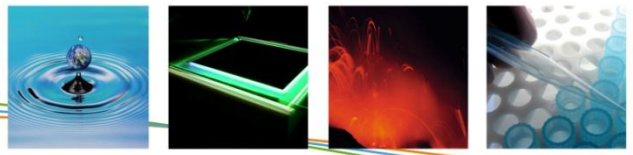
vito

vision on technology



24/05/2011

Impact of extreme events on crop production under climate change in Belgium

Dr.ir. Anne Gobin

COST 734

Importance of climate & weather impacts on crop production

- With climate change **extreme events** are likely to increase (droughts, heat stress, hail, floods, …)





- Common Agricultural Policy: farmers face more **risk** due to
  - Overall reduction of direct income support to farmers (pillar I)
  - In case of crop damage payments are reduced by 50% unless the farmer has an insurance

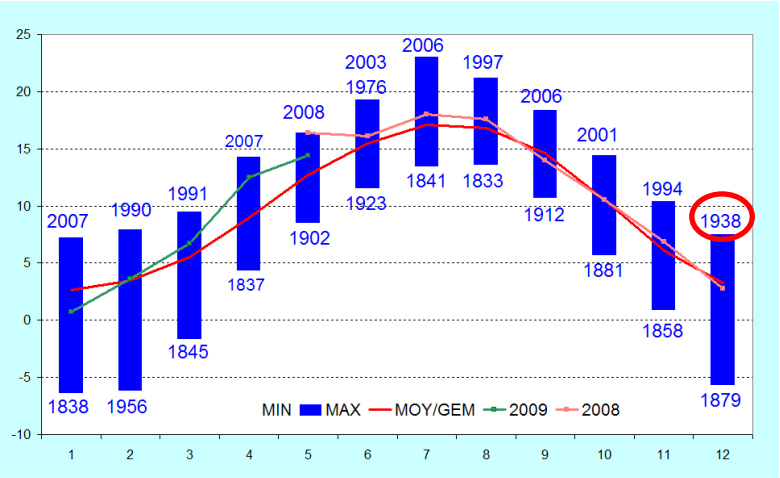
→ Demand for climate impact analysis and risk evaluation

Methods

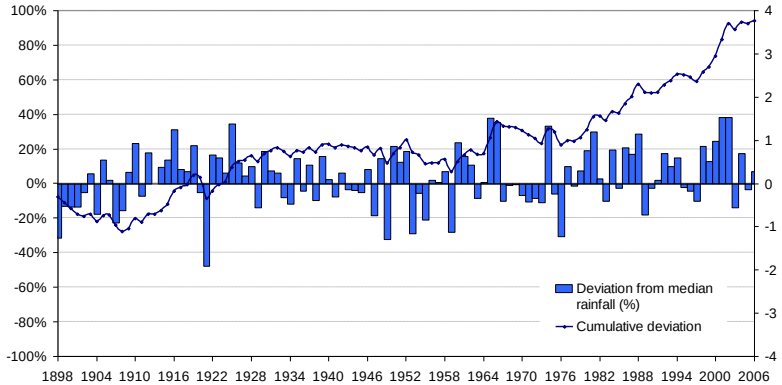
1. Observations & spatio-temporal trend analysis
   - » Meteo (1947 – 2008)
   - » Yields (1960 – 2008)
   - » Insurance (2006 as recent worst year)
2. Statistical analysis & statistical modelling
   - » Single meteo variables
   - » Agri-meteorological Indicators (e.g. drought, heat stress, waterlogging)
   - » Multivariate analysis & General Linear Modelling
3. REGCROP modelling framework
   - » Climate impacts under 3 climate change scenarios
   - » Capturing extreme events

OBSERVATIONS

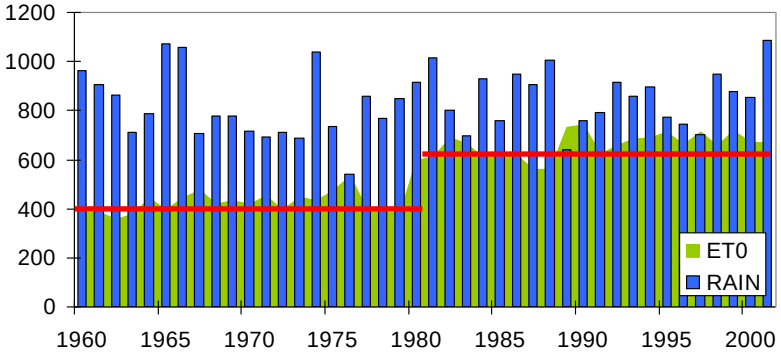
Meteorological observations



Temperature: 11 months had extremes after 1990 (RMI data)



Yearly Precipitation: 6.6% higher than 1960-1990 (25% increase in winter precipitation) (RMI data)



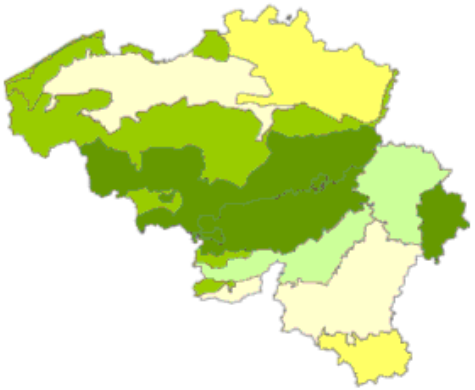
Water balance: 31 % less compared to last century due to summer droughts & higher temperatures

» Climate is changing (temperature, water balance, extreme events)

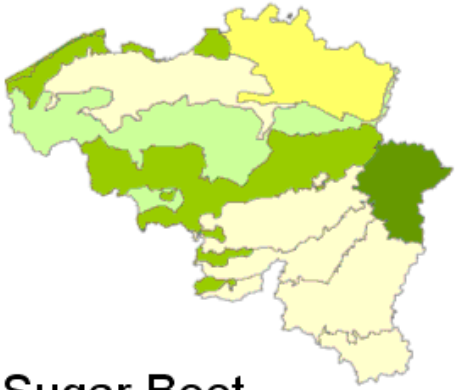
Yield – Meteo observations

- Temporal variability
- Spatial variability
- Implications for crop production

Winter wheat



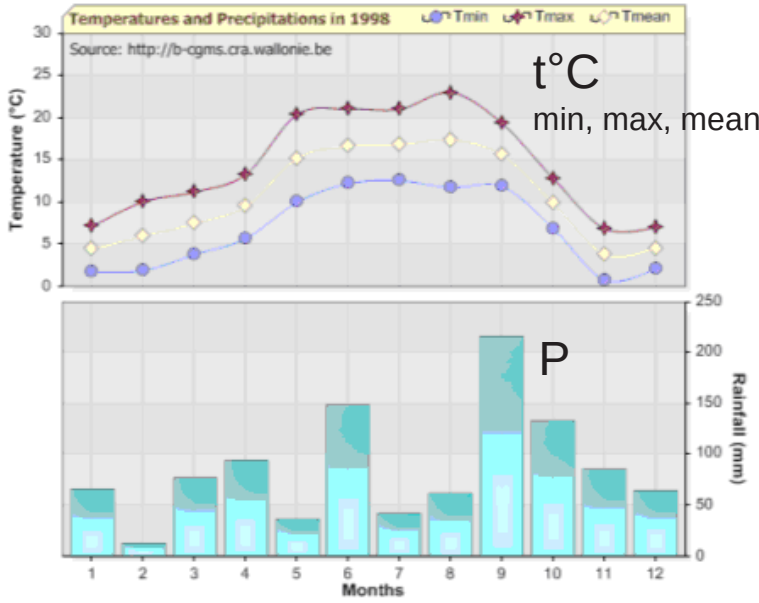
Winter Barley

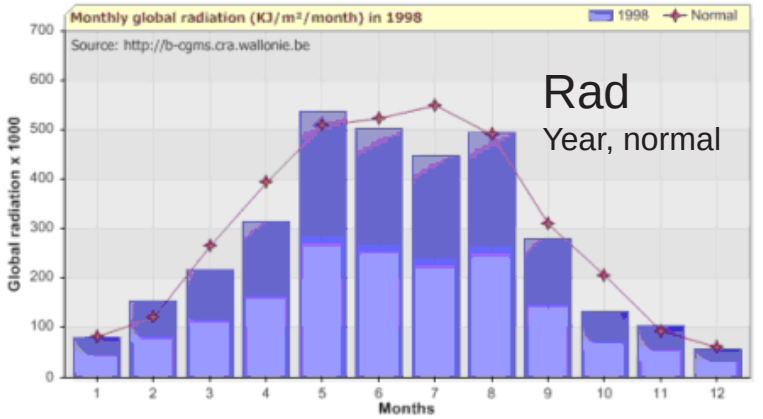


Sugar Beet

Potato (Bintje)

(data from BE-CGMS, 2006)

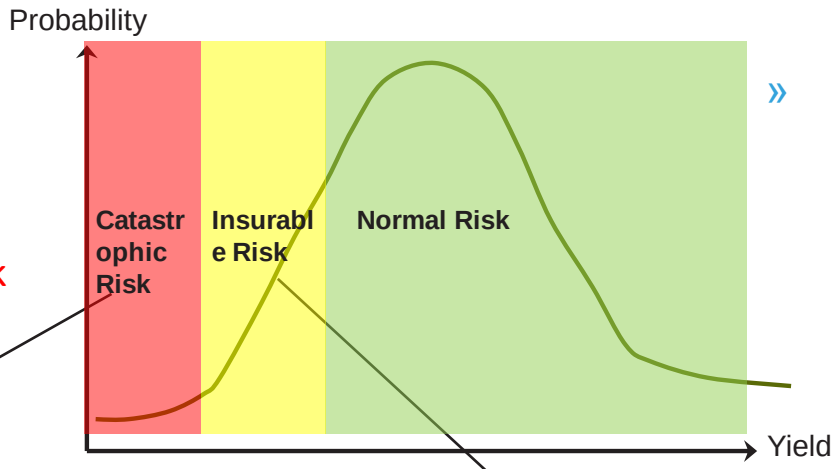




Insurance observations

- Risk Segmentation
  - 1 - Normal risk
  - 2 - Insurable risk
  - 3 - Catastrophic risk

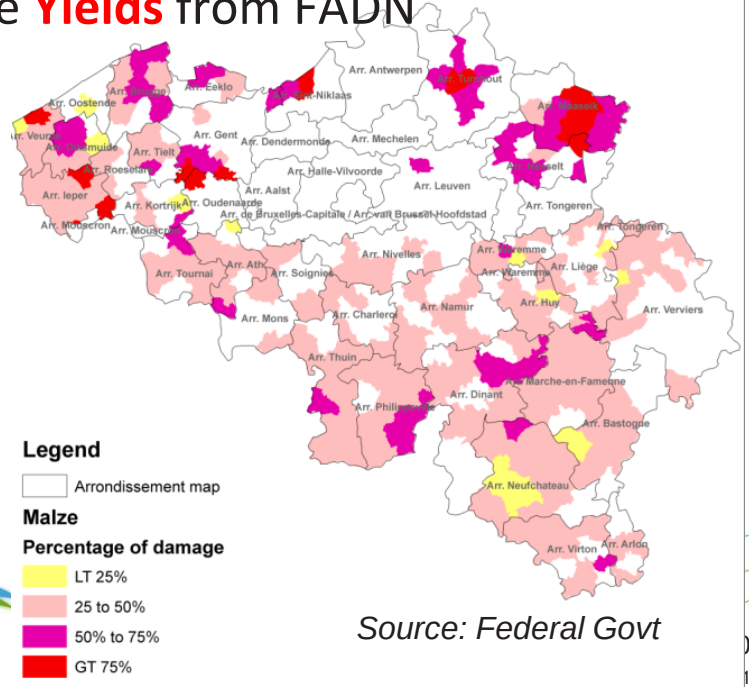
Source: Federal Govt



- Demand for impact analysis and risk evaluation
  ⇒farmers, government, insurance companies

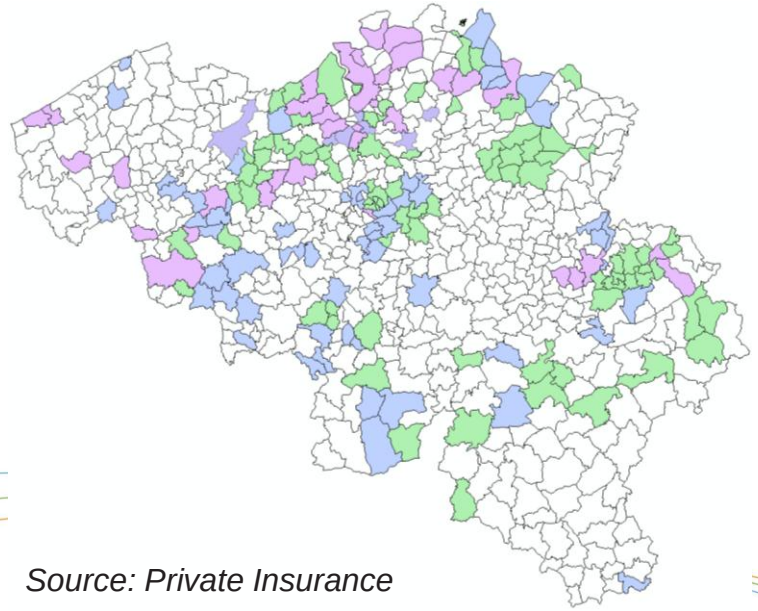
Belgian Calamity Fund

Extreme **Yields** from FADN



Source: Federal Govt

- Private Insurances: Claims for **Flood**, **Hail** & **Torrential Rain**



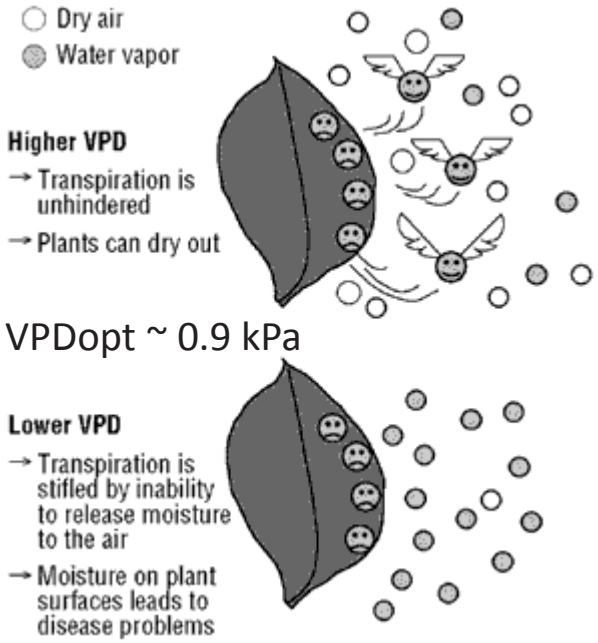
Source: Private Insurance

STATISTICAL RELATIONSHIPS
between meteo, climate change & yield

Temporal relationships VPD & CC

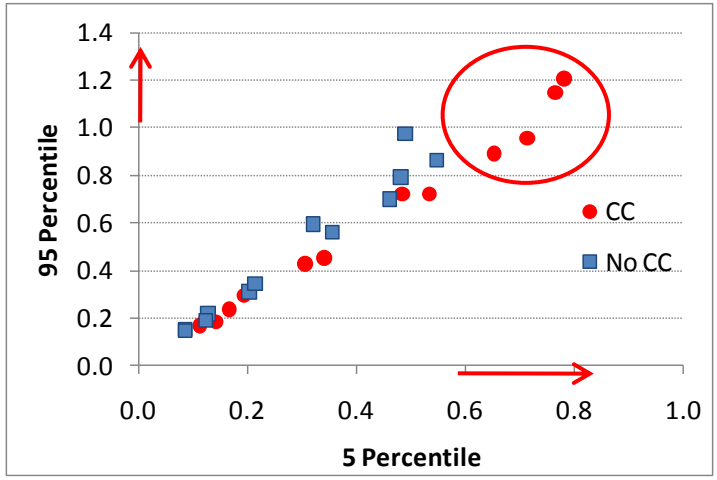
» VPD: difference between saturated and actual air moisture

VPDextr > 2 kPa
VPDhigh > 1.25 kPa

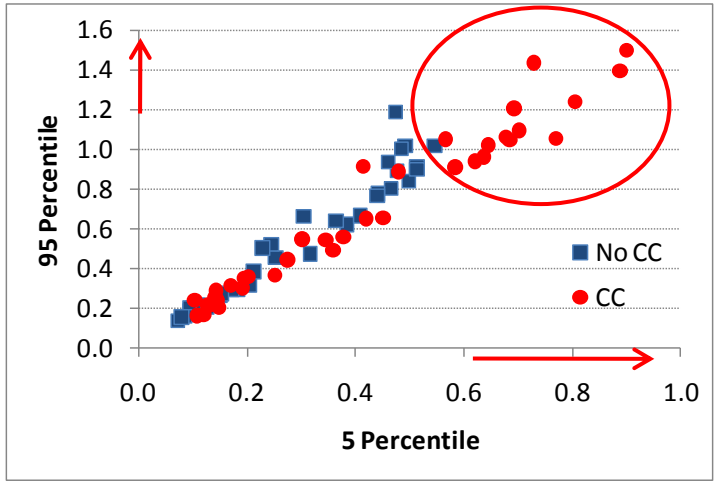


VPDopt ~ 0.9 kPa

VPDlow < 0.5 kPa



Monthly VPD



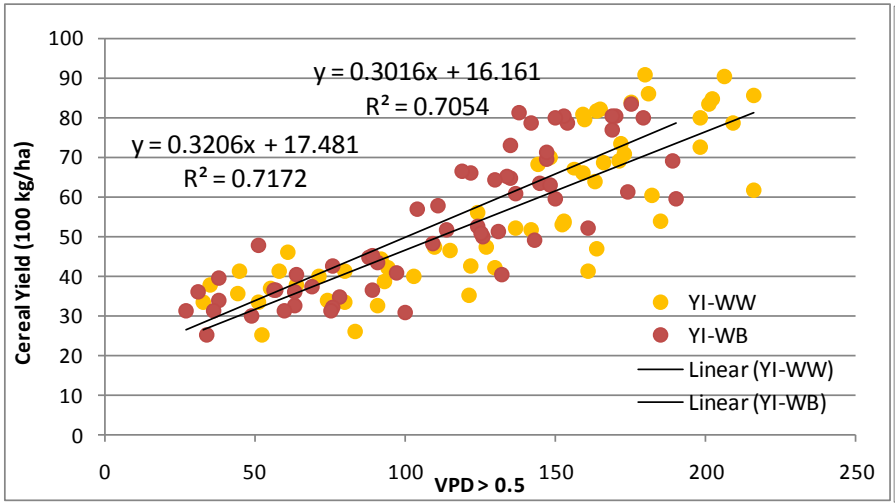
10-daily VPD

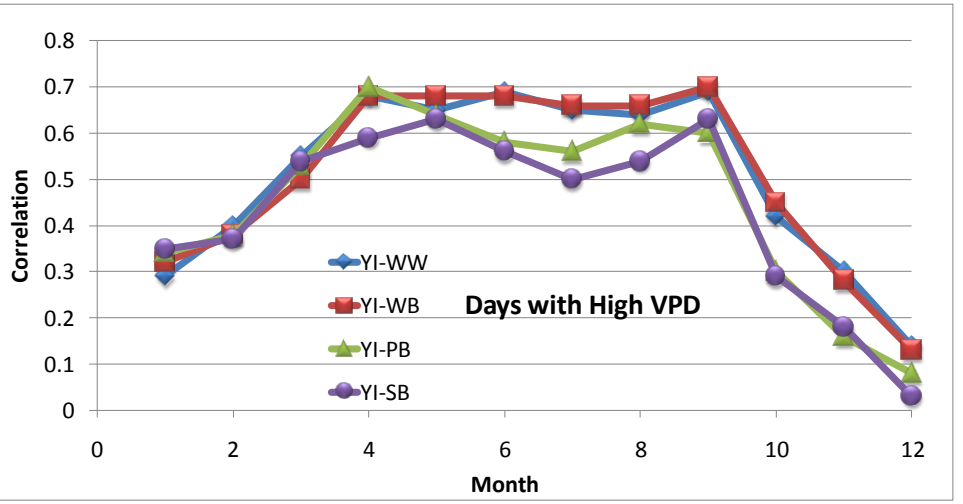
According to RMI
CC > 1987
No CC < 1987

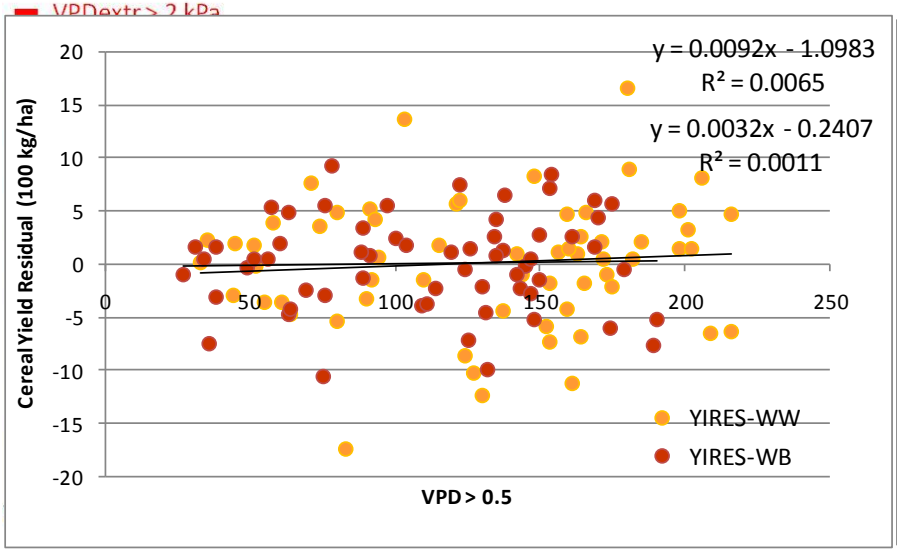
» With CC stretch towards VPDopt but increased risk for VPDextr

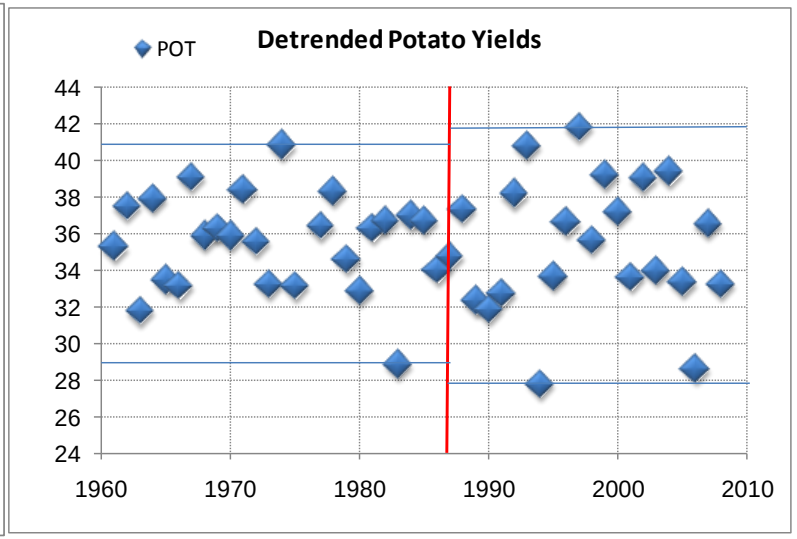
» Temporal aggregation masks extreme events (diff monthly – 10-daily)

Temporal relationships Yield - VPD









Cereal yield vs days with VPD > 0.5

- Significant relations between yield and VPD
- NO relation between yield residuals and VPD

Climate change & (meteorological) variables

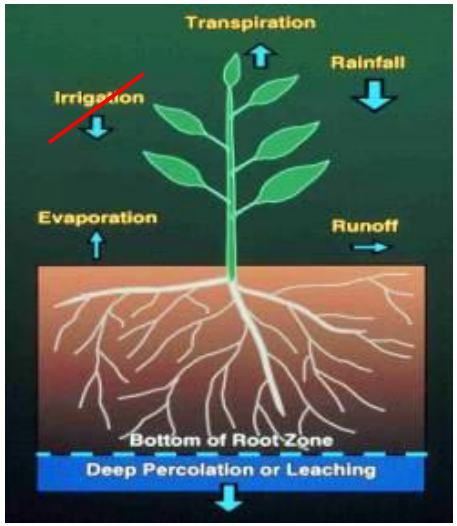
Meteo Indicator	Statistical Parameter	Winter Wheat				Winter Barley				Potatoes				Sugar Beet			
Yield (100 kg/ha)	*p*	*< 0.001*				*< 0.001*				*< 0.001*				*< 0.001*			
	M0 [SD]	43.5	11.2			42.2	11.3			287.5	59.5			453.4	87.9		
	M1 [SD]	77.8	8.4			72.5	7.9			428.6	45.8			637.2	57.3		
Yield Residuals (100 kg/ha)	*p*	*0.081*		Correlation		*0.442*		Correlation		*0.652*		Correlation		*0.825*		Correlation	
	M0 [SD]	-0.98	6.28	Yield	YIRES	-0.33	4.54	Yield	YIRES	-1.19	35.29	Yield	YIRES	-0.49	63.21	Yield	YIRES
	M1 [SD]	1.86	5.28			0.62	4.59			3.23	38.47			2.83	35.71		
Growing days *VPD* > 0.5 (kPa)	*p*	*< 0.001*				*< 0.001*				*< 0.001*				*< 0.001*			
	M0 [SD]	49.9	22.8	0.83	0.08	41.3	19.1	0.78	0.03	64.3	32.0	0.71	-0.07	68.5	35.3	0.66	-0.10
	M1 [SD]	91.8	11.9			76.5	10.6			110.1	10.4			119.8	12.3		
Σ THU (°C)	*p*	*< 0.001*				*< 0.001*				*< 0.001*				*< 0.001*			
	M0 [SD]	1651.4	116.6	0.58	0.08	1385.1	112.0	0.35	-0.03	1327.6	125.2	0.37	-0.24	1709.5	144.2	0.38	-0.30
	M1 [SD]	1910.0	138.8			1610.7	139.8			1483.3	89.9			1872.3	108.5		
Σ PET (mm)	*p*	*< 0.001*				*< 0.001*				*< 0.001*				*< 0.001*			
	M0 [SD]	507.5	56.0	0.67	0.20	445.8	50.1	0.66	0.12	490.6	64.5	0.32	-0.18	538.2	68.5	0.34	-0.21
	M1 [SD]	597.8	40.8			521.3	33.6			556.3	38.0			610.3	42.9		
Average of Tmin (°C)	*p*	*< 0.001*				*< 0.001*				*< 0.001*				*< 0.001*			
	M0 [SD]	4.7	0.6	0.59	-0.06	4.2	0.6	0.59	-0.05	10.0	0.6	0.52	-0.16	9.8	0.6	0.59	-0.20
	M1 [SD]	6.0	0.7			5.5	0.7			11.1	0.7			10.9	0.7		
Growing days rain < 0.2 mm (number)	*p*	*< 0.001*				*< 0.001*				*0.0045*				*0.0047*			
	M0 [SD]	132.6	18.0	0.43	0.37	122.0	17.0	0.83	0.20	79.5	13.2	0.08	-0.32	94.9	14.8	0.17	-0.37
	M1 [SD]	151.9	20.7			138.5	19.5			89.9	13.0			106.6	14.9		
Growing days rain > 15 mm (number)	*p*	*0.242*				*0.203*				*0.013*				*0.021*			
	M0 [SD]	6.0	3.3	0.10	-0.27	5.3	3.1	-0.03	-0.18	3.7	2.3	0.36	0.21	4.6	2.5	0.37	0.21
	M1 [SD]	7.0	2.8			6.4	2.9			5.2	2.0			6.2	2.4		

- Significant differences between pre-1987 (No CC) and post-1987 (CC)
  - NOT for yield residuals, and not for high rainfall days in winter crops
- Significant correlations between between T-related meteo and yields
  - NOT for yield residuals
- Significant correlations between P-related meteo and yield residuals
  - Summer crops relate positively to rain during the growing season
  - Winter crops relate positively to dry days during the growing season

REGCROP MODELLING FRAMEWORK
to capture relationships between meteo, climate change & yield

REGCROP: Dynamic Coupling of

Water balance (ET_0 driven)



$$\theta_t = \theta_{t-1} + P + (GW + I) - RO - ET_{crop}$$

Water balance corrected for:

- Water use (efficient at higher CO_2 concentrations)
- Reduced growth under water stress (shortage or water logging)

Biomass growth (Rad driven)

$$BIO = LUE * MIN(DR, WL, TR, VPDR) * BE * 0.5 * RAD * \left[1 - e^{-0.65*LAI}\right]$$

Monteith equation corrected for:

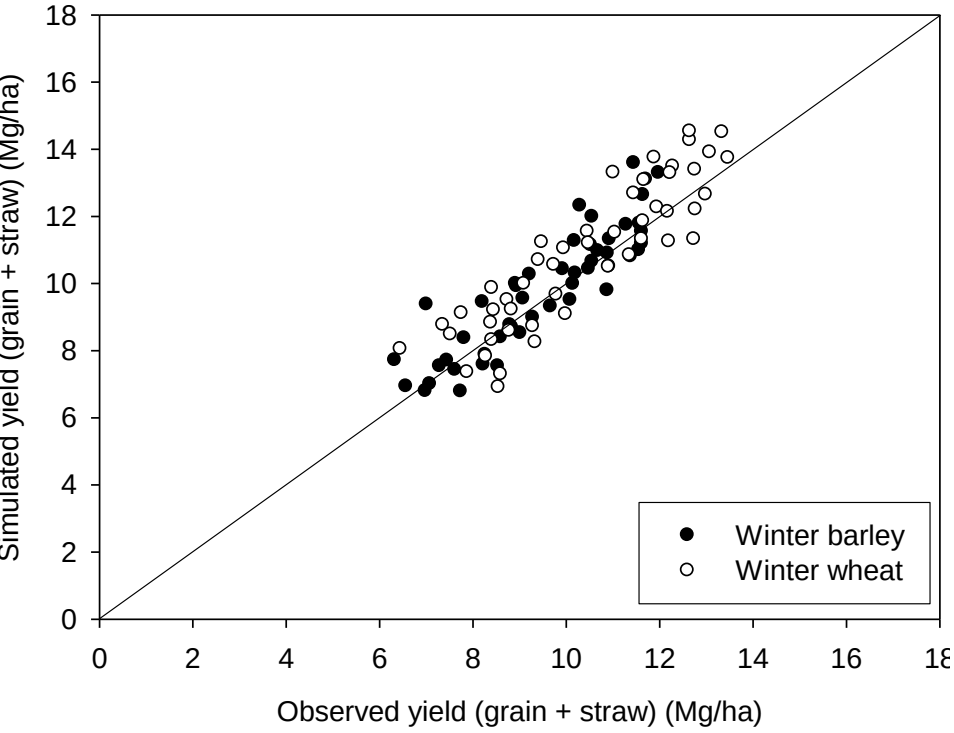
- Temperature increases
- Growth stress (VPD, WL, DR, TR)
- Changing CO_2 concentrations

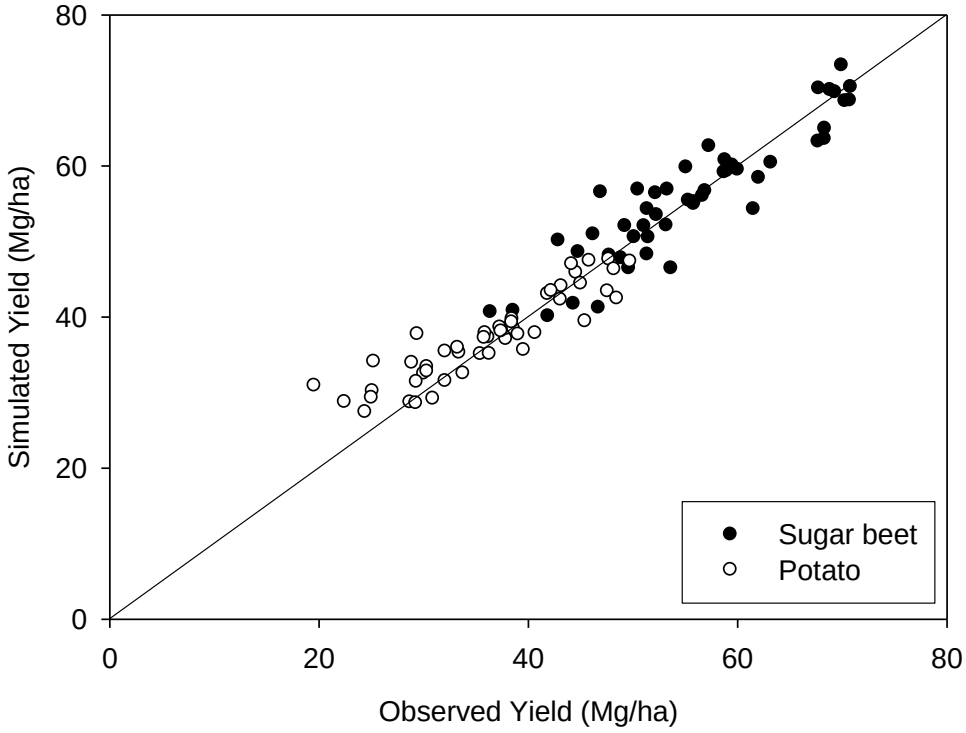
Phenological stadia: in cumulative temperature days with base and maximum temperature as boundaries of phenological activity

Source: Gobin, 2010

Output: water balance, yield , heat/drought/waterlogging stress

REGCROP goodness of fit on historical data



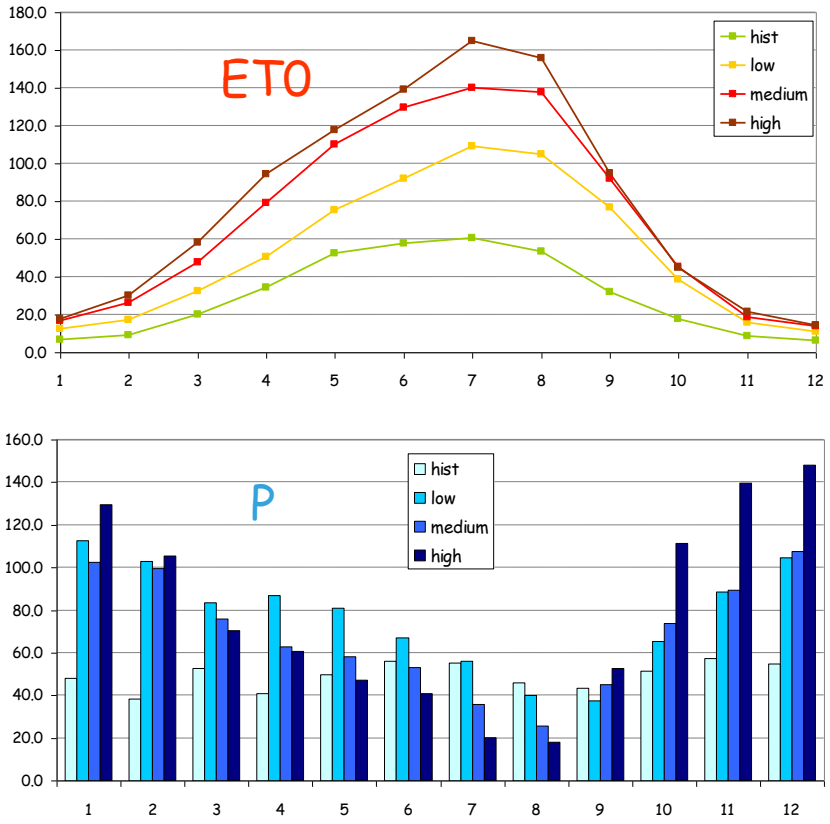


- Model efficiency: 68% (WW) – 84% (SB)
- R^2: 0.80 (cereal) - 0.83 (P) - 0.84 (SB)

Three climate scenarios compared to 1960-1989

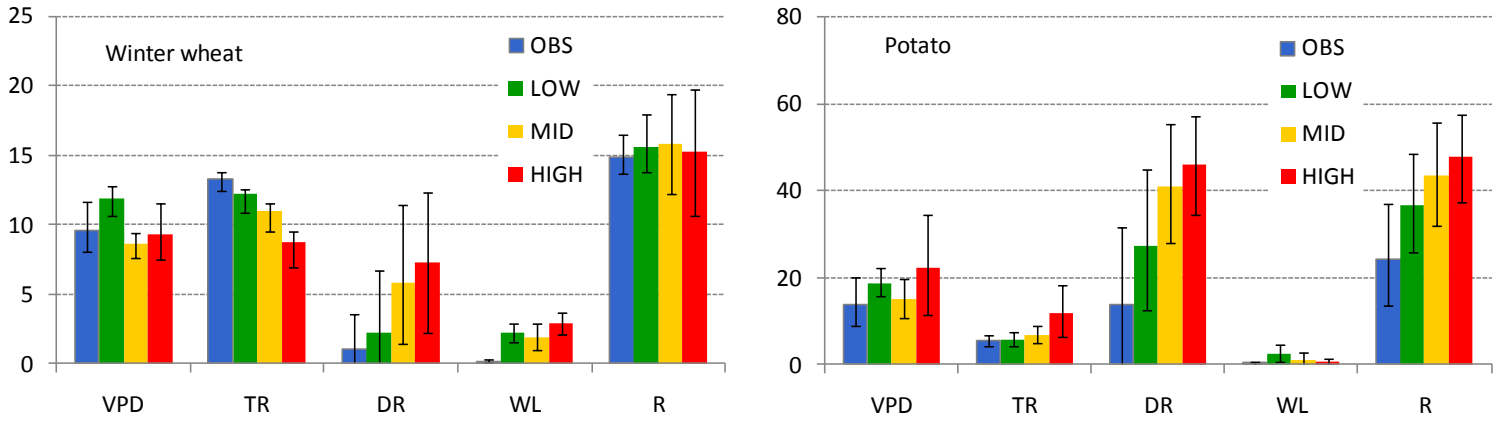
SELECTION OF 3 SCENARIOS

- PRUDENCE (FP5; *Christensen et al., 2007*):
  - Downscaling of GCMs to RCMs
  - RCM predictions for Grid 25 – 50 km
  - 3 GCMs (HADCM, ECHAM(/OPYC), HADAM)
  - 10 RCMs ; 28 Ensembles
- Daily hindcasted datasets: *n = 21*
  - Comparison for P (*Ntegeka & Willems, 2008*)
  - Comparison for ET0, M (*Gobin, 2010*)
- Simulations for 8 crops, 3 soils, observed & 3 climate change scenarios (*n = 3480*)
  - Three soil types (clay, loamy sand & loam) to capture regional variability *(Gobin, 2010)*
- REGCROP (Observed versus simulated)
  - *Model efficiency: 68% (WW) – 84% (SB)*
  - *R^2: 0.80 (cereal) - 0.83 (Potato) - 0.84 (SB)*



Climate impacts on Biomass Production

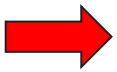
- Yield reduction calculated for 3 climate change scenarios and observations
  - Based on heat stress (VPD, TR), drought (DR), water logging (WL)
  - Overall biomass reduction (R)



- Winter cereals
  - Reduction may be up to 15%, no pronounced difference with CC scenarios, but variability increases
  - Positive effect of temperature, but negative of waterlogging
  - Ideally harvest before drought and heat stress occurs
- Summer crops
  - Serious yield reductions, expected to increase with climate change
  - Major contributors are drought and increased heat stress

Conclusions

- **Observations**
  - Climate is changing - spatio-temporal variability in yields & meteo
  - Demand for climate impact analysis and risk evaluation (insurance)
- **Statistical** Modelling
  - Meteo variables & indicators related to temperature explain the yield at the national level (General Linear Model: R^2 from 0.70 - 0.74)
  - Meteo variables & indicators that influence the water balance tend to explain the yield variability
- **REGCROP Modelling** Framework for climate impacts & weather related stress
  - Model captures stress due to drought, heat & waterlogging dynamically linked to the growing season cycle
  - Summer crops: serious impact of drought & heat; winter cereals: impact may be positive but risk of waterlogging



Climate impact & risk analysis necessitates a multi-modal approach

Thank you for your attention!

- More Information:
  - anne.gobin@vito.be