Adaptation to climate change - the case of forage maize

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Abstract

Climate change will likely change the relative competitiveness of different crops due to their different responses to temperature and water availability. However, the competitiveness of a given crop species is not only determined by climatic factors, but also by genetic traits, management considerations and subsidies. The cultivation of maize has increased considerably in Denmark during the past two decades from 11,000 ha in 1980 to 118,000 ha in 2003. The maize is harvested for silage and used as feed for dairy cows. During this period, maize has replaced fodder beets and cereals for whole-crop silage as winter feed for the cattle, and maize silage is now also used as an important feed supplement during the summer season. There are several reasons for this change, including the high quality of maize silage as a feed for cows, and a period from the mid 1990's where maize was subsidized and fodder beet was not. However, a main driver for the changes has been increasing yields and fewer years with yield failures. Among farmers and agricultural advisors this has mostly been attributed to new cultivars better adapted to the Danish climate.

Introduction

Most of Europe has experienced increases in surface air temperature during the 20th century, which amounts to 0.8°C in annual mean temperature over the entire continent (Kjellström, 2004; Schär et al., 2004). A large part of this increase has occurred over the past two decades, and it is likely that most of this observed warming have been due to the increase greenhouse gas emissions arising from anthropogenic activities (Houghton et al., 2001). Results of GCM model simulations indicate that large climatic changes may occur over the European continent as a result of the likely increase in atmospheric concentrations of greenhouse gases caused by anthropogenic emissions. The evaluation of climate change is usually based on simulations with global climate models (GCM) for the four IPCC emissions scenarios (SRES scenarios), which describe very different socio-economic futures (Ruosteenoja et al., 2003). These scenarios indicate that annual temperatures over Europe warm at a rate of 0.1 °C decade^{-1} to 0.4 °C decade^{-1}.

Climate change will likely change the relative competitiveness of different crops due to their different responses to temperature and water availability (Easterling, 1996). However, the competitiveness of a given crop species is not only determined by climatic factors, but also by genetic traits, management considerations and subsidies. Given these influencing factors, farmers make their decisions on which crops to grow. In a changing climate there will be a gradual change in the most suitable crops. However, current farm management may not al-

ways capture these changes sufficiently quickly, if there are inadequacies in the transfer of knowledge on climate change and in the sharing of cropping experiences.

The effects of climate change will be most pronounced for those crops, which are at their marginal distribution in a certain area under the current climate. Forage maize in Denmark is an example of such a crop. Maize is a tropical C_4 species, which requires relatively high temperatures for growth and development. The cropping of forage maize has increased greatly in Denmark over the past two decades due to various reasons.

Materials and methods

Data on the development of the area of forage maize in Denmark and other agricultural statistics for individual counties (Figure 1) were collected from the Danish Bureau of Statistics for the period 1982 to 2004. Data on normal mean temperatures for the counties were based on gridded normal temperatures (Scharling, 2000). Daily temperatures for calculating the thermal requirements for fodder maize were taken from six climatological stations selected to represent the Denmark (Olesen et al., 2000). The climatic suitability for forage maize in Denmark was described by corn heat units (CHU, Begna et al., 1999) accumulated from 15 April to 15 October. Data on yields for the individual years were taken as the average yield from variety trials in each individual year (Pedersen, 2004).

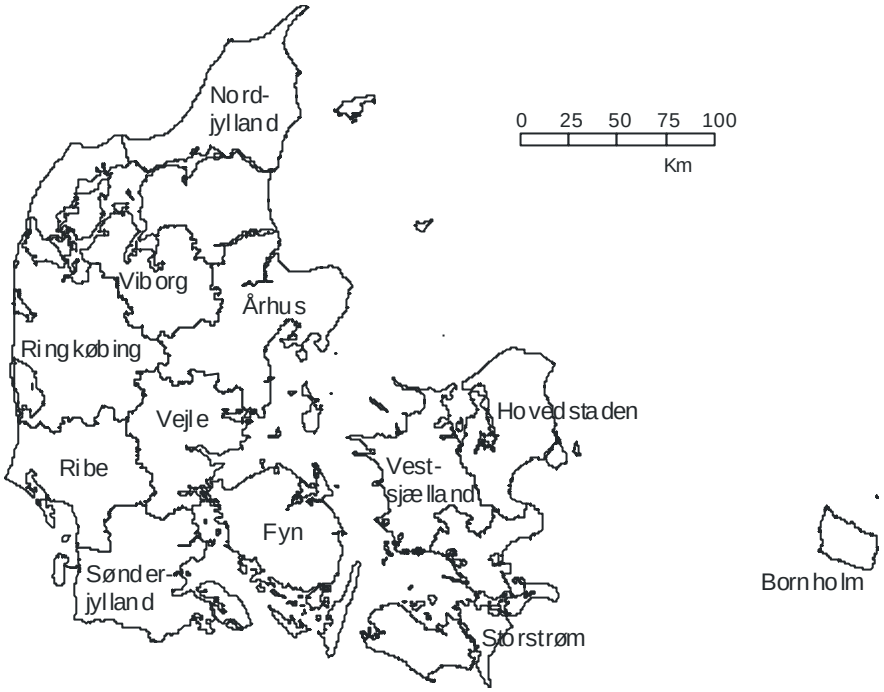

Figure 1. Counties in Denmark.

Results

The dairy production in Denmark is concentrated in the western part of the country, in particular in the counties of Sønderjylland, Ribe, Ringkøbing, Viborg and Nordjylland (Table 1). These counties also represent a climatic gradient with the highest summer temperatures in the southern parts of Jutland and the lowest to the north.

Table 1. Agricultural area of counties in Denmark, the number of cows and the maize area in 2004 and the normal mean temperature of May to October for 1961-90.

County	Agric. area (ha)	Maize area (ha)	Dairy cows (no)	Maize per cow (ha/no)	Temperature (°C)
Hovedstad	112319	881	5173	0.17	13.5
Vestsjælland	187679	2847	11626	0.24	13.4
Storstrøm	234098	2597	11520	0.23	13.6
Bornholm	33926	1004	4763	0.21	13.3
Fyn	224948	9640	38448	0.25	13.5
Sønderjylland	279351	26348	90963	0.29	13.0
Ribe	189873	20121	79389	0.25	13.0
Vejle	182332	7375	33729	0.22	12.8
Ringkøbing	293243	16464	82364	0.20	12.8
Århus	263759	6280	33538	0.19	12.8
Viborg	257424	14077	70997	0.20	12.8
Nordjylland	386353	21682	100943	0.21	12.8

The maize area has increased considerably over time with the largest increases from 1993 and onwards (Figures 2 and 3a). The increase started earlier in southern parts of Jutland than in the north (Figure 2). Since maize is grown as fodder for dairy cows, changes over time may best be illustrated by the area of forage maize per dairy cows (Figure 2b).

The climatic suitability for forage maize in Denmark is usually described by corn heat units accumulated from 15 April to 15 October, and this index has increased over the past ten years (Figure 3b). There is a close relationship between the average dry matter yields obtained in variety trials in Denmark and the corn heat units. A multiple linear regression of maize yield on CHU and year showed that CHU explained 64% of the variation in yield and year only 1% (Figure 3c). Figure 3d shows that 67% of the variation in the area cultivated with maize can be explained by the average of the CHU over the past two years.

Discussion

Forage maize is harvested for silage and used as feed for dairy cows. During the past ten years, maize has replaced fodder beets and cereals for whole-crop silage as winter feed for the cattle, and maize silage is now also used as an important feed supplement during the summer season. There are several reasons for this change, including quality of the fodder, the subsidy system, genetic improvements and climatic change.

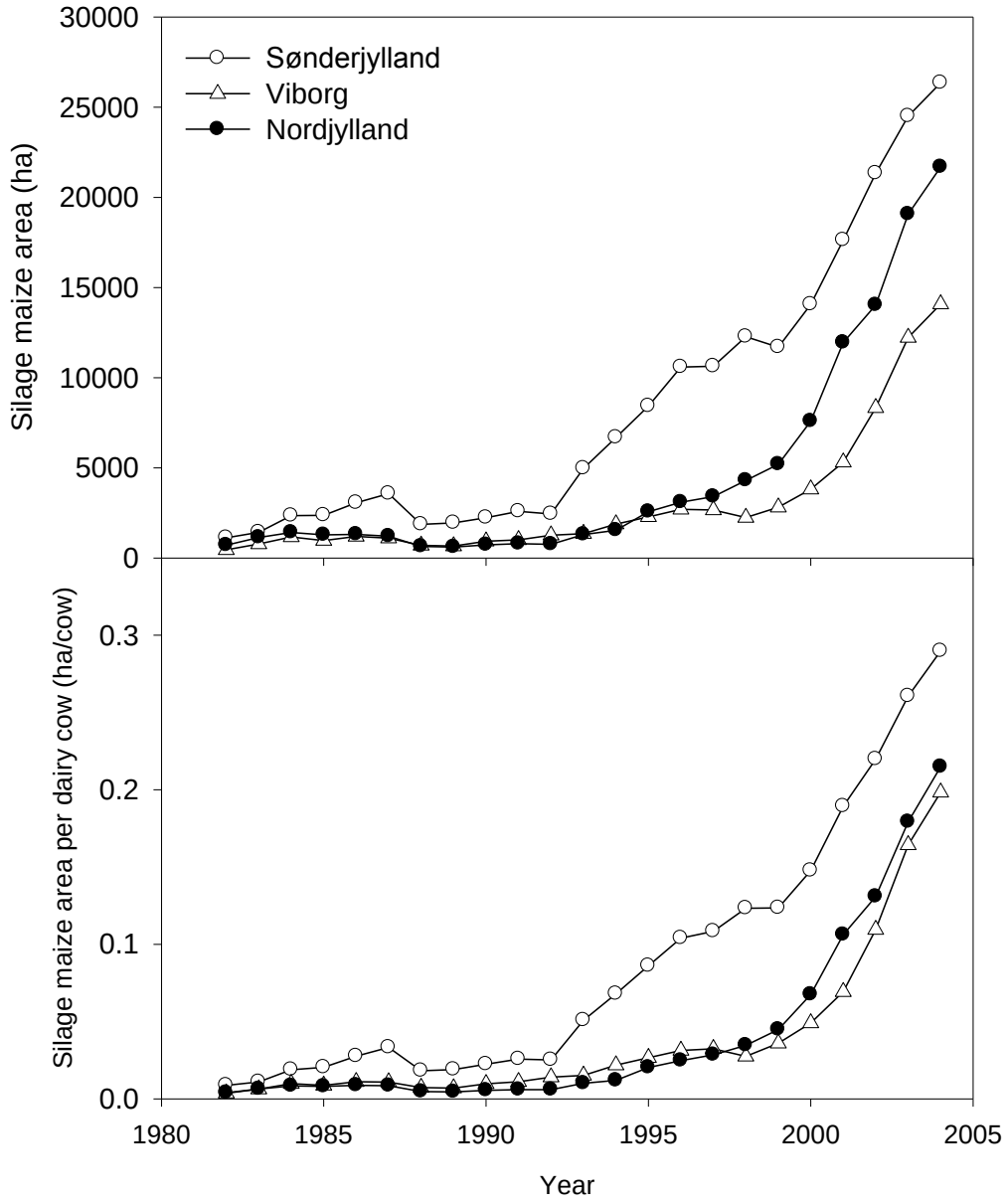

Figure 2. Development if silage maize area in three counties in Jutland expressed as area and area per cow.

Forage maize is a high quality forage crop, which also is very easy to handle during harvesting, storage and feeding on modern and rational dairy farms. A dairy cow with associated young stock has an annual feed requirement of about 8 ton dry matter, of which typically half comes from forage crops. Assuming a net forage maize yield of about 10 ton dry matter per ha, the theoretical maximum area of maize is about 0.4 ha per cow. It is probably not possible to achieve this maximum since other forage crops, e.g. grass, will also be used in the feed ration. The area of silage maize is therefore probably currently approaching the saturation level in several counties in Jutland (Table 1).

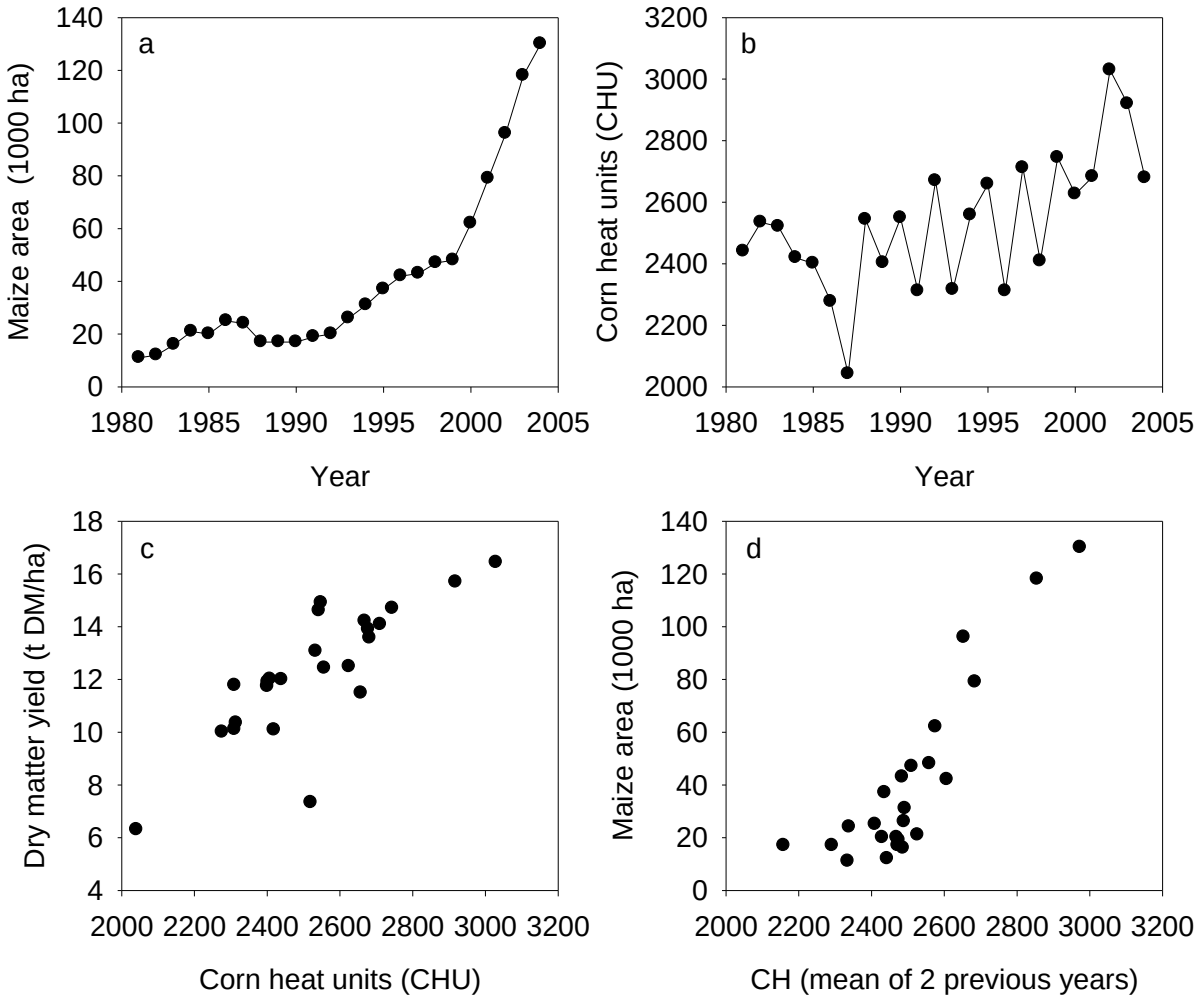

Figure 3. Development in silage maize area (a) and corn heat units (b) in Denmark. Dry matter yield for silage maize from variety trials in Denmark in relation to corn heat units (CHU) (c), and Danish maize area versus corn heat units of the two previous years (d).

Among farmers and agricultural advisors the increase in the maize area has mostly been attributed to new cultivars better adapted to the Danish climate and to the introduction in 1993 of an arable payment scheme under the EU Common Agricultural Policy. This change is the subsidy system meant that forage maize could get subsidised whereas other forage crops could not. It can be seen from Figure 2 than this gave rise to an increase in the mid 1990's in the area of forage maize, but mostly in Southern Jutland, whereas there was little change in some of the other counties during this period. Also most of the increase in maize area occurred after 1999, when the changed subsidy system had been in place for several years. It is therefore unlikely that the change in arable subsidies has been the main driver of the increased forage maize area in Denmark.

The assumption of better varieties as the driver of the increased maize area can be ruled out from the data from the variety trials, which show that the increase in maize yields over time can be explained by the variation in CHU and not by any linear trend in time. The climate therefore seems to be the main factor influencing maize yields, whereas improved technology (including varieties) only plays a small role. The increase in maize area in Denmark can therefore be explained by the warming that has occurred over the past two decades, and 67% of the variation in the area cultivated with maize can be explained by the average of the CHU over the past two years. Dairy farmers in Denmark have thus adapted quickly to the gradually warmer climate. This has not been a deliberate adaptation to climate change, and both farmers and advisors attribute the much of the change to other factors, such as improved varieties. Thus even undeliberate adaptation to climate change may be very effective. However, the lack of awareness of the role of climate change may mean that farmers would not be sufficiently prepared for the climatic variability that still exists, and which can result in yield failures in some years.

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