SENSAGRI Biomass and Yield proof-of-concept

The **SENSAGRI Biomass and Yield** products is a proof-of-concept service derived from Sentinel-1 (S1) and Sentinel-2 (S2) data over agricultural areas. It consists of maps of final biomass production and yield of the cash crop, as well as maps of the intermediate variables estimated to calculate them (annual crop photosynthesis, crop respiration, above and below ground biomass). Additionally, the net annual CO_2 fluxes components, the annual carbon (C) budget, the cover crop/spontaneous re-growth/weeds biomass and evapotranspiration (ETR) can be estimated. The model can estimate those variables at pixel (10m) or plot scale.

The strategy adopted to derive those products consists in assimilating LAI derived from S2 alone or S1 and S2 satellites into a semi-empirical crop model, SAFYE-CO2, in order to calibrate its phonological parameters as well as the light use efficiency for photosynthesis and therefore to force the model to reproduced the vegetation dynamics and intensity of development. The SAFYE-CO2 model was adapted from the original SAFY model (Duchemin et al., 2008) coupled with the FAO-56 soil water budget module (Allen et al, 1998). It is a daily time step model that simulates first the photosynthesis as a function of the absorbed photosynthetically active radiation (APAR) based on the Monteith and Moss's (1977) light-use efficiency theory. Then total biomass (NPP) is derived from the difference between the photosynthesis and the autotrophic respiration (Amthor, 2000), which was separated into two components: maintenance respiration and growth respiration (McCree, 1974). The biomass is then allocated to above ground, below ground, leaf and yield. Next soil respiration is calculated based on a Q_{10} approach (Delogu, 2017) and finally the net CO_2 flux is calculated as the sum of NPP and soil respiration. The model has to be parametrised for each crop specie but the model doesn't need any field management data to estimate biomass and yield, which makes it very suitable for large scale applications.

In our modeling approach, the evapotranspiration is estimated base on the dual-crop coefficient approach of the FAO56 method, separating the evaporation and transpiration contributions. In this soil module, only the vertical flows are considered, neglecting the runoff horizontal flows and three soil layers are involved in soil water transfer mechanisms: (1) a superficial layer that works as an interface with the atmosphere (evaporation), and supplies water to the deeper soil layers; (2) an intermediate layer that extends with the rooting system that pumps water in the soil for the crop transpiration; and (3) a deep layer that produces base flow. The water budget is calculated at daily step.

The **algorithm has been validated** in South West France for winter wheat, sunflower and maize by using various types of field observations, such ETR and CO_2 fluxes measured at two ICOS flux sites near Toulouse (FR-AUR and FR-LAM sites), LAI, biomass and yield measured during destructive sampling campaigns and LAI estimated by means of Digital Hemispherical Photographs (DHP). The performances of the model for estimating biomass in terms of RMSE, RRMSE and R^2 are 201 $g.m^{-2}$, 26.6% and 0.90, respectively for winter wheat (Pique et al., submitted to GEODERMA). Yield are also estimated with good precision with RMSE, RRMSE and R^2 of 1.02 $t.ha^{-1}$, 21.5% and 0.78, respectively. The simulation of the daily CO_2 fluxes agree well with the measurements, showing R^2 values between 0.82 and 0.94 for the photosynthesis and between 0.78 and 0.90 for the net CO_2 fluxes. Also, the RMSEs are between 1.34 and 2.39 $gC.m^{-2}.d^{-1}$ and 1.09 and 1.59 gC.m-2.d-1, respectively.

As an example, Figure 1 illustrates some maps of plot scale final biomasses, yields, net annual CO_2 fluxes, carbon budgets and ETRs estimated with the SAFYE-CO2 model assimilating GAI maps derived from Sentinel-2 like data (SPOT 4/5 and Formosat) over the French site for four contrasted climatic years.

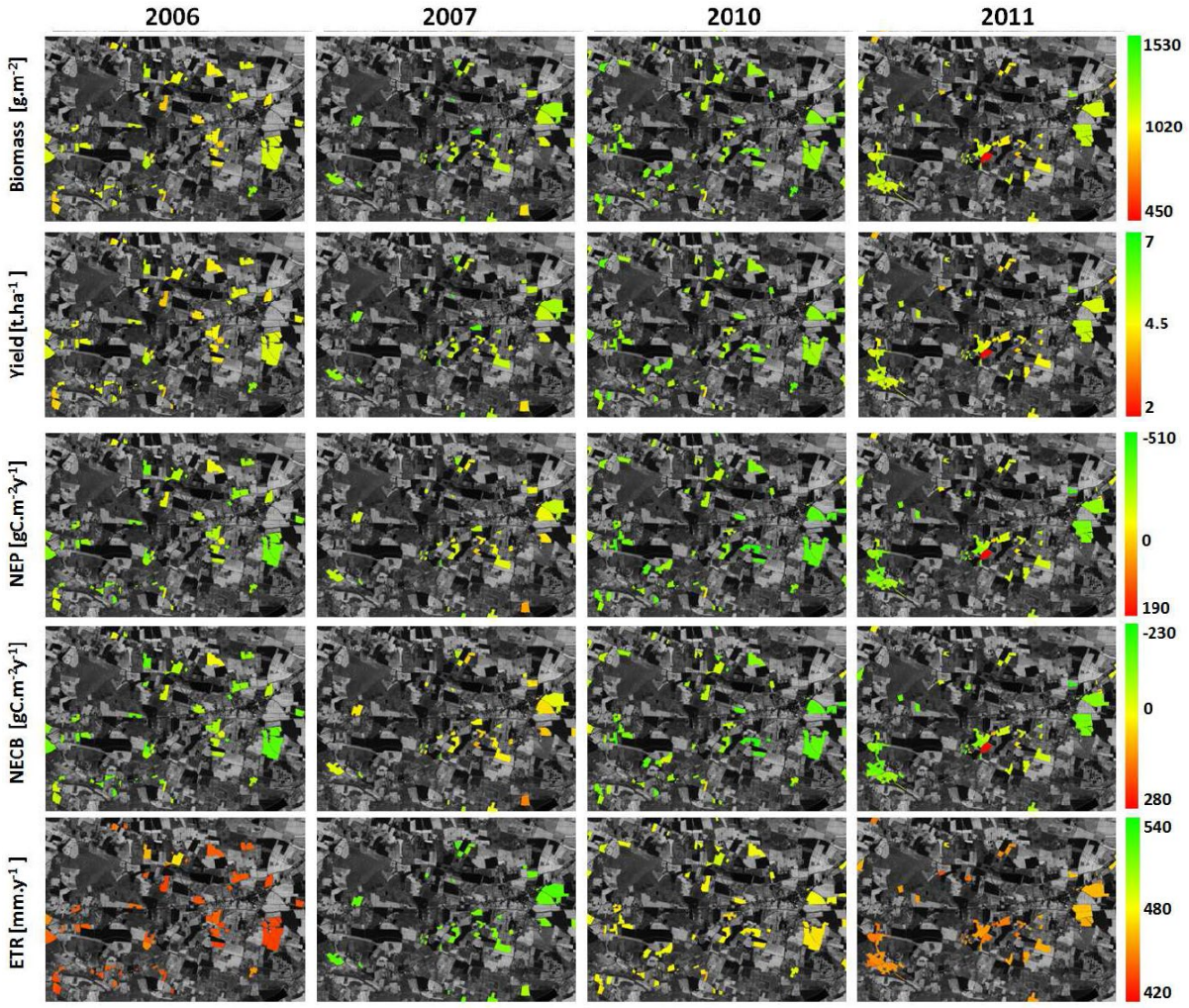

Figure 1. From the top to the bottom, maps of final biomass, yield, net annual ecosystem CO_2 flux (NEP), net annual ecosystem carbon budget (NECB) and cumulated evapotranspiration (ETR) estimated by the SAFYE-CO2 model for a number of winter wheat plots in 2006, 2007, 2010 and 2011. The color scales are displayed on the right of each serie.

References

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