil nitrogen supply at the time of measurement (Reau et al., 2011). Made early enough before the crop growth over 60 cm (to still allowed a N nitrogen application by the equipment), we can check the amount of nitrogen already absorbed by the crop. Additional supplies of nitrogen by fertilizer (dose X) are then calculated according to the yield goal and requirements per quintal (4.5u/ q for sunflower). The supplementation (if necessary) can be done over the vegetation (under dry conditions to prevent from burning). For these three applications, in addition to simplify the advice, the map produced can easily show the heterogeneity of the plots and possibilities for N modulation. During these two years of study, we therefore tried to validate those hypotheses.

MATERIALS AND METHODS

Our study was located in Poitou Charentes (west of France), second area for sunflower production. In collaboration with the cooperatives in the region, we identified 10 fields in 2009 and 25 in 2010. These were geo-referenced for location on the satellite maps. To reduce the variability from other parameters, we attempted to standardize the choice of sowing date and stand structure. The main controls were the biomass (stage E1), the levels of nitrogen, leaf area (LA) at E1, F1, F4 and F4+20 days according to CETIOM's scale. These ratings were made on plots, even geo-referenced. The leaf areas were measured by allometric method adapted from Pouzet and Bugat, (1985). Leaf area index (LAI) (m2 of leaves/sqm) was obtained as LAI=LA *plant /sqm. The leaf area duration (LAD, expressed in m2.day) was obtained by integration of leaf area index between the end of flowering until maturity (extrapolation of the regression of green LA between F4+20 days and maturity). Yields were monitored on each plot but also from the combine. In order to match the data acquired on the plots, the four satellite images were taken synchronous with field observations. The first year we establish the calibration of the satellite signal for estimating leaf area index. The second year was used to validate the calibration produced. The same approach was adopted for the parameters of the nitrogen status of plants (nitrogen content, nitrogen uptake). However, according to the few data's available the first year for N, a new calibration for the estimation of nitrogen uptake was produced in the second year. For all plots, a map was also produced and the results had been check by a control at the field level for validation of the observed heterogeneities.

RESULTS

Validation of the calibration for leaf area index.

The most accurate calibration was produced by combining all the data (plots and stage). The relationship produced (Figure 1) represents this calibration. Some data's could be considered as outliers (value for LAI close to 0): they came from the last image taken as leaf area was senescent and could come from capitule index.

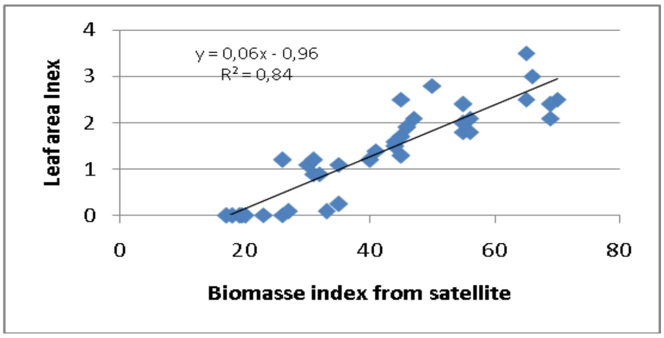

Figure 1 : Calibration for the satellite signal to predict LAI

From this calibration, established in 2009, we simulated the predicted values on the network plots of 2010. Figure 2 shows the estimated values (Y) versus the measured (X). This calibration seems acceptable and allowed us to map leaf area index.

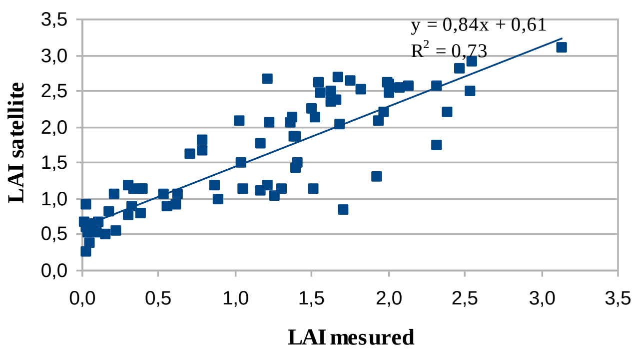

Figure 2 : Relationship between the LAI measured and the estimated

We present an example (figure 4). Estimating leaf area index before flowering revealed values to 2.5 witch are close to the optimal: the water supply is not necessary before anthesis. Water supplies (2 applications, 30 mm each) was delivered only at post blooming (schematically T3) and the effect on the persistence of green leaves is clear (figure 6 - T3 and T4). On the irrigated part of the field the leaf area index remains close to 2, while the leaf area index on the non-irrigated area decrease between 0.5 and 1. In the first case, this lead to LAD values close to 90 m2.days versus values close to 40 for the non-irrigated area. The yield benefits in this case was 7q/ha.

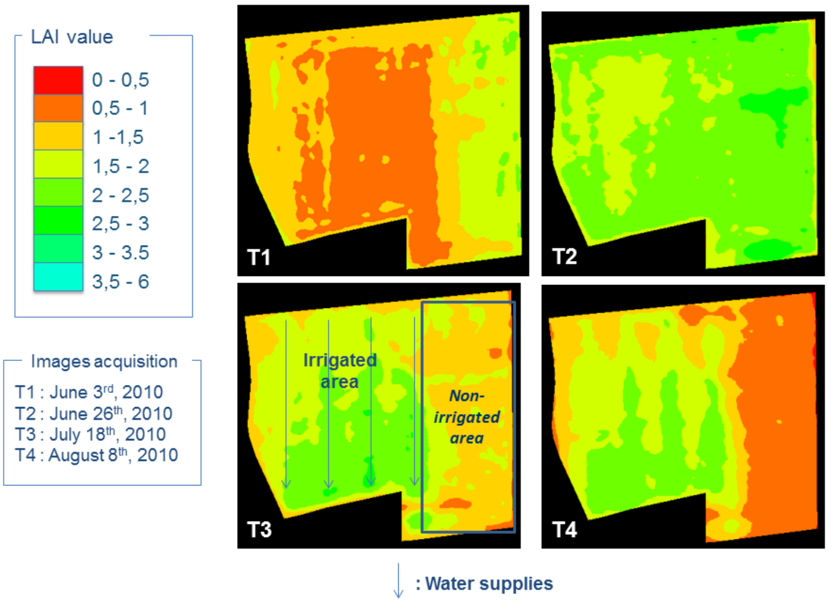

Figure 3 : Example of mapping the effect of post-flowering water supply on the stay-green of the leaves

Calibration for nitrogen absorption at «12 leaves stage"

From the satellite index (variable X), we have established a relationship on one hand for the nitrogen content of the canopy (A) and on the other for the nitrogen absorbed (B).

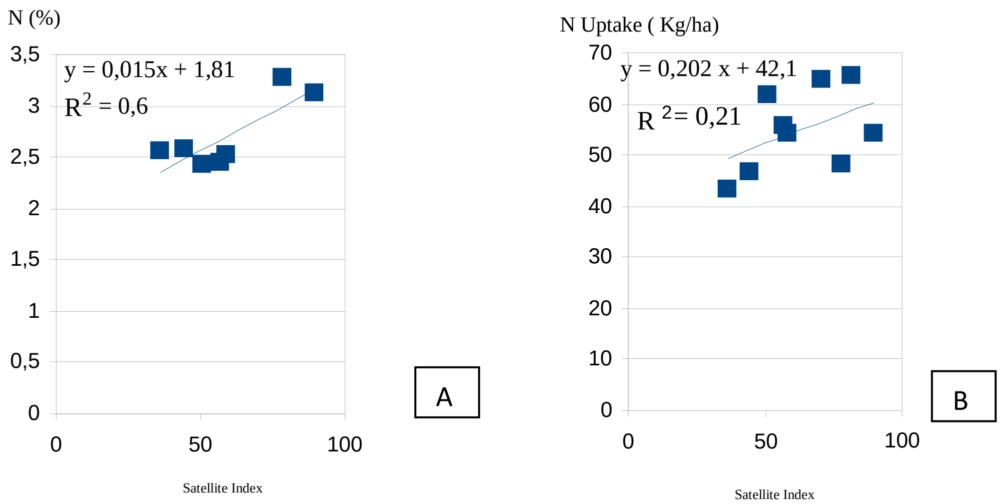

Figure 4 : Relation between satellite Index (X) and nitrogen content in the leaves (A) and N uptake (B)

Regarding the statistical values obtained, calibrations needs to be improve. Nevertheless, using this calibration, we were able to produce maps for early nitrogen absorption before budding stage. The results are showed on Figure 5. The satellite signal allows a quite accurate estimation of nitrogen uptake by the crop: the lower part of the image, we estimated between 5 and 20 kg of N absorbed. On the upper part of the image the application of 30 kg of N-fertilizer at sowing lead to a greater absorption, between 30 and 60 kg of N very well revealed by the satellite image.

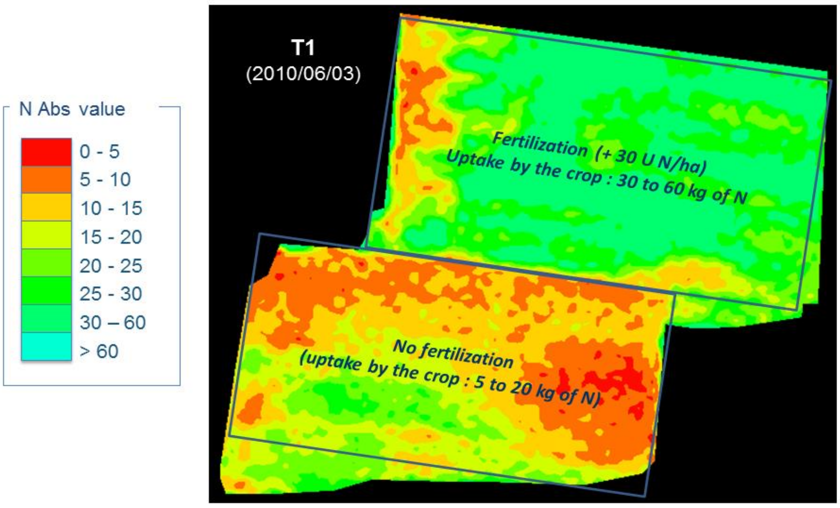

Figure 5 : Example of mapping of nitrogen uptake by sunflower crops: lower: no fertilizer, upper :+ 30kg N at "12 leaves stage".

Prediction for yield

From the LAI estimated after flowering (T3 and T4) using the calibration of the satellite signal approved in 2010, we calculated the LAD until physiological maturity. According to the relation between LAD and yield (Figure 6), we estimated the yield potential on the 25 plots followed in the study in 2010. The relation between the predict values according to the observes one is shone on figure 7.

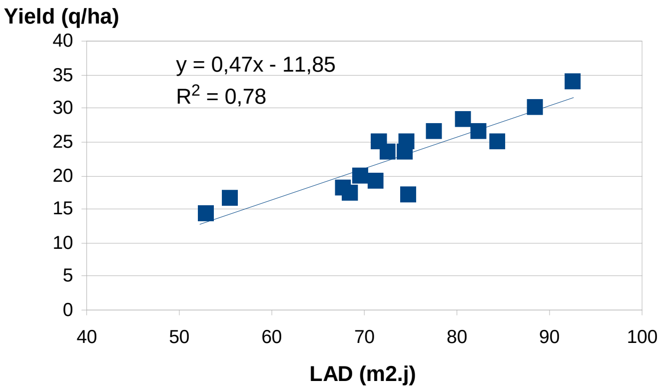

Figure 6 : Estimated yield of the 25 plots the networking 2010 by calculating the rate of decline in leaf area, estimated by satellite between late flowering and maturity.

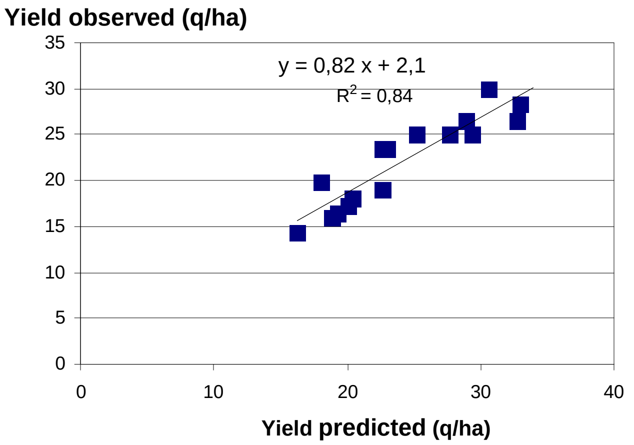

Figure 7 : Relation between yield observed (combine) and yield predicted.

Conclusions:

After 2 years of experimentation, we validate the possibility to implement a decision rule for sunflower irrigation using the satellite image. Forecasting yields, resulting from integration at the plot level of the regression of leaf area after flowering can also be used by cooperatives to anticipate the storage two or 3 weeks before harvest. The implementation for nitrogen fertilization has also progressed. The calibration need to be improved gathering the data from the two years. We now plan to test chain of information processing and to define the minimum time between image capture and return informations to the decision-making. In this study, we reduced the variability in phenology, resulting from different sowing dates. On a production area, the plots will be at different growth stages and it will be therefore necessary to simulate leaf area index of interest (similar to F1) from the value obtained on the plots the day of image capture. Modeling leaf area can be a suitable solution (Casadebaig et al., 2011). This technology also has a cost. Pooling the advice for all the producers of the same area is expected to make the costs of the processing chain acceptable to the farmer.

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