Assessing Drought Risks for UK Crops under Climate Change

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ROTHAMSTED RESEARCH

defra
Department for Environment Food and Rural Affairs

Outline

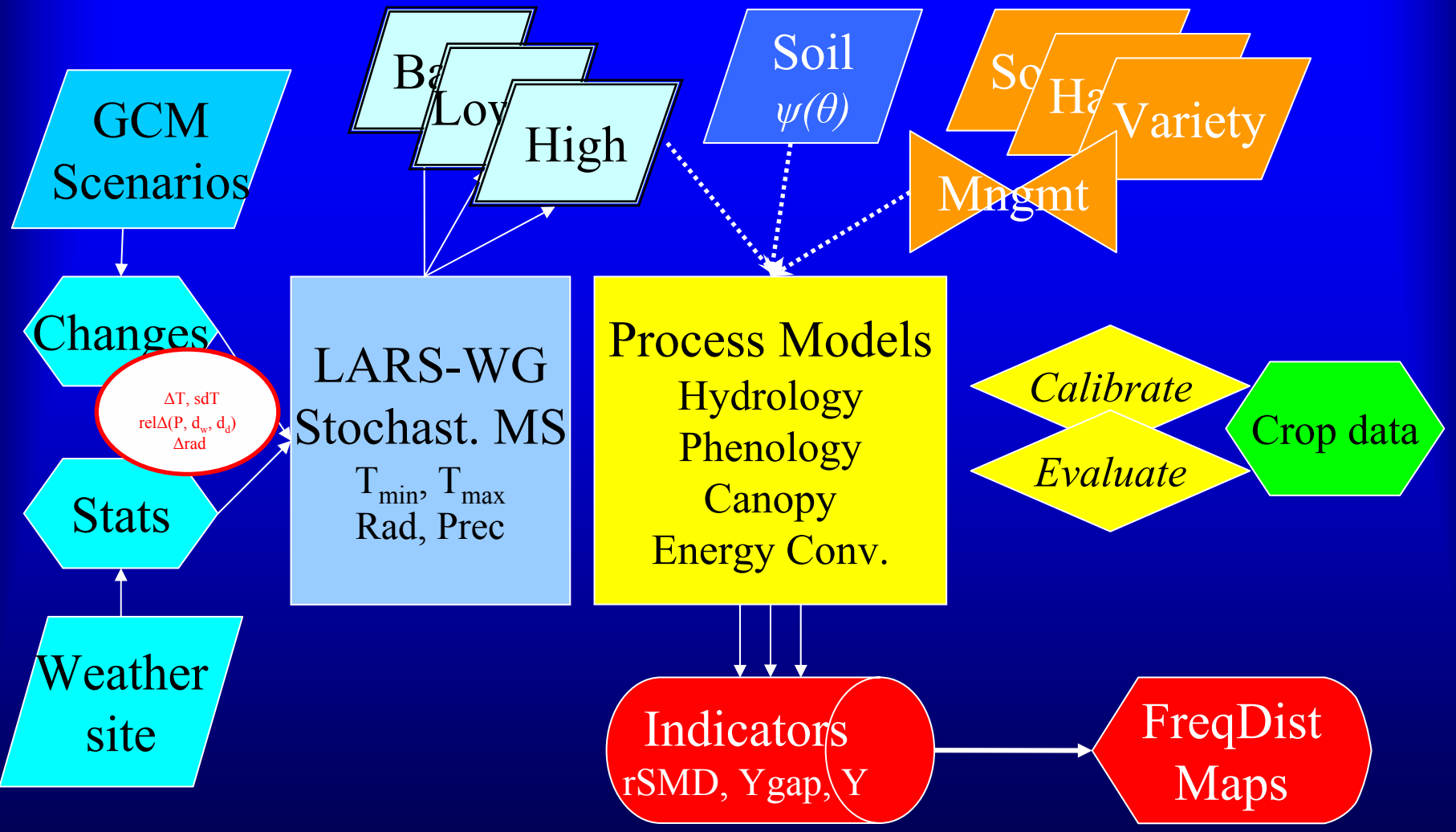
- Objectives
- Approach for impact assessment
- Model development and testing
- Key results (winter wheat and sugar beet)
- Conclusions
  - Adaptation [and mitigation]
  - Where to go from here…

Objectives of DEFRA projects

- Modify and evaluate existing models suitable for predicting drought risk and impact
- Generate daily weather from CC scenarios for representative UK sites
- Assess the regional distribution of soil moisture deficit and its impact on crop yields
- Analyse a range of management options to adapt to [increased] risks

Approach for impact assessment

System to model CC Impact



Model development and testing

Wheat modelling

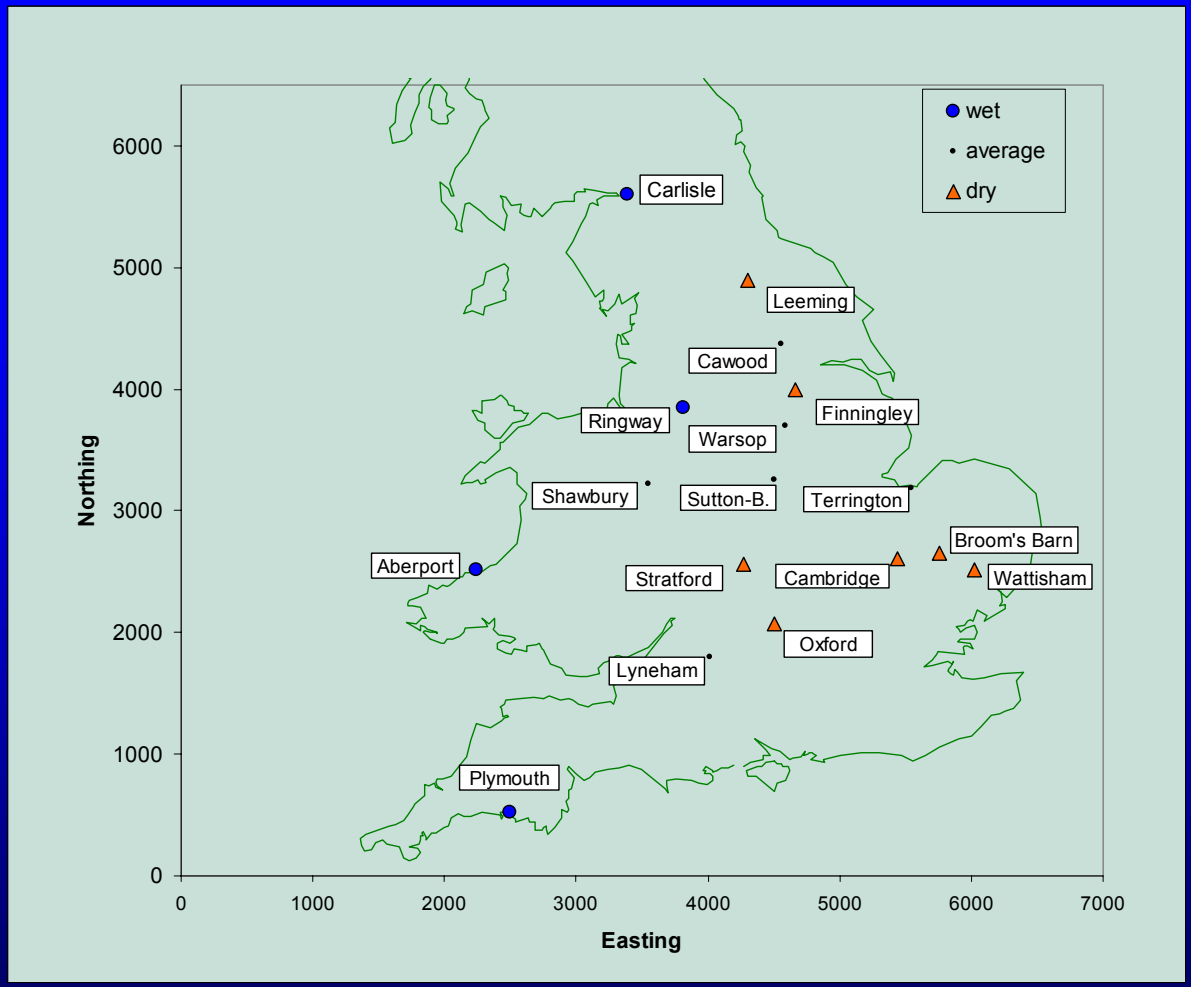
- Phenology using a new vernalisation model (Richter et al., 2001b; Modelling Cropping Systems, 2nd Symp, Florence, Italy, 165-166)
- Leaf area dynamics simplified (Lawless et al. 2005; Eur. J. of Agron. 22 (1): 19-32)

Sugar beet modelling

- Canopy dynamics affected by drought (Richter et al. 2001; *Agric. For. Meteorol.* 109, 13-25)
- Translocation in response to drought (Richter et al. 2001a; Modelling Cropping Systems, 2nd Symp, Florence, Italy, 79-80)
- Soil hydrology sub-model expanded
- Root growth module implemented

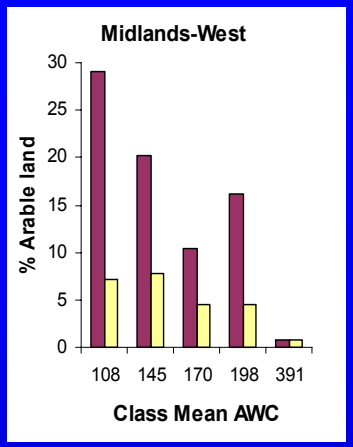
} Richter et al. 2005
Soil use and management, rev.

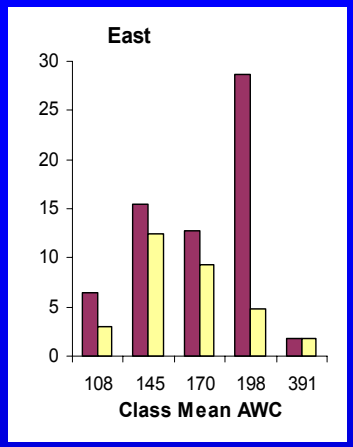
Spatial components in the analysis



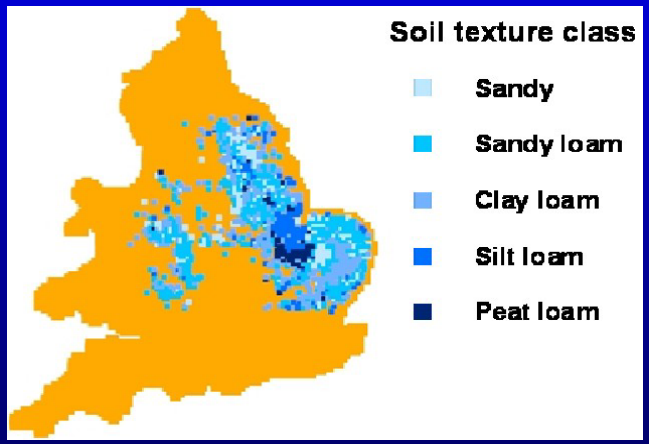
Selected weather stations

Spatial components in the analysis

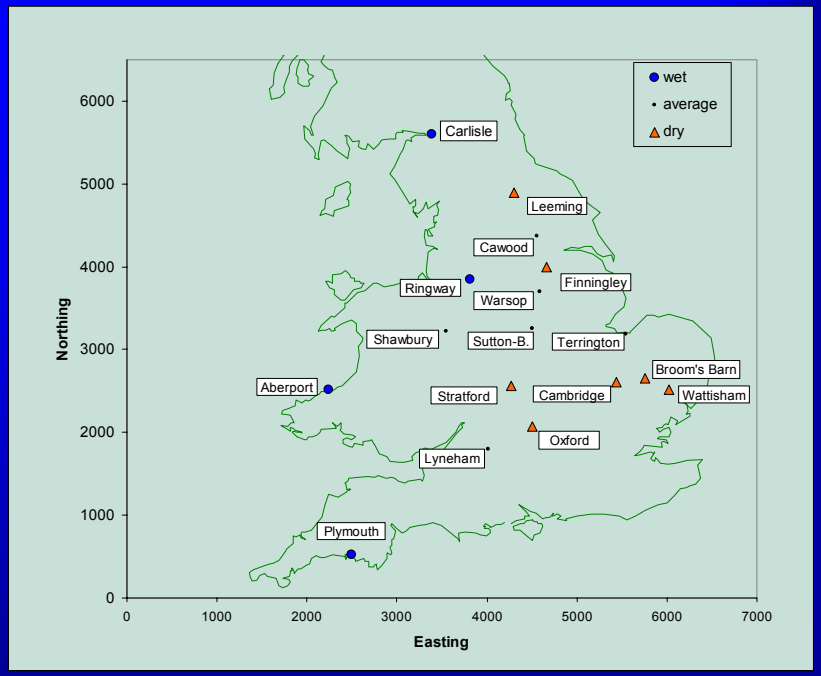




Soil Survey Bulletins, 1981

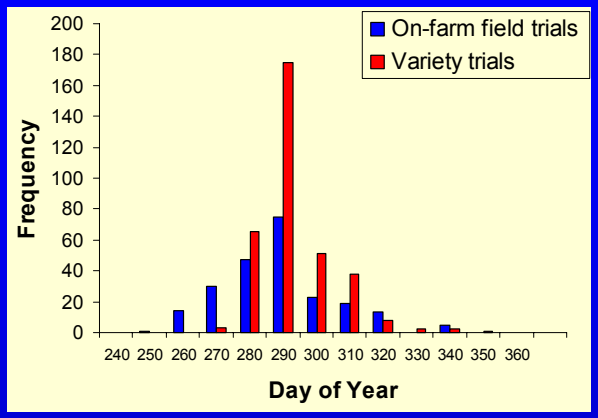


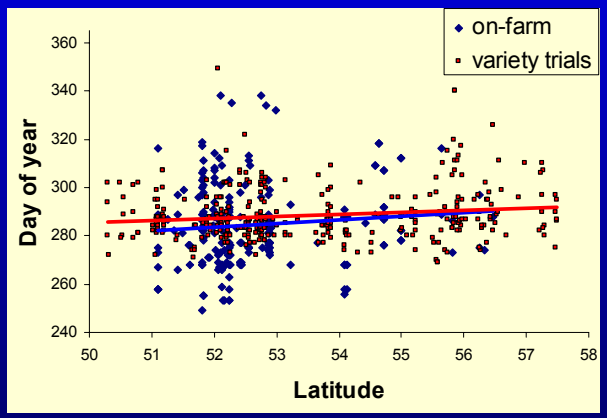
Predominant soil texture class;
5x5 km^2; surveys British Sugar



Selected weather stations

Temporal components, e.g. sowing date



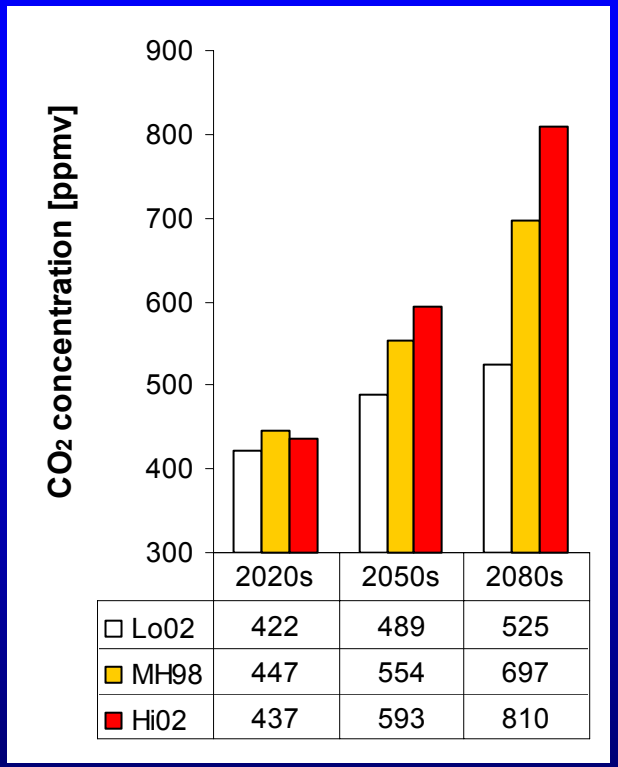


	Variety trials	On-farm field trials
Min	269	249
Max	349	338
Mean	**289**	**285**
SD	±11	±17

Management, e.g. sowing date

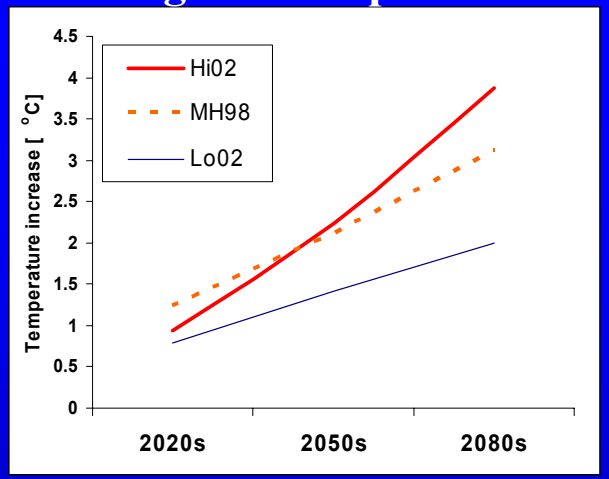
Predicted* climate change for the UK

Atm. CO_2-Concentration

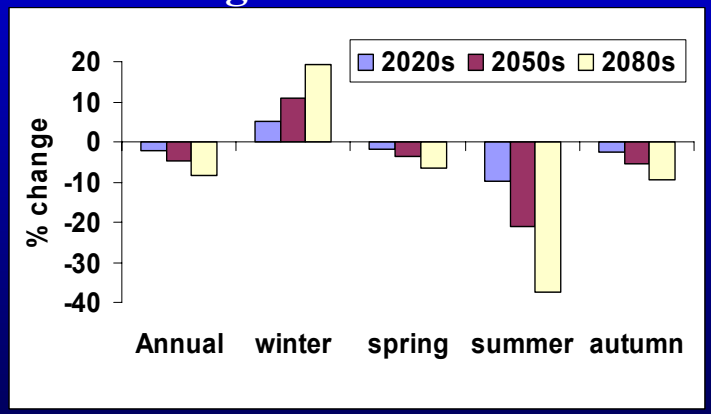


	2020s	2050s	2080s
Lo02	422	489	525
MH98	447	554	697
Hi02	437	593	810

Average air temperature



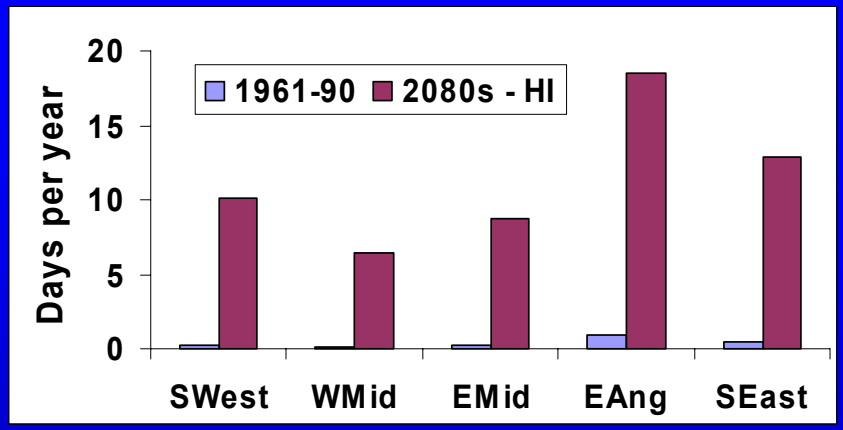
Change of rainfall

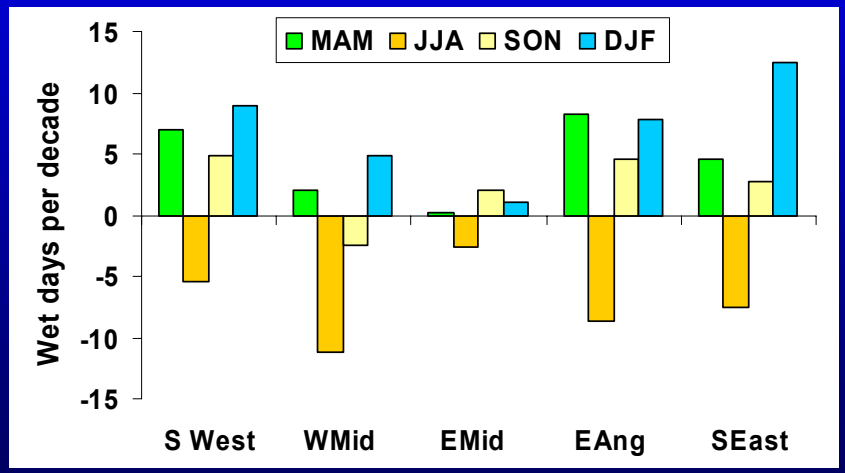


* HadCM2 (Hulme and Jenkins, 1998; HadCM3 (Hulme et al., 2002)

Predicted* changes for the UK

- Hot day forecast
  - Defined as T_{max} >30 C
  - Occurs July/August
  - **Winter wheat escapes**
  - Likely to **affect late crops (e.g. maize)**
- Wet day forecast (2080HI)
  - Will increase in autumn to spring, decrease in summer
  - May delay spring sowing
  - May delay harvest of root crop and sowing next cereal



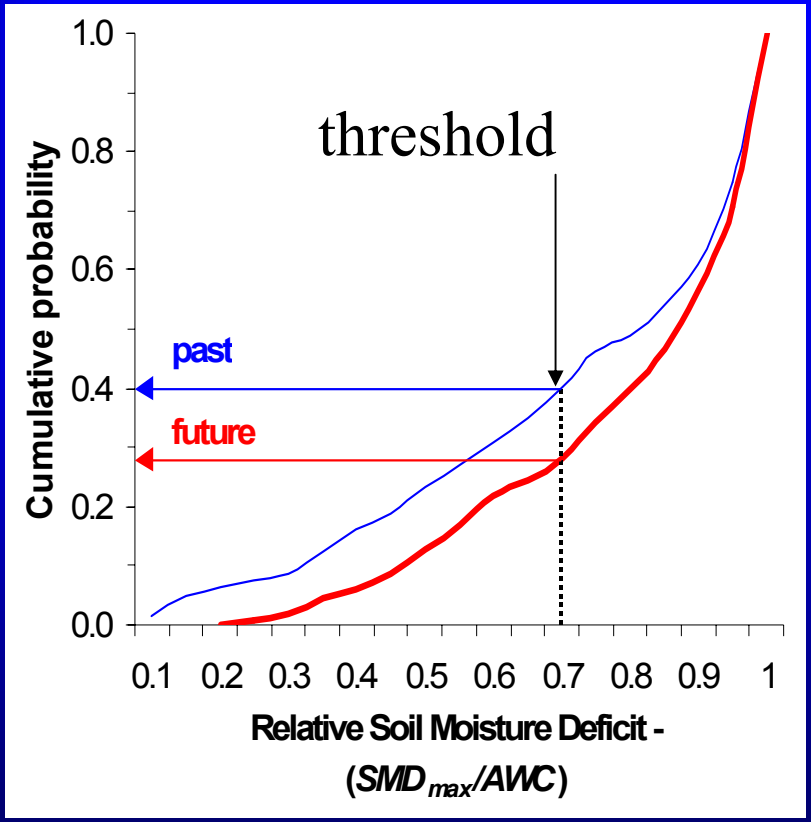


* HadCM3 (Hulme et al., 2002)

Indices for production risks

Soil Moisture Deficit (SMD)

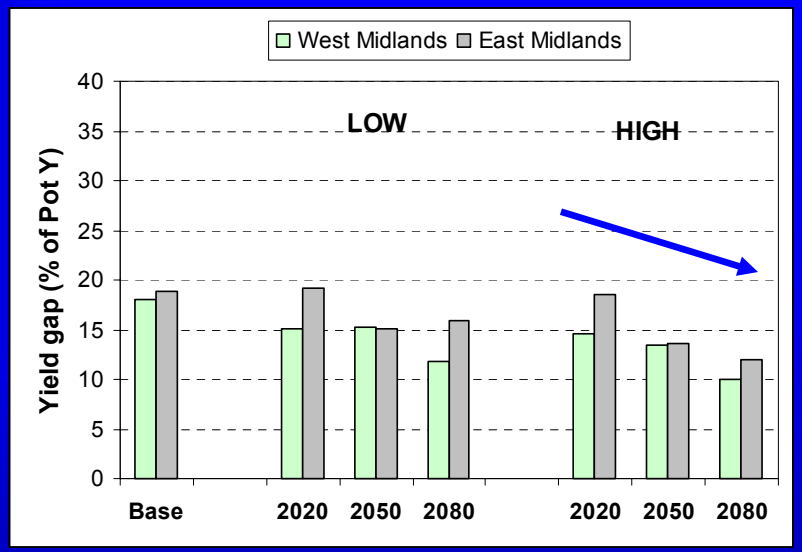
UKCIP98-MH2050

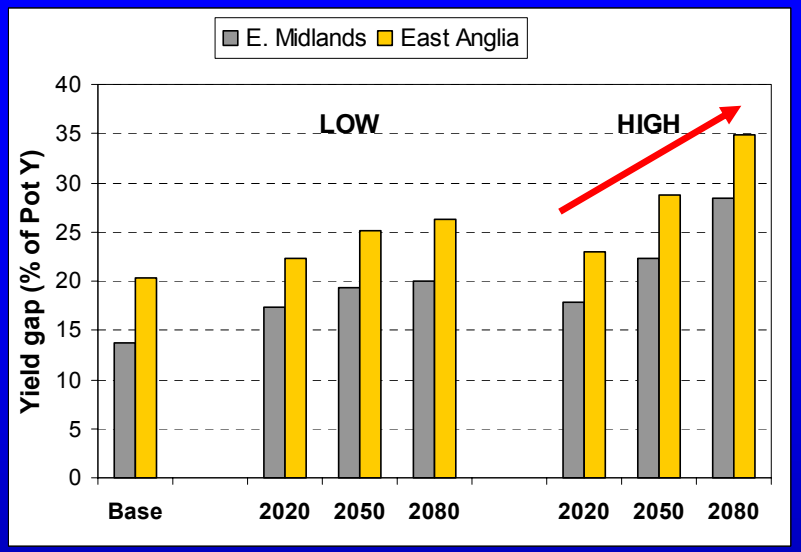


- Threshold marks enhanced senescence of crops
- Probability to exceed threshold may increase by > 10% in the future
- Under new emission scenarios threshold for **sugar beet** likely being exceeded >90 % of time
- Threshold of SMD is less likely to be exceeded under winter **wheat** (**escapes**!)

Drought related Yield gap:

YG = (1-ActY/PotY)





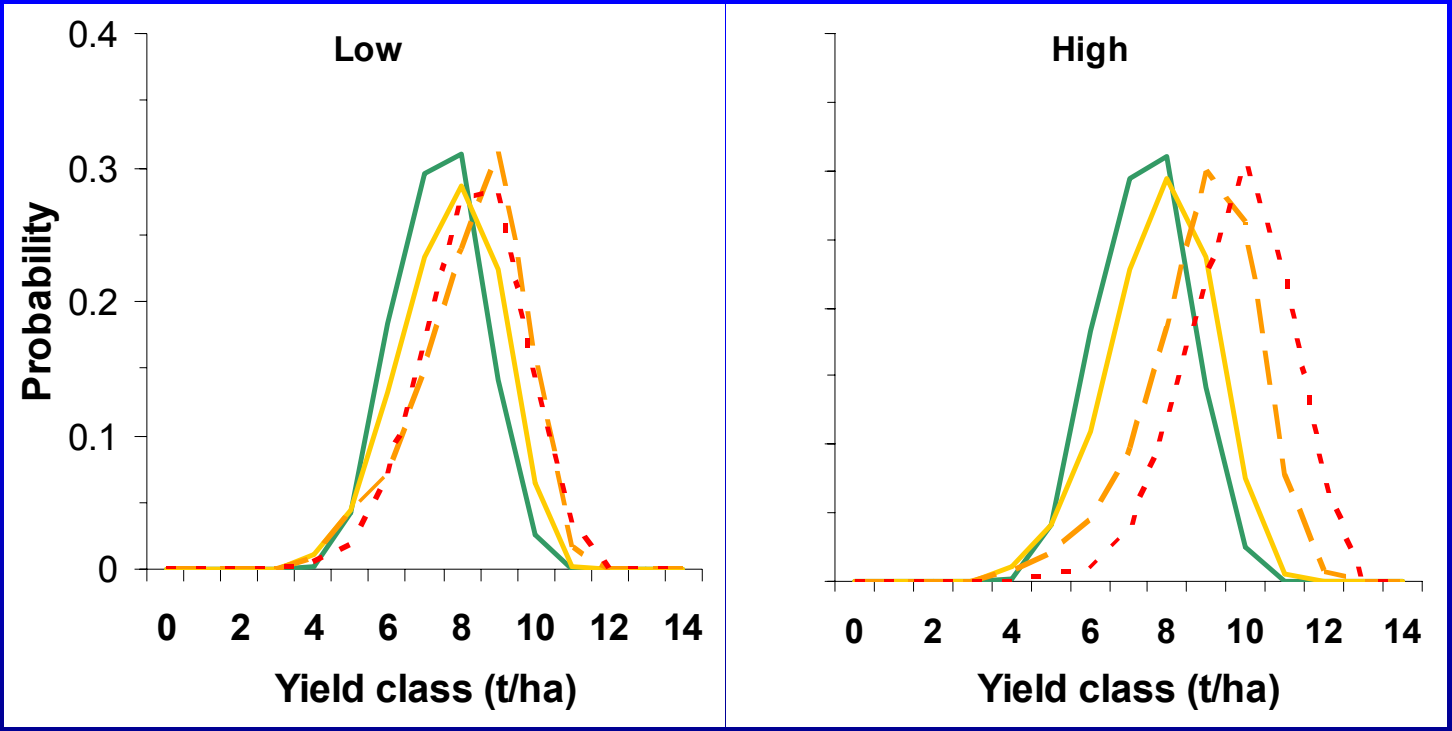
Winter wheat

- Yield gap is likely to decrease slightly

Sugar beet

- Yield gap could double by end of century
- Future YG comparable to SE Europe (2080 UKCIP02_HI)

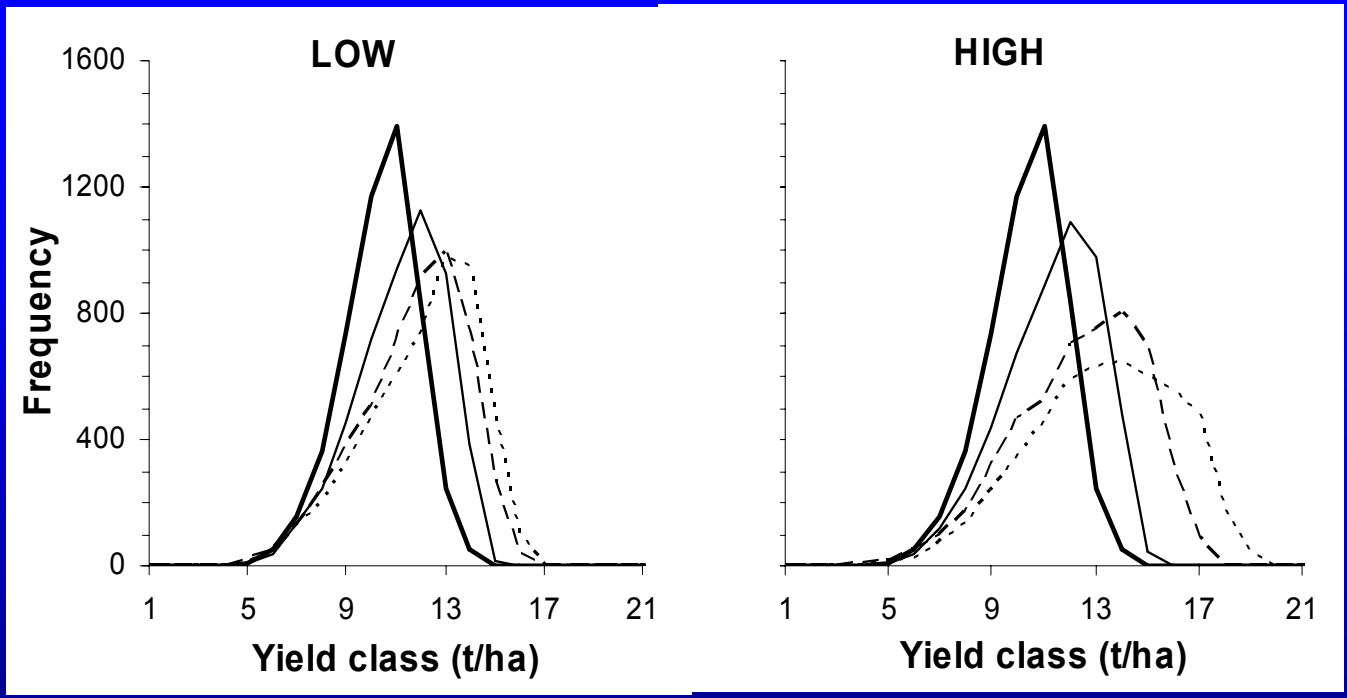
Yield distribution of winter wheat



Frequency distributions of wheat yields in the East Midlands for the UKCIP02 LO and HI emission scenarios (var. *Mercia*):

baseline (——), 2020s (——), 2050s (— —) and 2080s (– – –)

Yield distribution for sugar beet

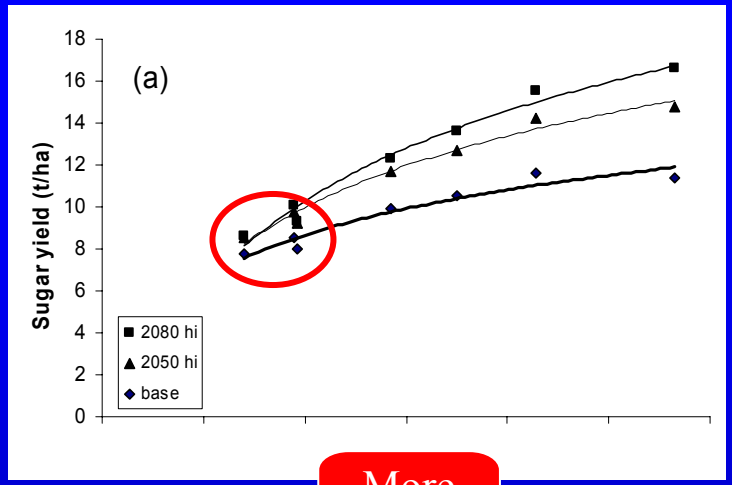


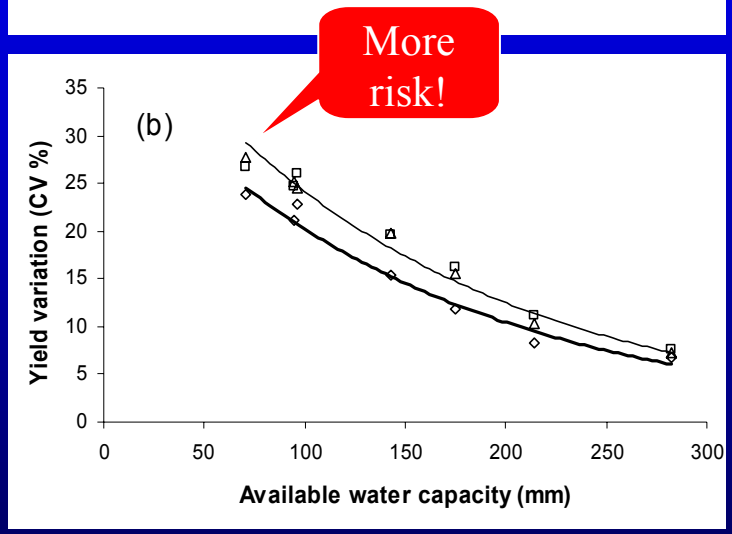
Frequency distributions of sugar yields in the East Midlands for two emission scenarios;

baseline (——), 2020s (——), 2050s (— —) and 2080s (– – –)

Adaptation of the cropping system

Soils affect sugar beet yields

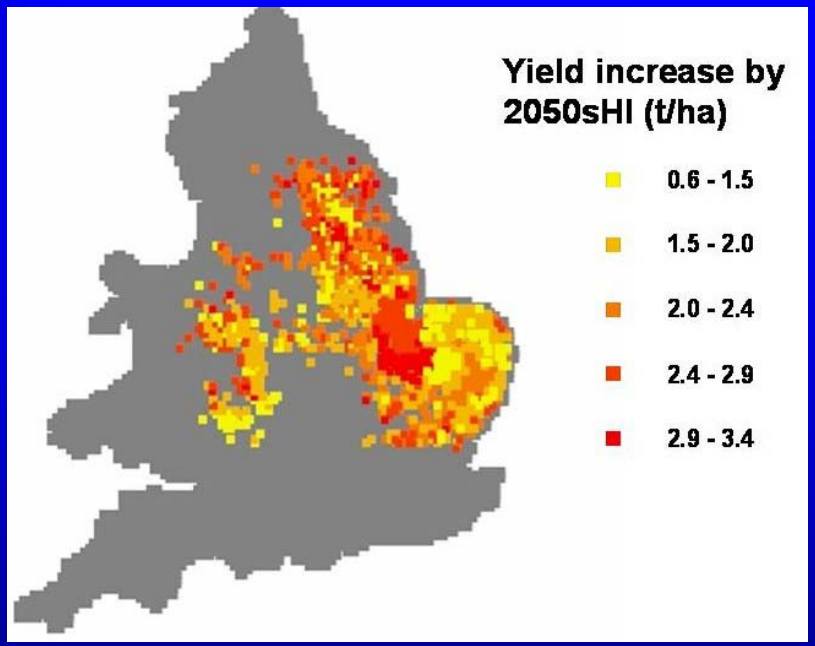


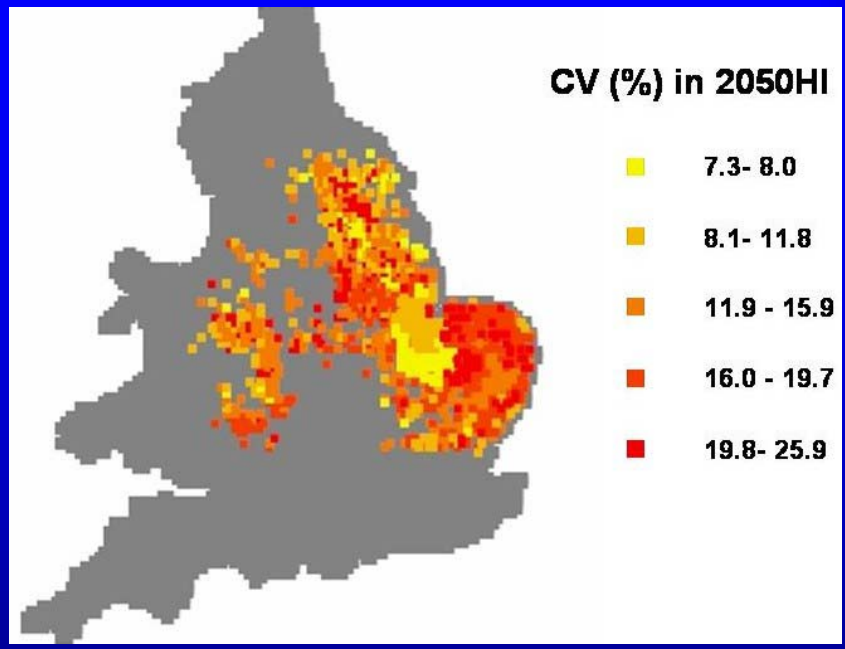


UKCIP02-HI

- On soils with high AWC sugar yields may increase by
  - > 3 t/ha by the 2050s
  - ~ 5 t/ha by the 2080s
- There is almost no yield increase on shallow soils
- Yields on shallow or sandy soils are more variable (CV >25%)

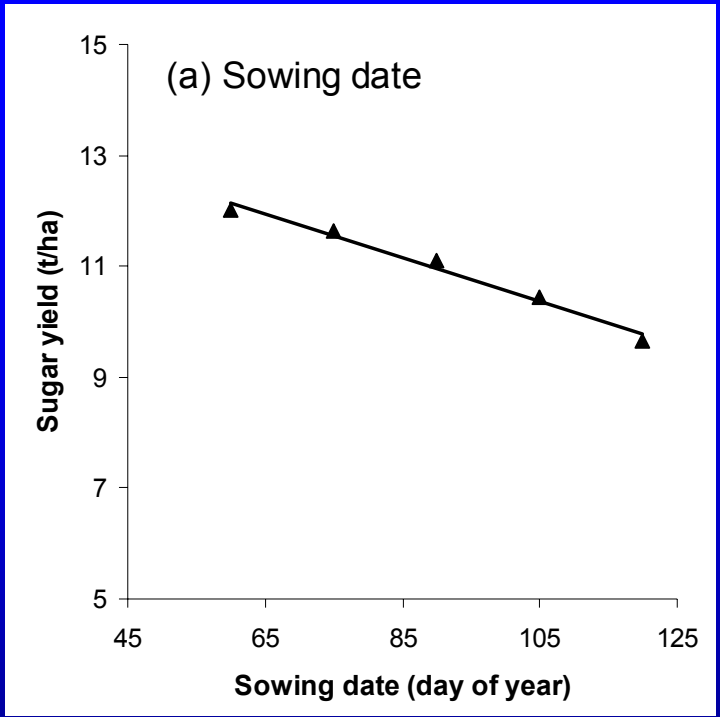
Variation of sugar beet yields

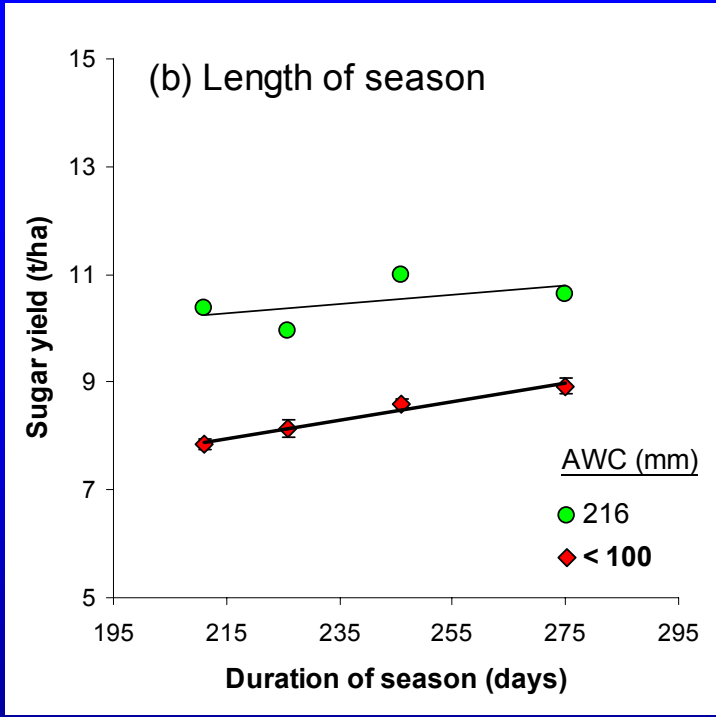




Maps generated with UKCIP02 scenario High emission scenario using dominant soil types (Brit. Sugar), average yield increase and variability of yields (% CV)

Adaptation options for sugar beet



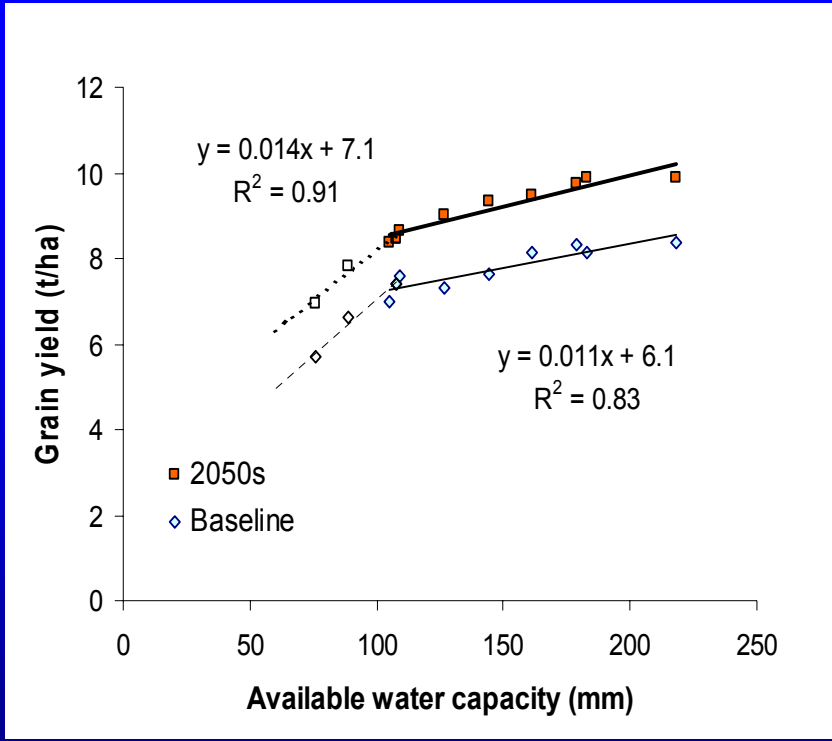


Average sugar yields (MH-2050s) are affected by

(a) sowing date (- 4 % /d) and

(b) length of season on sandy (+ 1%/d) and loamy soils (+ 2%/d)

Soils affect future wheat yields



Mean yields vs. AWC of soils in the Midlands; ● baseline, ■ future scenario (2050s); open symbols (○, □) and hatched lines describe model response to soil AWC < .

- Future yields of winter wheat are likely to increase more on soils with high AWC
- Soil degradation (shallow soils) doubles the effect of water limitation

Conclusions (1)

Wheat production:

- Wheat escapes summer drought
- YGap is likely to decrease from 19 % to 16 and 12 %
- Under UKCIP98 MH yields are likely to increase by 1 t/ha to 1.5 t/ha (Richter & Semenov, 2005)
- Updated simulations (UKCIP02) confirm this prediction:
  - 1.5 t/ha (2050s) to 2.4 t/ha (2080s) under HIGH
  - 1 to 1.1 t/ha in LOW emission
- Variability of yields is likely to decrease (18 to < 15 %)

Adaptation options

- Avoid shallow soils
- Avoid late sowing (6 weeks could cost 1.5 t/ha)
- Choose varieties with later maturation (e.g. *Consort*); yields 1 t/ha more

Conclusions (2)

Beet (spring crop) production:

- Soil moisture threshold (senescence) is very likely to be exceeded
- Yield gap is likely to increase from 15 to 25 % by 2050s and to >35 % by the 2080s (high emission)
- Average sugar yields are likely to increase with UKCIP02
  - by between 1.4 (LO) and 2-3 t/ha (HI) -2050s
  - By between 1 and 5 t/ha (2080s)

Adaptation options:

- Avoid shallow and droughty soils (- or irrigate!)
- Sow early (1 day of delay costs 4 % yield)
- Late harvests on droughty soil compensate for earlier yield loss

Scientific challenges ahead

- Measure and model the ***actual crop temperature*** (thermal stress) in relation to thresholds for sink reduction (yield and quality)
- Model crop-climate-interactions at matching scale, ***include terrain effects*** on water and energy flux
- Couple models for ***crop growth and disease/pest*** development
- Explore ***soil-plant interface*** (root) anew (ageing →root activity, NUE; Q, signalling, allocation; sequestration)

Acknowledgement of the team

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