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Improving Remote Sensing Derived Dry Matter Productivity By Reformulating The Efficiency Factors: Case Studies For Wheat And Maize

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Outline

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- Methodology
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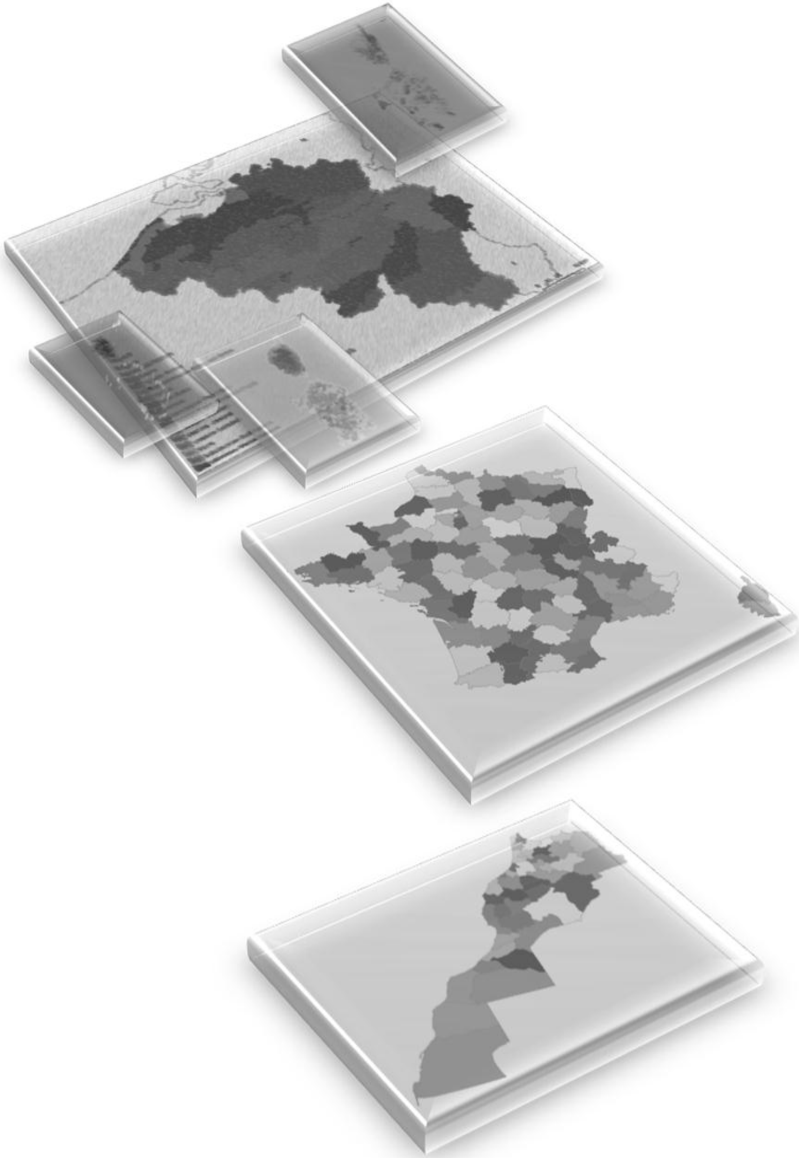


Introduction

- DMP
  - overall growth rate or dry biomass increase of the vegetation
  - kgDM/ha/day
  - directly related to NPP (Net Primary Productivity, in $gC/m^2/day$)

- DMP/NPP is a fundamental ecological variable because
  - it measures the energy input to the biosphere and terrestrial carbon dioxide assimilation.
  - it indicates the condition of the land surface area and status of a wide range of ecological processes.
  - it is a unique integrator of climatic, ecological, geochemical and human influences.

Introduction

- The Remote Sensing research unit of VITO has started to produce Dry Matter Productivity (DMP) estimate images on a regular basis since 2000.
- The DMP[1] product of VITO is based on the Light Use Efficiency (LUE) approach first formulated by Monteith.
  - $DMP = R * \varepsilon_p * fAPAR * \varepsilon_{ACT} * \varepsilon_{AR}$

    $\varepsilon_{ACT} = \varepsilon_{RUE} * \varepsilon_T * \varepsilon_{CO2} * \boldsymbol{\varepsilon_{H2O}}$

([1] Veroustraete, F., Sabbe, H. & Eerens, H. (2002) Estimation of carbon mass fluxes over Europe using the C-Fix model and Euroflux data. Remote Sensing of Environment, 83, 376–399.)

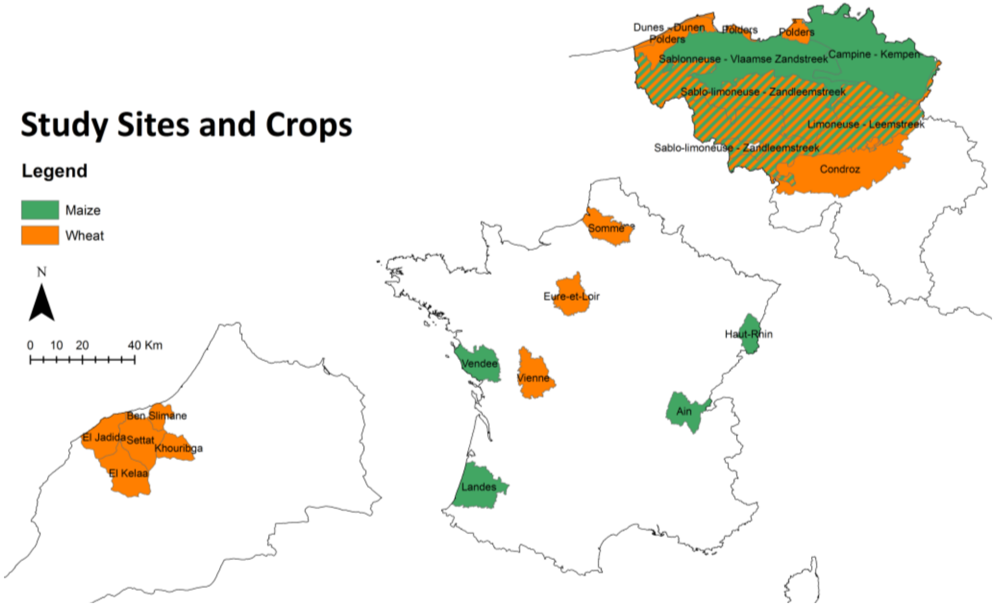
Research Questions

- In terms of crop yield estimations,
  - can adding water stress factor (ε_{H2O})
  - can reformulating stress factors for C_3 and C_4 plants

  make any improvements?

Methodology

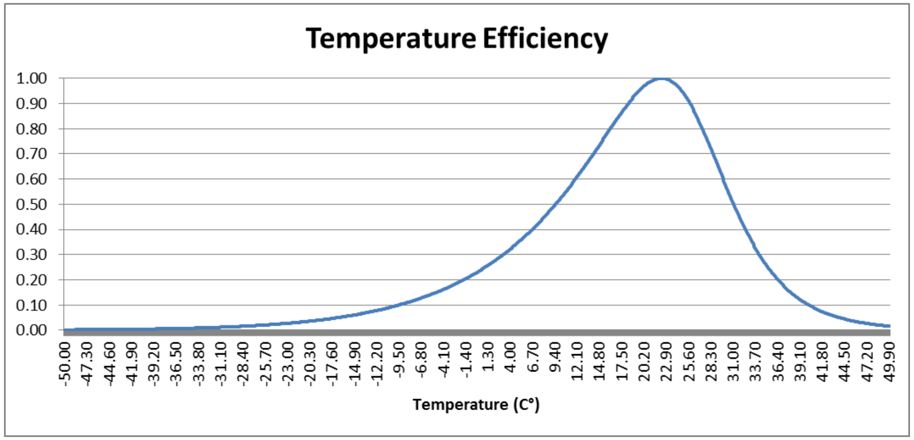
- Study sites and crops
  - Belgium and France - winter wheat (C_3) and forage maize(C_4)
  - Morocco - soft wheat (C_3)

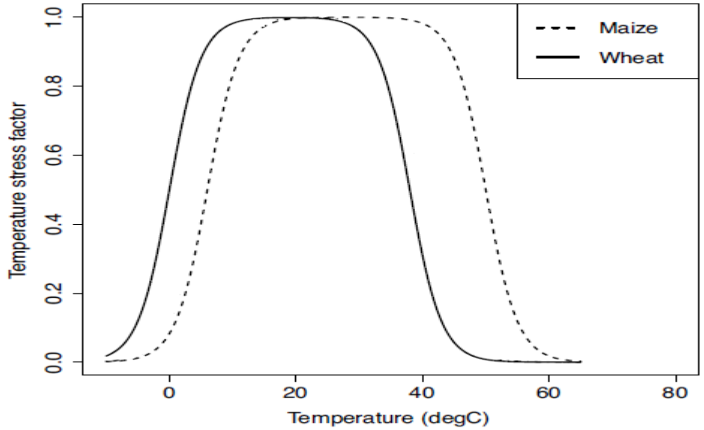


- Data (1999 – 2012)
  - fAPAR – SPOT VGT
  - Radiation, temperature – ALTERRA
  - Precipitation and potential evapotranspiration – ECMWF

Methodology

» ε_T – Temperature Effect





Source: (Deryng et al. 2011)

Table 1. Response of total and plant-component dry matter of an old hybrid (Pride 5) and a new hybrid (Pioneer 3902) at the 10-leaf stage to three temperature regimes

Temperature (°C)	Hybrid	Roots	Stems	Leaves	Total
		(g m^{-2})			
16/7	Pride 5	28.9	26.1	25.2	80.3
	Pioneer 3902	31.0	20.8	21.2	73.0
23/14	Pride 5	25.6	31.0	29.9	86.4
	Pioneer 3902	24.8	25.1	28.4	78.3
33/24	Pride 5	15.5	21.3	23.6	60.4
	Pioneer 3902	15.9	16.3	23.0	55.3
Mean	Pride 5	23.3	26.1	26.2	75.7
	Pioneer 3902	23.9	20.7	24.2	68.8
LSD (0.05)		NS^z	2.0	1.7	5.5

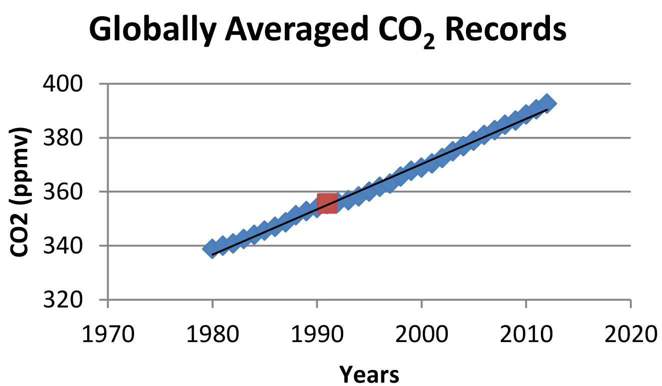
Source: Maize plants, Canada (Tollenaar et al. 1990)

CO_2 (μmol mol^{-1})	Temperature (°C)	Aboveground dry matter (g plant^{-1})
370	19/13	149.1 ± 4.81
	25/19	112.2 ± 3.02
	31/25	116.0 ± 3.19
	35/29	102.2 ± 3.36
	38.5/32.5	75.1 ± 3.46
750	19/13	159.2 ± 2.85
	25/19	108.0 ± 3.02
	31/25	104.3 ± 3.35
	35/29	107.7 ± 7.63
	38.5/32.5	75.6 ± 4.85

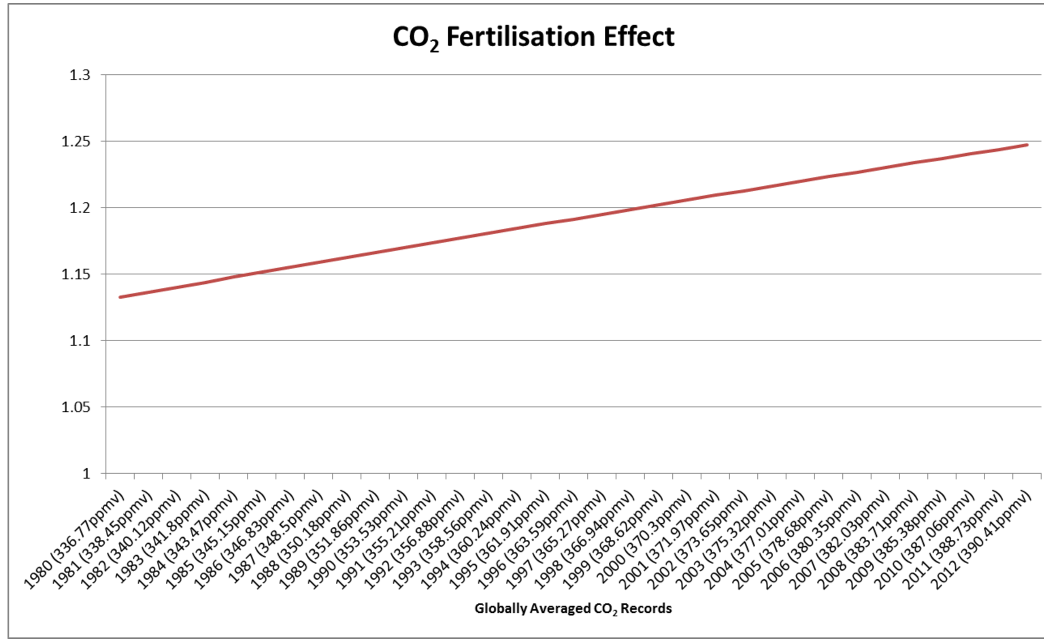
Source: Maize plants, the USA (Kim et al. 2007)

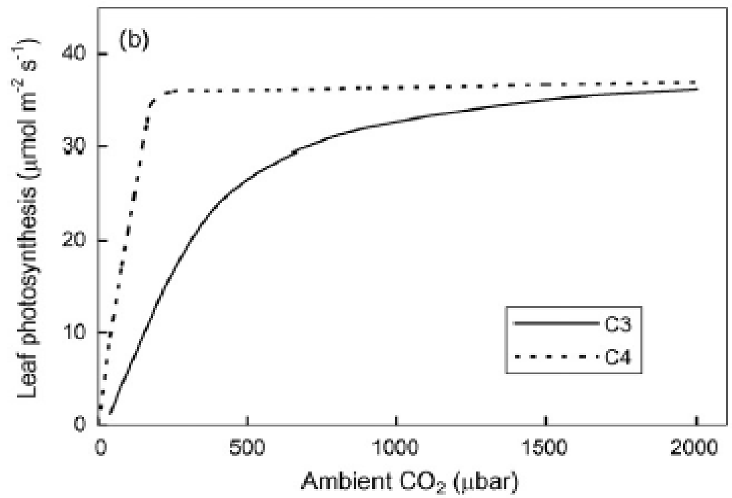
Methodology

» ε_{CO2} – CO_2 Fertilization Effect



Source: http://www.esrl.noaa.gov/gmd/ccgg/trends/global.html

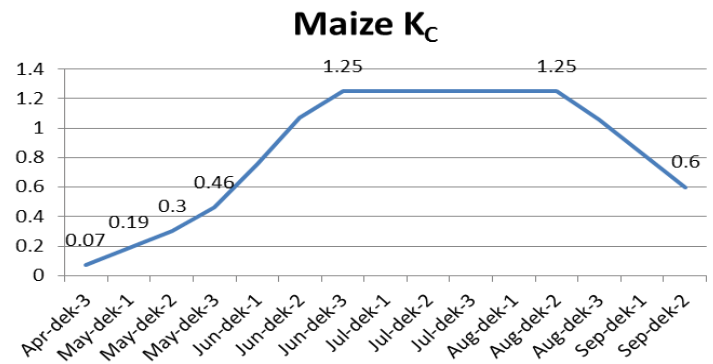


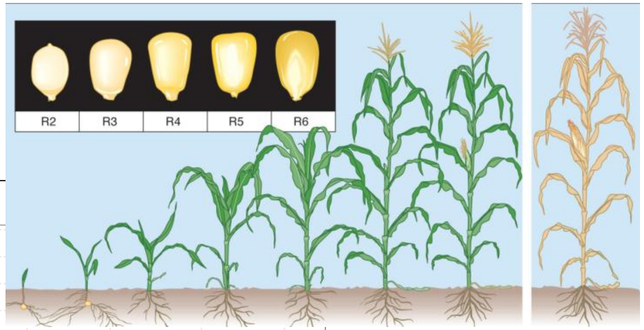


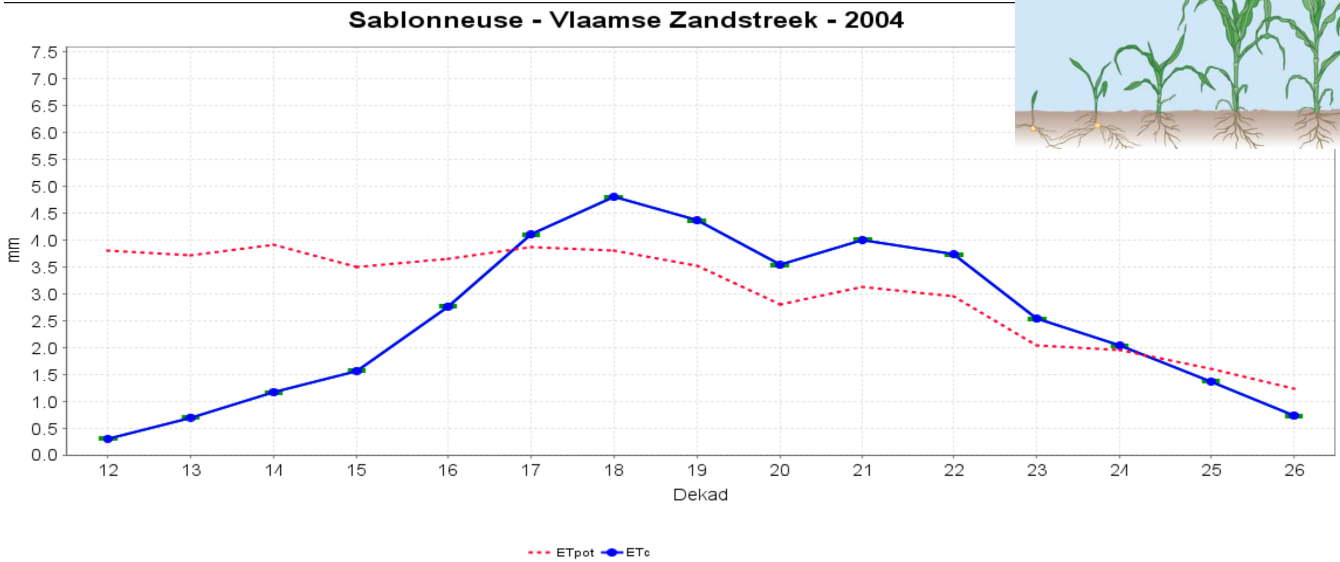
Source: Yin&Struik, 2009

Methodology

» ε_{H2O} – Water Stress Factor
  » Carnegie-Ames-Stanford approach (CASA): $0.5 + 0.5 * ET_{ACT} / ET_C$
  » ET_{ACT} calculated in AgroMetShell
  » ET_C: $ET_{POT} * K_C$

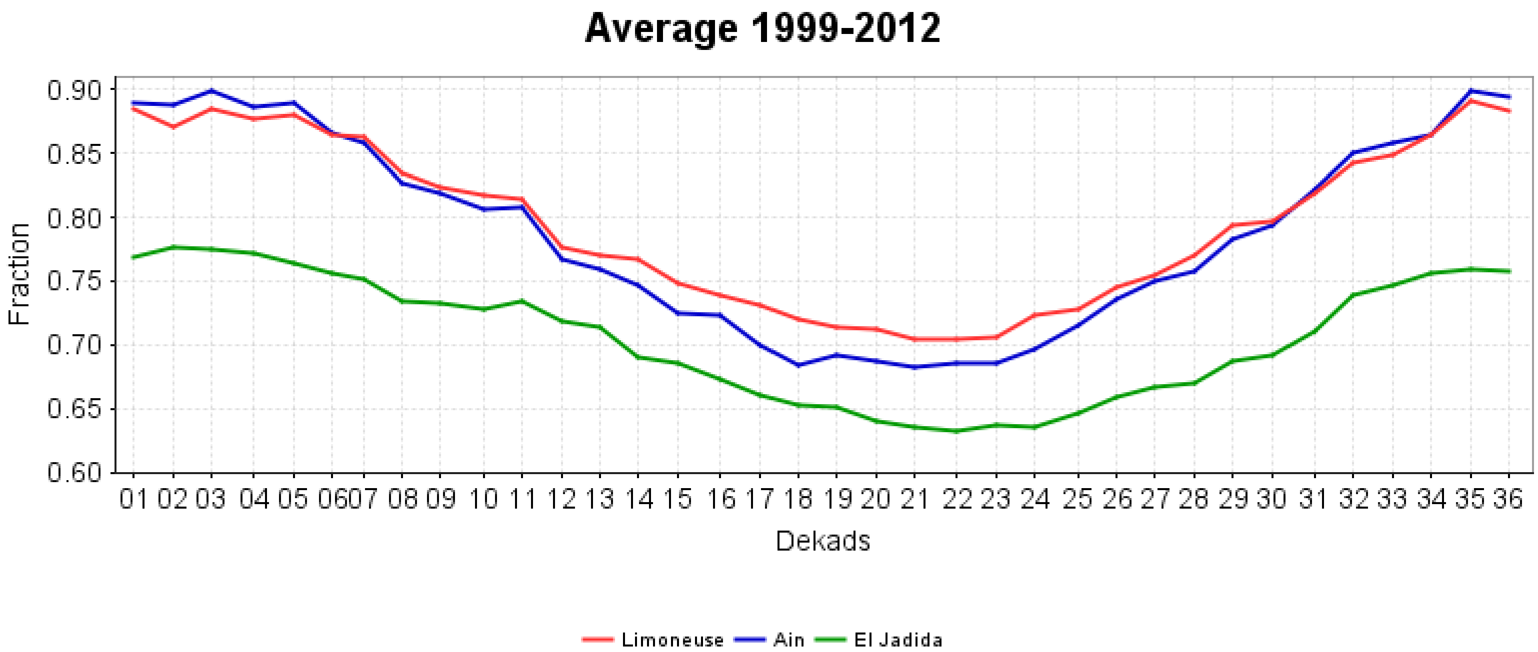






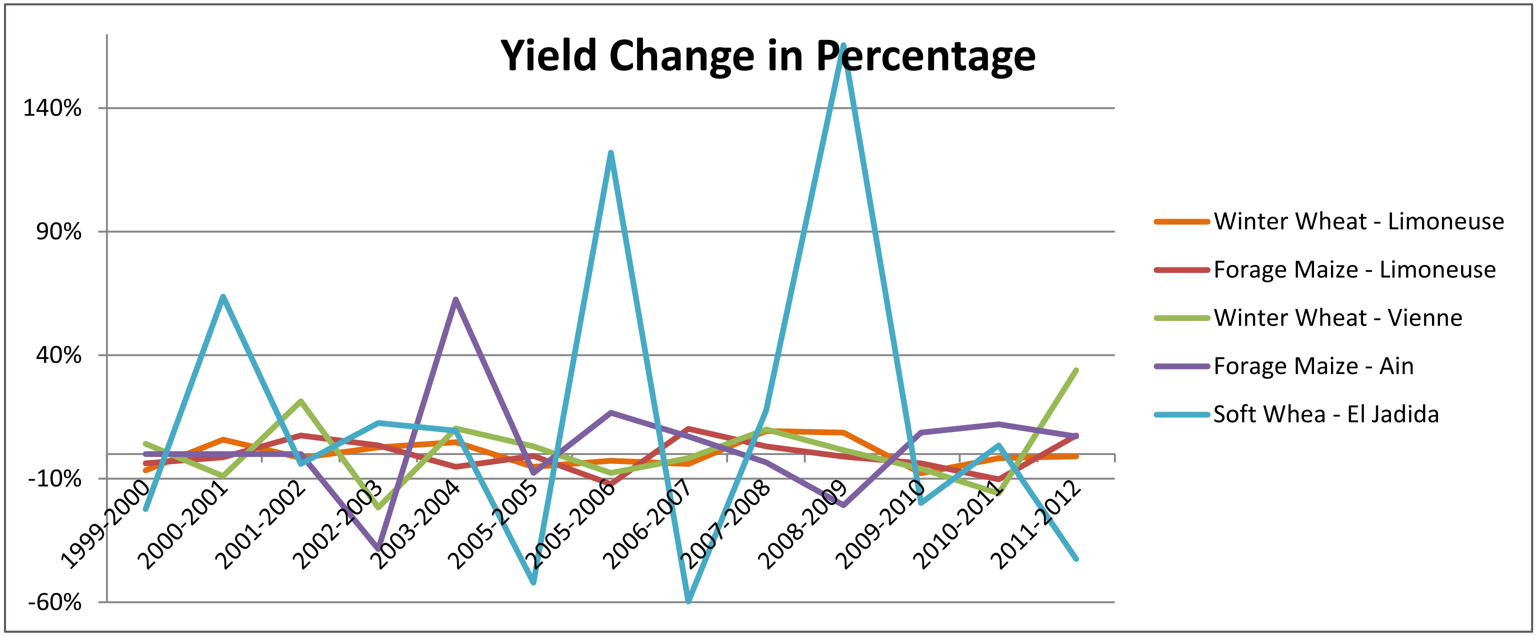
Methodology

» ε_{AR} – The fraction kept after autotrophic respiration (1-AR)



Results

» A single linear regression between DMP (cumulated over an optimal temporal window[1]) and actual yield statistics on a long term period (1999-2012) for forage maize and winter wheat.



[1] López-Lozano et al. 2013

Results

		Coefficient of Determination R^2				RRMSE			
Regions	**Crop**	**Original DMP**	**New DMP**	**fAPAR**	**NDVI**	**Original DMP**	**New DMP**	**fAPAR**	**NDVI**
Limoneuse (BE)	Winter wheat	0.52	**0.61**	0.36	0.40	2.94	**2.67**	3.36	3.28
Vienne (FR)	Winter wheat	0.33	**0.53**	0.41	0.35	5.88	**5.47**	6.13	6.44
El Jadida (MA)	Soft Wheat	0.64	**0.75**	0.57	0.54	20.05	**16.56**	22.03	22.38
Limoneuse (BE)	Forage maize	0.37	**0.55**	0.35	0.32	4.50	**3.78**	4.54	4.68
Ain (FR)	Forage maize	0.40	**0.85**	0.78	0.84	5.33	**5.13**	6.14	5.22

Results

» Sensitivity Analysis: to understand which stress factor is more important

		Stress Factors		
Regions	**Crop**	**CO_2**	**Temp**	**H_2O**
Limoneuse (BE)	Winter wheat	x		x
Vienne (FR)	Winter wheat	x		x
El Jadida (MA)	Soft Wheat	x	x	x
Limoneuse (BE)	Forage maize		x	x
Ain (FR)	Forage maize		x	x

Conclusions, Limitations and Future Work

- Conclusions:
  - Adding water stress factor improved single linear relation
  - For wheat, CO_2 and H_2O are the limiting factors for BE and FR; CO_2, Temp and H_2O are the limiting factors for MA
  - For maize, Temp and H_2O are the limiting factors for BE and FR
- Limitations:
  - Low interannual yield variability in Belgium & France
- Further work:
  - Validation with flux-net data

THANK YOU