Wheat response to climate changes in Denmark between 1992 and 2007

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Data – Grain yield

- Wheat trials in Denmark (conventional treatments)
  - By Danish Agricultural Advisory Service
  - 1992 to 2007
    - Variety trials
    - Fertiliser trials
    - Other types
  - Data from 5872 trials with winter wheat
    - From a large number of locations
    - 1857 on Sandy loam

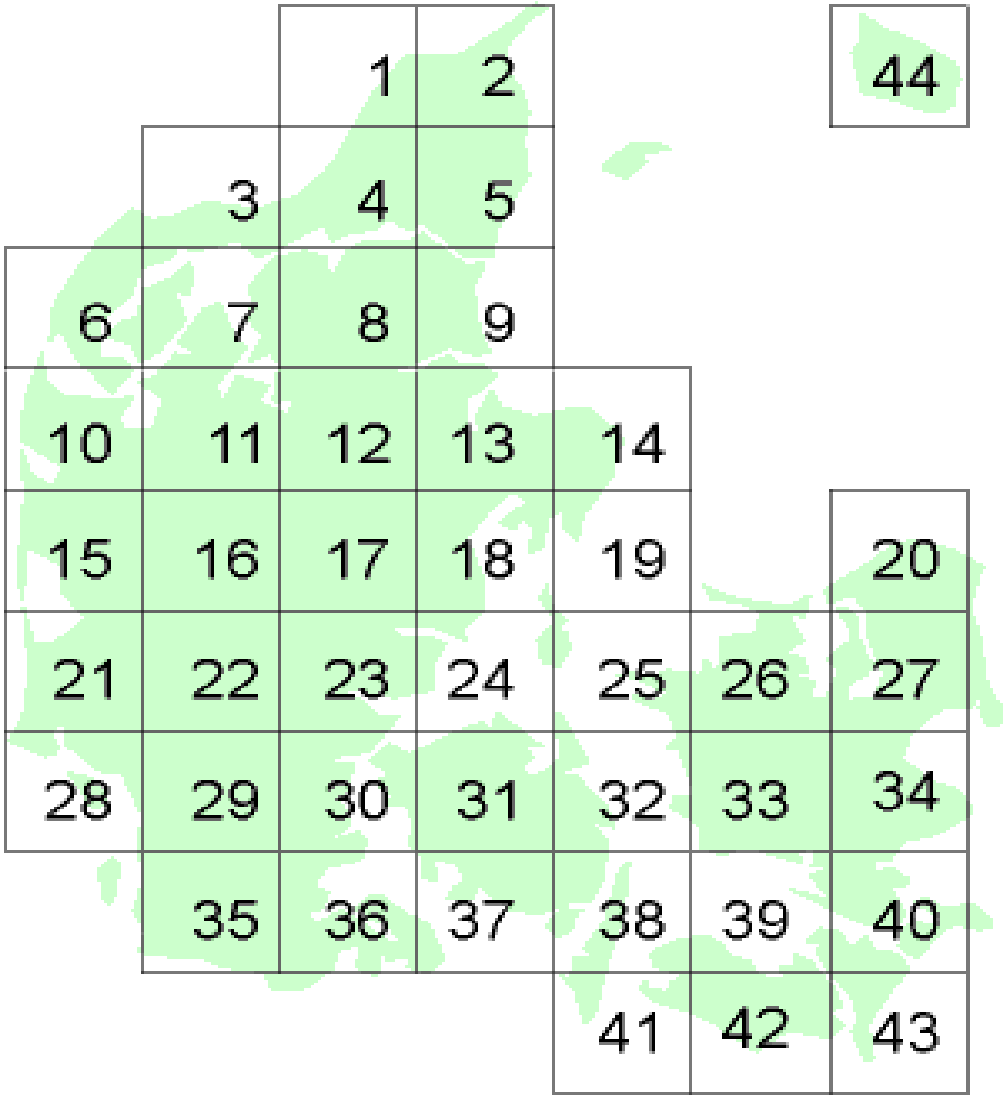
Data – climate data

- Daily values of
  - Temperature (average, minimum and maximum)
  - Global radiation
  - Precipitation
- Derived variables
  - Potential evaporation
  - Available soil water
  - Number of days with precipitation
  - Weighted water days

Data – climate data

- Aggregated data used in the model shown here
  - Average monthly values
    - Available soil water
    - Minimum temperature
    - Precipitation at low intensity
  - Indices
    - Average temperature. October to March
    - Global radiation, October to March
    - Global radiation, July and August

Data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Model

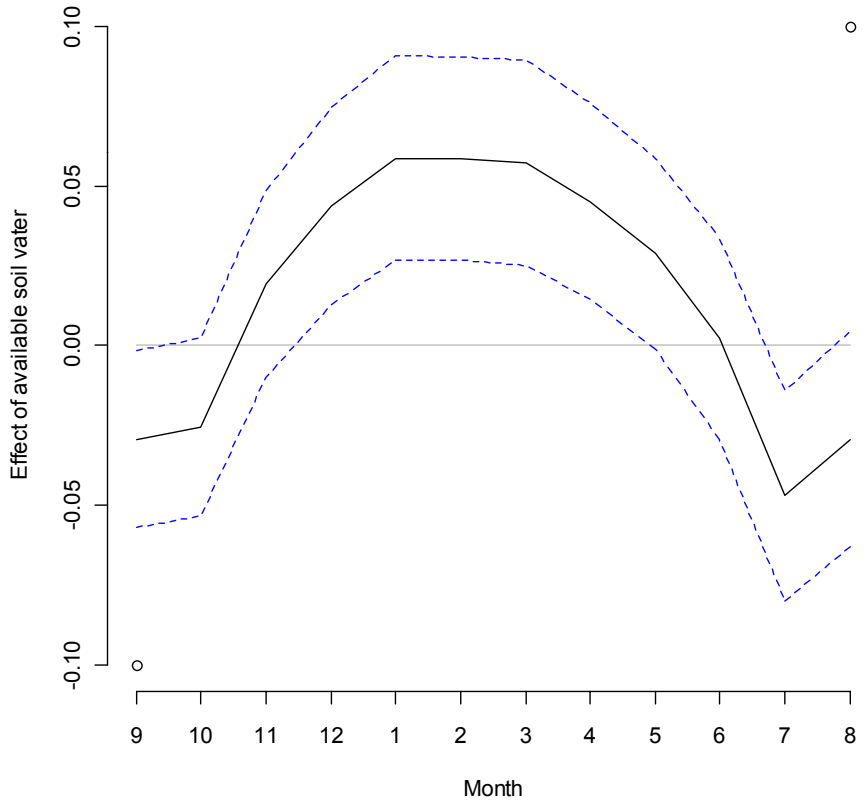
- Linear mixed model
  - Preselected indices
    - Average minimum temperature (October-March)
    - Global radiation (October-March)
    - Global radiation (July-August)
  - Monthly values of (derived) climate variables
    - Available soil water
      - Field capacity + Σ(precipitation-evaporation)
    - Minimum temperature
    - Low to medium precipitation

Problems

- Climate variables are highly correlated
  - Between months
  - Between some variables (not serious here)

Estimated effects of available soil water

Each month estimated separately



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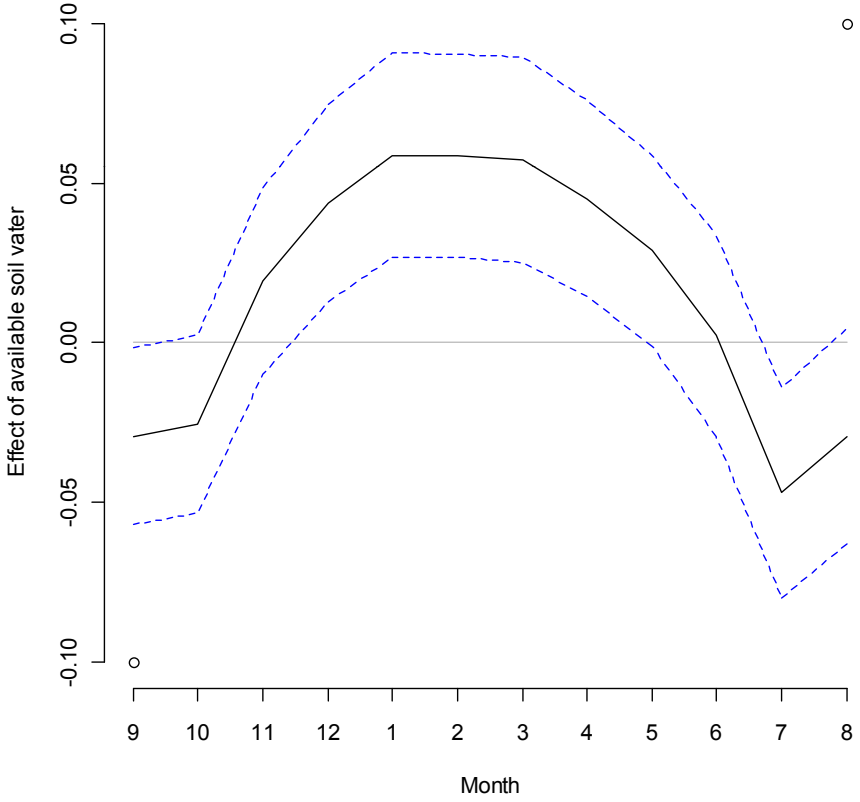
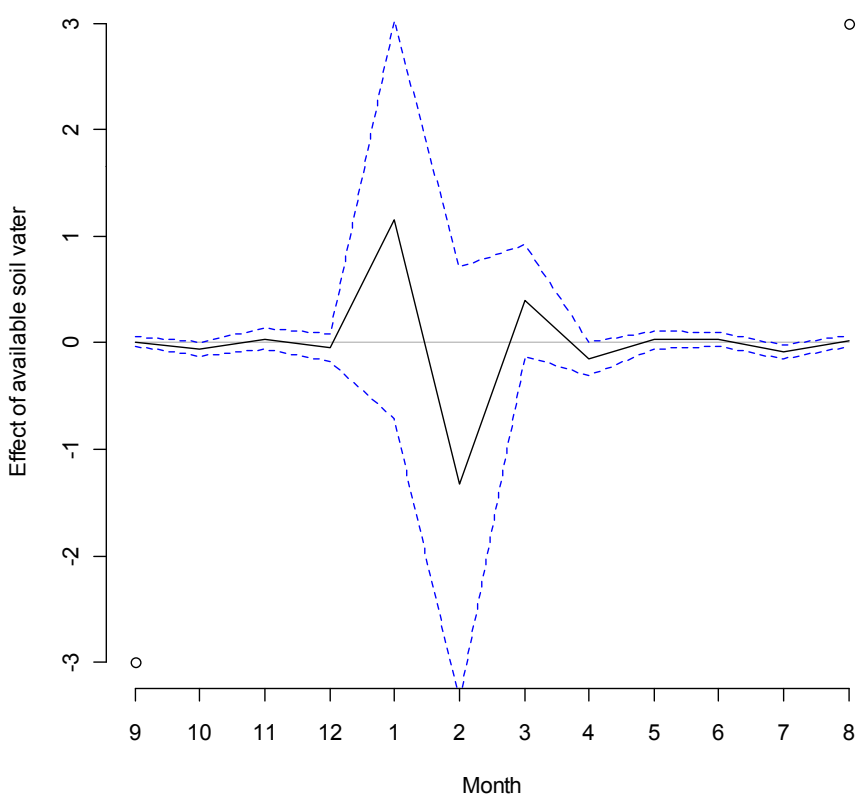


All months estimated simultaneously



Estimated effects of available soil water

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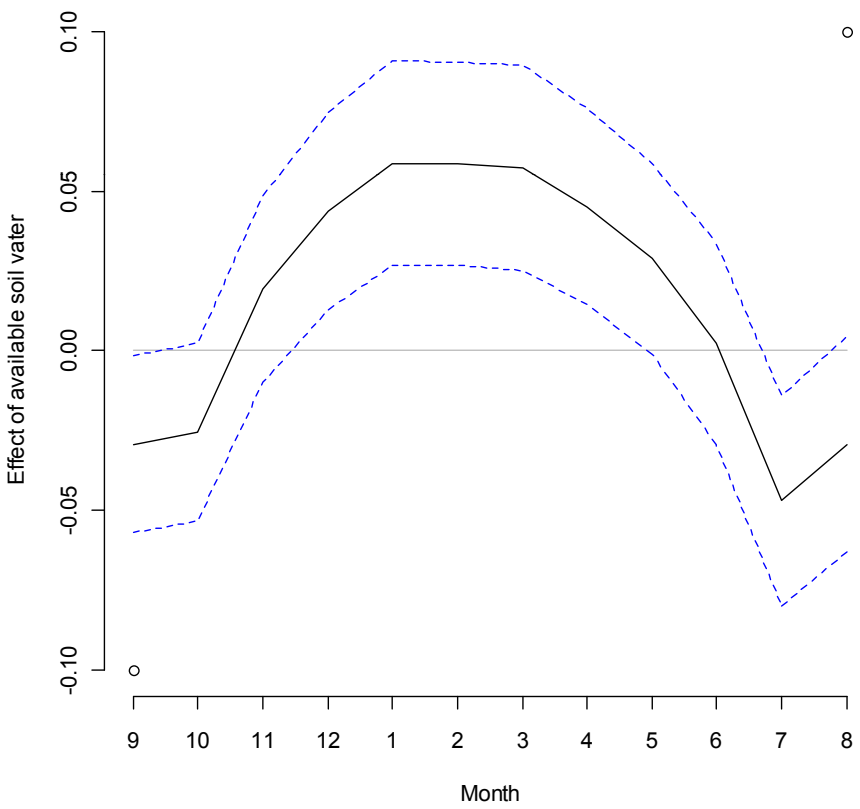
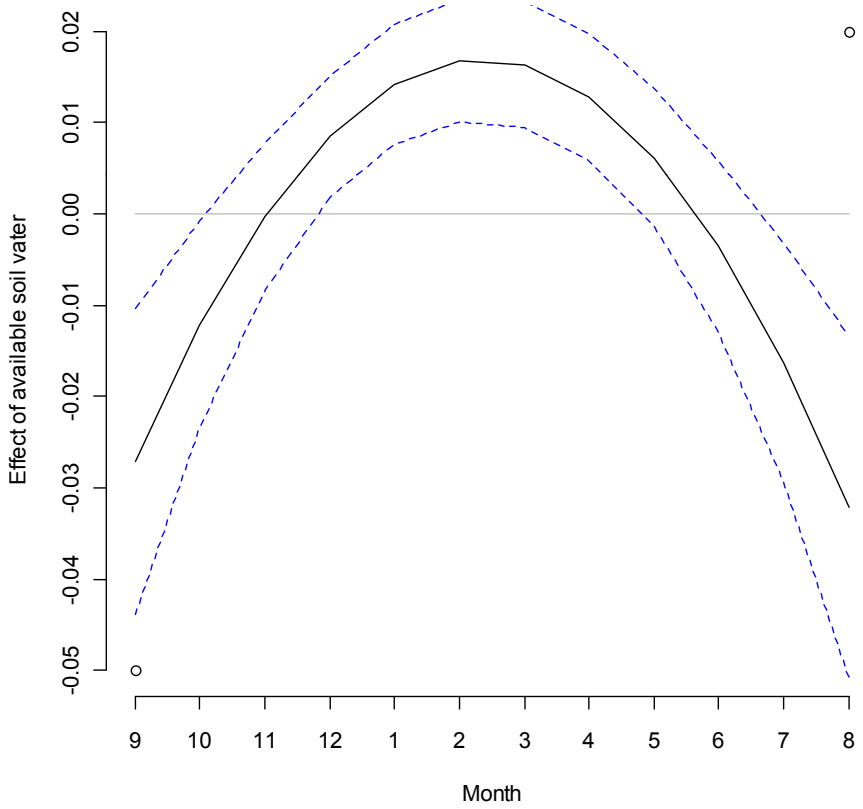


Simultaneously - penalised regression



Penalized regression

$$Y_i = \mu + \gamma_{Sep} x_{iSep} + \gamma_{Oct} x_{iOct} + \gamma_{Nov} x_{iNov} \cdots\cdots \gamma_{Jul} x_{iJul} + \gamma_{Aug} x_{iAug} + E_i$$

Ordinary regression: Minimize $\sum_{i=1}^{n} \mathrm{E}_{\mathrm{i}}^2$

Penalised regression: Minimize $\sum_{i=1}^{n} \mathrm{E}_{\mathrm{i}}^2 + \lambda \sum_{m=2}^{12} (\gamma_{m'} - \gamma_{m'-1})^2$

Which value of λ to use?

- We used mixed model approach after reformulation
- Defined a model over the months as fixed effects (polynomial)
- Deviations from this as random effects
- Based on the method given by Sims et al., 2007

Model

$$Y_i = \mu + \alpha_1 x_{1i} + \beta_1 x_{1i}^2 + \alpha_2 x_{2i} + \beta_2 x_{2i}^2 + \alpha_3 x_{3i} + \sum_{j=September}^{August} \left\{ \gamma_{1j} z_{1ji} + \gamma_{2j} z_{2ji} + \gamma_{3j} z_{3ji} \right\} + \delta_{y(i)}$$

where

Y_i is the yield of observation *i*

x_{1i} is the average minimum temperature during October to March for observation *i*

x_{2i} is the accumulated global radiation during October to March for observation *i*

x_{3i} is the accumulated global radiation in July and August for observation *i*

z_{1ji} is the average amount of available soil water in month *j* for observation *i*

z_{2ji} is the average minimum temperature in month *j* for observation *i*

z_{3ji} is the average amount of low and medium precipitation (< 20 mm day^{-1}) in month *j* for observation *i*

α_1, α_2, α_3, β_1 and β_2 are parameters to be estimated using ordinary regression

γ_{1j}, γ_{2j} and γ_{3j} are parameters estimated using penalised regression

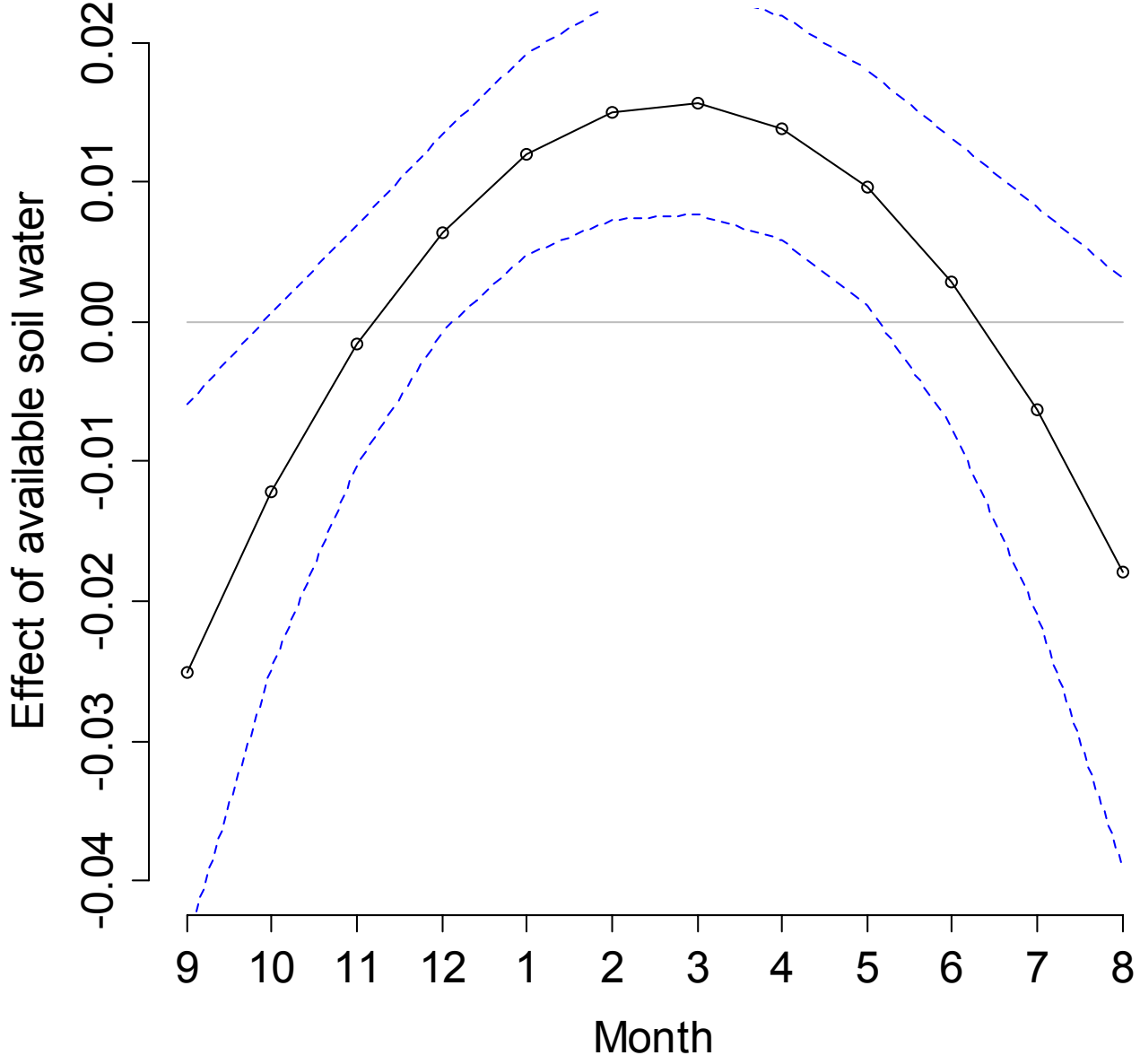
$\delta_{y(i)}$ is effect of the year (not explained by climate variables) for observation *i*

Preliminary results

Table 1 Estimates and standard errors for parameters quantifying the effects of indices based on T_{min} and global radiation

Parameter name	Associated index	Estimate	Std.Err
α_1	$[T_{min\_Oct\text{-}Mar}]$	-7.4	5.0
α_2	$[Rad_{Oct\text{-}Mar}]$	13.5	4.7
α_3	$[Rad_{Jul\text{-}Aug}]$	0.160	0.210
β_1	$[T_{min\_Oct\text{-}Mar}]^2$	-0.246	0.219
β_2	$[Rad_{Oct\text{-}Mar}]^2$	-0.286	0.106

Preliminary results



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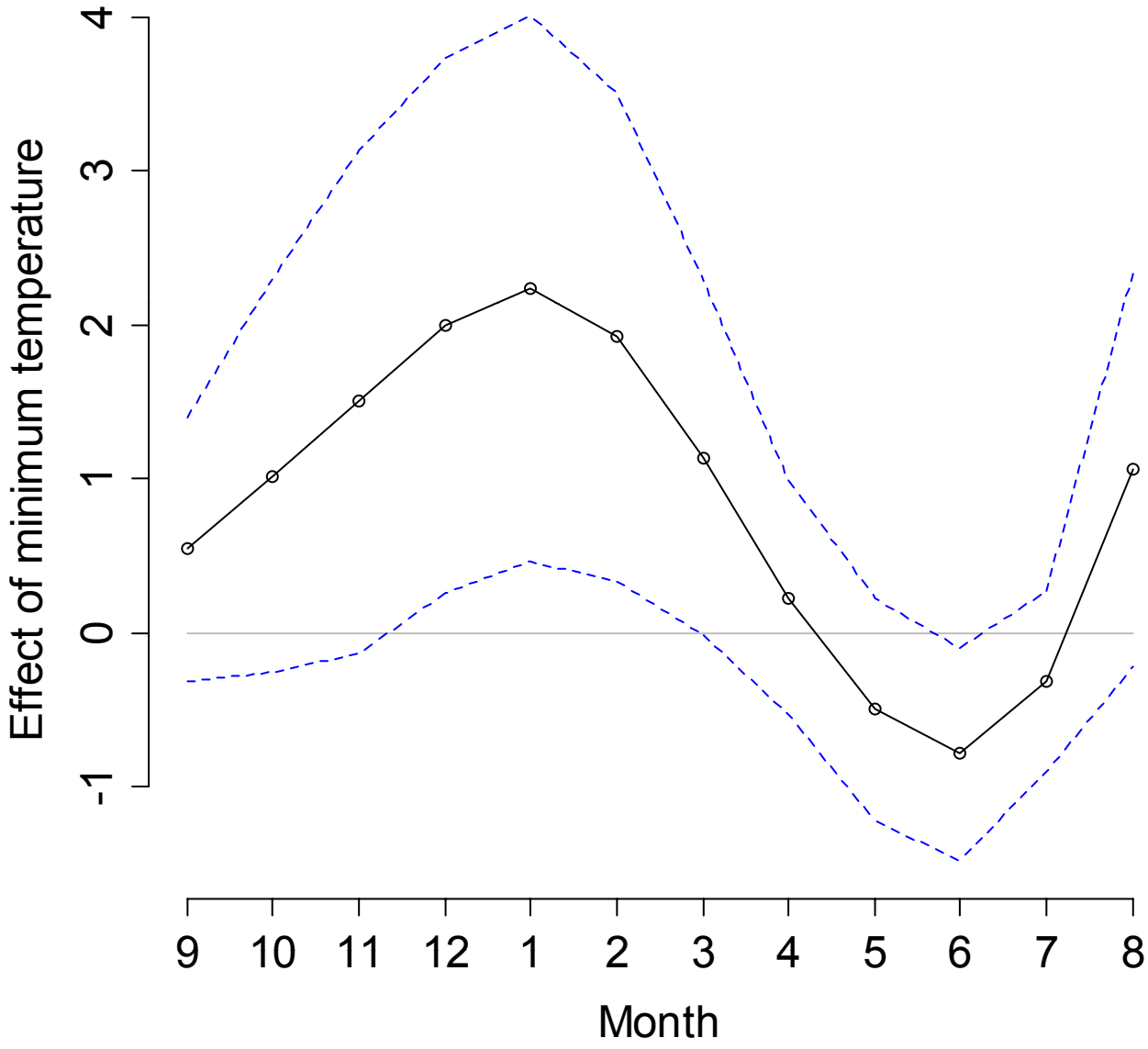

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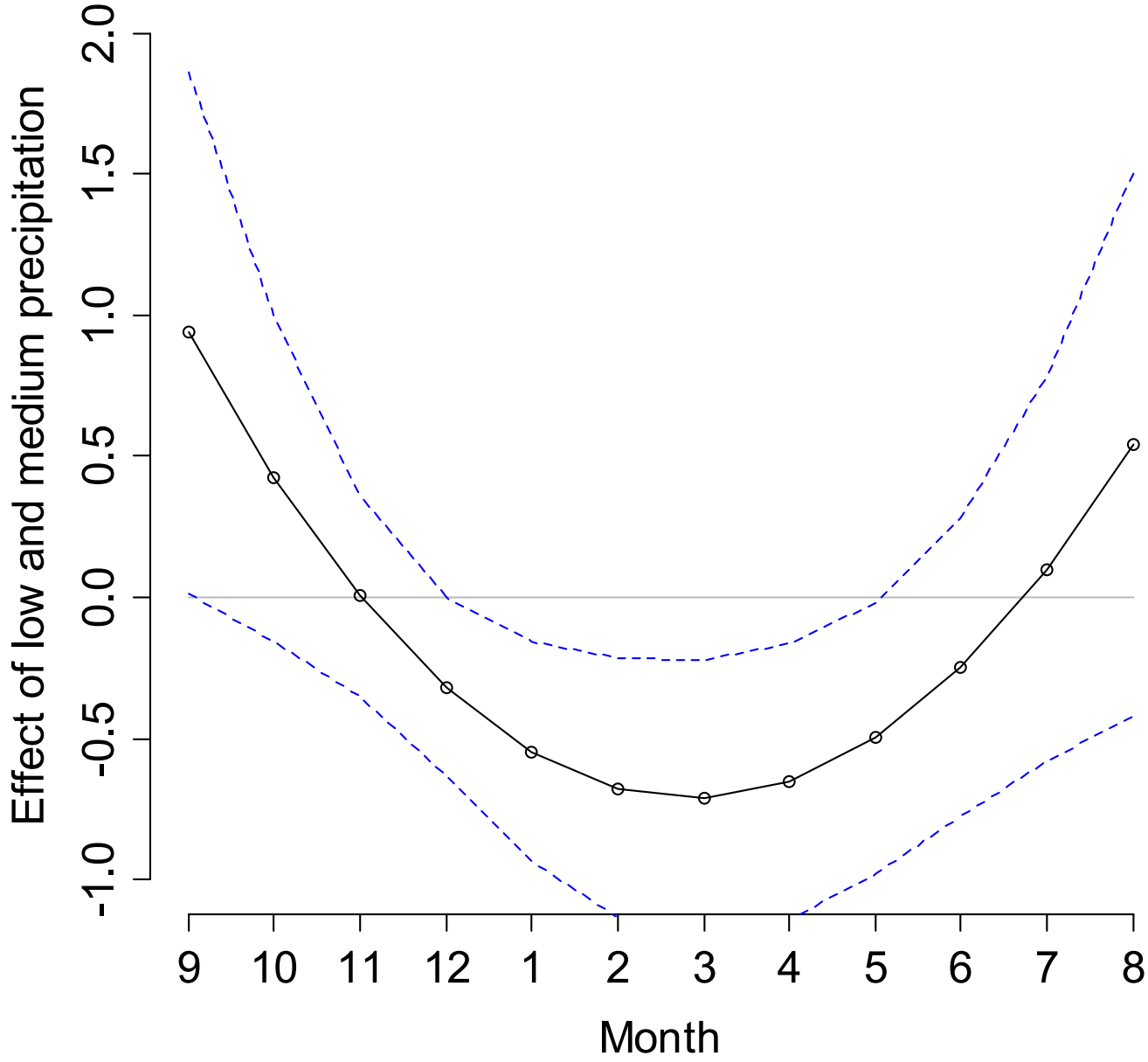

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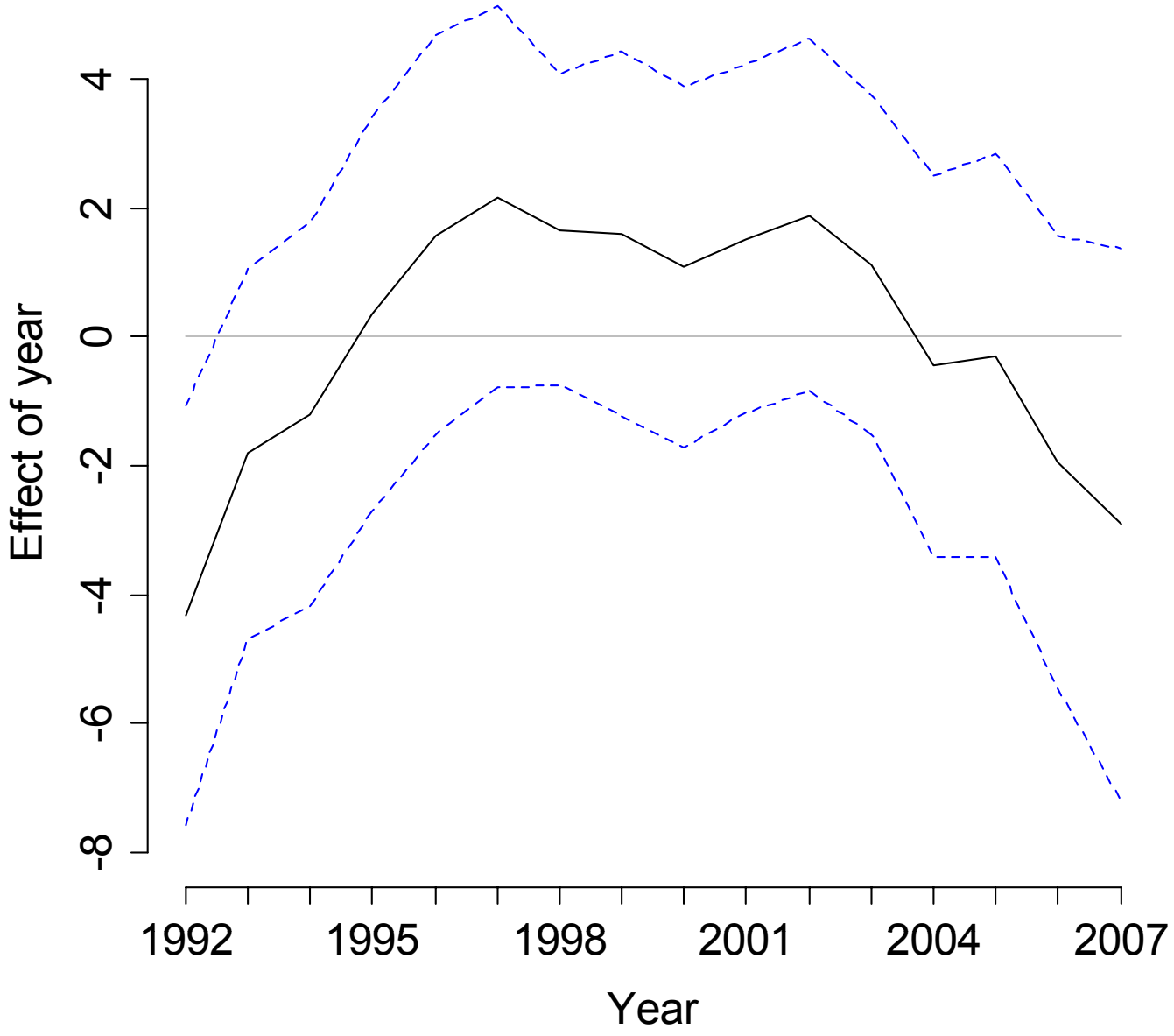

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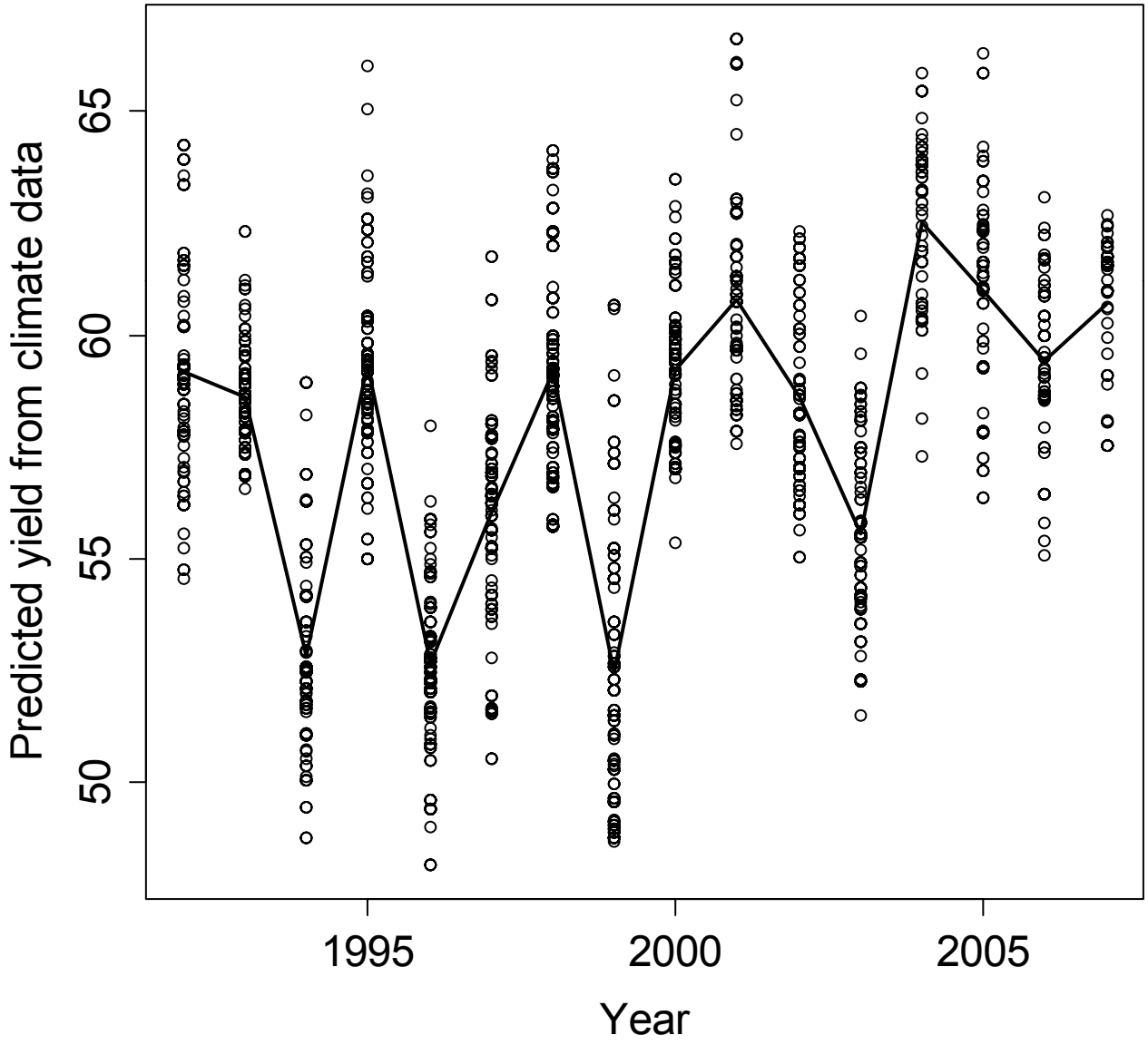

Discussion

- Estimating the effects of climate propose some difficulties
  - Correlation between consecutive months
  - (Correlation between variables)
  - Penalised regression may be used to handle correlation between months (shown here)
  - (May be also used for correlation between variables)

Discussion

- Amount of available soil water seem to be important
  - Negative effect around sowing and harvest
  - Positive effect during January-May
    - Effect in Jan-Feb has to be examined further
- Minimum temperature
  - High values had a positive effect in autumn and especially in winter
  - May be negative effect around June
  - Otherwise small or zero effects

Discussion

- Low and medium precipitation (< 20 mm/day)
  - Seemed to decrease yield during winter and spring (but available soil water is important)
- Climate changes
  - A tendency for increase yield
- Non-climate changes
  - Climate adjusted yield seem to have increased to about 1997 and to have decreased after about 2002