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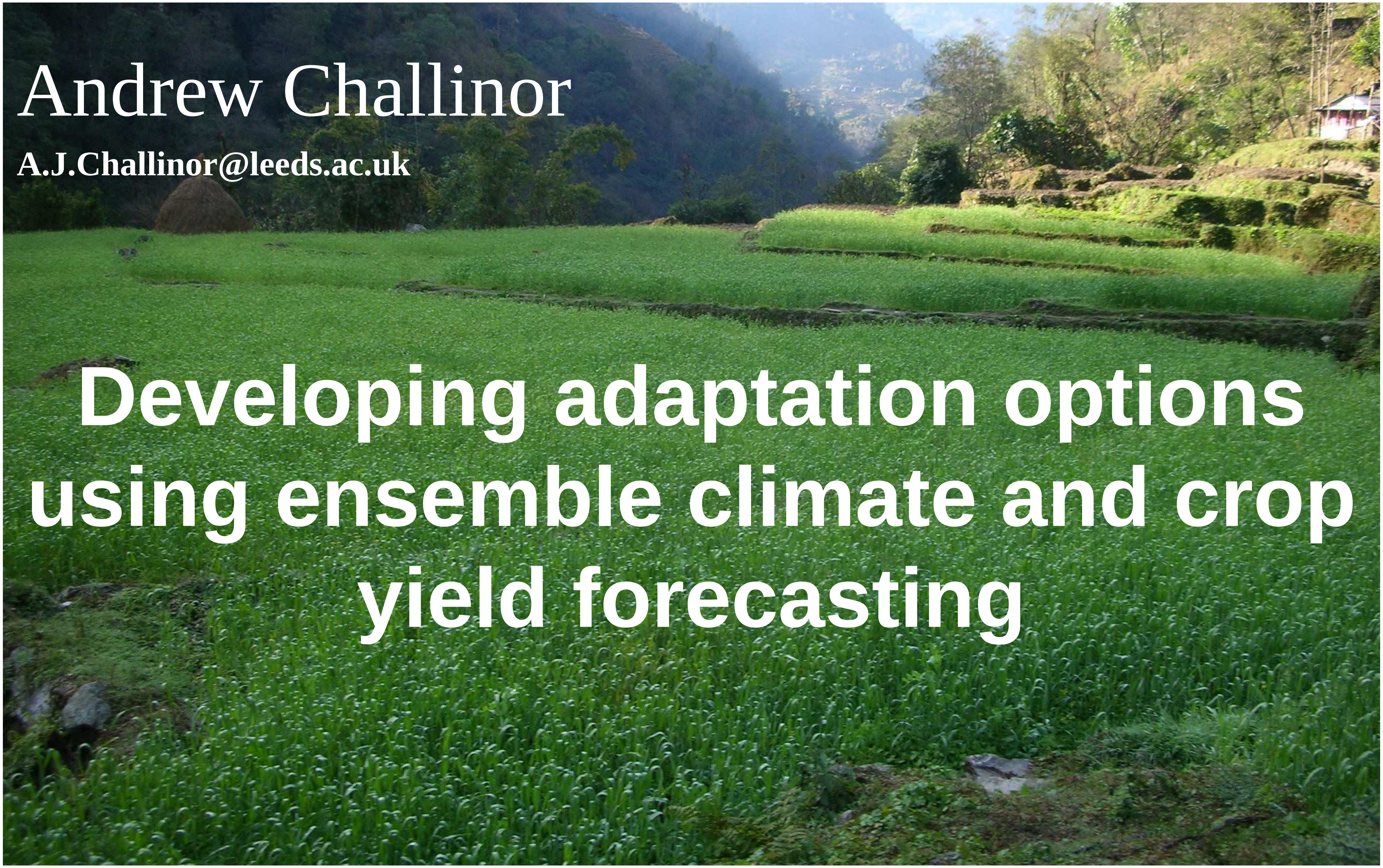

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# Developing adaptation options using ensemble climate and crop yield forecasting

# Context

Dangerous rates of climate change:
those for which adaptation is difficult or impossible

Need to know:

1. The impact of climate change
2. Whether or not adaptation is possible

# 1. The impact of climate change on yield

| | | | |
|---|---|---|---|
| 2 x $CO_2$<br>N. America | Wheat | -100 to +234% | Reilly and Schimmelpfennig, 1999 |
| 2080s<br>Africa | Cereals | -10 to +3% | Parry et al., 1999 |
| +4$^o$C local $\Delta$T<br>'low latitude' | Wheat | -60 to +30% | IPCC AR4, chap. 5 (Easterling et al., 2007) |
| +4$^o$C local $\Delta$T<br>'mid- to high-latitude' | Wheat | -30 to +40% | IPCC AR4, chap. 5 (Easterling et al., 2007) |

See Challinor et al. (2007a)

# Context

- Dangerous rates of climate change: those for which adaptation is difficult or impossible.
- Need to know:

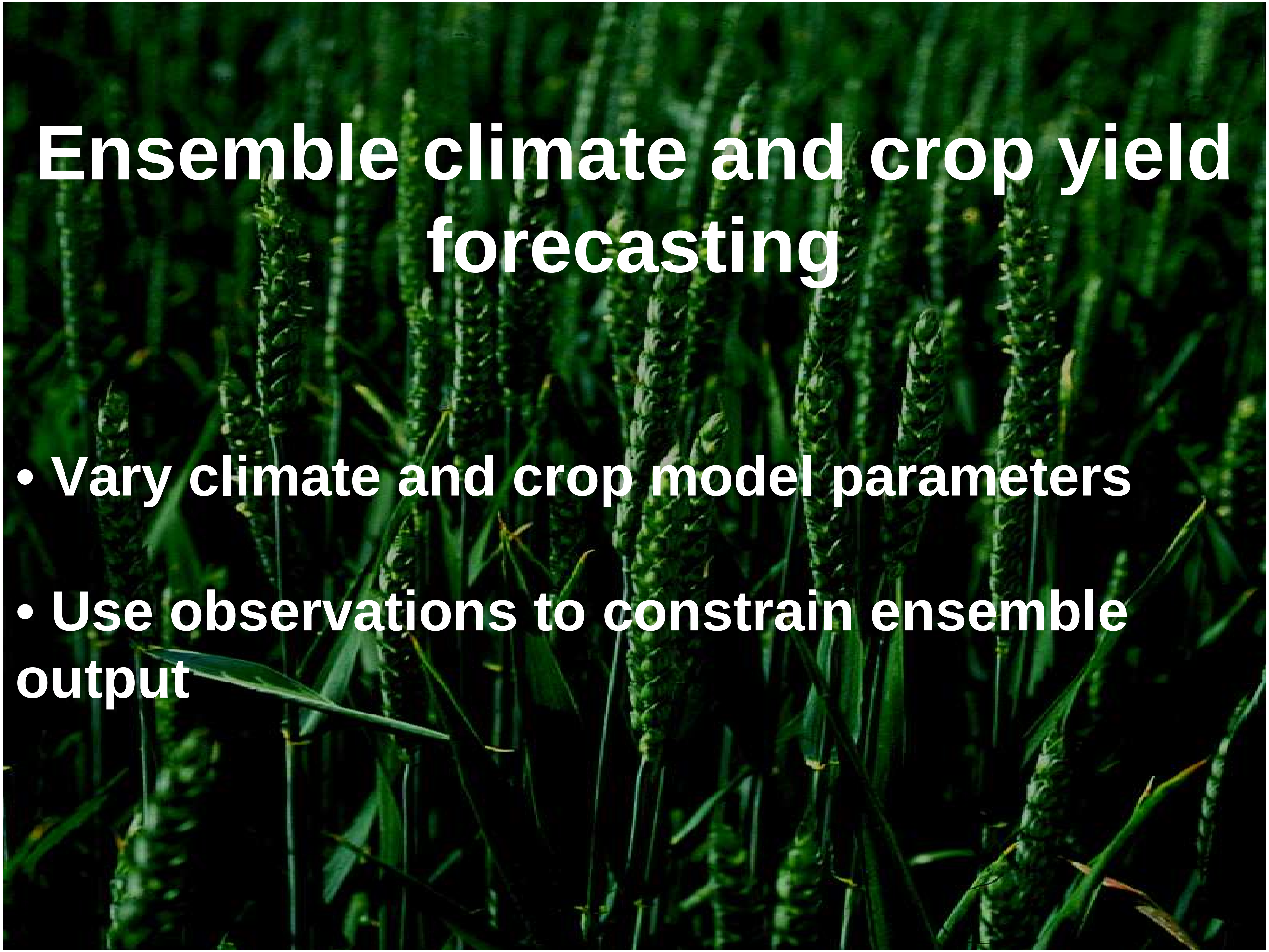
1. The impact of climate change
2. Whether or not adaptation is possible

At both of these stages

**Aim to make probabilistic statements, rather than provide subjective ranges**

i.e. objective quantification of uncertainty

**Otherwise conclusions regarding adaptation may be incorrect**

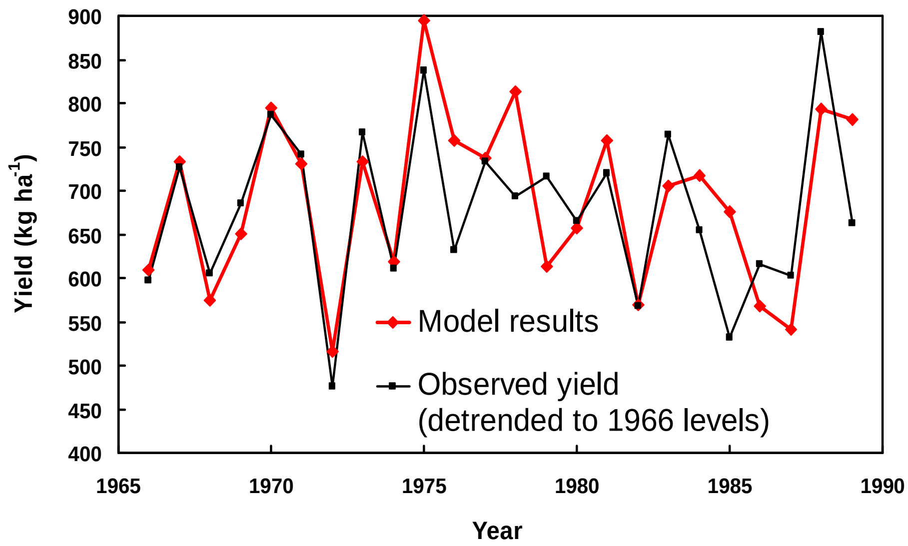


# Ensemble climate and crop yield forecasting

- Vary climate and crop model parameters
- Use observations to constrain ensemble output

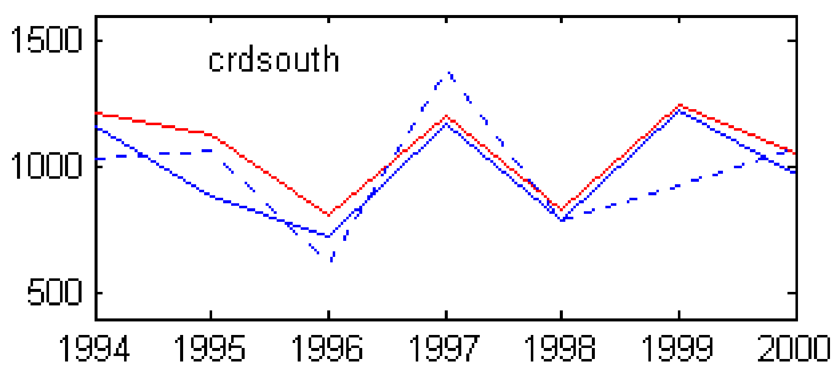
# General Large Area Model for annual crops

Combines the benefits of empirical and process-based approaches

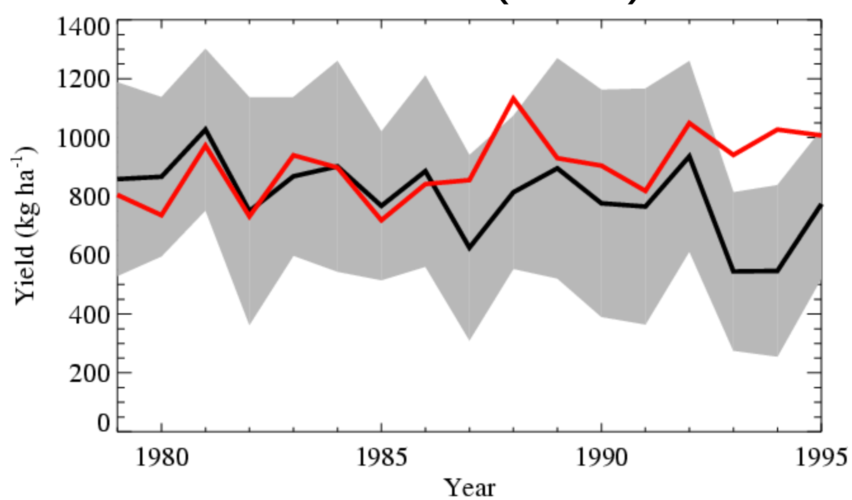



Challinor et al. (2004)

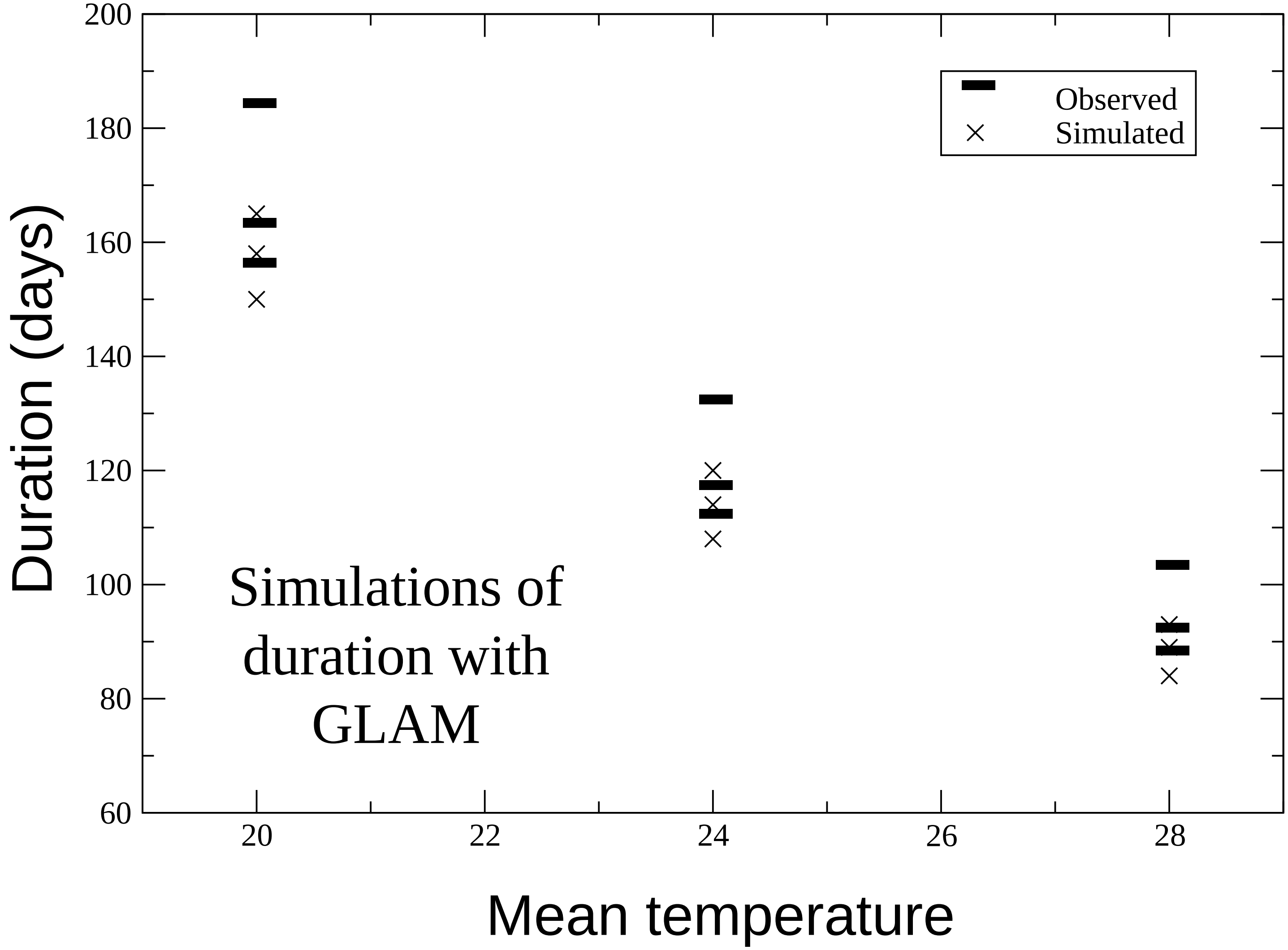
Chee-Kiat (2006)



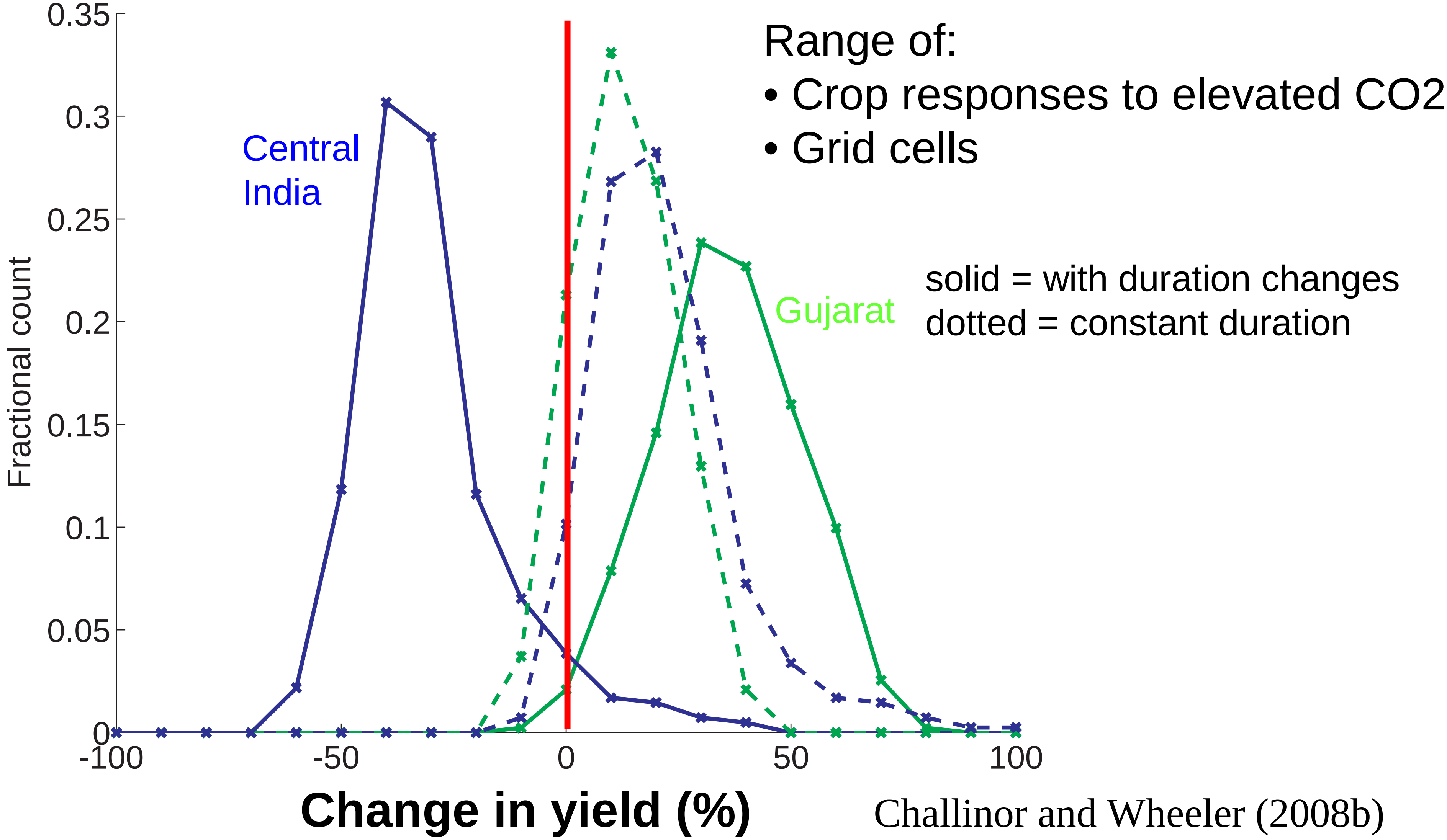

Osborne (2004)



# The impact of mean temperature on crop development rate



# Impact of mean temperature increases on yield

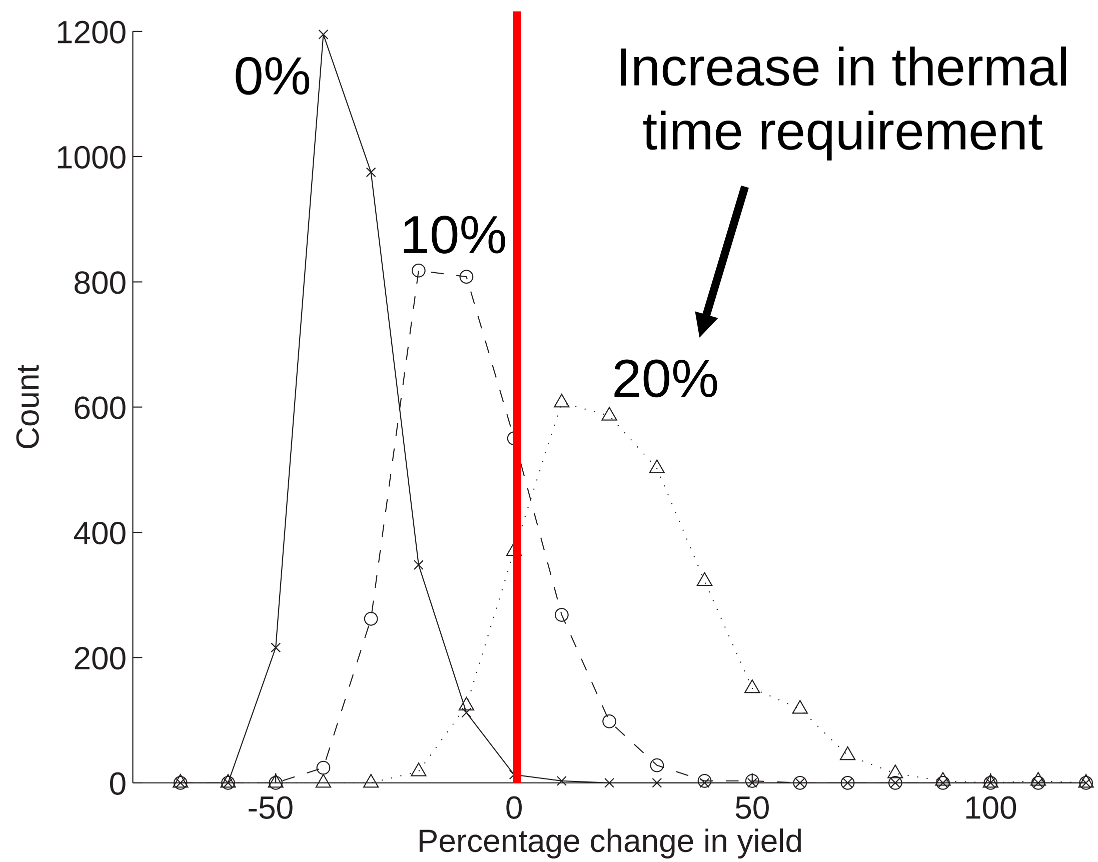



Challinor and Wheeler (2008b)

# 2. Assessing adaptive capacity

**180,000+ crop simulations, varying both climate (QUMP) and crop response to doubled CO2**

- Further simulations and analysis of crop cardinal temperatures suggest a **30% increase may be needed**
- Field experiments suggest the potential for a **14 to 40% increase within current germplasm**
- Suggests some capacity for adaptation




Challinor et al. (2008b)

# The impact of temperature extremes

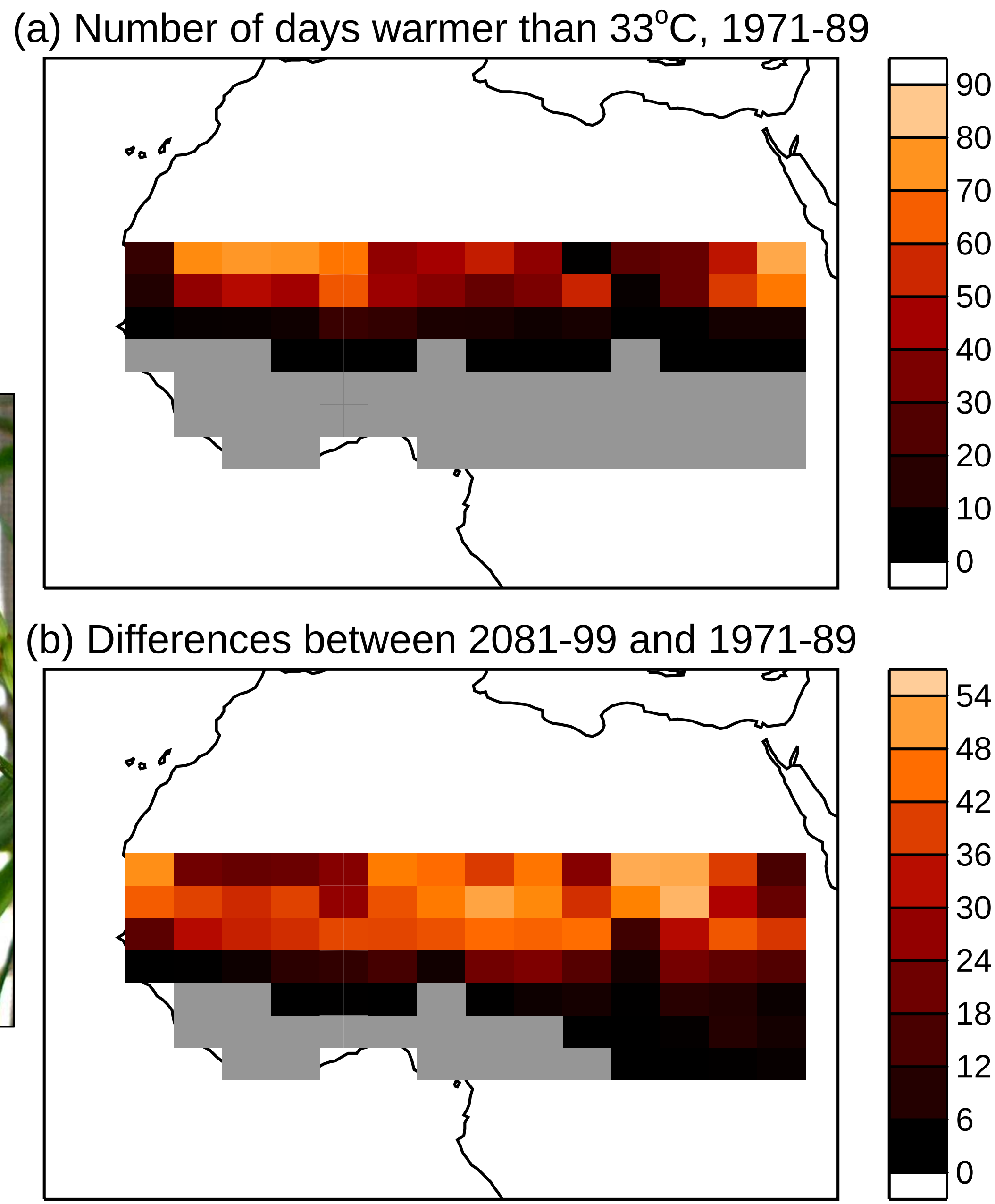
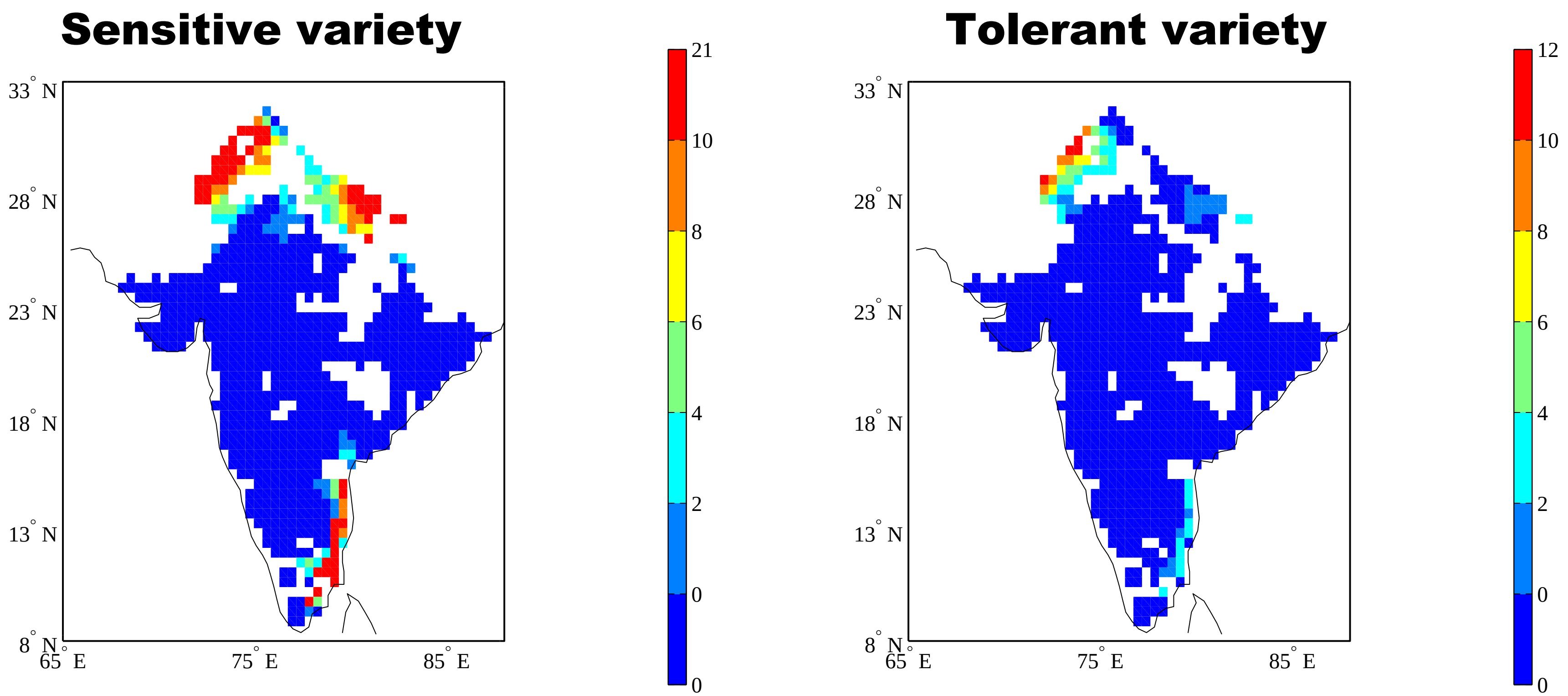



Photo: Tim Wheeler Plot: Huntingford et al (2005)

# Adaptation to temperature extremes across India

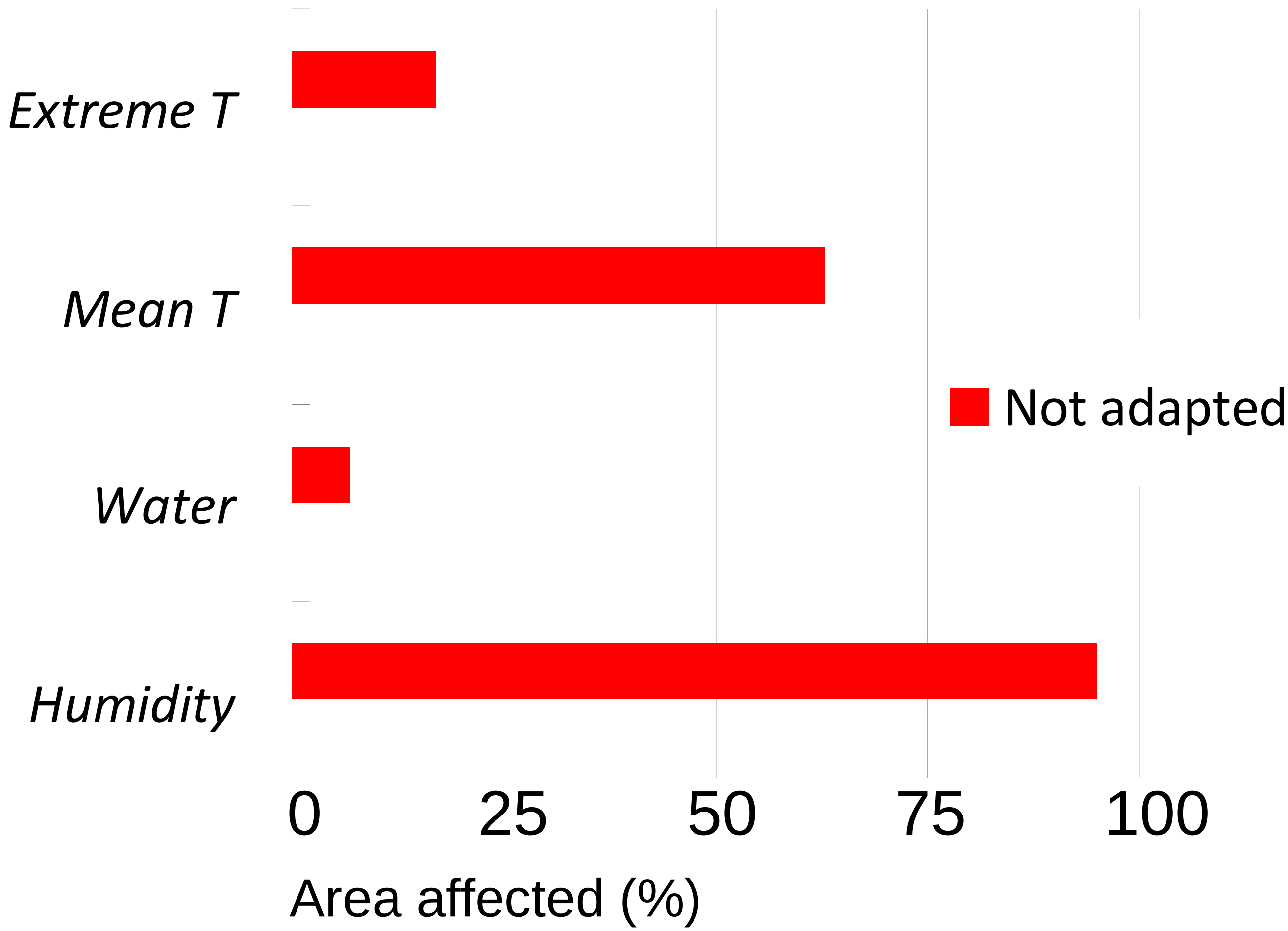
**Hadley Centre PRECIS model, A2 (high emission) scenario 2071-2100**

Number of years when the total number of pods setting is below 50%.



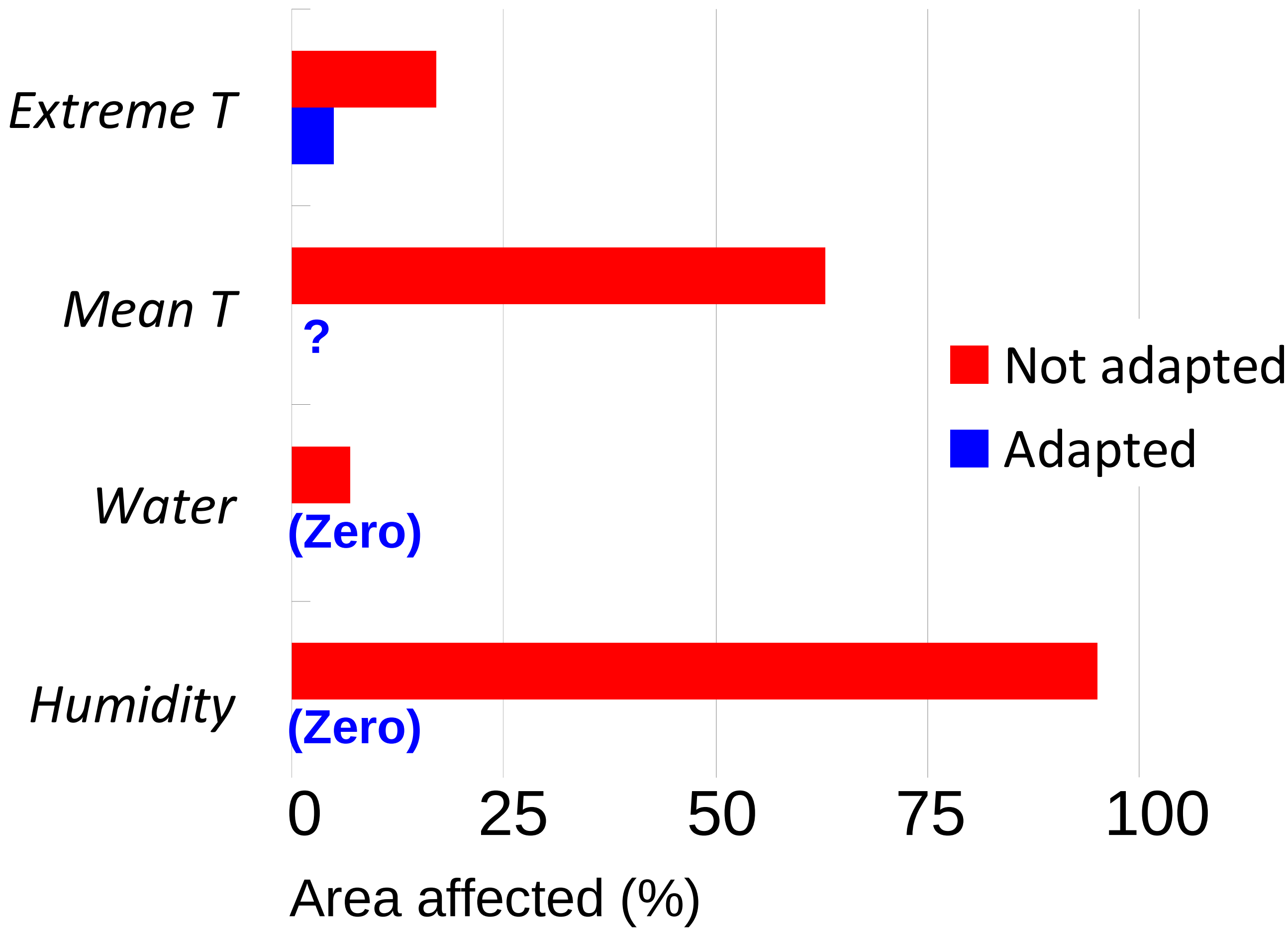

Challinor et al. (2007b)

# Assessing adaptive capacity to a range of processes




Challinor (2008): Env. Science & Policy

# Assessing adaptive capacity to a range of processes




Challinor (2008): Env. Science & Policy

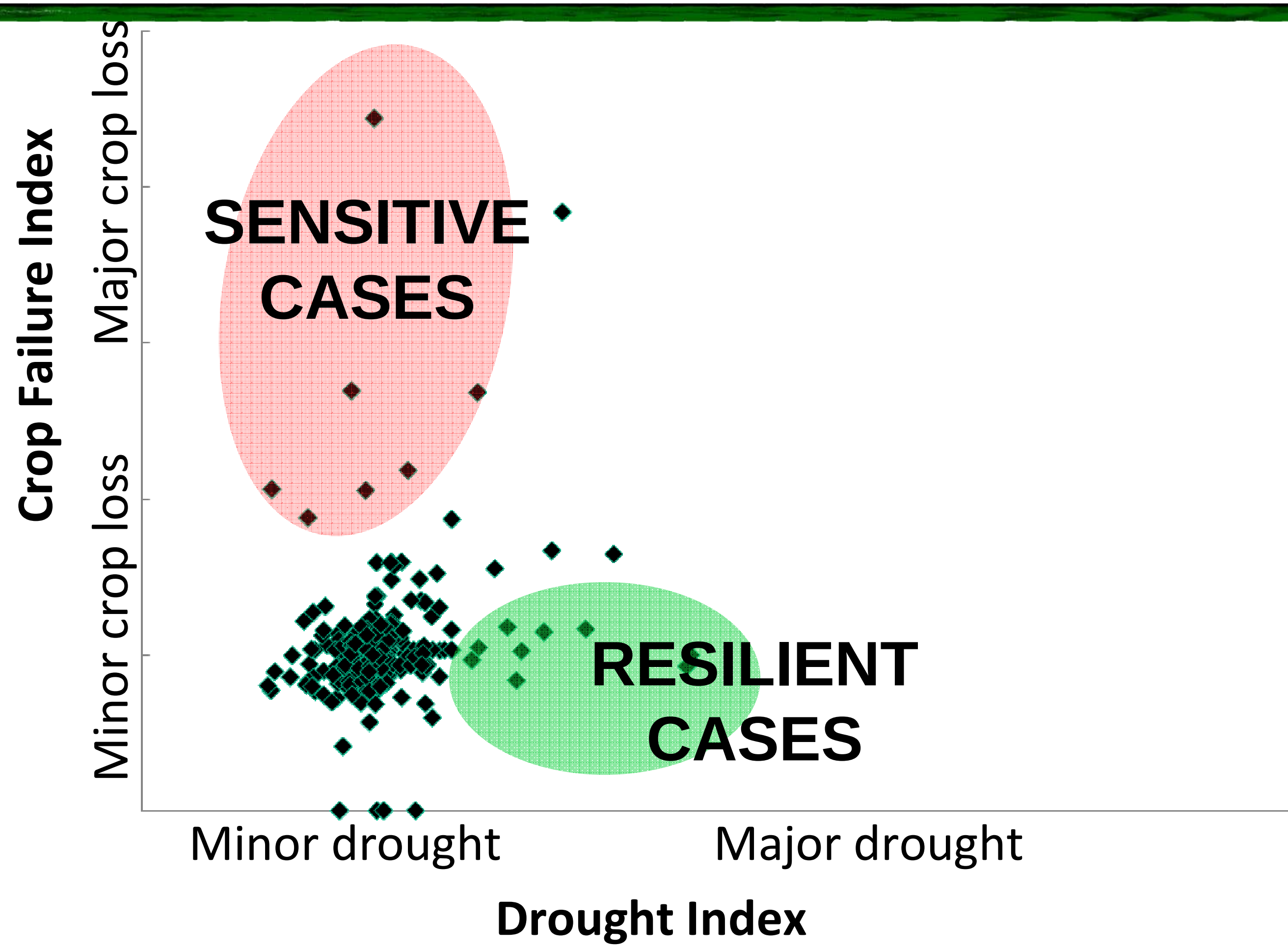
# Adaptation at shorter timescales

- Dangerous rates of climate change: those for which adaptation is difficult or impossible.
- Need to know:
  1. The impact of climate change
  2. Whether or not adaptation is possible

Also need to account for autonomous adaptation

- Implies focus on farmer action at shorter timescales
- Ensemble seasonal prediction can support adaptation
  - Prediction of crop failure (Challinor et al., 2005a)

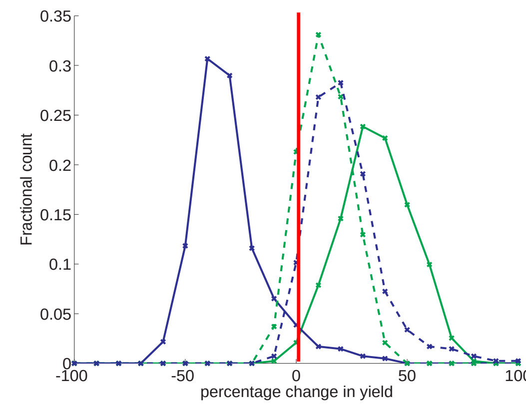
# **Focussing on the farmer:** identifying sensitivity to drought

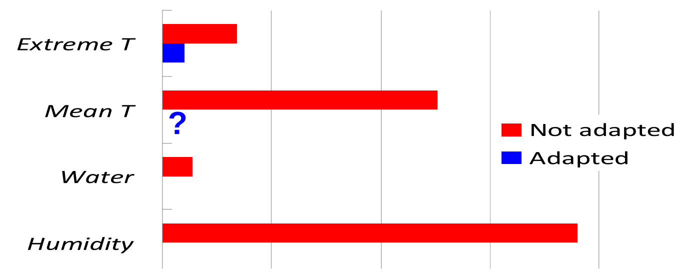



Simelton et al. (in review) Env. Science & Policy

# Conclusions

- Quantifying uncertainty does not preclude high confidence in some statements
- Confidence increases when spatial domain is restricted (up to a point)
- We can link climate prediction to adaptive capacity (i.e. existing germplasm)



# Acknowledgements

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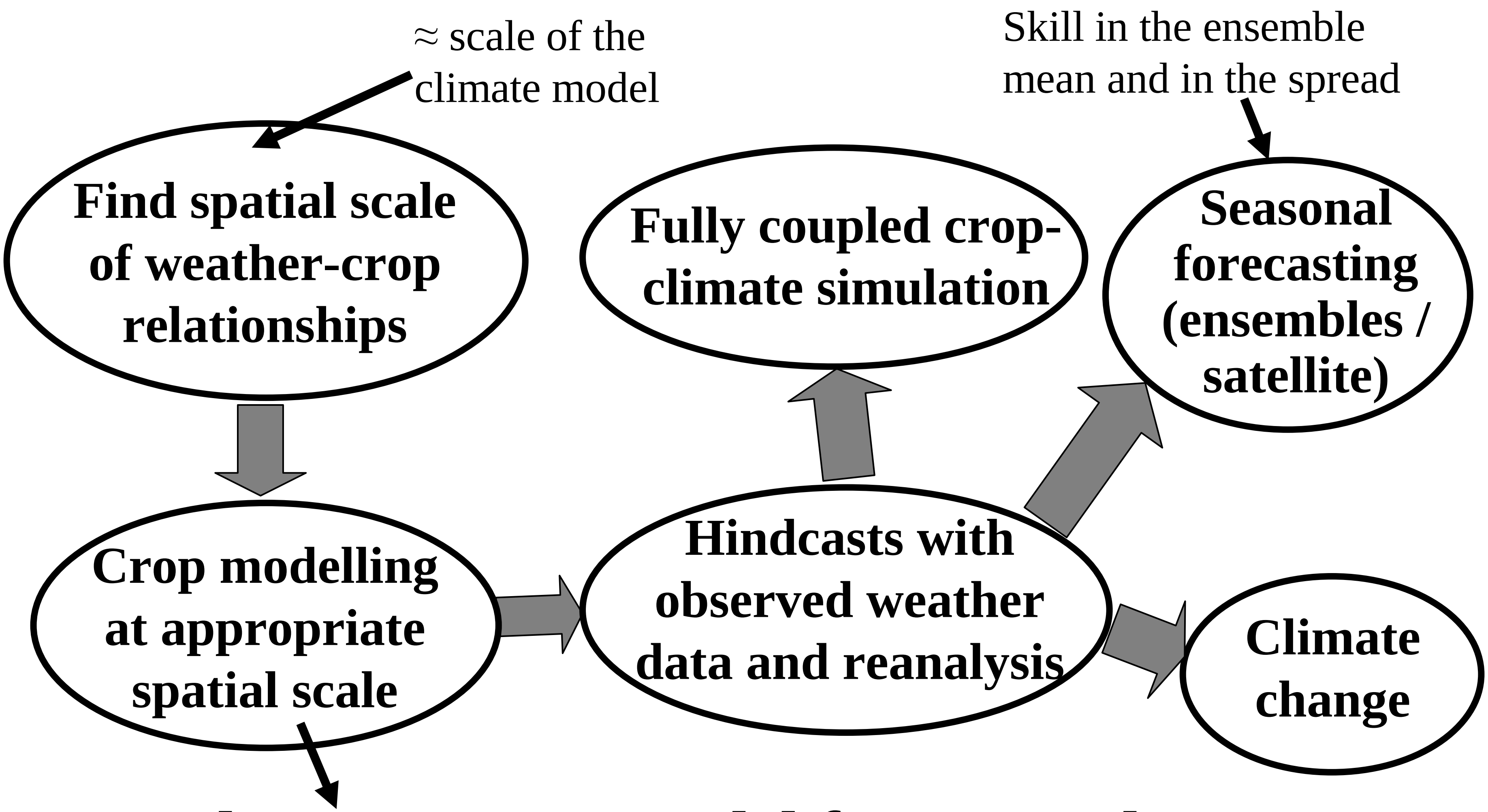
# Combining crop and climate models




**General Large Area Model for Annual Crops**

Combines the benefits of empirical and process-based approaches

# Method: QUMP simulations

- Climate model parameters varied one at a time using expert opinion to determine the values
- 53 Present-day and 53 doubled-$CO_2$ runs carried out
- 20-year time series
- 12 (current climate) or 54 (doubled-$CO_2$) GLAM parameter perturbations
- 1 grid cell used

Resulting in

12,720 baseline GLAM simulations

57,240 doubled $CO_2$ GLAM simulations

# Results

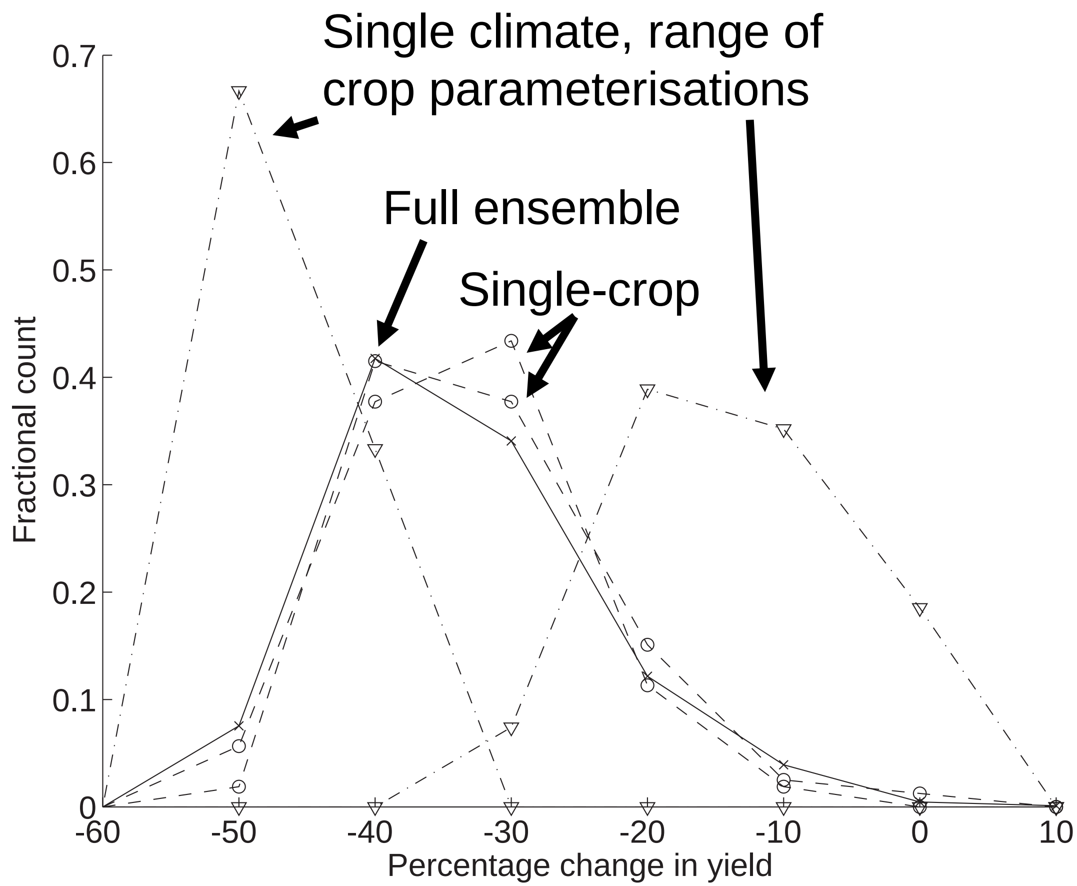
- Mean yield loss of 30-40%
- Large number of simulations enables crop and climate to be held constant in turn

- Plot the two single-ensembles that show the largest and the smallest mean change in yield

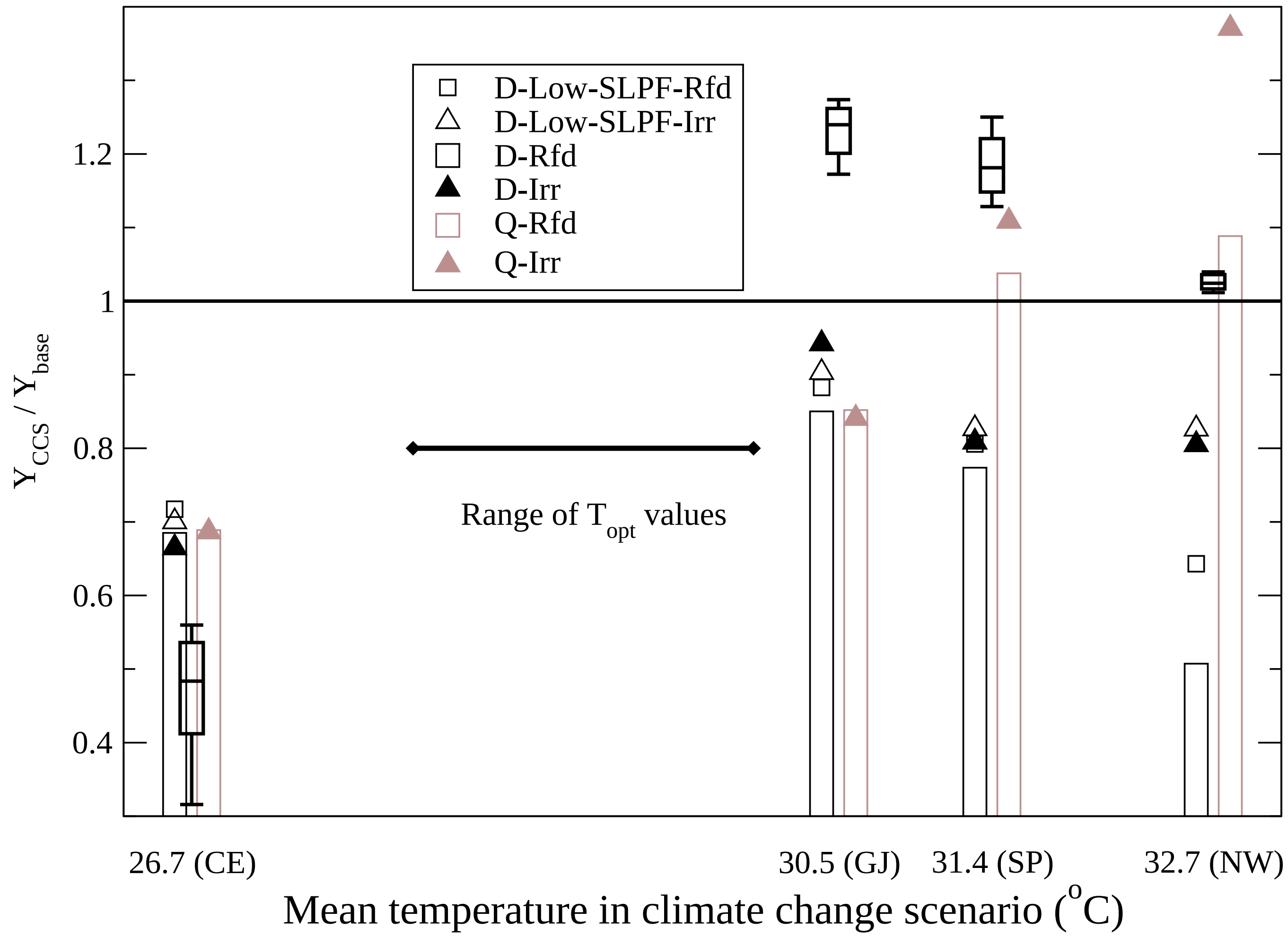
- Can capture most of the range of uncertainty using climate perturbations alone

- This result contrasts with previous study

- Pos. reason: constraint of



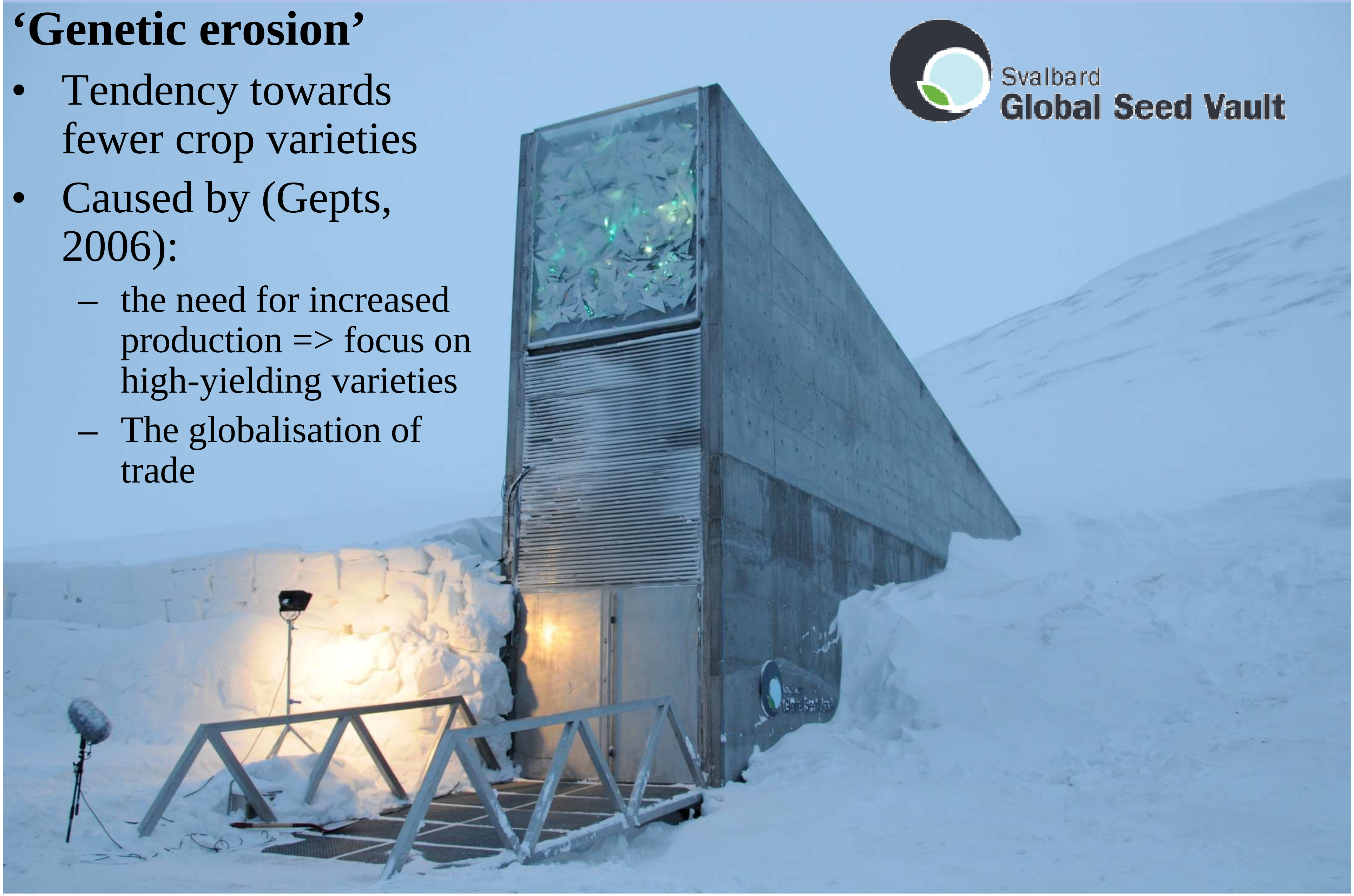
# Impact of large mean temperature increases : DSSAT, Qnut and GLAM



# On longer timescales: will farmers have access to the genetic resources for adaptation?

## ‘Genetic erosion’

- Tendency towards fewer crop varieties
- Caused by (Gepts, 2006):
  - the need for increased production => focus on high-yielding varieties
  - The globalisation of trade



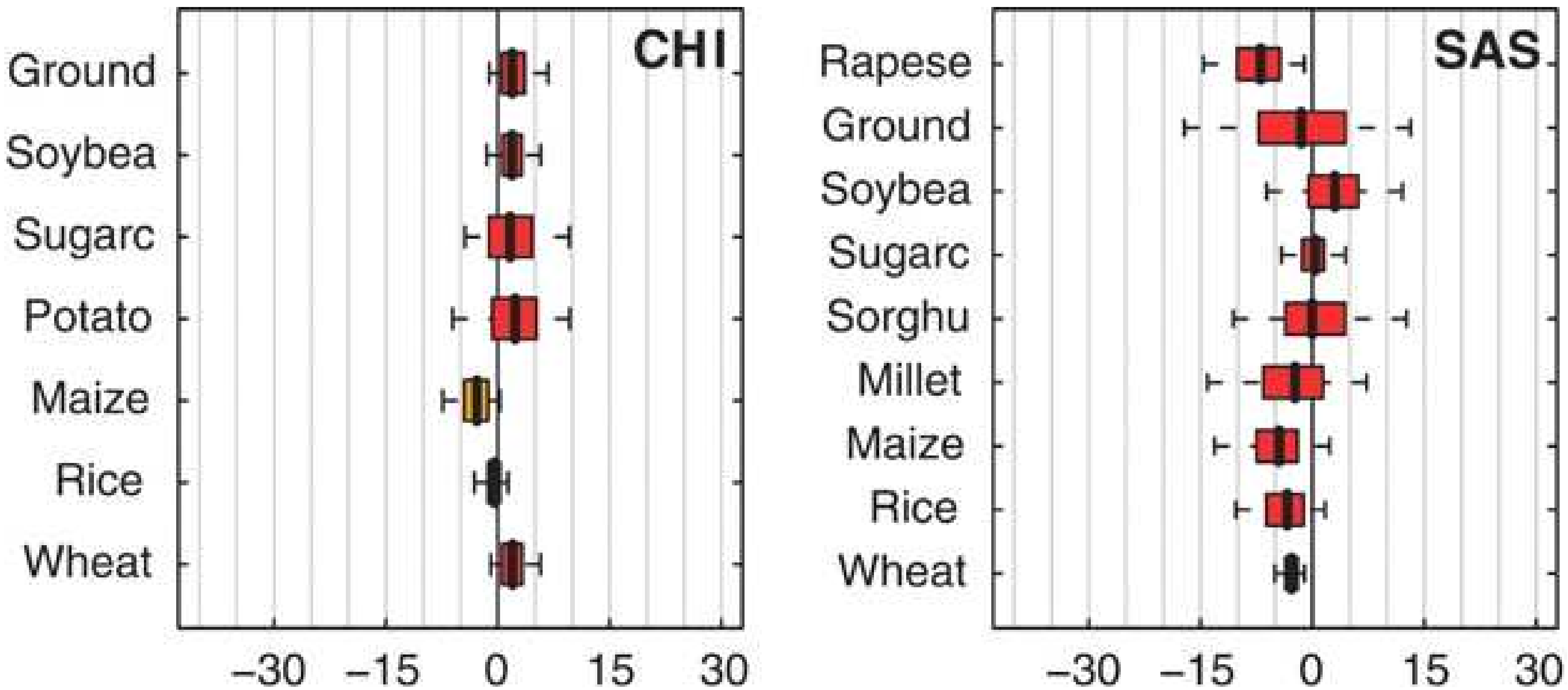
# Why so much uncertainty?

- Multiple nonlinear processes acting on crop yield.
  - Both positive and negative effects.
  - These can interact.
- Not only biophysical processes
  - Soil nutrient status
  - crop management: variety, irrigation, pest(icide)
- Many of these processes happen at the farm level

  => High spatial heterogeneity
- Climate and crop model uncertainty
  - Including disparity in spatial scale

China

South Asia



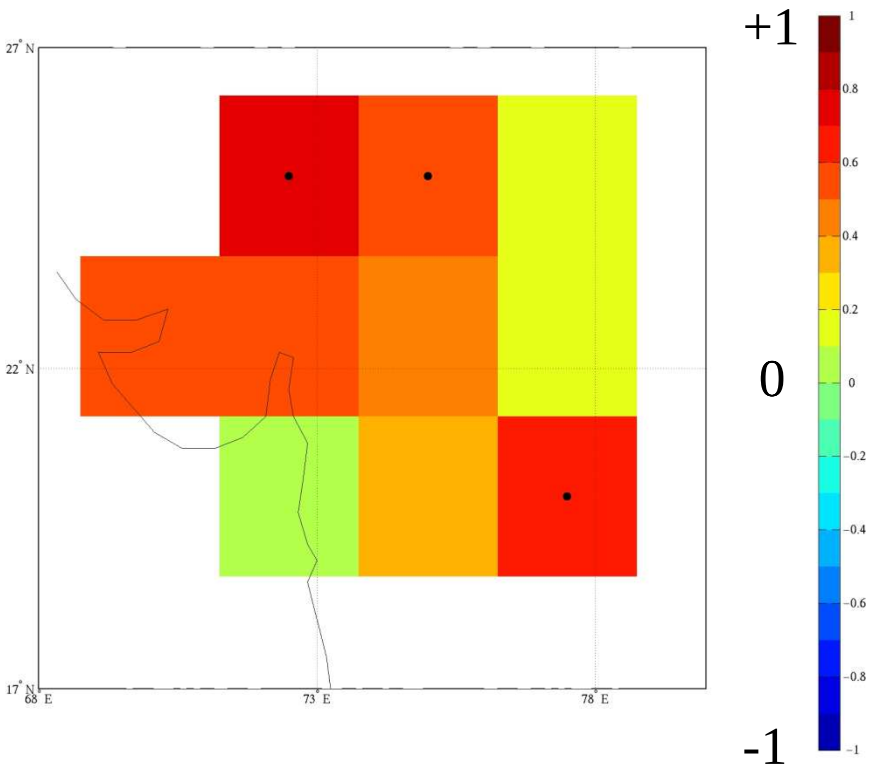

Change in yield (%)

Lobell et al. (2008). Prioritizing Climate Change Adaptation Needs for Food Security in 2030. Science 319.

# Ensemble prediction can support adaptation

**Correlation coefficients between observed and simulated yield**

Ensemble mean

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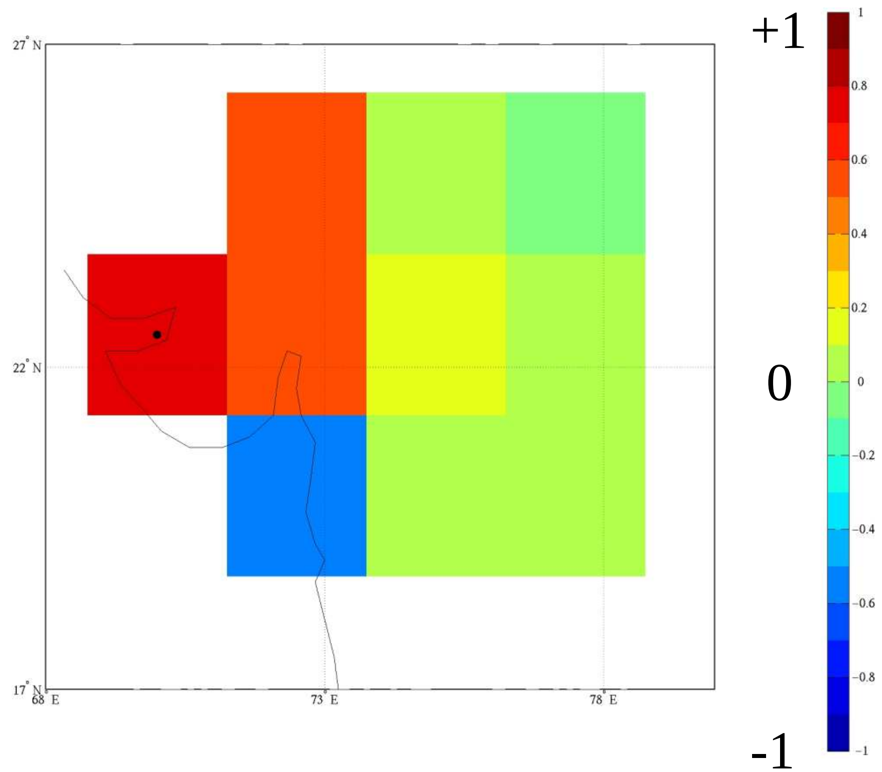


Challinor et al. (2005a)