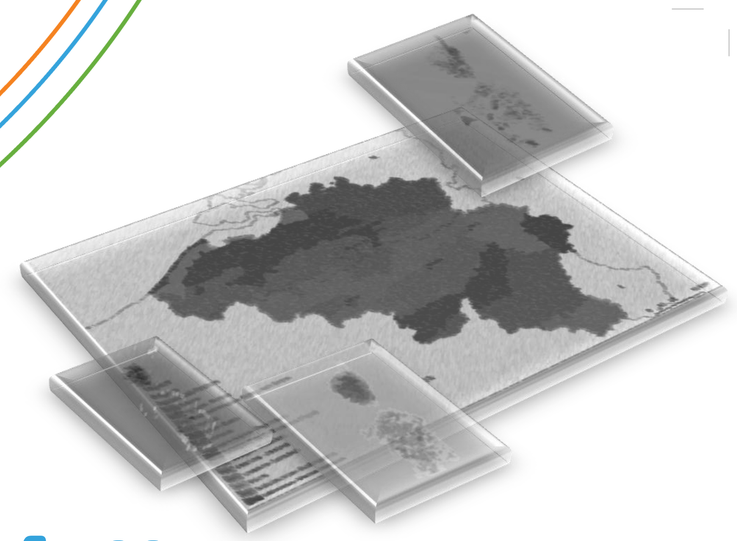

Improving Remote Sensing Derived Dry Matter Productivity by Adding A Water Limitation Factor: A Case Study of Belgium

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Introduction

Based on the Monteith approach, the Remote Sensing research unit of VITO has started to produce Dry Matter Productivity (DMP) estimates on a regular basis since 2000. The current DMP products are potential products since there is no water limitation factor. This study presents the improvement of remote sensing derived DMP by adding a water stress factor relate to improve the relation between DMP and official crop yield time series for fodder maize and winter wheat over agro-ecological regions of Belgium for a long-term period (1999-2012).

Data and Methods

Remote Sensing Data

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

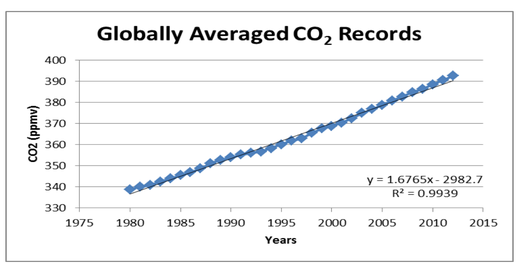
$$DMP = APAR \times \varepsilon_{ACT}$$

$$DMP = (R * \varepsilon_p * fAPAR) \times (\varepsilon_{RUE} * \varepsilon_T * \varepsilon_{CO2} * \varepsilon_{AR} * \varepsilon_{H2O})$$

TERM		MEANING	VALUE	UNIT	SENSOR
DMP		Dry Matter Productivity	0-320	kgDM/ha/day	SPOT VGT
R		Total shortwave incoming radiation (0.2 – 3.0µm)	0-320	GJ/ha/day	ALTERRA
ε_p		Fraction of PAR (0.4 – 0.7µm) in total shortwave	0.48	J/J	-
fAPAR	smoothed fAPAR	PAR-fraction absorbed by green vegetation	0-1	J/J	SPOT VGT
ε_{RUE}	$\varepsilon_{RUE\ C3}$	Radiation use efficiency for C3 crops at optimum	3.11	kgC/GJ	-
	$\varepsilon_{RUE\ C4}$	Radiation use efficiency for C4 crops at optimum	4.44		
	ε_T	Normalized temperature effect	0-1	-	ALTERRA
	ε_{CO2}	Normalized CO2 fertilization effect	0-1	-	ALTERRA
	ε_{AR}	Fraction kept after autotrophic respiration	0-1	-	ALTERRA
	ε_{H2O}	Water stress factor (WSF)	0-1	-	METEO

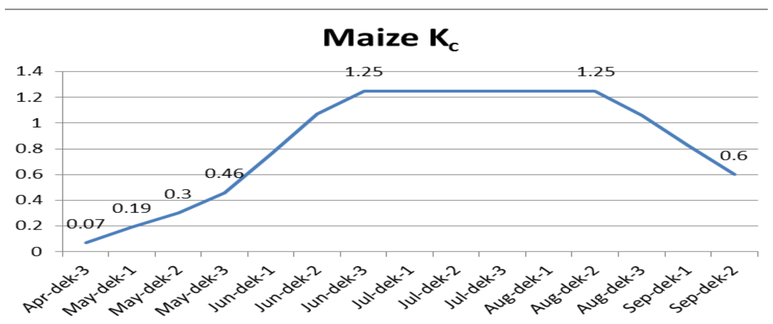
DMP is the increase in dry matter biomass on a daily base and is affected by several environmental factors. Three of these factors used in the algorithm were changed in the new version:

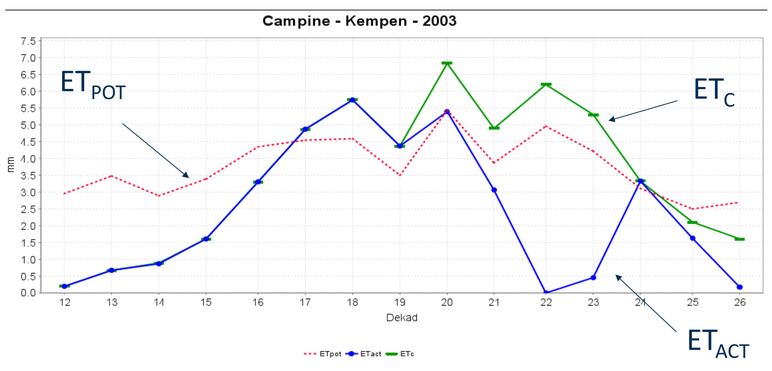
- Crop species → We used C_3 and C_4 specific maximum RUE values.
- Leaf CO_2 assimilation rate → We used yearly variable CO_2 value.



- Drought stress → We added ε_{H2O} as a water stress factor. There are two versions:
  1. ET_{ACT} / ET_C
  2. $0.5 + 0.5 * ET_{ACT} / ET_C$ (described as in CASA model)
     - ET_{ACT} was calculated in AgroMetShell (FAO Water Balance Model)
     - $ET_C = K_C \times ET_{POT}$

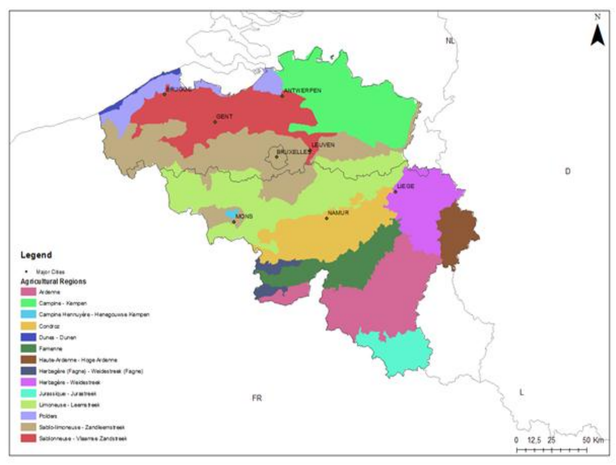
     ET_{POT} is the evapotranspiration rate from a hypothetical grass reference crop.





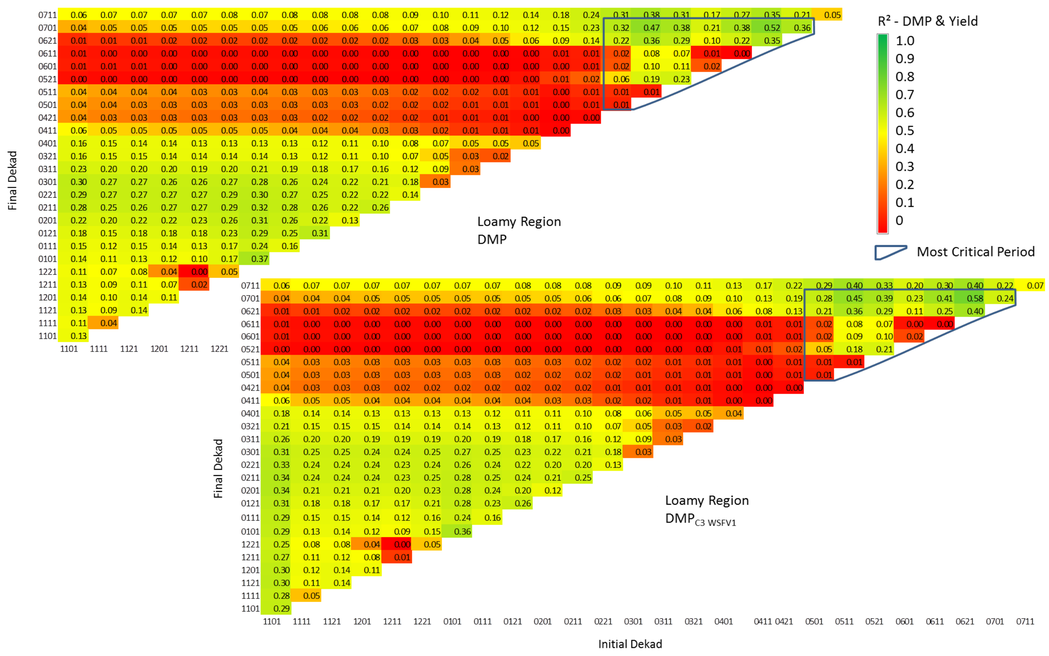
Yield Statistics

Official yield statistics of forage maize and winter wheat were collected from national statistical service at agro-ecological regions level in Belgium.



Linear Regression

A single linear regression between water-limited DMP cumulated over an optimal temporal window and actual/detrended yield statistics was calculated for the 1999-2012 period. Temporal window was defined by an initial and final dekad within the season as 3rd dekad of April-2nd dekad of September for fodder maize and 1st dekad of November-2nd dekad of July for winter wheat. Coefficient of determination (R^2) and relative root mean square error (RRMSE) were computed at agro-ecological level.



Results

The following results were drawn based on four agro-ecological regions where maize and wheat are the dominant crops:

- As theoretical analyses indicate that increases in CO_2 concentrations had beneficial physiological effect on plant growth especially for wheat as a C_3 plant. Maize as a C_4 plant did not demonstrate a benefit to CO_2 enrichment.
- No significant effect was found between using C_3 and C_4 specific RUE values compared to the original RUE value used in the algorithm.
- Analysis conducted with detrended yield performed better than real yield for maize which is the opposite case for wheat.
- Adding a water stress factor made a significant improvement for maize for all agro-ecological regions. Its effect on wheat was significant only in Loamy and Condroz regions.

	For Most Critical Period	R^2	RRMSE (%)
Maize	Dunes + Polders	0.25 → 0.31	6.65 → 6.30
	Sandy	0.14 → 0.26	5.94 → 5.70
	Kempen	0.27 → 0.44	6.13 → 5.02
	Sandy-loamy	0.28 → 0.45	3.92 → 3.42

	For Most Critical Period	R^2	RRMSE (%)
Wheat	Dunes + Polders	0.63 → 0.64	4.49 → 4.43
	Sandy-loamy	0.60 → 0.68	3.85 → 3.47
	Loamy	0.52 → 0.58	2.94 → 2.97
	Condroz	0.22 → 0.22	4.13 → 4.13

Conclusions and Limitations

- Adding water stress factor to DMP has a strong potential to improve the crop yield estimates. However, in general, Belgium does not suffer from water-stress. Thus, this study will be conducted also in water-stressed regions in France and Morocco.
- The inter-annual variability of the official yield is low in Belgium.
- Crop specific map was not available.

Acknowledgements

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

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