A Regional Dynamic Biomass model to assess climate adaptation

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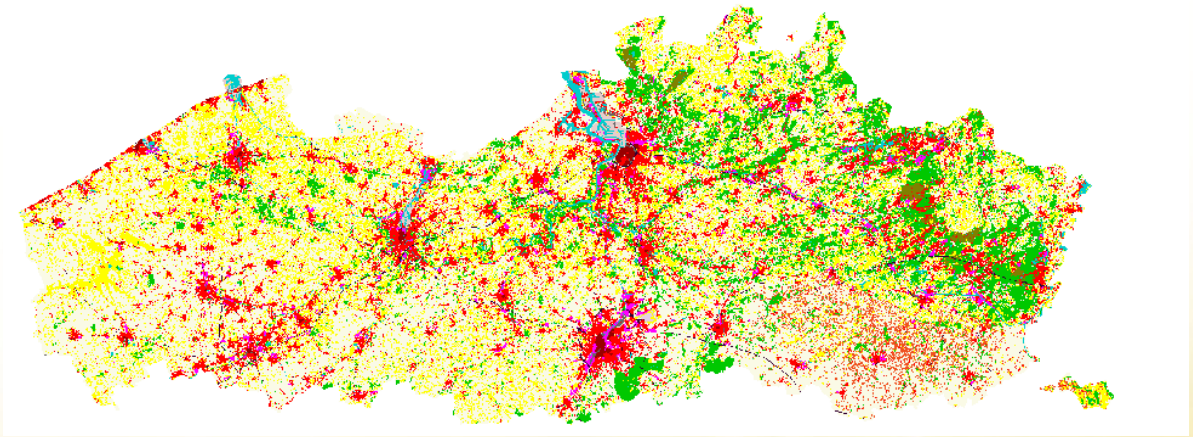
Agriculture and Climate Change

- Agriculture is one of the sectors most sensitive to climate change

- More than 60% of land use and open space in Flanders is managed by agriculture

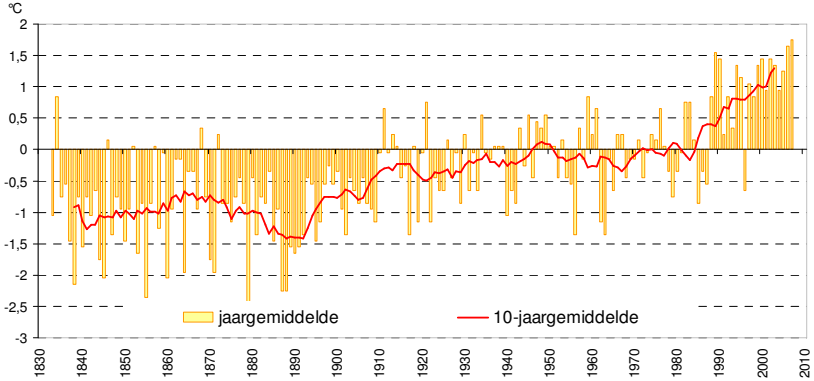


2007: 61.4 % of the total land is used by agriculture

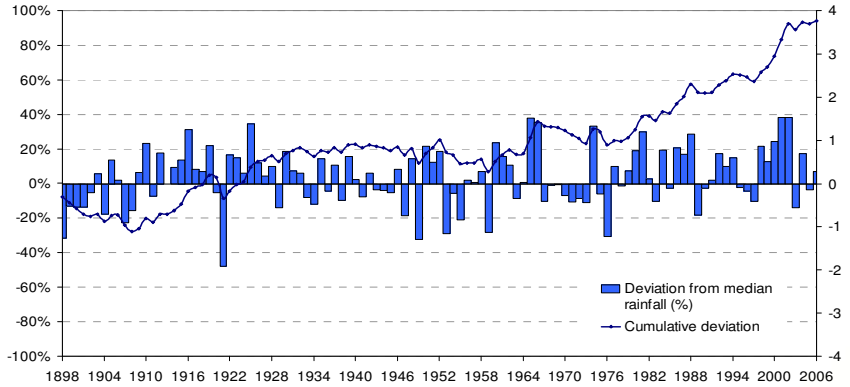
High impact of climate change is expected

→ Analysis of climate impacts is needed to assess adaptation potential & opportunities

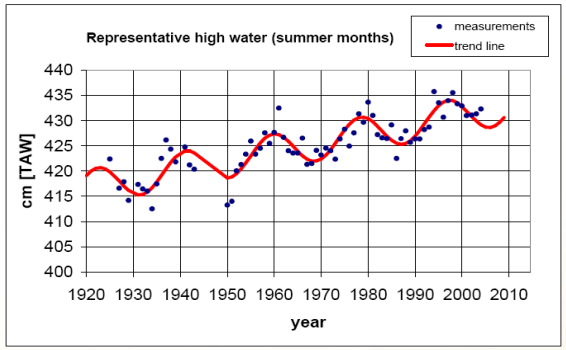
Observations in belgium



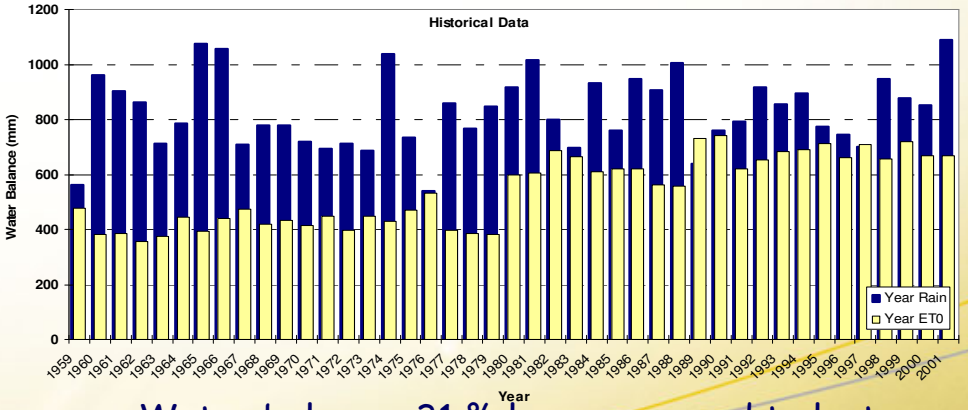
Temperature: 1.3°C higher than normal 1960 – 1990 (KMI/MIRA, 2008)



Yearly Precipitation: 6.6% higher than 1960-1990 (25% increase in winter precipitation) (KMI/MIRA, 2008)



Sea level Rise: 18 cm / century
No recent acceleration
(AWZ, 2005)

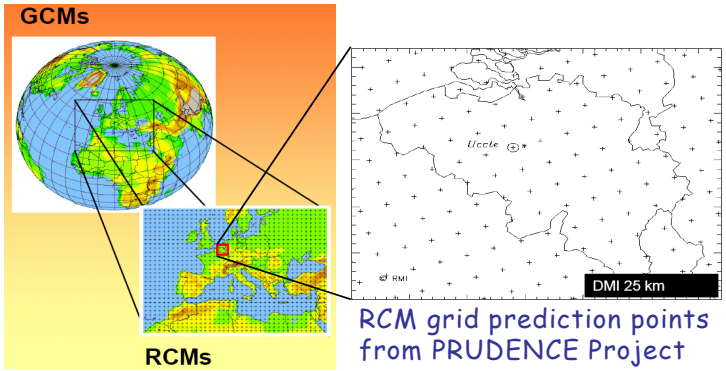


Water balance: 31 % less compared to last century due to summer drought

Climate change is a fact

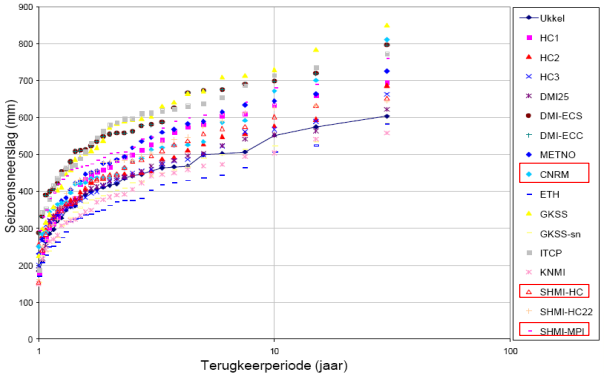
Climate change scenarios

- low-middle-high CC scenarios based on a comparison of Europese Regional Climate Models (PRUDENCE Project)



RCM grid prediction points from PRUDENCE Project

Downscaling of GCMs to RCMs
RCM predictions for Grid 25 – 50 km
(PRUDENCE, FP5; Christensen et al., 2007)



E.g.: Ukkel summer precipitation versus return period

Grids with meteorological variables for Ukkel downloaded
Multi-criteria analyse (KMI/KULeuven)

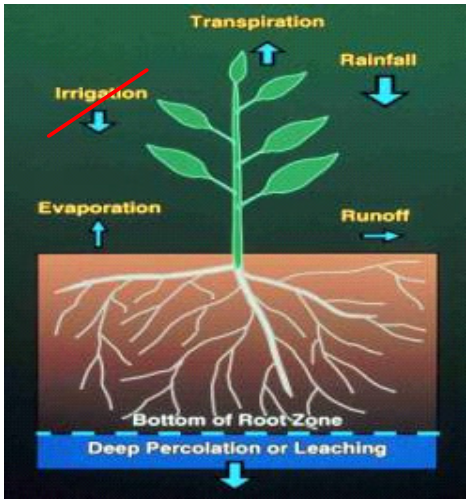
→ 3 scenarios (2070-2099) with temperature changes:

	Low	Middle	High
Winter (DJF)	0.9	1.4	2.3
Summer (JJA)	1.1	1.7	2.9

- Meteorological variables as input for biomass model
  - KMI/KULeuven low-middle-high CC scenarios for T & P
  - Time series 2070-2099 for P, T, Rad, windspeed, … for Ukkel grid
  - Data handling: 360/gregorian, calculation of ETO & other agri-met parameters

Dynamic Coupling of climate with biomass production (own model)

- Waterbalance (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)

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

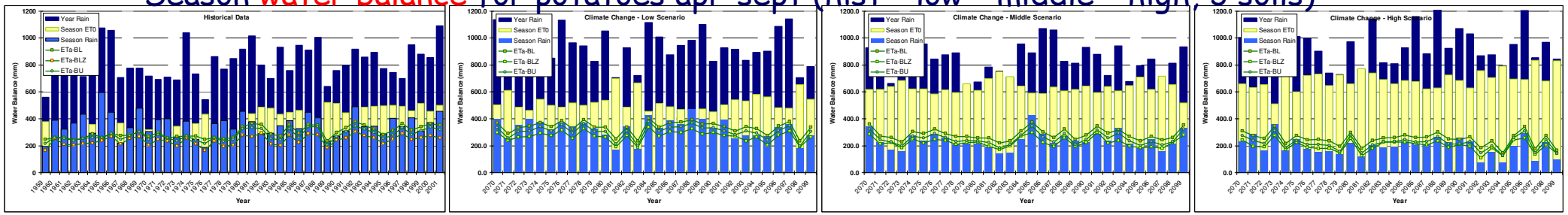
Monteith equation corrected for:
- Temperature increases
- Moisture stress (VPD)
- Changing CO_2 concentraties

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

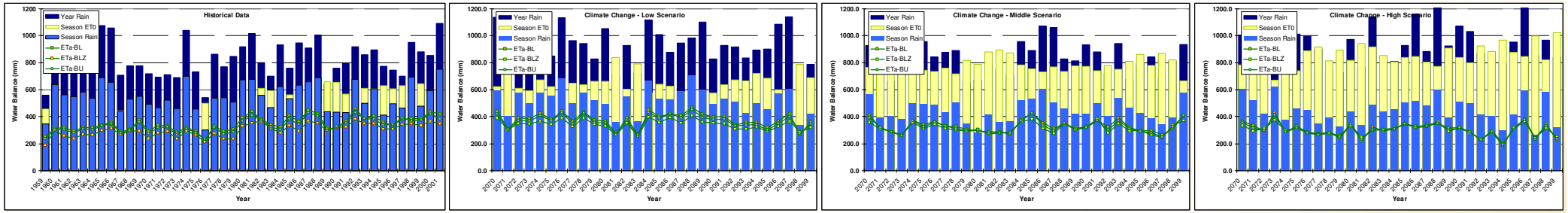
Output: waterbalance variables & yield fractions

SEASON WATER BALANCE - Results of 3480 Simulations (8 crops, 3 soils, observations & 3 climate change scenarios)

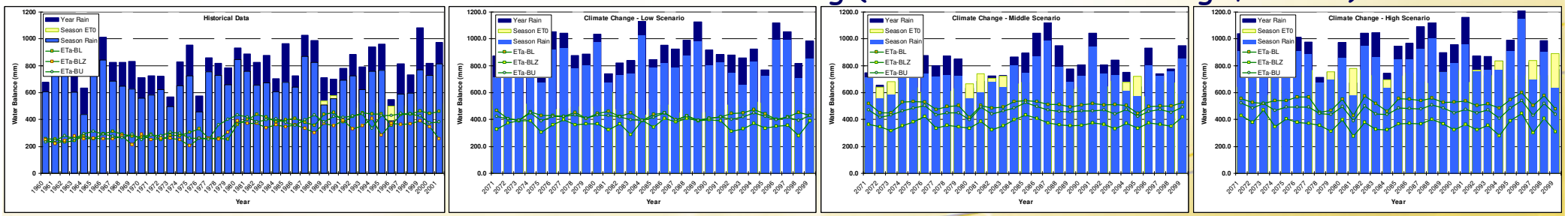
Season water balance for potatoes apr-sept (hist – low – middle – high, 3 soils)



Season water balance for temporary grass mar-nov (hist – low – middle – high, 3 soils)



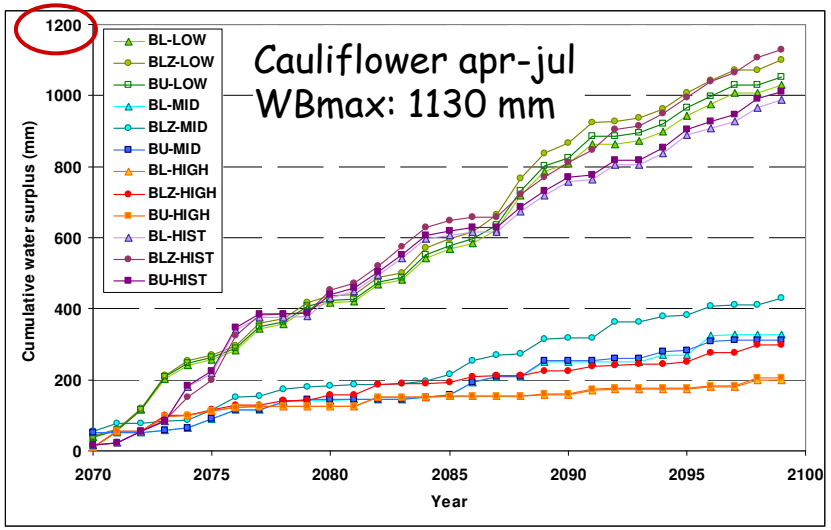
Season water balance for winter wheat oct-aug (hist – low – middle – high, 3 soils)



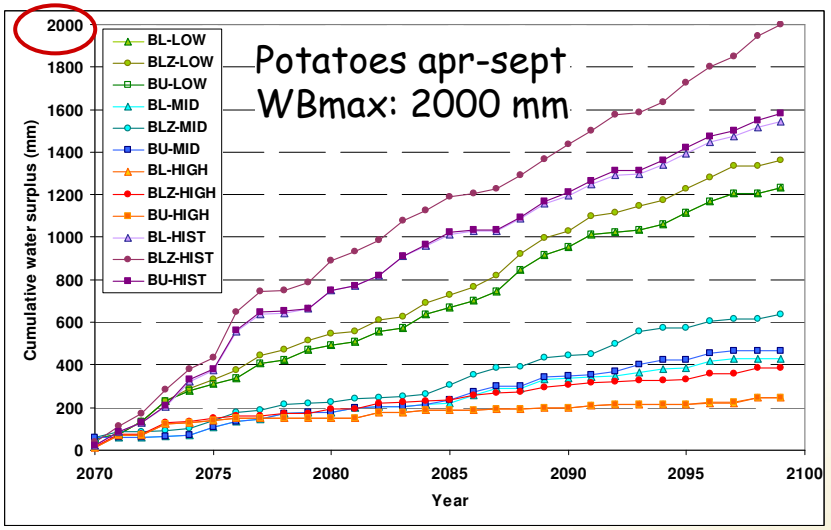
- Most problems: shallow rooting summer crops when the sensitive stage coincides with dry spells
- Winter crops may suffer from water logging
- Yearly balances fail to reflect seasonal dry spells!

CUMULATIVE WATER BALANCE - Results of 3480 Simulations (8 crops, 3 soils, observations & 3 climate change scenarios)

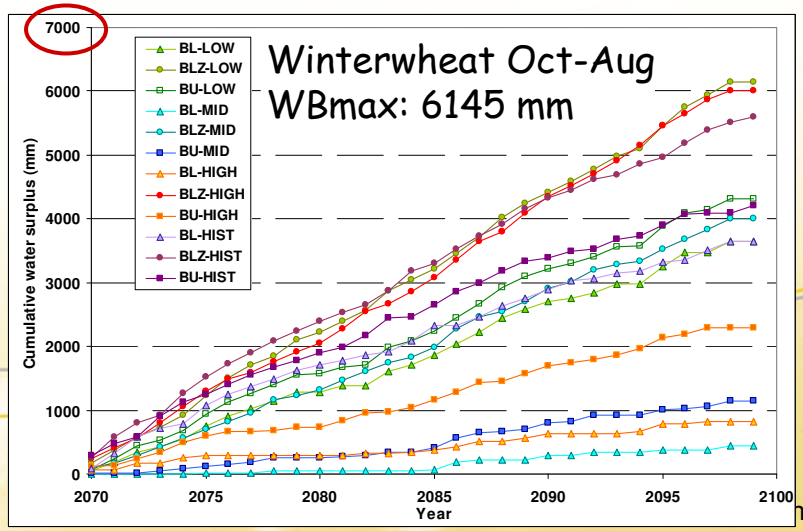
Cumulative seasonal surplus on the water balance (Runoff & Drainage)



Hist ~ low > middle ~ high



Hist > low > middle > high

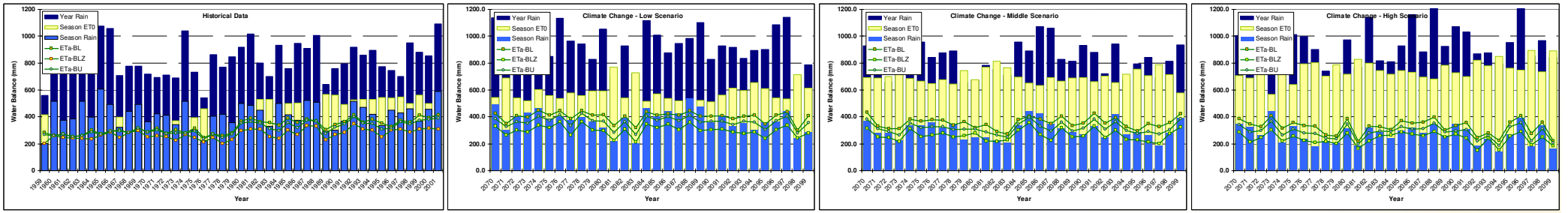


WW: Differences between CC-scenarios are less pronounced

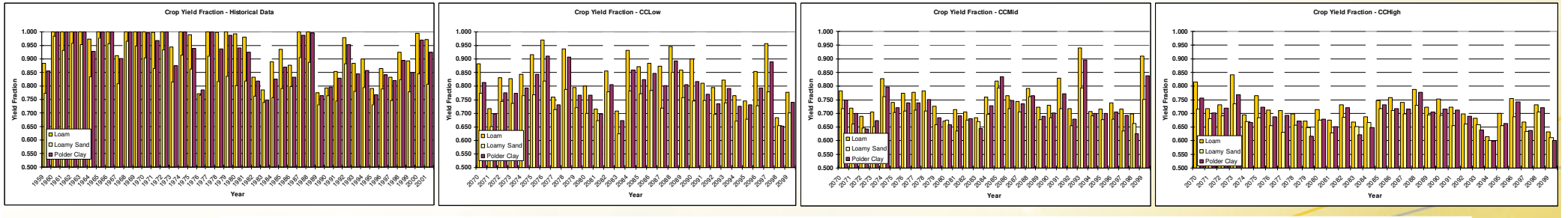
PLANT GROWTH & BIOMASS - Results of 3480 Simulations (8 crops, 3 soils, observations & 3 climate change scenarios)

Biomass: actual yield related to optimal yield

Water balance for sugar beet (hist – low – middle – high, 3 soils)



Yield fractions for sugar beet (hist – low – middle – high, 3 soils)



Yield loss ranges

sugar beet: 16-40%, grass: 14-41%, fodder maize: 13-33%, grain maize: 9-30%, potatoes: 12-30%, cauliflower: 2-14%, winterwheat: 0-8%

Modelled variability in historical series is of the same magnitude as the relative yield fractions calculated from statistical data

Economic Upscaling

BASELINE: Gellynk et al. 86.5% of total production (5639 MEuro)

End Production

Economic productivity

Technical Productivity

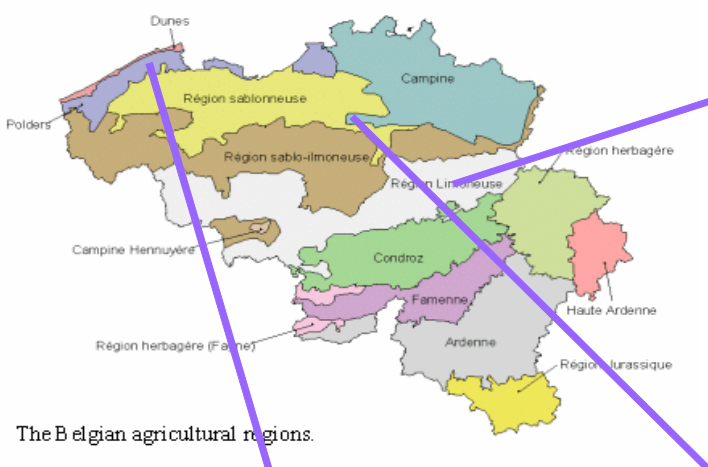
Climate effect!!!

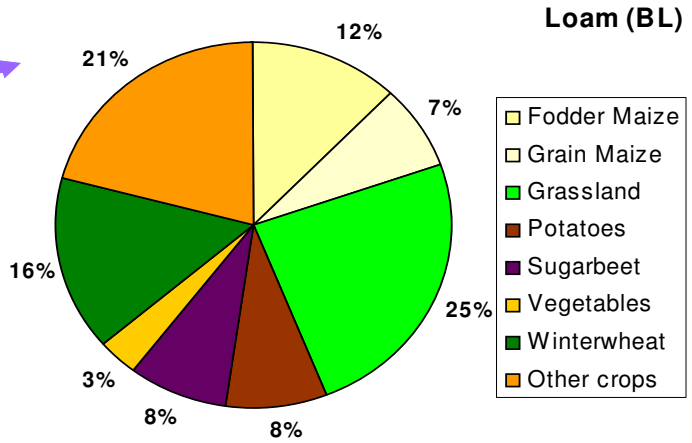
Price effect

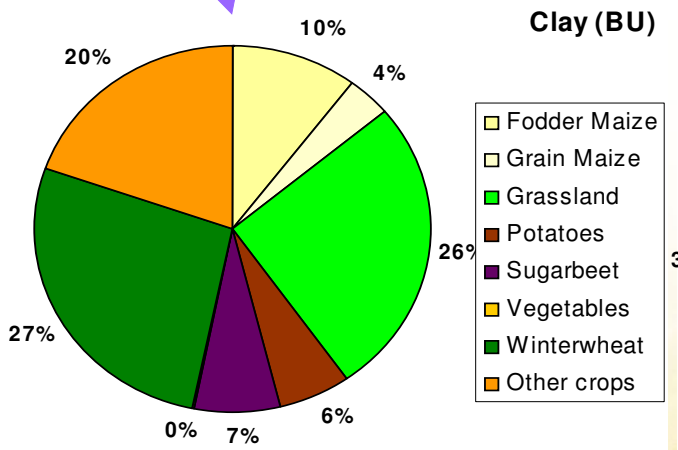
Nr	Production Activity	EW2020	EP 2020	TP 2020	PE 2020	Amount in 2020
	Crops	(mEUR)	(EUR/ha)	(Ton/ha)	(EUR/Ton)	Netto area (ha)
1	Cereals	38.00	651.00	9.48	68.71	58,371.74
2	Potatoes	386.00	5,071.00	48.60	104.35	76,119.11
3	Sugar beet	123.00	2,417.00	69.98	34.54	50,889.53
4	Grain Maize & Other Arable	NA	1,393.00	11.71	118.94	48,113.00
5	Fruit & Veg	442.00	13,544.00	22.36	605.82	32,634.38
6	Fruit & Veg under glass	635.00	235,072.00	108.15	2,173.50	2,701.30
7	Fruit	540.00	21,534.00	26.73	805.74	25,076.62
8	Non consumable crops	443.00	69,707.00	15.00		6,352.00
9	Fodder Maize & Grass					335,468.00
Nr	Animals	(mEUR)	(EUR/animal)	(Liter or Ton/animal)	(EUR/liter or Ton)	Number of animals
10	Dairy milk	477.00	789.00	3,837.27	0.21	604,563.00
11	Dairy meat	235.00	789.00	0.33	2,395.60	286,439.00
12	Pigs	2,007.00	202.00	0.09	2,187.07	9,935,644.00

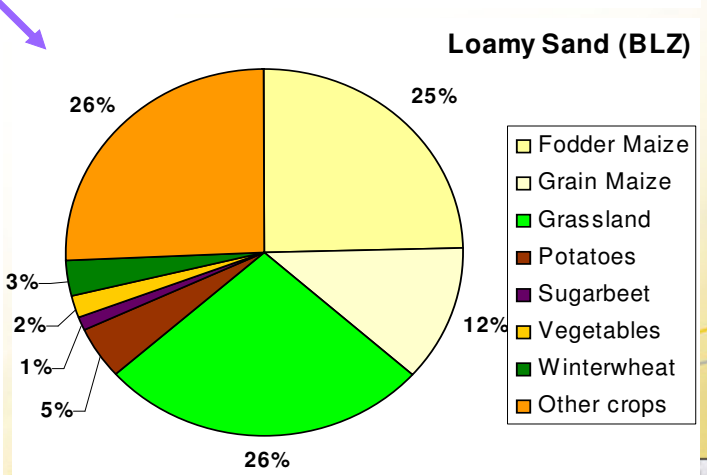
Production at regional scale (Aggregation)

- Technical Productivity from model runs per soil type & crop & Climate scenario
  - -Distribution of Production Activities per agricultural zone (soil type)









based on IACS

Technical productivity per crop for Flanders

Adoption of adaptation measures

- Adoption rate of adaptation measures

AD1

AD3

Typologie (in economische termen)	Aandeel in totaal aantal bedrijven	Aandeel in totale landbouwoppervlakte	Aandeel in totaal aantal dieren
Innovatieve bedrijven (met grote omzet)	20%	40%	40%
Middelgrote bedrijven (met medium omzet)	50%	50%	50%
Kwetsbare bedrijven (met kleine omzet)	30%	10%	10%

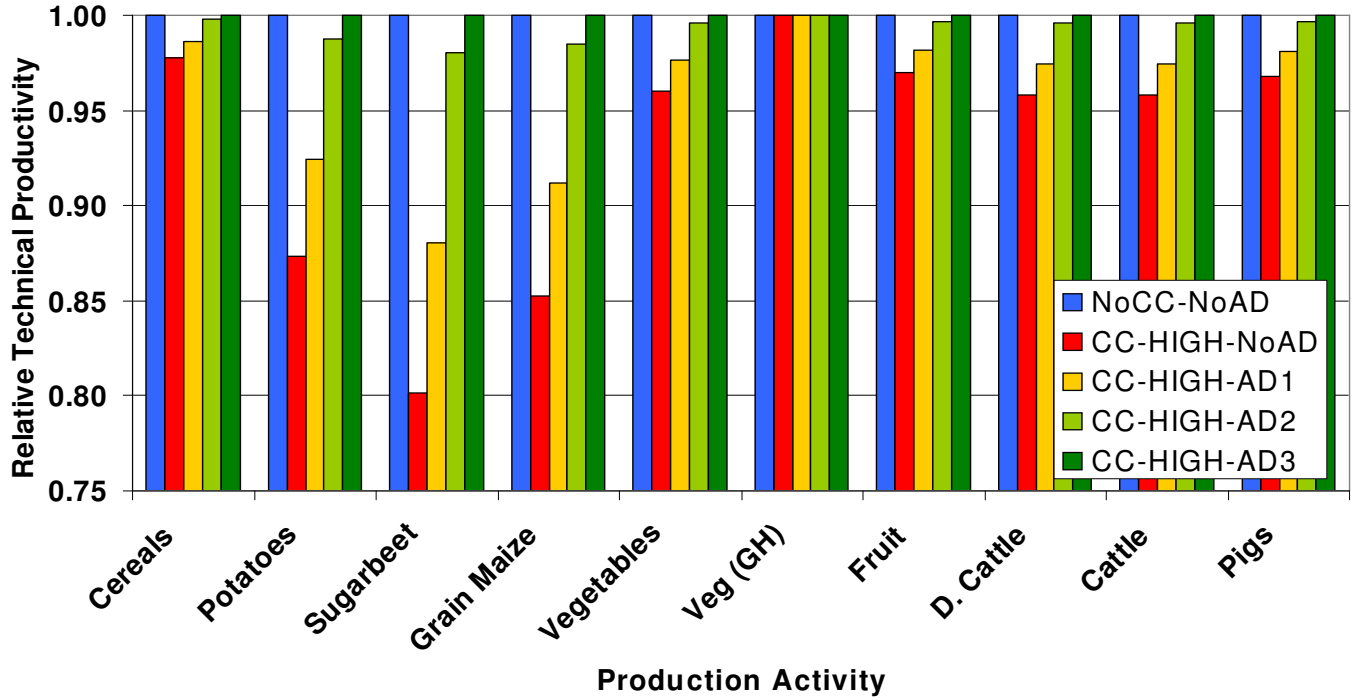
FADN **Estimate**

Adoption rate = f(farm size, climate change scenario)

- Adaptation packages (21 measures in total)
  - Adaptation Package consists of animal (D) & plant production (P), Environment (O)
  - Gradation of adaptation AD1 to AD3

Impacts on Flemish Agriculture

- Relative Productivity (= extrapolated price effect x Weighted Technical Productivity relative to reference)
  - Calculated for 3 climate change scenarios and 4 gradations of adaptation



Example of high Climate Change Scenario

Without adaptation (NoAD) the effects of climate change are:

- 0.1% or 6.6 MEuro for low climate change scenario
- 1.5% or 71 MEuro for middle climate change scenario
- 4.1 % or 201 MEuro for hoog climate change scenario

The total amounts reflect the acceptable costs of adaptation.

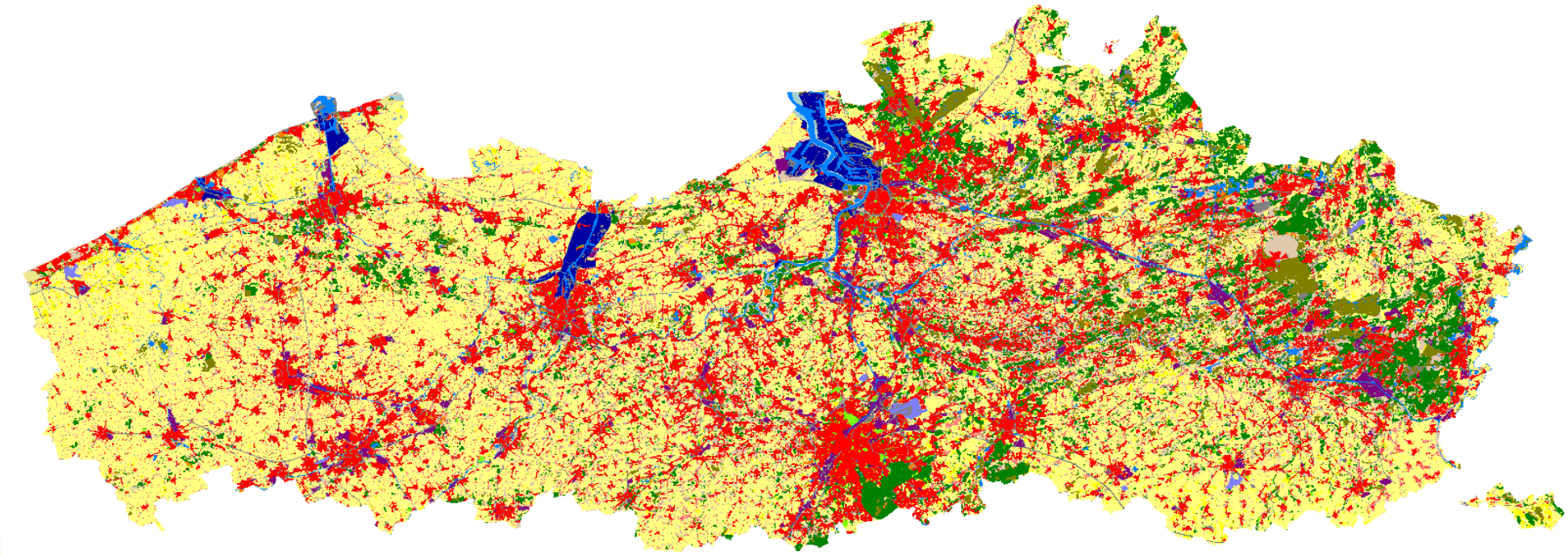
Conclusions

- Climate change offers opportunities for Flemish agriculture:
  - Productivity = f(temp, CO_2, moisture, photoperiod, …)
    - New varieties, crops, rotations, agro-ecosystems, new functions …
  - Adaptation measures need to respect sustainability of natural resources
    - e.g. Water for irrigation vs drinking water
  - Increased attention to relation between adaptation measures and agro-ecosystem services (multifunctionality)
    - Flooding areas on agricultural land
  - Important role for policy & science to deliver correct information
- Can loss of yield / biomass be compensated for with increased agricultural area ?
  - Land is scarce in Flanders
    - Urban sprawl !
  - Climate change in Flanders will necessitate other land uses
    - Space for water

Land use changes in Flanders

Land use/cover in Flanders
(solely on the basis of socio-economic variables)
Timespan 2005 – 2030

2005



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