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Response of winter wheat to climate in Denmark and prediction of yield in future climate projections

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Contents

Introduction

- Winter wheat is an important crop
- Winter and summer temperatures have increased over the last years
- Further increase in temperature is expected
- More extreme weather conditions are expected in the future

How will this influence the yield of winter wheat in Denmark?

To answer this we must:

Model how weather conditions influence the wheat yield
Predict yield under future expected weather conditions

Empirical model

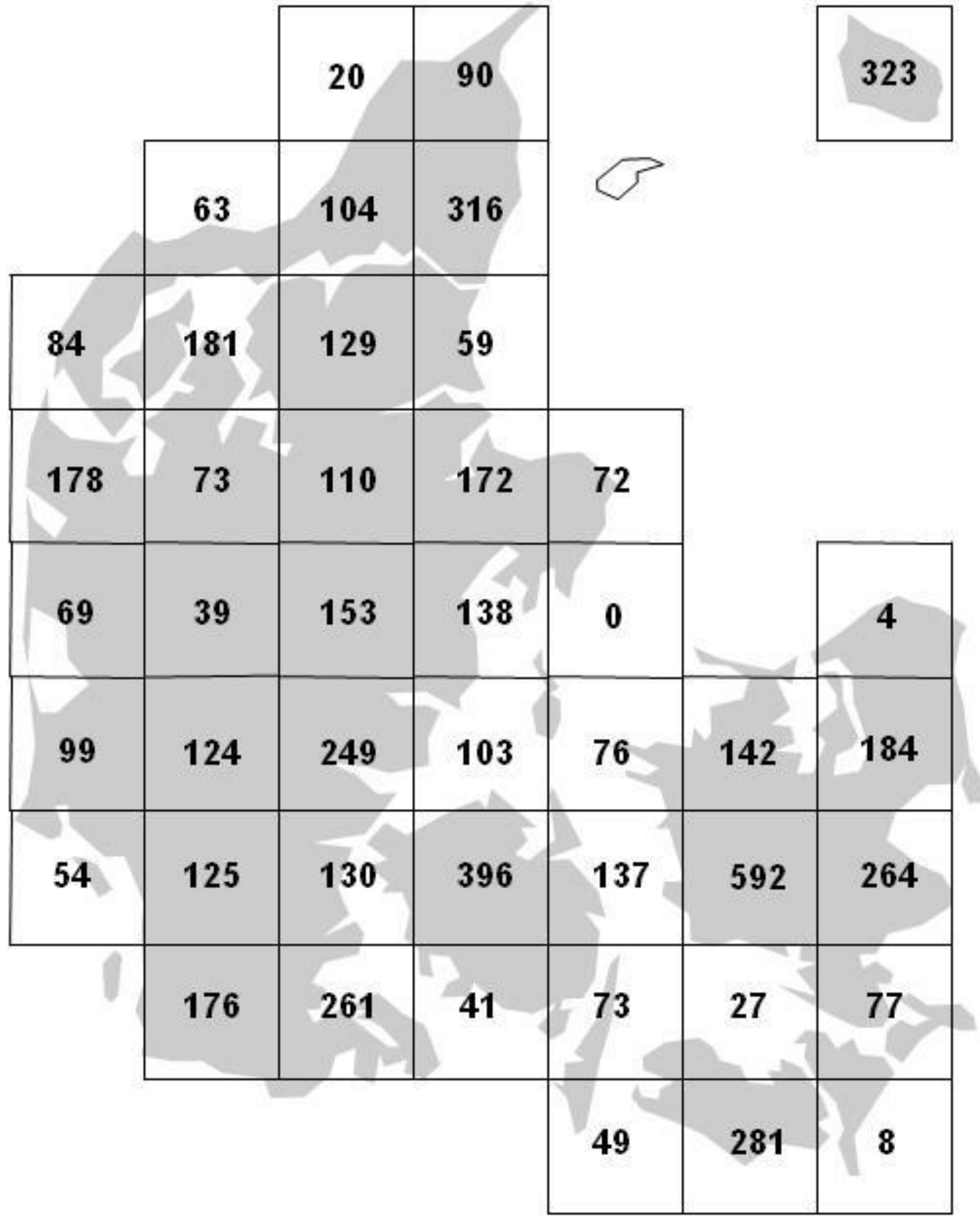
Winter wheat yield

- Field trials by the Danish Agricultural Advisory Service
- During 1992 to 2008
- The standard treatment or the control treatment was extracted
- In total 1897 observations on sandy soils and 4148 observation on loamy soils

Climate data

- Daily values (temperature, radiation and precipitation) for each of 44 grids in Denmark

Number of wheat yield observations from each of the 44, 40 km by 40 km, climate grids covering Denmark



The applied model

Mixed model for each of two soil types:

Fixed effects

- Nine agro climatic indices:
  Temperature, global radiation and precipitation in each of three periods:

Winter (1 Oct – 31 Mar)	Crop establishment
Spring (1 Apr – 15 Jun)	Vegetative growth
Summer (16 Jun – 31 Jul)	Grain filling

- Soil type within sandy and loamy soils
- Trend over year (to take management changes over years into account)

Random effects

- Grid, year, grid/year combinations and residual

Complete model

$$Y_i = \mu + \varphi_i + \theta_i + E_i$$

$$\varphi_i = \alpha_1 x_{1i} + \alpha_2 x_{2i} + \alpha_3 x_{3i} + \alpha_4 x_{4i} + \alpha_5 x_{5i} + \alpha_6 x_{6i} + \alpha_7 x_{7i} + \alpha_8 x_{8i} + \alpha_9 x_{9i}$$
$$+ \beta_1 x_{1i}^2 + \beta_2 x_{2i}^2 + \beta_3 x_{3i}^2 + \beta_4 x_{4i}^2 + \beta_5 x_{5i}^2 + \beta_6 x_{6i}^2 + \beta_7 x_{7i}^2 + \beta_8 x_{8i}^2 + \beta_9 x_{9i}^2$$

$$\theta_i = \lambda_{s(i)} + \gamma y_i$$

$$E_i = A_{v(i)} + B_{g(i)} + C_{y(i)g(i)} + D_i$$

Reduced model

Excluding all effects that were not significant for any of the two soil types

< Temperature > < Global radiation > < Precipitation >

Sandy soil

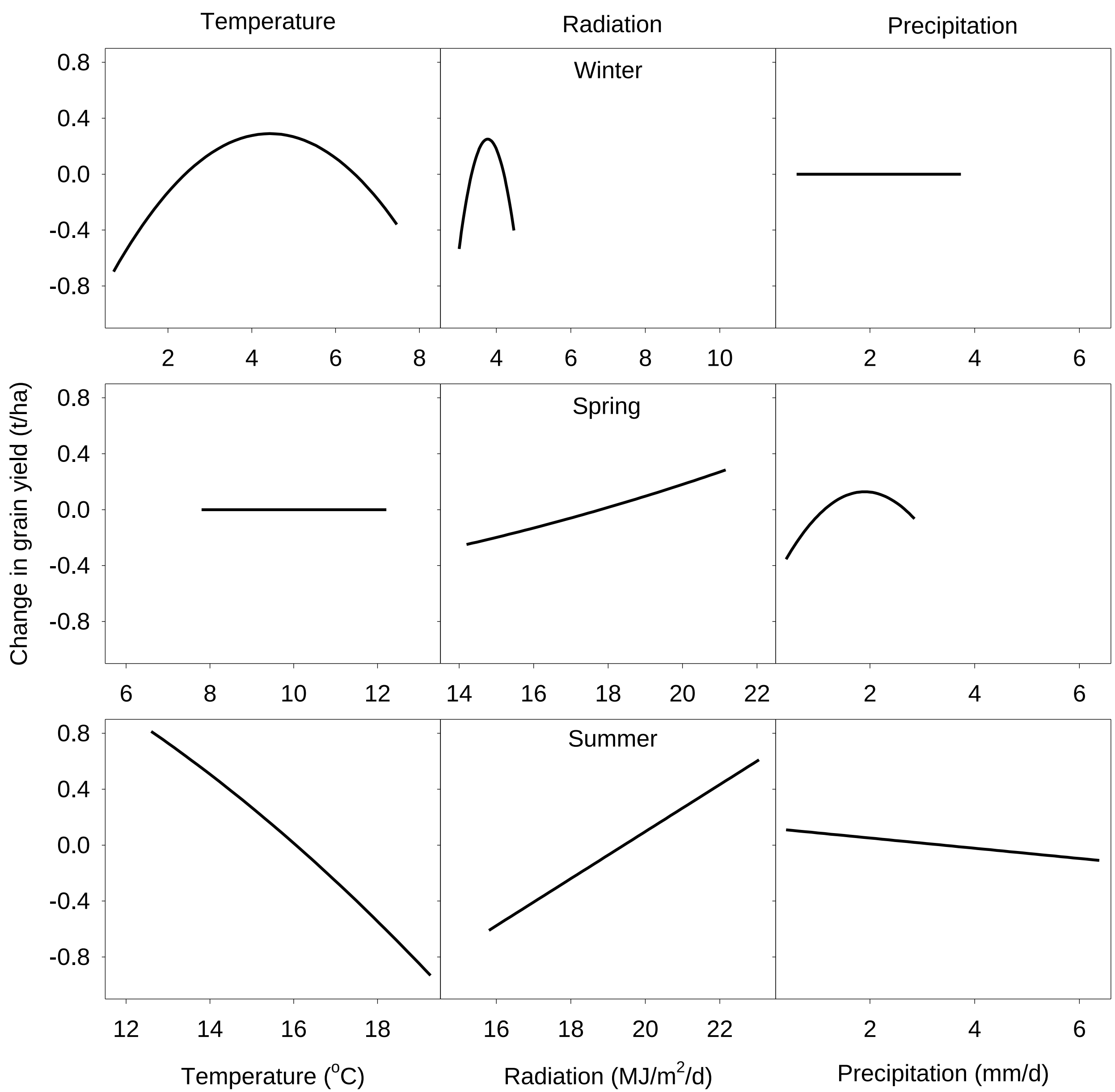
$$\varphi_i = .63x_{1i} + 0 + 0 + 10x_{4i} + 0 + .17x_{6i} + 0 + .82x_{8i} - .04x_{9i}$$
$$- .07x_{1i}^2 + 0 - .01x_{3i}^2 - 1.3x_{4i}^2 + .01x_{5i}^2 + 0 + 0 - .21x_{8i}^2 + 0$$

Loamy soil

$$\varphi_i = .68x_{1i} + 0 + 0 + 6x_{4i} + 0 + .13x_{6i} + 0 + .80x_{8i} - .14x_{9i}$$
$$- .08x_{1i}^2 + 0 - .01x_{3i}^2 - 0.8x_{4i}^2 + .01x_{5i}^2 + 0 + 0 - .28x_{8i}^2 + 0$$

< Temperature > < Global radiation > < Precipitation >

Effect of agroclimatic indices in final model for *sandy soils*



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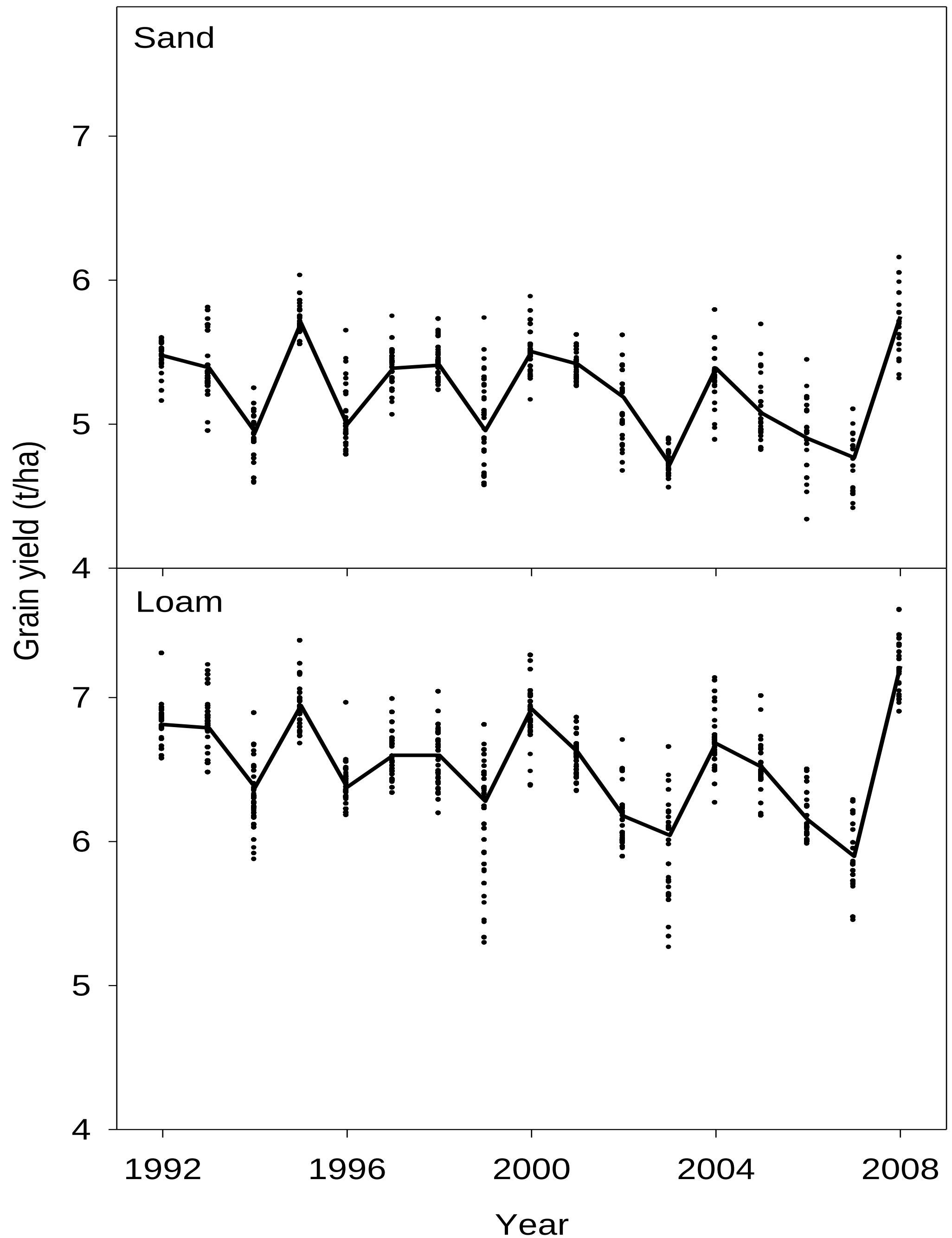
Predicted yield for each grid and year



Prediction of Yield

- The reduced model was then used to predict the yield for

- Five climate projections:
  1985 (a baseline)
  2020 KNMI and 2020 METO
  2040 KNMI and 2040 METO

- Two soil types:
  Sandy soil
  Loamy soil
- Two locations in Denmark:
  Central Jutland (relatively cool and wet)
  Western Zealand (relatively warm and dry)

Mean predicted yield (t/ha)

Soil type	Year	Climate projection	Central Jutland	West Zealand
Sand	1985	Baseline	6.5	6.1
	2020	KNMI	6.3	5.9
		METO	6.2	5.7
	2040	KNMI	6.1	5.7
		METO	5.7	5.3
Loam	1985	Baseline	7.3	7.0
	2020	KNMI	7.2	6.8
		METO	6.9	6.6
	2040	KNMI	7.0	6.6
		METO	6.5	6.2

Coefficient of variation over years

Soil type	Year	Climate projection	Central Jutland	West Zealand
Sand	1985	Baseline	0.18	0.21
	2020	KNMI	0.21	0.19
		METO	0.26	0.35
	2040	KNMI	0.33	0.28
		METO	0.36	0.45
Loam	1985	Baseline	0.16	0.18
	2020	KNMI	0.20	0.18
		METO	0.33	0.29
	2040	KNMI	0.25	0.25
		METO	0.46	0.38

Discussion and conclusions

- The model application to future climate projections shows that the yield of winter wheat is expected to decrease in the future
- The calculations applied here do not include the effect of the expected increase in CO_2 concentration, which may partly counteract the decrease found here
- Breeding of new varieties that better tolerate future climate than present varieties may help compensating for a possible decrease
(over the 17 years we found a yield increase of 50-70 kg/ha/year apparently caused by management changes (new varieties, improved pesticides etc.))
- A larger yield variation from year to year must be expected – posing higher risks to wheat production