Improving Remote Sensing Derived Dry Matter Productivity by Adding Water Limitation Factor

Yetkin Özüm Durgun[1*], Sven Gilliams[1], Bernard Tychon[2**], Bakary Djaby[2**], Gregory Duveiller[3**]**

[1] Flemish Institute for Technological Research (VITO), Centre for Remote Sensing and Earth Observation Processes, Belgium
[2] University of Liège, Department of Environmental Sciences and Management, Belgium
[3] European Commission - Joint Research Centre, Institute for Environment and Sustainability, Italy
[*]Corresponding author: ozuem.durgun@vito.be
[**]Thesis supervisors

Introduction

Crop condition monitoring throughout the growing season and crop yield forecasting are both important to estimate the seasonal production. Making accurate and timely evaluation of crop production allows better planning and more efficient management of harvesting, storage and distribution systems. Dry matter productivity (DMP) is one of the vegetation indices which is used to estimate crop yields. DMP reflects the daily increase of the dry matter biomass (growth rate) of the crop.

Objective

Estimates of the productivity of terrestrial vegetation can be made by combining satellite imagery with solar radiation and temperature information using the classical Monteith approach. The Remote Sensing research unit of VITO started to produce DMP estimates on a regular basis since around 2000. The current DMP algorithm does not include water limitation. Thus, the purpose of this study is to reproduce DMP images by adding a water stress factor to the formula.

Data and Methods

Monteith formulated a radiation use efficiency (RUE) model to estimate Net Primary Production (NPP), a variation of DMP. According to the model, the biomass accumulation of the plant is correlated with the amount of absorbed radiation (APAR) and the actual efficiency of converting atmospheric CO_2 into plant tissue (ε_{ACT}) as

$$DMP = APAR * \varepsilon_{ACT}$$

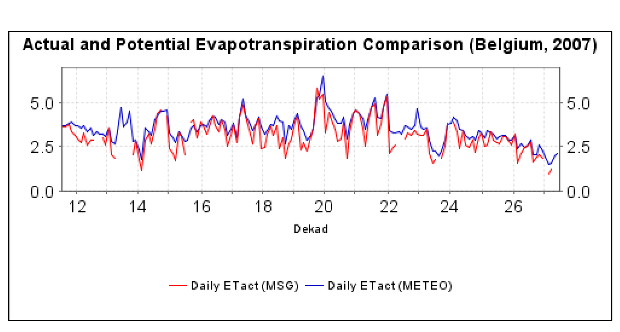
It can be reformulated as following:

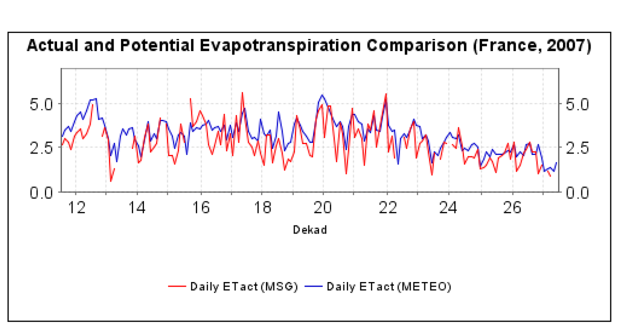
$$DMP = \underbrace{R * \varepsilon_p * fAPAR}_{APAR} * \underbrace{\varepsilon_{RUE} * \varepsilon_T * \varepsilon_{CO2} * \varepsilon_{AR} * [\varepsilon_{RES}]}_{\varepsilon_{ACT}}$$

TERM	MEANING	VALUE	UNIT
DMP	Dry Matter Productivity	0 – 320	kgDM/ha/day
R	Total shortwave incoming radiation (0.2 – 3.0µm)	0 – 320	GJT/ha/day
ε_P	Fraction of PAR (0.4 – 0.7µm) in total shortwave	0.48	JP/JT
fAPAR	PAR-fraction absorbed (PA) by green vegetation	0.0 ... 1.0	JPA/JP
ε_{RUE}	Radiation use efficiency (DM=Dry Matter) at optimum	2.54	kgDM/GJPA
ε_T	Normalized temperature effect	0.0 ... 1.0	-
ε_{CO2}	Normalized CO2 fertilization effect	0.0 ... 1.0	-
ε_{AR}	Fraction kept after autotrophic respiration	0.0 ... 1.0	-
ε_{RES}	Fraction kept after omitted effects (drought, pests...)	1.0	-

And as a water stress factor, a water stress coefficient can be added:

$$\varepsilon_{H2O} = ET_{ACT} / ET_{POT}$$

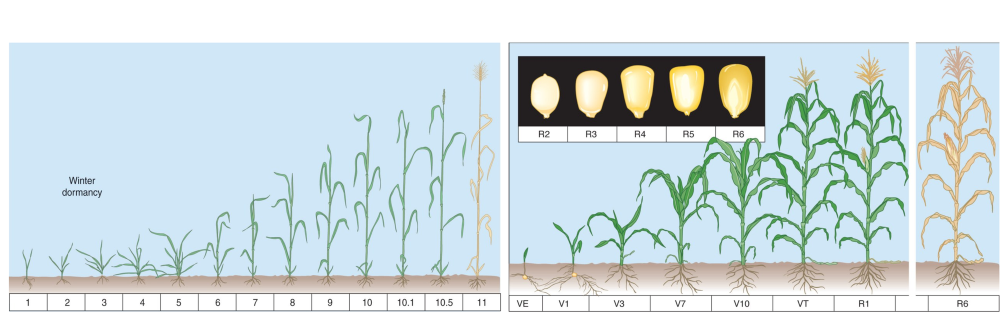




The input remote sensing data for the study is given in the following table:

Data	Sensor	Resolution	Since
fAPAR	SPOT VGT	1km	1998
Radiation	ECMWF (modelled)	25km	1975
Minimum Temperature	ECMWF (modelled)	25km	1975
Maximum Temperature	ECMWF (modelled)	25km	1975
Actual Evapotranspiration	MSG	5km	2006
Potential Evapotranspiration	ECMWF (modelled)	0.25°	1989

Furthermore, due to different behavior of plant type regarding photosynthetic activity, it is important to use different RUE values for C_3 and C_4 plants. Maize (C_4 plant) and wheat (C_3 plant) have been selected as study crops as they are grown in three study areas, Belgium, France and Morocco.

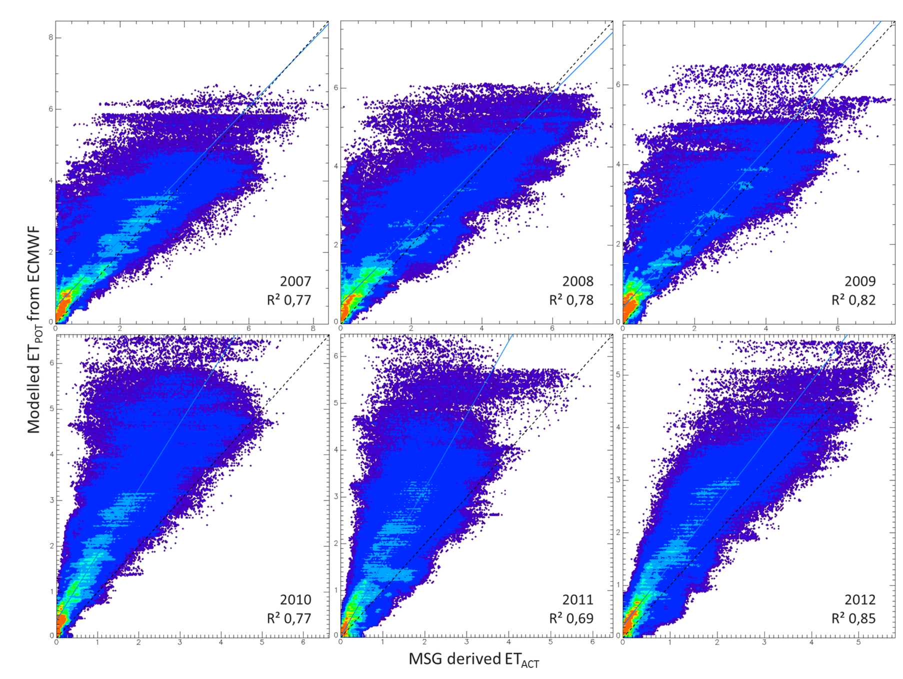


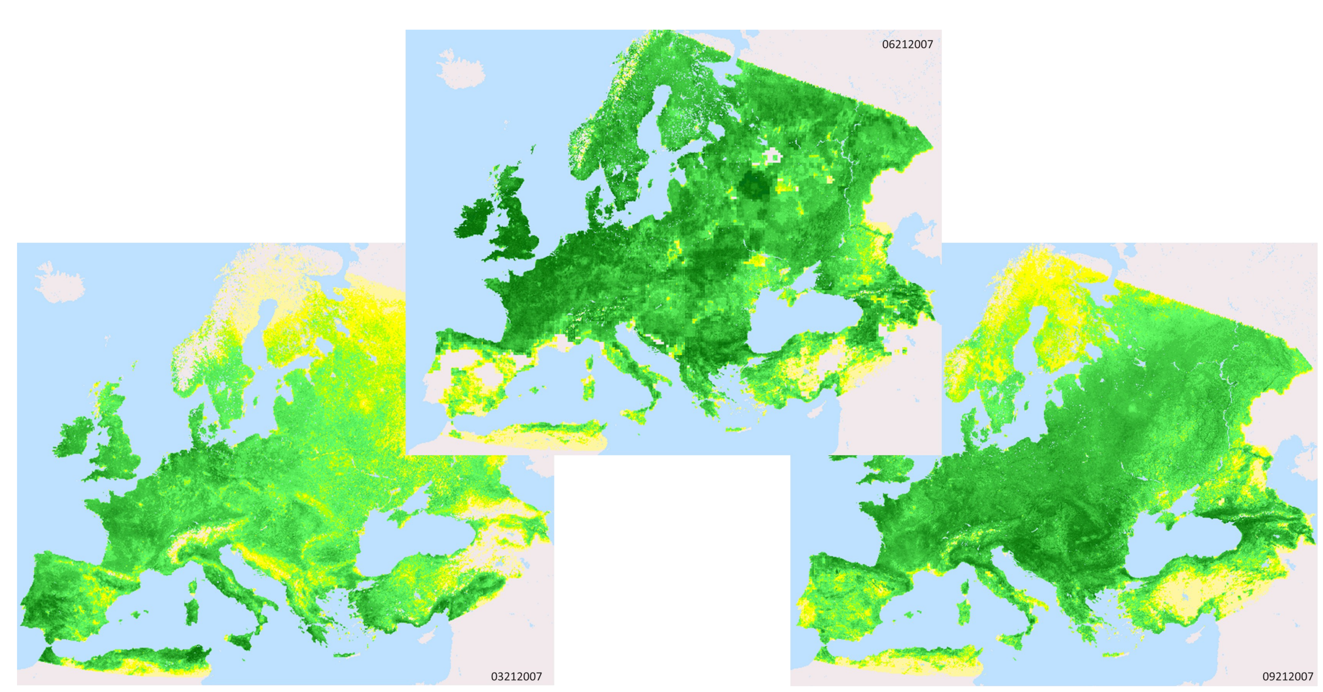
Growth stages of wheat — Maize plant development

Source: Illinois Agronomy Handbook

Ongoing Study, Limitations and Future Prospects

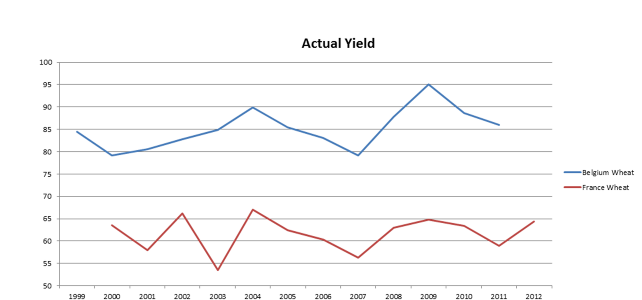
MSG derived ET_{ACT} and modelled ET_{POT} from ECMWF are two datasets used for water stress coefficient calculation. Thus, in order to see the correlation between these two datasets, they have been plotted. A good correlation was observed. The same comparison will be done for AgrometShell derived ET_{ACT} images - modelled ET_{POT} from ECMWF, and MSG derived ET_{ACT} - AgrometShell derived ET_{ACT} images.





New DMP images including water limitation factor have been computed for Belgium and France. Two methods have been chosen to validate the improved DMP products. First method looks at indirectly how yield estimates have been improved. The cumulative values of DMP estimates have been correlated with the actual yield. Actual yield data are available for the period of 1999-2012. However, MSG derived ET_{ACT} is available since 2007 only. Thus, the comparison has been done for the period of 2007-2012 which is short. In order to extend the dataset, ET_{ACT} will be calculated for the complete time series in AgrometShell.

Additionally, the variability of the yield over the years is not high. This might be a drawback while looking at the correlation between the yield and the cumulative values of DMP images.



Second validation method is using directly FLUXNET data to validate DMP products. FLUXNET data are collected by observations from micrometeorological tower sites. The data will be used in this study are gross primary production (GPP) and net primary production (NPP) observations for croplands. The dataset for croplands is available in Belgium only one site (Lonzee) and in France two sites (Grignon and Avignon).

Furthermore, in spring 2013, ESA's new microsatellite PROBA-V was launched and in 2014 Sentinel-3 will be launched. Both of these satellites will be the successors of SPOT-Vegetation sensor. Since data continuity is crucial for agricultural monitoring, this study will be extended by using the products of above mentioned satellites.

Acknowledgements

This thesis is realised in the framework of VEGETATION project Collaboration and support of VITO.

vito vision on technology — Université de Liège