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Climate Change Impacts on Agricultural Productivity in Norway

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Sammendrag:
Produktiviteten i jordbruket vil venteleg bli påverka av ei klimaendring.
I denne studien brukar vi ein bio-fysisk statistisk modell for å analysere samanhengen mellom avlingar per dekar av poteter, bygg, havre, og kveite, og temperatur (vekstdøgn) og nedbør i perioden 1958 til 2001 på fylkesnivå i Noreg. Dersom vi kan påvise eit klimasignal på fylkesnivå burde det vere av interesse for planleggarar av klimapolitikk, jordbruks-styresmaktene, og bønder når dei skal førebu seg på ei varmare framtid. Vi finn at i 18% av tilfella (avlingstype og fylke) er det ein positiv effekt av auka temperatur på avlingane. Effekten er størst for poteter. Samanhengen er sterkast i Nord-Noreg, der temperaturen sannsynlegvis er ein viktigare skranke på avlingane enn i andre norske regionar. Effekten av større nedbør er negativ i 20% av tilfella, noko som kan komme av overskot av vatn i jordsmonnet eller redusert solinnstråling knytt til meir skydekke. Prediksjonar basert på RegClim scenariet for år 2040 indikerer at potetavlingane kan stige med rundt 30% i Nord-Noreg, noko som svarer til ein verdi på om lag 9 millionar kroner i året.

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Abstract

Climate change is likely to affect agricultural productivity. In this study, a biophysical statistical model is used to analyze the relationship between yields of potatoes, barley, oats and wheat per decare, and temperature (growing degree days) and precipitation, for the period 1958 - 2001 at county level in Norway. If a climate signal can be detected at county level this should be of interest for climate policy planners, agricultural authorities and farmers preparing for a warmer climate. We find that in 18 % of (the crop and county) cases there is a postive impact on yield from increased temperature. In the case of crops the effect is strongest for potatoes. Regionally, the correlations are strongest in Northern Norway, where temperature is likely to be more important as a limiting factor for crop growth than other regions of the country. The effect of increased precipitation is negative in 20 % of the cases, which could be due to excess soil moisture or reduced sun radiation associated with more cloud cover. Predictions based on the RegClim scenario for 2040 indicate that potato yields will increase by around 30 % in Northern Norway, which amounts to about 9 million NOK annually.

1 Introduction

Climate change may have significant impacts on society and ecosystems over the next decades. Since a substantial part of expected climate change is likely to be man-made, we are faced with a challenge to decide on emission mitigation policies at international, national and local level [6]. Furthermore, adaptation policies have the potential to lower the overall costs associated with climate change. Given the large number of uncertainties in future emissions, climate system responses, and potential impacts, policy design must be based on best available knowledge, and regularly updated when new results become available. For a number of years, impacts research has been hindered by a lack of climate

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change scenarios with resolution high enough to capture sub-national variations. Such scenarios are now available from downscaled results of Global Circulation Models (GCMs). In this study, we analyze the effects on agricultural productivity using a regional climate change scenario for Norway for the period 2030 to 2050 - RegClim.[1] Agriculture is one of the sectors that is most likely to be sensitive to the primary effects of climate change, such as changes in growing season, temperature, and precipitation. We seek to establish a statistical relationship between yield per decare for four crops, based on meteorological data from 1958 until 2001, through regression analysis at county level in Norway. In addition, we undertake analyses at the national level. The four crops we investigate are potatoes, wheat (spring and winter), oats, and barley. The meteorological data consist of growing degree days (GDD) and annual precipitation. In addition, a time trend is included to account for long-term technology and productivity changes in agriculture. It will in part account for the CO_2 fertilization response due to the steady rise in the CO_2 concentration level in the atmosphere. Assuming that there are no major changes in agricultural production technologies and practices during this period, we make a prediction of yields per decare for 2040 (as a representative year for the period 2030 - 2050) based on the RegClim scenario. Through this analysis we try to detect a climate signal in the annual weather variation and agricultural yield data at this relatively aggregated level (county) in Norway. If such a signal is found, the estimated impacts on agricultural production across regions and four major crops in Norway should be of interest for climate policy planners, agricultural authorities and farmers in preparing for warmer future.

The main methodological approaches studying impacts on agriculture from climate change are presented in a handbook by the UNEP and IVM [4]. There are two categories of tools, biophysical and economic. Biophysical tools can be divided into experimentation, agro-climatic indices, statistical models, process-based models, and spatial or temporal analogues. Economic tools can be divided into economic regression models, microeconomic models, and macroeconomic models.

In this study, we have chosen a biophysical statistical model, which links the primary climate change impacts on temperature and precipitation to changes in yield per unit of land. This choice gives priority to the secondary impacts of climate change. A weakness of this approach is its limited ability to predict the effect of future climate change that lies outside the climate variability of the last decades (upon which the estimates of the model parameters are based); another is that there is an implied assumption of fixed technology [4]. Furthermore, the method is founded on correlation analysis and not necessarily on causal mechanisms. There may be dependency between explaining variables (multicollinearity), and relationships between yield, precipitation and temperature may be non-linear. Moreover, the simple model we have chosen is not able to account for effects caused by variability in weather and extreme weather events on yields [7]. Since we are studying a smaller change in climate (as defined by

[1] See http://regclim.met.no.

the RegClim scenario), a linear model is probably an acceptable approximation even if the relationships are non-linear. In addition, data availability has put strong restrictions on which variables could be included in the analysis. One example of an important weather variable for plant growth that could not be included is sun radiation, which could be represented through a measure of cloud cover. Through the chosen approach we are able to link changes in climate variables at local level (weather stations) to secondary climate change impacts in terms of changes in agricultural productivity for some crops at county level in Norway. Some major benefits of the approach are simplicity, limited data requirements, and the ability to get some control over the significance of various explaining factors. The study is in line with the call of Zilberman et al. (2004) to analyze the impact of climate change on agriculture within a disaggregated modeling framework and a focus on empirical research [25]. The results should indicate if county level is a suitable aggregation level to disclose significant effects, or if this is a aggregation level that only produce moderate effects since more distinct local effects are averaged out [25].

A recent overview and assessment of climate change impacts in Europe, including agriculture, can be found in Parry (2000) [3]. NILF (1990) provides a comprehensive survey of climate change impacts for the agricultural sector in Norway [12]. Based on average yields in various climate zones, the climate change impact on agricultural productivity is analyzed through a shift in climate zones leading to increased yields for most crops.

An early application of a statistical model is Warrick (1984), who simulated wheat yields on the US Great Plains, assuming technology as in 1975 and climate conditions as under the 1936 drought [24]. Leemans and Soloman (1993) study the potential yield changes for spring and winter wheat and other major crops at a global scale under a warmed climate. Using a crop-prediction model with Geographic Information Systems (GIS), they report that high-latitude regions will be the beneficiaries of climate change, enjoying extended growing seasons and increased productivity [8]. Rötter and Van de Geijn (1999) provide a comprehensive review of climate change impacts on livestock and crops yields, including wheat, potatoes, barley and oats. They emphasise the importance of elevated CO_2 concentration and quantify potential yield responses to predicted rises. The authors give a detailed overview of the findings of studies concerned with crop growth, physiology and phenology [20]. Bootsma et al. (2001) use linear regression analysis to examine the relationship between barley yields (among others) and climate variables in Atlantic Canada. They conclude that climate change is unlikely to have a significant impact on barley yields, though a doubling of CO_2 could lead to a 10-15 % increase [1]. Nonhebel (1996) examines the effects of rising temperature and increases in CO_2 concentration on simulated wheat yields in Europe. She finds that higher temperatures cause faster crop growth, leading to a shorter growing period and a decline in yield. CO_2 has the opposite effect, with a doubling of atmospheric concentration leading to a 40 % rise in yields. Nonhebel also suggests that in general, changes in the availability of water can have a greater impact on yield than changes in temperature, but summarises that where precipitation patterns remain largely constant, negative effects of higher temperature are offset by positive effects of CO_2 enrichment [13]. Riha et al. (1996) and Mearns et al. (1996) stress the importance of taking variability in temperature and precipitation into account when making crop yield predictions; both studies demonstrate that increased inter-seasonal variability can reduce yields [10][18]. Ozkan and Akcaoz (2003) analyzed the impacts of annual and season variation of 27 climatic variables on the yield of wheat, maize and cotton in the Cukurova region of Turkey based on data from 1975 to 1999 [14]. They found that the most significant climatic factors for wheat yields were maximum temperature during planting time and maximum rainfall during flowering time. The wheat model could explain 46 % of the variation of yield.

Parry and Carter (1989) provide an overview of higher-order impacts of climate change on agriculture following first-order impacts. They report the results of impact and adjustment experiments conducted in five case studies (Iceland, Finland, Japan, Saskatchewan in Canada, and northern parts of the former USSR), employing farm simulations and input-output models. They discuss the consequences of biophysical effects for farm income and profitability, food production, regional production costs and the wider economy. They then go on to consider potential managerial, technological and policy responses to these possible outcomes [16]. Mendelsohn et al. (1994) use Ricardian analysis to examine the impact of global warming on agriculture in the USA. They report negative climate impacts using a 'farm land' model, but a positive outcome using a 'crop revenue' approach. Their findings highlight the importance of taking adaptation factors into account when evaluating climate effects [11].

The following section introduces the statistical model, while Section 3 goes on to give details of how data were collected and prepared for the analysis. In Section 4 results are discussed. Section 5 considers further analysis, before ending with conclusions in Section 6. Data tables can be found in Annex 1, detailed results from the analysis in Annex 2 and 3, and finally a description of model variants in Annex 4.

2 Description of the model

A statistical model relating yield per decare to meteorological data is employed. The relationship between yield per decare, Y, and temperature, T, precipitation, P, and a time trend, τ, is assumed to be linear. Temperature is measured in growing degree days (GDD). The equation is

$$Y_{ijt} = \alpha_{ij} + \beta_{ij} T_{ijt} + \gamma_{ij} P_{ijt} + \theta\tau + \omega_{ijt}$$

where i is the index for crop, i is $potatoes, wheat, oats$,and $barley$, j is the county index, and t is the time index denoting annual observations from 1958 until 2001. ω_{ijt} is the error term.[2] GDD is defined as the annual sum of degrees accumulated above a 5°C threshold. Through an ordinary least squares (OLS) regression we seek to correlate variations from year to year, in yield per decare, to the variability in growing degree days (GDD) and precipitation. The estimated parameters are $\widehat{\alpha}, \widehat{\beta}, \widehat{\gamma}, \widehat{\theta}$, where the indices are left out for simplicity.

We were unable to take explicit account of a number of non-climate factors. However, a time trend variable was included in the regression runs to account for general long-term time trends which may have been influenced by a number of other factors. Examples of such influences are technological change and innovations (e.g. improvements in agricultural inputs and/or practices, and/or changes in production patterns), increased productivity due to other climate variables, and a fertilizer effect from increased CO_2 concentration in the atmosphere. As an alternative to the time trend we included CO_2 concentration in some of the regressions (see Annex 4 for a closer description of this model variant). Sunlight is another important weather variable for crop yields since it provides energy for photosynthesis. However, as meteorological stations were unable to provide relevant proxy data (i.e. cloud cover observations) for the complete period of our study, we were not able to include this variable in the analyses.

We carried out regressions at the national level by merging county data into two different variants of the model. In the first, we allowed different constant terms for each county, whereas we assumed that the marginal effect of changes in weather data was the same for all counties. This model variant implies that there are differences in the yield level across counties, but no differences in the marginal yield of changes in the weather (i.e. GDD and precipitation). This is modelled through an additive dummy variable for each county with the exception of Akershus/Oslo, which is taken as the reference county. In the second model variant, different constant terms are retained, but in addition we allow for a shift in the marginal effect (slope) of annual precipitation by adding a multiplicative dummy variable to the precipitation variable for each county. The latter model variant implies that there are systematic differences between counties with respect to the level of yield per decare for a crop, as well as with respect to the marginal effect on yield of changes in precipitation, but no differences in the marginal effect of changes in GDD. The different treatment of GDD and precipitation is based on regression results at county level, that indicated there is a larger variance in the marginal effect of precipitation across counties than in temperature (GDD) (see Section 4).

[2] We assume that the error variances are constant and that the errors are not autocorrelated. Given that these assumptions are fulfilled, the ordinary least squares estimators are the best linear unbiased estimators. Checking the Durbin Watson statistic for some country cases revealed no indications of autocorrelation problems.

2.1 Variants of the model

The main model contains GDD, annual precipitation, and a time trend as independent variables, and was employed on each crop at county level and at national level. However, a number of model variants were tested on the crop yield and weather data before ending up with this model. The chosen model produced more significant coefficients and a better fit to the data than the alternatives. The model variants included growing season precipitation, carbon dioxide concentration (in different data formats), frost events in the spring (in different data formats), fertilizer use for the latter part of the estimation period, and logarithmic or quadratic weather variables.[3] See Annex 4 for a more detalied account of the model variants that were tested.

2.2 Yield predictions for the RegClim scenario

The equation for predicting yield per decare for crop i in county j under the RegClim climate change scenario, $\widehat{Y}_{ijR}$, is

$$\widehat{Y}_{ijR} = \widehat{\alpha}_{ij} + \widehat{\beta}_{ij}\widehat{T}_{jR} + \widehat{\gamma}_{ij}\widehat{P}_{jR} + \widehat{\theta}\tau_R$$

where $\widehat{T}_{jR}$ is GDD and $\widehat{P}_{jR}$ is precipitation in the RegClim scenario in county j, and τ_R is the time trend in 2040 (representing the RegClim period 2030-2050). R is the index for the RegClim scenario.

3 Data

The dependent variable is yield per decare for each of the crops potatoes, barley, oats and wheat. The independent variables are the weather data GDD and annual precipitation, in addition to the time trend.

3.1 Time periods

For each crop and county analyses were undertaken for the main period 1958-2001, given that the required data was available. In the absence of sufficiently comprehensive data at county level to enable the incorporation in the model of a variable for technological change, national fertiliser use figures were examined for clues as to what sort of impact one might expect farming practices to have

[3] Thompson (1962) advocates the use of quadratic terms for weather variables [22]. Parry and Carter (1989) also find changes in climate to have non-linear effects [16].

had on crop yields from the 1950s until today.[4] It appeared that the 44-year period of our study could be split into three 'phases' with respect to fertiliser consumption (in terms of the total value of all varieties sold). The first phase, from 1958-1973, saw a slow, steadily increase in the amount of fertiliser bought, the second, from 1974-88, demonstrated a continuous, sharp rise in sales, while the third phase, 1989-2001, was less clearly defined, but illustrated an overall declining trend. In light of this information, separate regressions were conducted for each of these three time periods. If yields were found to have responded differently during the three phases, this might be detected when we compared each sub-set of the analysis.

3.2 Crop data

Annual yield data was supplied by Statistics Norway and collected at county level for each of the four crops in this study [21].[5][6] In Norway there are 19 counties. However, since yield data for Akershus and Oslo are reported together there are 18 geographical units in this study. Annual yield was calculated by dividing the total production of each crop per county by the agricultural area employed in the cultivation of that crop (in that county), and was measured in kilograms per decare.

A complete set of crop data for the years 1958 - 2001 for each county was not available, most notably in northern and western regions. In such cases, one of three approaches was taken: where a single value was missing from a time series, it was interpolated by calculating the average of the recordings directly preceding and following it; where more than one consecutive figure for a crop was unavailable, the missing years were removed from our analysis and the data series was broken up into two shorter time periods; and finally, where there were more than two consecutive breaks in the data, the entire crop for that county was omitted from the analysis.

[4] Budsjettnemnda for jordbruket, NILF (Norwegian Agricultural Economics Research Institute), 2002.

[5] Approximately 70 per cent of wheat grown in Norway is sown in the spring and the remainder is planted in the autumn. Annual and regional variations are largely determined by weather conditions, though a general rule, winter wheat production is confined to the counties of South-Eastern Norway (Østfold, Vestfold and Akershus), where the climate is milder and thus more suitable for crops with a high sensitivity to low temperatures.

[6] In the period 1957 - 1983 the area data was based on annual sample surveys, except in 1959, 1969 and 1979, when a full censuses were carried out. Since 1984, administrative sources have been used, that is, applications for governmental production subsidies, except 1989, when a full census was carried out. In terms of production and yield, up until the mid-1970s, the best judgement by officials in agricultural administration at municipality level has been used. From the mid-1970s until 1989, the source has been annual sample surveys. Since 1990, cereals production has been based on an administrative source, i.e. deliveries reported to the Norwegian Grain/Norwegian Agricultural Authority. Potato production is still based on annual sample surveys.

3.3 Weather data

The analysis required data on two climate variables important for crop growth, namely temperature and precipitation, at county level in Norway. The data was obtained from the Norwegian Meteorological Institute as retrospectively as records permitted, allowing our period of study to extend from 2001 as far back as 1958.

The chosen parameter for temperature was growing degree days (GDD), which is the annual sum of degrees accumulated above a 5°C threshold. It was calculated by aggregating the number of degrees that the daily mean temperature fell above 5°C [23].[7] This is a useful temperature parameter as it gives an indication of the quality of the growing season over a defined period ([23], p. 17).[8][9] Given that the Norwegian climate restricts the growing season for most crops from April to September, it was decided to exclude recorded GDD from months outside this period.[10]

Annual precipitation, measured in millimetres, is the second weather variable. Precipitation accumulated outside the growing season was included for two reasons. Firstly, it is likely that a significant part of the precipitation falling outside this period would be retained as moisture in the soil, and thereby eventually affecting crop growth when the growing season begins. Secondly, as a large proportion of precipitation commonly falls in the form of snow during the Norwegian winter, when the onset of spring causes it to melt, a large share of it is likely to serve as a water supply, potentially feeding both soil and crops, before and during the growing season. As temperature increases some of the effect of increased precipitation will disappear due to increased evaporation([15]).

As the Norwegian Meteorological Institute (DNMI) collects data from weather stations that are located on the basis of meteorological interest rather than along county boundary lines, it was necessary to make some decisions regarding which stations to use and how to aggregate station data to the county level. This process was made more precise with the use of GIS mapping. A digital land use map of Norway, identifying areas of agricultural activity, was obtained from the Norwegian Institute of Land and Forest Mapping (NIJOS), and geographical coordinates of weather station locations were provided by DNMI

[7] To give a simple example, if a month contained just two days where the average temperature rose above 5°C, and the average temperature was 7°C on the first day and 9°C on the second, then GDD for that month would be 6°C (i.e. 2°C + 4°C).

[8] See http://www.smhi.se/hfa_coord/nordklim/report06_2001.pdf.

[9] An alternative temperature parameter is Effective Growing Degree Days (EGDD), employed by Bootsma et al. (2001). The authors justify their use of over Growing Degree Days (GDD), explaining that GDD, 'are designed to represent the growth period for perennial forage crops, while EGDD are specifically designed to be more applicable to the growth period for spring-seeded small grains cereals'. EGDD is defined as the sum of GDD from ten days after the start of the growing season until the day preceding the average date of the first frost. They find a negative correlation between yield and EGDD, and suggest that this might be due to a higher development rate of crops under warmer temperatures.

[10] In Norway, the length of the growing season is defined as the annual sum of days in which the mean temperature exceeds 5°C. The growing season can also be understood as the actual time period (e.g. April - September).

[2]. With the use of GIS software, these two maps were overlaid, allowing stations in closest proximity to the main area(s) of agricultural activity in each county to be identified and selected. This choice was heavily constrained by the availability of continuous time series data over our period of study (due to some stations being built after 1958, some being taken out of service for some years, and others being closed down), and by the fact that not all weather stations had the facilities to collect both precipitation and temperature data. In some cases, output from more than one station was averaged to produce the final data set for a county, for example, where it spanned a broad geographic area and no single weather station was thought to be solely representative. In other cases, data from neighbouring counties were also incorporated, based on the assumption that they contributed relevant information about the weather conditions, which stations situated in the county may not have captured due to their location. Where data was simply unavailable and there were no suitably placed stations in neighbouring counties to provide proxy data, the time period in question was omitted from our analysis for that county.[11] Finally, on three occasions, individual observations were interpolated.[12] In these instances, only one month's data was missing from an otherwise complete series.

3.4 Analysis at the national level

In order to conduct regression analyses at the national level, it was necessary to produce aggregate weather and crop figures based on the county data used in previous analyses. Production of each crop per county was calculated as a proportion of total national output (for that crop), and then weather data was weighted accordingly. This gave weather data in counties producing a larger share of the national yield (such as in South-Eastern Norway) a higher weight than in those counties where production of that crop was lower. Where data was omitted from analysis at county level, it was, by necessity, also excluded at the national level.

3.5 The RegClim scenario

Projected future values for GDD and annual precipitation were obtained from the RegClim Project - a regional climate scenario for Northern Europe over the next fifty years [17]. Regional Climate Development Under Global Warming Project (RegClim) uses an "Atmospheric Regional Climate Model to estimate the regional climate in Northern Europe and adjacent sea areas, given the best estimates of climate scenarios from a coupled Atmospheric-Oceanic GCM" (RegClim Website, 2002).[13] RegClim predictions consist of a single, average figure for each weather variable for the twenty-year period from 2030 to 2050. The

[11] I.e. Telemark 1990-2001 and Hedmark 1999-2001.
[12] I.e. Telemark: precipitation, August 1989; Hedmark: GDD, August 1987 and May 1989.
[13] For further details of the RegClim Project, visit: http://regclim.met.no.

RegClim scenario only presents one climate change outcome for Northern Europe, whereas other outcomes can be just as likely given a large number of uncertainties involved in such climate scenario estimates.

3.6 Predicting future yields

The crop and county cases where the model was able to explain a sizeable proportion of the annual yield variation through changes in annual precipitation and/or GDD during the growing season, and yielding significant coefficients, were selected for the RegClim projections (see Table 1). RegClim data, which forecasts the average percentage change in climate variables between two time periods, 1980-2000 and 2030-2050, were then used as the basis for future predictions. We take 2040 as a representative mid-year for the RegClim period.

Before any calculations could take place, however, it was necessary to adjust both model and RegClim weather data to improve their compatibility. As RegClim figures were only available for individual 50 km^2 grid cells throughout Norway, data were first of all aggregated up to county level. Furthermore, to bring figures in line with model data, predicted weather values were calculated to correspond to regions of agricultural activity, rather than to the county as a whole. Then, using RegClim data, average figures for the relative, forecast percentage change in GDD and annual precipitation between 1980-2000 and 2030-2050 were calculated for almost every county (with the exception of Vestfold). The next step was to find model estimates of the yield for all relevant crops and counties based on average GDD and precipitation for the period 1980-2000. In some cases, our interest extended to all four crops in a particular county, while in others, it was restricted to just one or two. Similarly, in some counties, the model referred to the entire time period of the study, in others it was limited to one or two sub-periods. Next, the average GDD and precipitation for each county was multiplied by the percentage change given by the RegClim scenario. Finally, RegClim GDD and precipitation values were entered into the model to give yield predictions for the selected crops and counties. The effects of changes in GDD and precipitation were calculated separately to measure the independent impact of each variable on agricultural production, and were expressed as a percentage change in estimated average yield in the period 1980-2000.

4 Discussion of results

4.1 General findings

The regression results show that there is a positive effect of increased GDD (temperature) on yield per decare only for some crops, counties, and time periods, confer Table 1 (see Annex 2 for a detailed account of results). Overall about 18 % of the 236 cases have a significant and positive GDD coefficient. For 3 % of the cases the GDD coefficient is negative and significant. In the case of crops there are most significant results for potatoes. In terms of regions, the most significant results are found for Northern, mid-, Western, and Southern Norway. Sunlight and high temperatures are more likely to be a limiting factor in northern and western counties than in the south and east. Coefficients for potatoes are between 1.0 and 3.0, with the highest values evident in Northern Norway. This means that an increase of one GDD unit induces a yield increase of 1-3 kg per decare.[14] In addition, there are postive coefficients for barley in seven counties situated in Western and mid Norway, and in Nordland. The coefficients are between 0.13 and 0.27. There are also a few significant coefficients for oats ranging from 0.16 to 0.31. These results are consistent with the findings of Leemans and Soloman (1993) since high-latitude regions are the primary beneficiaries of a warmer climate [8]. They also reinforce the hypothesis that temperature is a more important limiting factor for crop growth in Northern and Western Norway than in other regions of the country such as Southern and Eastern Norway, where the weather conditions provide higher temperatures during the growth season.

The effect of increased annual precipitation on yield is negative and significant for many counties and crops, in particular, for Western and mid Norway, and for Nordland (20 % of all cases). On the other hand 5 % of the cases give a postive and significant precipitation coefficient. Another study that finds a negative impact from increased precipitation on agricultural production is Rosenzweig et al. (2002), where a dynamic crop model is modified to simulate effects of heavy precipitation and excess soil moisture on corn production in the US Corn Belt [19]. The few positive coefficients are found in Eastern Norway. The coefficients range from -2.5 to 1.9 for potatoes, whereas the coefficients for the cereals range between -0.34 and 0.63 (see Table 1, and Annex 2 for details). There are two possible explanations for the interesting finding that coefficients have, in some instances, been negative. The first is that precipitation may become so abundant that it leads to excess soil moisture. The second could be a result of the positive correlation between increased precipitation and cloud cover. Thus increased precipitation means reduced radiation from the sun, leading to reduced photosynthesis, and thereby reduced yield. Both explanations go some way towards explaining the negative correlations between precipitation and yield evident in Western, mid-, and parts of Northern Norway.

The time trend is positive in most significant cases (overall 37 % of instances), with the exception of potatoes in Northern Norway (and Sør-Trøndelag), where it is negative (which is equivalent to 4 % of the cases). The positive trend can be attributed to long-term productivity gains in agriculture, that can include stuctural changes (fewer and larger farms), better crop varieties, improved farming techiques and equipment, and more efficient fertilizer use. On the other hand, the negative time trend may reflect structural changes in agriculture that affect productivity negatively; these could be related to government policies.

[14] GDD increases by one unit if the average temperature on a particular day in the growing season increases by 1°C from a minium base of 5°C.

County/Crop			Constant		Growing degree days		Precipitation		Time Trend	
	Observations	R^2	Coefficients	t-stat	Coefficients	t-stat	Coefficients	t-stat	Coefficients	t-stat
Østfold										
Barley	43	0.46	**506.602**	4.61	-0.122	-1.71	**-0.098**	-1.83	**3.704**	5.57
Akershus & Oslo										
Potato	44	0.43	712.304	1.05	0.330	0.74	**0.952**	2.53	**18.302**	4.72
Hedmark										
Barley P3	10	0.50	12.602	0.05	0.137	1.06	**0.478**	2.32	-2.485	-0.72
Oats P3	10	0.46	-203.027	-0.53	0.288	1.59	**0.632**	2.18	-4.756	-0.97
Potato P3	10	0.41	-184.553	-0.10	**1.774**	1.97	2.121	1.47	-18.381	-0.76
Oppland										
Potato	42	0.24	839.194	1.23	0.530	1.09	**1.237**	2.49	**8.098**	1.95
Buskerud										
Potato P2	15	0.66	1790.157	1.61	-1.046	-1.57	**1.879**	2.53	14.205	0.62
Potato P3	13	0.55	**3452.009**	2.49	0.346	0.38	**-1.775**	-2.73	-1.969	-0.08
Telemark										
Wheat P1	16	0.74	-174.219	-1.46	**0.264**	3.35	0.021	0.28	**7.376**	4.13
Barley P1	16	0.69	-111.873	-0.81	**0.229**	2.52	0.037	0.43	**8.293**	4.01
Oats P1	16	0.87	-110.622	-1.22	**0.186**	3.13	0.081	1.45	**10.548**	7.78
Potato P1	16	0.40	-105.132	-0.12	**1.120**	1.88	0.780	1.40	**27.838**	2.06
Aust-Agder										
Potato P1	16	0.45	-154.192	-0.16	0.936	1.44	**0.647**	1.99	**41.801**	2.74
Potato P3	13	0.35	-967.087	-0.49	**2.394**	1.84	-0.560	-1.31	6.071	0.20
Vest-Agder										
Barley P1	16	0.49	48.918	0.45	**0.156**	1.98	-0.021	-0.55	**3.491**	2.35
Potato P1	16	0.42	-694.517	-0.62	**1.976**	2.45	0.119	0.30	25.334	1.67
Barley P2	15	0.30	291.789	0.90	0.140	0.63	**-0.318**	-1.99	8.585	1.49
Rogaland										
Wheat1*	14	0.82	**348.063**	3.67	0.073	1.10	**-0.137**	-4.75	**6.102**	3.97
Wheat2*	21	0.34	**490.947**	2.47	0.102	0.70	**-0.246**	-2.99	1.662	0.64
Oats	44	0.34	**384.630**	3.27	0.134	1.52	**-0.193**	-4.06	**1.580**	2.19
Potato	44	0.29	**1880.336**	2.85	**1.233**	2.51	**-0.804**	-3.01	5.526	1.36
Barley P1	16	0.68	**323.103**	2.07	0.135	1.24	**-0.171**	-3.67	**4.200**	2.07
Barley P2	15	0.70	154.652	0.82	**0.258**	2.29	**-0.285**	-4.10	**10.212**	3.28
Barley P3	13	0.62	**524.713**	3.31	0.132	0.81	**-0.265**	-3.28	0.222	0.07
Hordaland										
Potato	44	0.22	**2378.405**	3.06	0.378	0.58	**-0.343**	-2.08	-7.526	-1.46
Barley P1	16	0.68	156.510	1.25	**0.174**	1.91	**-0.072**	-3.06	**6.706**	3.82
Oats P1	16	0.57	175.261	1.02	0.139	1.10	**-0.069**	-2.13	**9.038**	3.72
Barley P2	15	0.53	71.068	0.20	0.192	0.73	**-0.163**	-2.52	**15.328**	2.98
Sogn and Fjordane										
Potato	44	0.23	**1526.346**	2.18	**1.048**	1.84	**-0.236**	-1.81	-7.238	-1.56
Barley P1	16	0.66	-24.730	-0.18	**0.243**	2.49	-0.014	-0.59	**6.709**	3.63
Møre & Romsdal										
Potato	43	0.29	1126.926	1.66	**1.612**	2.66	**-0.563**	-2.47	7.984	1.73
Sør-Trøndelag										
Barley	44	0.41	**163.147**	2.04	**0.144**	2.19	**-0.081**	-2.20	**2.048**	4.13
Oats	44	0.29	**182.735**	1.88	**0.157**	1.96	**-0.099**	-2.19	**1.592**	2.63
Potato	44	0.45	**1394.896**	2.46	**1.605**	3.44	**-0.783**	-2.98	**-10.047**	-2.84
Nord-Trøndelag										
Barley	44	0.38	**173.116**	2.59	**0.125**	2.34	**-0.073**	-2.21	**1.384**	3.20
Potato	44	0.42	**1579.955**	3.35	1.269	3.38	**-0.732**	-3.13	5.212	1.71
Oats P1	16	0.40	**390.134**	2.20	-0.011	-0.08	**-0.200**	-2.44	5.150	1.77
Wheat P3	13	0.47	-107.354	-0.47	0.033	0.22	**0.292**	2.69	4.320	1.21
Nordland										
Barley	37	0.55	93.765	1.10	**0.239**	3.55	**-0.083**	-3.23	0.245	0.31
Oats	26	0.49	101.807	0.77	**0.233**	2.30	**-0.089**	-2.15	1.607	1.09
Potato	44	0.64	578.412	1.45	**2.051**	5.98	**-0.442**	-3.45	**-9.656**	-3.18
Troms										
Potato	44	0.51	157.064	0.35	**2.290**	5.36	0.054	0.21	**-14.297**	-3.67
Finnmark										
Potato	44	0.64	253.329	0.61	**2.678**	7.24	-0.982	-1.37	**-14.616**	-4.20
Potato P1	16	0.66	-560.858	-0.53	**3.005**	4.61	0.041	0.02	3.459	0.17
Potato P2	15	0.74	**1884.200**	2.17	**2.271**	3.45	**-2.474**	-2.07	**-46.213**	-2.89
Potato P3	13	0.44	558.698	0.93	**1.516**	2.08	0.480	0.65	-18.200	-1.45

KEY:

P1: 1958-1973
P2: 1974-1988
P3: 1989-2001

*Wheat1: 1958-71
*Wheat2: 1974-1994

Data in bold: t-stat >= 1.8

Table 1: Summary of regression results at the county level

The national level analyses only provided significant results for potatoes and barley in the model variant allowing for different constant terms (but with the same marginal effect of GDD and precipitation, see Table 2). For potatoes the sign of coefficients is the same as in county level analyses, though the size of coefficients is smaller. Instead, the model provides for different constant yields across counties (i.e. the yield component that is not influenced by GDD, precipitation, or time), where the highest significant yield is found in Rogaland (1871 kg), and the lowest in Finnmark (904 kg). For barley, the GDD effect is not significant. Instead the significant constant terms vary between 378 kg in Sogn og Fjordane, and 229 kg in Nordland.[15] The precipitation coefficient is close to zero, but negative and significant.

	Potato		**Barley**	
	Coefficient	**t-stat**	**Coefficient**	**t-stat**
National - GDD	0.864	6.89	0.002	0.11
National - Precipitation	-0.316	-5.19	-0.062	-6.53
National - Time Trend	0.304	0.28	2.673	15.13
Constant term				
Akershus and Oslo	1450.814	8.10	308.209	10.64
Østfold	1408.290	-0.55	334.091	2.24
Hedmark	1569.159	1.45	315.359	0.59
Oppland	1634.395	2.24	298.217	-0.82
Buskerud	1330.441	-1.55	301.974	-0.54
Vestfold	1621.466	2.19	347.441	3.38
Telemark	1179.064	-3.23	295.154	-1.04
Aust-Agder	1242.762	-2.53	301.376	-0.56
Vest-Agder	1300.017	-1.86	288.074	-1.67
Rogaland	1870.702	5.24	366.499	4.88
Hordaland	1626.031	1.68	364.073	3.40
Sogn and Fjordane	1717.985	2.65	377.930	4.38
Møre and Romsdal	1702.704	2.80	273.754	-2.53
Sør-Trøndelag	1491.112	0.48	276.644	-2.51
Nord-Trøndelag	1764.810	3.88	268.485	-3.28
Nordland	1238.523	-2.24	229.810	-5.27
Troms	1203.093	-2.33	N/A	N/A
Finnmark	904.066	-4.89	N/A	N/A

Potato: 733 observations ($R^2 = 0.50$)

Barley: 660 observations ($R^2 = 0.48$)

Table 2: Regression results at the national level

4.2 Predictions

Using the model to give predictions for the RegClim climate change scenario in 2040, we find that the positive contribution from increased GDD in most of the significant cases (shown in Table 1) dominates the negative contribution

[15] There is no barley yield in Finnmark and there are too few observations in Troms to include in the analysis.

from increased precipitation. The predictions for potatoes are shown in Table 3 (details for all crops are found in Annex 3). Only robust predictions are presenteed, which we calculated to +/- 20 % (at 95 % interval levels). In these cases, the predicted yield is higher than in the reference situation, which is based on the model's estimated yield for average GDD and average annual precipitation in the period 1980-2000. However, in many cases the yield increase is small, and in some cases yield is reduced. The largest effect is found in Northern Norway, where the predicted yield increase for potatoes is between 30 and 35 %. Other cases where the yield increase is more than 20 % is potatoes in Aust-Agder (1989-2001), potatoes in Vest-Agder (1958-73), and barley in Sogn og Fjordane (1958-1973). In the remaining cases the change is less than 20 % and not considered robust. The relative large prediction intervals reflect that the model can only explain part of the year-to-year variation in yield per decare.

In the final column of Table 3, we give estimates of the changes in the value of potato production resulting from climate change in each of the five counties where results proved to be reliable. These figures are calculated based on the assumption that all factors, other than temperature and precipitation, remain constant from now until 2040; for example, we assume that the same proportion of land is employed in potato production in the future as today. The change represents the difference between the value of production in 1980-2000 (taken as a single average figure), and the value of production in 2040, that is, if our model predictions do in fact materialise. Future values are based on current prices. Climate change appears to be most beneficial in Nordland, where yield increases may increase the crop value by almost 6 million NOK, and least advantageous in Finnmark, where the equivalent figure is around 0.3 million NOK. The latter may seem surprising given that our model predicts that climate change will have the greatest positive impact on yields in this northernmost county of Norway, but when you consider that potato farming is small-scale in the county due to its climate constraints, this finding seems plausible. If adaptation is taken into account, however, it may well be the case that this figure turns out to be an underestimate, as farmers may chose to dedicate more resources to potato cultivation as climate change improves productivity.

County	Period	Estimated yield from model	Predicted % change in yield under RegClim scenario: GDD	Precipitation	Predicted % change in yield: Net effect	Estimated increase in yield value (million NOK)*
Aust-Agder	P3	2 830	26 %		26 %	3.7
Vest-Agder	P1	2 375	24 %		24 %	2.1
Nordland	All	2 165	32 %	-2 %	30 %	5.9
Troms	All	1 987	33 %		33 %	3.2
Finnmark	All	2 285	35 %		35 %	0.3

*Based on 1998 prices

Table 3: Yield predictions for potatoes in the RegClim scenario

5 Further analysis

The estimated (significant) GDD and precipitation coefficients could be used as inputs to estimation of climate change damage functions for the agricultural sector in a cost-benefit economic modelling framework. In terms of expanding the model, important crop yield variables like sunlight (e.g. using cloud cover as a proxy), fertilizer use, and soil quality could be included. Due to limited data availability, such factors could not be incorporated in this study. Where such data did exist, it was either restricted geographically (e.g. only collected at local sites or at national level) or temporally (only available for limited time periods). Furthermore, the chosen statistical model limited the type of data that could be incorporated. An alternative could be using a crop model, where a more extensive set of relevant plant growth variables could be introduced. However, this approach, together with limited data availability, would limit the representativeness of the results, and lead to difficulties when trying to aggregate findings to the county level. On the other hand, one could choose an economic model that is representative for larger regions, but that would limit the the model's ability to account for weather variables that are decisive for yield per decare, see for example, Gaasland (2003) [5]. The model approach employed in the study could be transferred to other weather dependent production activities in the primary sectors, for example other crops, and in forestry. And the same modelling could be used for similar studies in other Scandinavian countries.

6 Conclusions

This study shows that climate change is likely to affect agriculture in Norway. The effect on yield per decare varied with geography and crop. There was a positive yield response to temperature increases in most parts of Norway, with the exception of Eastern Norway. Furthermore, there were indications of a North-South gradient, in the sense that the climate change effects grew stronger as we moved from south to north. This finding suggests that growing season temperature was more important as a growth limiting factor in colder regions (i.e. Northern and Western Norway) than in warmer regions. In terms of crops, the strongest effect was evident for potatoes. Barley yields, and in particular oats and wheat, were less responsive to changes in temperature. There was a negative yield response to increased precipitation in many parts of Norway, particularly in the west, and in Trøndelag and Nordland. This negative yield effect could be caused by excess soil moisture, which can be harmful to plant growth, or be related to reduced incoming sunlight due to the link between increased precipitation and cloud cover. Western Norway has the highest precipitation rate in the country. Therefore additional precipitation may do crops more harm than good. This negative effect is most pronounced for barley, sometimes apparent for potatoes, but occurs more rarely for oats and wheat. On the other hand, there have been instances where increased precipitation has had a positive effect on productivity, though this has been restricted to potato crops. Indeed, building on the RegClim scenario for 2040, there were robust predictions for increased potato yields in Northern Norway by around 30%, which is equivalent to about 9 million NOK annually, and for some sub-periods in Aust-Agder and Vest-Agder by around 25 %, which is equivalent to about 6 million NOK annually. Through adaptation the negative effects of climate change could be reduced and the postive effects enhanced. Examples of potential adaptive measures include the introduction of new crops and crop variants, earlier sowing, ditching to drain more water from the soil, and the ultilisation of land that has previously been considered too marginal for agricultural cultivation.

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Annex 1: Crop and weather data

	Østfold						Akershus and Oslo					
	Yield in kilograms per decare*				Weather data**		Yield in kilograms per decare*				Weather data**	
	Wheat	**Barley**	**Oats**	**Potato**	**GS-GDD**	**Ann-Pre**	**Wheat**	**Barley**	**Oats**	**Potato**	**GS-GDD**	**Ann-Pre**
1958	213	249	237	2 289	1290	757.1	196	219	224	2 128	1215	749.1
1959	182	168	137	1 258	1558	789.2	187	146	141	1 488	1485	870.2
1960	228	302	276	2 288	1358	1021.2	236	270	260	2 079	1285	1018.9
1961	278	294	284	2 490	1366	809.4	278	292	284	2 427	1302	860.6
1962	198	216	194	1 500	1087	1009.4	172	203	186	1 494	996	922.7
1963	244	259	251	2 166	1330	829.6	221	242	244	2 071	1269	868.9
1964	264	277	235	2 165	1217	800.8	251	259	237	1 983	1153	816.5
1965	226	237	243	1 737	1199	907.1	209	213	211	1 837	1111	965.8
1966	264	245	243	2 533	1333	967.6	192	208	203	2 460	1250	999.8
1967	345	296	285	2 443	1309	1106.3	304	262	270	2 296	1236	1013.2
1968	373	364	339	2 620	1386	752.0	335	354	343	2 441	1341	757.4
1969	310	281	264	2 266	1393	674.1	287	254	241	2 028	1440	694.4
1970	306	315	348	2 856	1277	766.7	273	318	334	2 481	1298	850.2
1971	391	375	396	2 797	1258	577.4	369	337	322	2 453	1225	704.6
1972	354	283	330	1 947	1302	905.4	314	251	307	1 972	1227	706.5
1973	411	348	373	2 592	1329	662.6	365	340	347	2 268	1255	630.6
1974	462	429	438	2 934	1378	900.6	346	402	394	2 868	1275	880.4
1975	339	287	293	1 943	1513	623.2	286	226	209	1 612	1418	697.3
1976	325	291	275	1 550	1401	665.3	305	260	240	1 239	1369	597.9
1977	367	395	379	2 408	1309	807.2	369	389	385	2 294	1188	746.2
1978	381	430	429	2 795	1237	651.5	324	370	358	2 371	1164	672.8
1979	397	361	425	2 314	1184	875.8	366	359	386	1 968	1095	837.4
1980	399	396	413	2 308	1465	797.0	388	326	367	2 441	1324	757.2
1981	442	359	413	2 283	1347	807.5	434	336	384	2 200	1285	699.8
1982	442	387	390	2 013	1406	937.8	453	377	363	2 299	1324	852.8
1983	437	354	391	2 046	1424	704.9	388	309	319	2 172	1352	704.4
1984	504	433	517	2 745	1353	866.0	494	400	467	2 607	1318	842.3
1985	418	413	404	2 427	1150	874.8	404	370	386	2 407	1177	948.2
1986	402	325	329	2 357	1100	839.1	356	278	264	2 345	1188	724.7
1987	415	413	435	2 159	1006	981.4	417	373	380	2 121	1059	936.1
1988	328	337	320	2 363	1376	1177.2	312	293	276	2 650	1422	1084.2
1989	381	381	318	2 292	1308	727.9	349	358	317	2 360	1322	783.1
1990	440	463	469	2 430	1387	903.6	455	462	475	2 455	1367	777.0
1991	463	431	451	2 312	1326	704.4	446	413	429	2 383	1255	694.4
1992	389	266	246	2 455	1450	772.5	327	250	237	2 618	1390	786.0
1993	553	430	422	2 423	1186	825.1	514	371	329	2 611	1147	823.5
1994	290	294	267	1 774	1400	847.5	202	282	226	1 910	1368	740.7
1995	513	369	425	2 161	1382	792.2	481	343	372	2 383	1308	701.8
1996	480	451	444	2 231	1268	673.4	439	423	391	2 364	1229	702.2
1997	446	396	395	2 687	1587	677.6	376	381	360	2 875	1556	642.2
1998	477	368	421	2 791	1280	795.7	487	378	419	3 155	1233	819.8
1999	418	325	381	2 483	1436	1173.1	444	348	408	2 937	1401	983.9
2000	462	363	442	2 101	1356	1311.9	477	364	438	3 070	1321	1204.5
2001	*385*	*384*	*432*	*2 181*	*1395*		358	364	388	2 823	1344	846.9

*Sources: *Statistics Norway; ** Norwegian Meteorological Institutue*
Data in italics = incomplete data, excluded from analysis

	Hedmark						Oppland					
	Yield in kilograms per decare*				Weather data**		Yield in kilograms per decare*				Weather data**	
	Wheat	**Barley**	**Oats**	**Potato**	**GS-GDD**	**Ann-Pre**	**Wheat**	**Barley**	**Oats**	**Potato**	**GS-GDD**	**Ann-Pre**
1958	243	233	232	2 315	1070	544.6	238	248	241	2 532	1041	572.0
1959	221	224	205	1 505	1307	553.8	250	218	197	1 741	1296	586.3
1960	273	277	272	2 300	1142	769.6	267	269	259	2 457	1107	788.4
1961	301	293	282	2 563	1129	720.2	273	283	271	2 784	1098	799.7
1962	201	184	187	1 300	833	659.8	198	177	167	1 698	817	657.5
1963	261	268	271	2 254	1153	645.9	279	261	255	2 490	1131	696.9
1964	287	261	228	1 859	1004	639.3	346	255	269	1 727	978	694.2
1965	318	269	253	2 162	977	653.1	333	275	277	2 376	948	676.2
1966	260	212	206	2 480	1116	729.1	289	244	183	2 655	1108	765.7
1967	335	283	297	2 147	1084	700.0	353	295	291	2 233	1054	738.0
1968	332	357	355	2 358	1196	542.5	344	368	344	2 532	1175	577.2
1969	274	217	228	1 858	1320	482.3	283	248	252	1 988	1285	547.3
1970	292	343	345	2 441	1163	562.9	333	309	303	2 444	1121	610.7
1971	345	360	335	2 403	1067	536.9	382	357	350	2 314	1031	561.8
1972	326	290	292	2 055	1121	548.9	369	279	315	2 116	1069	575.7
1973	380	331	341	2 277	1132	515.1	391	293	328	2 395	1111	525.5
1974	469	382	344	2 975	1105	644.9	465	370	398	2 942	1082	690.9
1975	305	288	267	1 982	1274	515.4	360	264	248	1 760	1252	525.6
1976	357	330	319	1 915	1179	463.8	334	262	251	1 604	1179	542.9
1977	402	371	360	2 355	1028	609.1	415	342	346	2 494	993	681.6
1978	427	364	348	2 723	1052	473.5	443	320	325	2 562	1035	498.2
1979	428	351	368	2 453	1025	588.9	438	333	366	2 506	1003	633.0
1980	418	332	334	2 384	1213	646.2	432	351	362	2 701	1200	654.0
1981	498	366	372	2 283	1124	550.8	522	368	404	2 539	1109	562.7
1982	453	376	354	2 288	1177	570.7	459	375	371	2 092	1171	560.1
1983	462	346	345	2 341	1221	485.7	431	315	305	2 009	1208	472.5
1984	547	424	433	2 861	1152	715.5	546	398	455	2 756	1131	768.2
1985	444	335	343	2 319	1038	725.9	470	335	352	2 504	1033	800.4
1986	443	352	349	2 582	1069	569.4	376	282	280	2 297	1071	559.8
1987	462	336	301	2 041	**960**	710.3	463	326	339	1 973	909	851.2
1988	437	346	322	2 840	1322	689.3	364	299	258	2 857	1276	787.2
1989	465	404	375	2 743	**1232**	576.5	428	388	379	2 445	1150	568.9
1990	534	450	475	2 811	1211	717.2	524	441	480	2 794	1182	712.4
1991	535	403	400	2 502	1134	614.7	516	408	435	2 503	1085	484.6
1992	408	342	344	2 903	1228	629.0	406	289	254	3 048	1201	673.1
1993	436	396	326	2 390	985	744.2	416	335	251	2 427	950	763.0
1994	386	355	323	2 671	1244	549.6	344	292	243	2 361	1163	645.4
1995	491	349	350	2 193	1183	596.2	438	301	337	2 470	1142	503.7
1996	472	424	361	2 428	1061	709.7	446	360	358	2 311	1042	707.9
1997	463	404	372	2 718	1375	606.6	445	372	379	2 613	1306	637.4
1998	515	421	430	2 815	1070	736.4	476	388	404	2 795	1033	734.6
1999	*550*	*390*	*398*	*2 815*	*1227*		497	338	396	2 670	1227	824.9
2000	*480*	*400*	*403*	*2 190*			*438*	*385*	*399*	*2 585*		*891.0*
2001	*461*	*384*	*391*	*2 678*			*435*	*395*	*416*	*2 888*		*643.1*

*Sources: *Statistics Norway; ** Norwegian Meteorological Institutue*
Data in bold = figure calculated using interpolated data
Data in italics = incomplete data, excluded from analysis

	Buskerud						Vestfold					
	Yield in kilograms per decare*				Weather data**		Yield in kilograms per decare*				Weather data**	
	Wheat	**Barley**	**Oats**	**Potato**	**GS-GDD**	**Ann-Pre**	**Wheat**	**Barley**	**Oats**	**Potato**	**GS-GDD**	**Ann-Pre**
1958	183	214	199	2 278	1275	787.1	177	230	202	2 188	1290	862.0
1959	192	185	171	1 536	1567	775.3	173	210	180	1 445	1534	837.3
1960	208	270	236	2 216	1360	906.7	231	290	252	2 411	1373	1025.1
1961	268	268	248	2 615	1384	827.0	281	321	304	2 615	1377	912.9
1962	207	225	213	1 821	1062	786.5	235	273	256	1 986	1091	1024.8
1963	217	249	243	2 311	1331	756.0	215	268	261	2 122	1322	901.4
1964	270	272	240	1 955	1224	718.2	243	297	267	2 210	1220	784.7
1965	246	236	228	2 113	1169	883.0	226	268	272	2 317	1199	901.5
1966	267	229	214	2 458	1305	913.2	210	245	231	2 482	1328	1004.2
1967	260	243	237	2 210	1300	902.4	320	267	247	2 423	1321	1074.6
1968	300	348	339	2 447	1431	689.0	352	404	384	2 852	1431	792.3
1969	340	301	308	2 218	1502	639.6	360	349	322	2 280	1468	741.9
1970	361	293	303	2 414	1372	801.2	311	324	338	2 723	1381	880.2
1971	410	332	346	2 469	1301	626.3	345	362	379	2 728	1335	616.0
1972	324	281	297	2 093	1292	638.9	335	316	353	2 241	1338	884.7
1973	381	322	334	2 322	1351	584.1	376	370	379	2 486	1364	720.7
1974	438	394	360	2 514	1375	777.2	504	454	465	2 596	1436	970.9
1975	197	189	188	1 336	1519	590.7	324	280	269	1 670	1538	727.9
1976	267	229	229	1 214	1480	601.0	345	320	297	1 582	1457	729.5
1977	400	379	384	2 122	1339	708.2	373	378	384	2 804	1348	870.5
1978	363	337	371	1 975	1288	652.0	438	418	442	2 685	1286	697.7
1979	386	360	378	1 899	1215	827.8	399	366	438	2 371	1205	859.9
1980	421	362	402	2 073	1479	766.8	464	418	452	2 666	1494	808.5
1981	489	347	358	2 189	1352	712.2	432	353	295	2 315	1361	845.5
1982	466	383	366	2 285	1417	840.5	454	384	401	2 493	1452	992.0
1983	384	288	297	2 039	1439	646.1	400	311	349	2 467	1451	754.8
1984	502	404	462	2 381	1400	871.4	523	424	531	3 117	1407	921.5
1985	444	382	399	2 715	1247	910.4	469	435	434	3 086	1247	948.6
1986	372	284	272	2 338	1248	709.6	432	353	377	2 679	1216	890.8
1987	461	417	394	2 470	1128	852.5	433	438	438	2 664	1106	983.2
1988	304	253	228	2 521	1501	1082.8	348	334	311	2 918	1489	1205.5
1989	356	339	281	2 696	1386	777.8	327	335	260	2 923	1397	760.7
1990	449	465	466	2 596	1450	746.1	465	491	485	2 963	1470	886.3
1991	448	417	440	2 491	1363	613.6	447	433	457	2 250	1379	705.6
1992	292	193	203	2 764	1475	753.5	319	211	207	3 029	1494	811.5
1993	480	329	318	2 426	1243	762.0	567	442	478	3 372	1234	832.1
1994	266	283	262	2 674	1459	661.4	295	336	305	2 426	1448	946.3
1995	434	291	367	2 509	1401	699.3	448	377	431	2 574	1371	782.0
1996	423	396	392	2 517	1328	669.0	444	444	438	2 465	1261	707.3
1997	424	373	412	2 665	1646	587.3	454	432	433	3 010	1576	725.9
1998	456	397	437	2 635	1320	797.4	437	423	451	3 062	1280	835.5
1999	450	333	380	2 614	1490	944.9	430	337	383	2 482	1433	1243.3
2000	441	360	439	1 283	1419	1172.6	467	377	466	2 285	1347	1427.0
2001	422	388	444	2 680	1445	817.8	409	427	437	2 735	1396	1003.8

*Sources: *Statistics Norway; ** Norwegian Meteorological Institutue*

	Telemark						Aust-Agder					
	Yield in kilograms per decare*				Weather data**		Yield in kilograms per decare*				Weather data**	
	Wheat	Barley	Oats	Potato	GS-GDD	Ann-Pre	Wheat	Barley	Oats	Potato	GS-GDD	Ann-Pre
1958	153	187	173	2 200	1216	767.7	*169*	213	184	1 893	1264	1387.2
1959	188	216	193	1 823	1400	780.0	*171*	219	210	2 080	1512	1283.7
1960	230	249	256	2 234	1343	933.5	*235*	280	264	2 126	1362	1545.0
1961	239	270	277	2 280	1330	910.1	*238*	259	248	2 354	1387	1488.0
1962	173	211	200	1 596	1050	828.1	*215*	252	216	1 782	1111	1265.7
1963	198	224	235	1 905	1278	788.7	*:*	225	247	1 968	1282	1175.1
1964	205	269	244	1 911	1178	750.4	*:*	273	286	1 923	1231	975.1
1965	195	250	246	2 096	1146	802.0	*243*	262	232	2 326	1207	1232.6
1966	195	240	246	2 362	1217	911.1	*:*	240	235	2 247	1274	1558.3
1967	246	272	274	2 298	1249	1009.5	*:*	294	288	2 522	1285	1601.9
1968	315	377	336	2 410	1353	862.3	*:*	361	351	2 627	1395	1251.5
1969	302	329	304	2 151	1399	671.0	*224*	312	295	1 999	1434	1005.4
1970	238	311	345	2 403	1309	773.0	-	322	274	2 656	1338	1224.4
1971	290	305	309	2 190	1248	618.3	-	257	203	2 217	1316	889.1
1972	220	247	309	1 862	1213	715.7	*:*	244	251	1 852	1277	1166.6
1973	304	350	343	2 464	1278	577.9	300	320	308	2 577	1322	965.4
1974	430	412	345	2 457	1266	773.9	350	328	311	2 355	1354	1359.4
1975	211	219	187	1 221	1441	612.5	279	256	212	1 478	1444	1190.6
1976	260	255	235	1 453	1373	569.5	310	216	254	1 798	1422	1358.9
1977	295	290	278	2 037	1255	764.7	220	210	142	2 121	1288	1375.1
1978	362	316	338	1 905	1206	712.9	345	291	313	2 254	1260	1131.2
1979	334	293	334	2 208	1146	795.5	359	278	273	2 219	1173	1277.7
1980	333	343	335	1 976	1399	606.2	481	324	269	2 000	1436	1001.5
1981	315	268	247	1 617	1281	700.1	82	259	222	1 768	1325	1196.6
1982	420	349	349	1 990	1306	885.0	540	329	339	1 873	1398	1314.7
1983	280	240	223	1 357	1353	697.6	300	175	122	1 399	1387	1152.1
1984	383	315	353	1 932	1369	941.0	536	370	349	2 162	1419	1300.9
1985	390	350	359	2 495	1178	811.6	296	320	288	1 992	1247	1216.4
1986	342	285	299	2 084	1160	790.4	397	324	247	2 053	1217	1425.3
1987	364	449	388	2 293	1077	942.0	506	370	314	1 703	1099	1386.4
1988	268	279	208	2 004	1430	1178.3	203	257	137	1 786	1468	1636.5
1989	203	325	205	2 015	1351	**610.5**	279	222	138	1 973	1388	972.5
1990	*472*	*469*	*448*	*2 800*			302	379	360	2 000	1424	1423.7
1991	*419*	*408*	*421*	*2 390*			314	341	383	1 877	1333	1078.5
1992	*261*	*220*	*202*	*2 181*			232	220	201	1 693	1412	1108.3
1993	*458*	*393*	*370*	*2 566*			314	366	349	1 858	1257	1031.3
1994	*291*	*342*	*290*	*2 147*			198	297	232	1 786	1396	1226.4
1995	***364***	*298*	*358*	*2 291*			*:*	313	**248**	2 245	1426	1147.1
1996	*437*	*404*	*392*	*2 567*			-	309	263	1 934	1263	930.2
1997	*413*	*368*	*398*	*2 799*			-	323	354	2 468	1532	940.7
1998	*390*	*355*	*377*	*2 833*			*273*	216	279	1 205	1277	1258.5
1999	*380*	*329*	*341*	*2 775*			*258*	235	148	1 156	1412	1554.6
2000	*430*	*344*	*393*	*3 027*			*361*	284	345	1 873	1386	1866.5
2001	*430*	*386*	*424*	*2 422*			*381*	323	364	2 196	1397	1433.1

*Sources: *Statistics Norway; ** Norwegian Meteorological Institutue*
Data in bold = figure calculated using interpolated data
Data in italics = incomplete data, excluded from analysis

	Vest-Agder						Rogaland					
	Yield in kilograms per decare*				Weather data**		Yield in kilograms per decare*				Weather data**	
	Wheat	**Barley**	**Oats**	**Potato**	**GS-GDD**	**Ann-Pre**	**Wheat**	**Barley**	**Oats**	**Potato**	**GS-GDD**	**Ann-Pre**
1958	162	204	197	1 839	1208	1254.5	301	293	285	2 549	1202	1003.4
1959	179	220	200	2 245	1401	1183.2	347	360	355	2 703	1329	842.5
1960	226	246	249	2 061	1273	1260.8	320	339	330	2 371	1258	840.1
1961	228	242	237	2 122	1275	1409.8	303	314	307	1 924	1184	1265.6
1962	179	218	218	1 502	1047	1210.9	299	317	290	2 659	1002	1217.5
1963	213	206	223	1 740	1202	1112.3	292	299	292	2 316	1185	1081.4
1964	225	223	215	1 571	1136	1004.3	281	253	260	1 579	1107	1221.1
1965	225	238	262	2 353	1138	1123.5	358	373	360	2 985	1121	883.9
1966	238	243	256	2 348	1191	1387.0	308	294	328	2 859	1159	1104.4
1967	178	210	238	1 864	1214	1624.7	240	215	205	1 701	1168	1732.8
1968	275	319	354	2 419	1315	1175.5	385	429	446	2 982	1316	970.8
1969	278	279	297	2 070	1314	973.5	354	377	387	2 433	1351	1067.1
1970	:	247	291	2 291	1251	1200.6	368	335	357	2 874	1263	1231.7
1971	:	236	364	2 283	1204	920.3	360	363	426	3 021	1255	1199.5
1972	-	245	309	1 802	1205	1080.1	:	301	352	1 946	1202	1127.1
1973	:	290	360	2 407	1227	987.8	:	371	425	3 110	1239	1093.7
1974	357	287	378	2 426	1257	1343.0	470	389	437	3 304	1326	1178.1
1975	350	233	296	1 719	1338	1211.3	322	347	385	2 595	1391	1202.1
1976	**295**	182	215	1 231	1273	1179.0	429	350	401	2 717	1308	855.4
1977	240	128	138	2 042	1151	1290.5	307	341	343	2 825	1057	1102.8
1978	422	319	262	1 966	1171	1093.2	364	354	348	2 622	1261	1105.2
1979	331	185	351	1 827	1043	1274.1	231	256	303	1 814	1016	1233.3
1980	365	375	332	2 095	1357	1023.7	350	408	422	2 800	1348	1084.5
1981	324	293	327	2 073	1253	1209.8	**324**	304	378	2 536	1209	1385.8
1982	706	372	411	2 160	1295	1303.9	297	379	398	3 015	1248	1355.1
1983	**606**	106	181	1 406	1253	1216.1	310	236	244	2 083	1178	1415.1
1984	506	326	490	2 396	1274	1159.3	544	505	505	2 838	1203	993.8
1985	255	366	331	1 964	1147	1058.7	456	439	363	2 622	1104	970.8
1986	469	197	348	2 046	1100	1366.3	356	308	387	2 358	1043	1392.6
1987	498	393	367	2 007	1030	1245.9	471	470	450	2 391	1064	927.8
1988	340	203	260	1 781	1393	1704.9	300	420	379	2 456	1298	1313.0
1989	**512**	253	213	2 348	1292	1126.5	376	309	263	2 601	1189	1256.3
1990	683	343	496	1 847	1358	1655.9	397	358	343	2 469	1235	1433.5
1991	534	369	373	1 913	1267	1108.0	272	404	370	2 338	1190	1135.3
1992	222	169	232	1 679	1367	1335.0	274	269	150	2 587	1353	1539.6
1993	:	352	425	2 115	1171	1017.5	395	478	384	2 842	1130	864.3
1994	*326*	329	340	2 216	1330	1312.0	411	355	**411**	2 467	1286	1223.5
1995	:	374	**379**	2 152	1323	1030.1	-	410	438	2 472	1250	1241.5
1996	:	331	417	2 257	1183	949.7	:	376	352	2 465	1176	1108.1
1997	-	296	286	1 976	1458	1149.3	*343*	377	340	2 782	1436	1315.2
1998	*131*	294	353	1 598	1192	1317.7	*337*	353	304	2 651	1196	1238.2
1999	*369*	286	379	1 848	1367	1440.3	*395*	404	424	2 743	1379	1274.0
2000	*375*	337	388	1 961	1325	1730.2	*353*	355	358	2 522	1249	1378.2
2001	*214*	385	415	1 871	1293	1345.4	*348*	374	357	2 850	1241	1070.3

*Sources: *Statistics Norway; ** Norwegian Meteorological Institutue*
Data in bold = figure calculated using interpolated data
Data in italics = incomplete data, excluded from analysis

	Hordaland						Sogn and Fjordane					
	Yield in kilograms per decare*				Weather data**		Yield in kilograms per decare*				Weather data**	
	Wheat	**Barley**	**Oats**	**Potato**	**GS-GDD**	**Ann-Pre**	**Wheat**	**Barley**	**Oats**	**Potato**	**GS-GDD**	**Ann-Pre**
1958	*240*	249	242	2 159	1139	1587.9	-	258	254	2 291	1125	1531.4
1959	:	271	257	2 141	1224	1428.6	:	272	264	2 286	1198	1386.6
1960	-	297	264	1 847	1262	1334.2	:	271	243	1 901	1232	971.9
1961	-	267	260	1 602	1153	1787.2	:	242	261	1 917	1118	1862.6
1962	:	264	260	2 232	937	1833.3	:	241	285	2 468	924	1621.3
1963	-	234	280	2 102	1121	1560.8	:	271	250	2 562	1226	1304.4
1964	-	157	109	643	954	2115.2	:	176	115	991	930	2147.9
1965	*250*	274	275	2 541	1081	1376.8	:	261	300	2 775	1059	1302.8
1966	-	240	270	2 386	1067	1960.7	:	212	200	2 430	1074	1614.7
1967	-	214	225	1 257	1074	2772.3	:	205	158	1 357	967	2475.8
1968	-	342	315	2 566	1145	1438.8	:	288	320	2 591	1145	1465.9
1969	:	302	283	2 392	1237	1805.3	:	327	318	2 418	1250	1661.1
1970	-	308	320	2 471	1073	1843.4	-	295	319	2 549	1107	1564.5
1971	-	295	320	2 512	1070	2146.9	-	300	320	2 449	1032	2619.9
1972	-	303	339	2 042	1030	1773.8	-	343	387	2 513	1104	1507.4
1973	-	253	288	2 338	1011	2375.0	-	318	290	2 108	1017	2346.1
1974	-	240	215	2 688	1121	1889.0	:	317	297	2 731	1120	1621.2
1975	:	256	339	1 996	1106	2239.6	:	299	204	1 973	1085	2349.2
1976	:	350	385	2 041	1138	1314.4	-	330	300	2 268	1016	1585.5
1977	-	300	336	2 163	968	1551.2	-	320	401	2 386	1018	1354.1
1978	-	302	311	2 344	1077	1577.1	-	381	300	2 550	1147	1832.3
1979	*396*	113	222	1 422	1002	2051.1	*396*	330	204	1 553	914	1973.9
1980	:	405	363	2 434	1195	1837.4	:	246	201	2 202	1291	1843.4
1981	-	320	67	1 977	1042	2104.3	-	351	300	1 605	989	1816.4
1982	-	177	139	2 267	1104	2095.8	-	395	236	2 001	1124	2037.1
1983	-	221	333	1 926	985	2326.5	-	328	400	1 925	1076	2707.6
1984	:	489	423	2 291	1045	1450.9	:	323	127	2 180	1165	1622.6
1985	:	424	382	1 981	1002	1700.9	*407*	347	300	1 824	1102	1698.6
1986	:	407	257	1 732	894	2313.6	:	321	402	1 857	1022	2195.0
1987	:	396	211	2 268	969	1604.8	*515*	427	:	2 086	1071	1465.7
1988	:	**384**	229	1 736	1172	2252.3	*266*	361	:	2 001	1329	1845.9
1989	-	372	**302**	1 617	1035	2532.7	*473*	522	:	1 374	1106	2647.9
1990	-	288	375	1 907	1113	2662.5	*422*	313	*295*	2 122	1178	2976.0
1991	-	310	357	1 817	1060	2195.8	*300*	371	*204*	1 887	1184	1974.6
1992	-	166	-	1 889	1213	2891.0	*436*	272	*197*	2 247	1199	2279.5
1993	-	:	-	1 941	997	1542.2	:	:	:	2 259	1038	1754.8
1994	-	*267*	:	1 449	1088	2100.2	:	*296*	*294*	1 890	1078	2215.2
1995	-	:	-	1 879	1095	2288.2	-	:	-	2 044	1156	1918.9
1996	-	-	-	1 542	1044	1634.7	-	-	-	1 705	1102	1101.3
1997	-	-	-	1 623	1331	1946.1	*351*	-	-	1 823	1318	2112.0
1998	:	:	:	1 066	1051	2237.0	*306*	:	*321*	1 831	1196	2061.3
1999	:	*222*	:	1 715	1250	2580.4	*305*	*284*	:	2 443	1205	2244.8
2000	:	*194*	:	1 277	1142	2163.5	*322*	*277*	:	1 929	1167	1964.8
2001	:	*199*	:	1 857	1112	1926.9	*290*	*297*	:	2 089	1196	1583.9

*Sources: *Statistics Norway; ** Norwegian Meteorological Institutue*

Data in bold = figure calculated using interpolated data

Data in italics = incomplete data, excluded from analysis

	Møre and Romsdal						Sør-Trøndelag					
	Yield in kilograms per decare*				Weather data**		Yield in kilograms per decare*				Weather data**	
	Wheat	**Barley**	**Oats**	**Potato**	**GS-GDD**	**Ann-Pre**	**Wheat**	**Barley**	**Oats**	**Potato**	**GS-GDD**	**Ann-Pre**
1958	*264*	*234*	*230*	*2 371*			224	243	238	2 382	997	827.2
1959	*277*	252	250	2 283	1041	1155.4	259	263	264	2 617	1052	772.7
1960	*300*	247	236	1 487	1100	815.7	273	254	270	2 093	1118	630.3
1961	*300*	211	218	1 882	1039	1254.7	249	228	236	2 294	1057	973.8
1962	*282*	204	187	2 233	831	1299.6	185	195	206	1 804	846	960.2
1963	*269*	269	290	2 823	1063	974.4	292	279	298	2 850	1189	906.9
1964	*220*	202	207	937	846	1561.0	249	233	261	1 333	928	1095.4
1965	:	253	261	2 787	928	943.3	255	273	281	2 624	969	895.2
1966	*140*	121	150	2 211	951	1088.6	152	165	190	2 589	977	819.1
1967	-	243	248	1 685	995	1490.4	270	248	275	1 952	1013	933.3
1968	-	253	263	2 679	1022	944.0	315	316	361	2 404	993	733.6
1969	:	189	209	2 250	1100	1309.0	180	206	227	2 514	1178	802.2
1970	:	277	278	2 478	1013	929.7	320	307	340	2 604	1111	803.9
1971	-	153	135	1 698	936	1592.5	:	125	87	1 337	986	1339.9
1972	-	310	332	2 701	1018	1005.1	:	322	364	2 780	1113	822.5
1973	-	218	224	1 802	965	1812.6	-	231	242	1 855	951	1294.9
1974	:	305	342	2 720	1042	1271.6	350	309	343	2 914	1093	737.3
1975	-	224	279	1 639	982	1633.8	300	207	216	1 595	913	1370.4
1976	-	273	277	2 050	1023	1090.6	394	290	334	2 041	897	952.6
1977	-	253	261	2 090	796	1073.5	342	276	256	1 986	804	756.6
1978	-	310	304	2 329	934	1566.6	340	329	351	2 457	1031	1049.4
1979	:	244	383	1 461	856	1423.1	**430**	232	222	1 801	946	1047.0
1980	:	274	381	2 301	1065	1165.0	519	304	301	2 342	1214	865.5
1981	:	262	185	1 834	1003	1316.5	341	310	342	1 877	1035	827.4
1982	-	360	205	2 220	995	1185.7	530	340	330	2 180	983	881.6
1983	:	302	173	1 906	918	1596.3	405	298	319	1 932	1028	1334.7
1984	:	266	158	2 220	962	1096.7	345	296	291	1 922	1046	845.5
1985	:	230	300	1 845	875	1567.9	469	326	278	1 886	1023	1124.3
1986	*401*	324	300	2 024	848	1241.0	419	338	329	1 866	1007	790.9
1987	:	374	**410**	2 001	835	1055.9	333	281	269	1 717	913	954.3
1988	:	346	519	2 295	1064	1315.4	444	308	284	2 158	1229	976.9
1989	*376*	258	360	2 065	941	1708.4	424	332	318	1 877	1037	1168.4
1990	*253*	286	275	2 471	1017	1763.3	307	304	313	1 893	1114	994.4
1991	*138*	158	158	1 622	980	1411.2	310	213	250	1 349	1005	905.7
1992	*127*	247	238	2 475	1138	1557.0	194	314	291	1 877	1151	1009.8
1993	:	241	:	2 202	845	1224.8	**239**	295	272	1 737	902	867.3
1994	:	157	*176*	2 003	971	1405.6	284	226	203	2 118	1013	987.4
1995	-	266	:	2 252	956	1560.2	**284**	254	256	2 173	916	975.9
1996	-	213	:	2 075	969	978.9	283	312	280	1 752	969	637.5
1997	-	289	*255*	2 463	1165	1359.9	264	346	321	2 078	1201	1029.0
1998	:	189	*225*	2 570	1017	1630.2	289	292	346	2 200	1037	974.3
1999	:	290	*283*	2 631	1160	1458.8	338	370	409	2 114	1119	991.9
2000	-	251	*219*	2 047	1009	1373.8	243	326	323	1 910	1026	750.6
2001	:	265	*219*	2 344	965	1427.5	240	301	325	2 035	975	988.3

*Sources: *Statistics Norway; ** Norwegian Meteorological Institutue*
Data in bold = figure calculated using interpolated data
Data in italics = incomplete data, excluded from analysis

	Nord-Trøndelag						Nordland					
	Yield in kilograms per decare*				Weather data**		Yield in kilograms per decare*				Weather data**	
	Wheat	**Barley**	**Oats**	**Potato**	**GS-GDD**	**Ann-Pre**	**Wheat**	**Barley**	**Oats**	**Potato**	**GS-GDD**	**Ann-Pre**
1958	251	227	225	2 194	1017	758.1	-	204	196	1 678	881	1510.0
1959	289	282	281	2 732	1103	614.5	:	167	171	1 584	872	1313.5
1960	279	258	259	2 286	1161	644.4	:	230	228	2 125	1110	739.6
1961	284	235	240	2 370	1087	830.2	:	203	218	1 649	944	1847.4
1962	231	194	181	1 948	866	888.3	-	175	133	1 699	747	1386.9
1963	277	247	245	2 705	1238	846.6	-	251	258	2 386	1046	1351.1
1964	300	264	247	1 551	973	983.1	-	142	143	1 190	767	1899.7
1965	306	281	278	2 852	1012	831.6	-	222	210	1 946	818	1094.9
1966	213	153	181	2 462	1028	788.3	-	122	140	1 651	782	1259.7
1967	319	260	267	1 909	1029	873.2	-	168	204	1 451	913	1300.9
1968	325	295	326	2 376	1034	657.7	-	185	216	1 109	743	1285.4
1969	150	220	211	2 557	1219	716.2	*200*	260	245	2 247	1021	1131.5
1970	300	307	310	2 851	1184	720.7	-	251	238	2 196	987	1092.2
1971	185	196	149	1 967	1040	1286.6	-	184	90	1 501	841	1776.4
1972	350	317	316	2 761	1157	832.4	-	240	298	2 237	1036	1471.0
1973	300	230	260	2 069	1001	1165.5	-	107	140	1 392	822	1822.3
1974	350	307	343	3 095	1123	682.3	*300*	274	270	2 535	1009	1029.9
1975	310	216	213	1 996	957	1250.7	-	40	60	556	660	1903.8
1976	350	276	295	2 358	913	816.9	*320*	146	283	1 558	752	1176.6
1977	329	280	289	2 447	863	643.9	-	190	200	1 374	719	1285.7
1978	341	315	316	2 806	1103	959.6	-	257	385	1 775	954	1243.3
1979	326	209	151	1 729	1041	954.9	:	193	252	1 579	885	1205.7
1980	354	311	304	2 440	1303	813.4	-	293	276	1 560	1131	903.9
1981	439	329	327	2 450	1105	725.4	-	273	201	1 471	823	1143.6
1982	407	325	353	2 567	1069	821.3	-	189	200	1 268	730	1535.4
1983	361	296	327	2 343	1110	1199.4	-	100	90	1 199	851	1670.5
1984	366	304	328	2 298	1119	709.1	:	165	:	1 583	844	868.3
1985	387	299	268	2 387	1083	1009.8	:	231	:	1 704	853	1070.9
1986	431	309	322	2 478	1069	793.4	*401*	207	*171*	1 628	781	739.7
1987	405	273	308	2 143	942	1049.6	:	262	:	1 489	699	763.6
1988	465	312	327	2 917	1284	952.4	-	263	:	1 989	937	848.8
1989	417	286	317	2 429	1074	1082.8	:	165	:	1 231	812	1272.1
1990	304	301	319	2 526	1175	880.9	-	248	*85*	1 945	908	963.3
1991	350	254	256	2 468	1083	813.3	-	152	*67*	1 383	807	990.4
1992	291	305	292	2 756	1233	889.9	-	228	*91*	1 686	948	1021.4
1993	346	317	275	2 728	986	844.1	-	332	-	1 815	859	827.2
1994	318	256	204	2 467	1113	885.2	-	184	:	1 272	824	943.6
1995	268	221	210	2 358	979	867.4	-	-	-	783	724	1532.6
1996	254	317	287	2 573	1026	554.5	-	-	-	1 280	868	1238.7
1997	363	348	323	2 621	1281	938.4	-	-	-	1 655	1041	1208.8
1998	401	319	315	2 635	1092	872.4	-	*220*	:	1 918	1026	1491.5
1999	421	284	299	2 487	1195	853.5	:	*222*	:	1 242	912	1337.4
2000	299	299	259	2 519	1115	668.7	:	*114*	:	1 569	824	1346.5
2001	372	245	248	2 518	1039	982.0	-	*120*	*149*	1 396	824	1404.5

*Sources: *Statistics Norway; ** Norwegian Meteorological Institutue*
Data in bold = figure calculated using interpolated data
Data in italics = incomplete data, excluded from analysis

	Troms						Finnmark					
	Yield in kilograms per decare*				Weather data**		Yield in kilograms per decare*				Weather data**	
	Wheat	**Barley**	**Oats**	**Potato**	**GS-GDD**	**Ann-Pre**	**Wheat**	**Barley**	**Oats**	**Potato**	**GS-GDD**	**Ann-Pre**
1958	-	*190*	-	1 866	576	923.9	-	-	-	1 248	614	348.6
1959	-	*120*	-	1 576	559	1101.4	-	-	-	1 875	701	495.4
1960	-	*205*	-	1 977	861	764.6	-	-	-	2 075	979	365.8
1961	-	*201*	-	1 660	713	1059.8	-	-	-	1 978	794	438.6
1962	-	*135*	-	1 432	470	1107.7	-	-	-	841	503	410.4
1963	-	*215*	-	2 195	735	984.6	-	-	-	1 840	755	395.0
1964	-	*150*	-	1 623	536	1438.0	-	-	-	1 602	619	510.8
1965	-	*140*	-	1 356	598	821.0	-	-	-	555	482	454.5
1966	-	-	-	1 846	671	729.2	-	-	-	1 582	629	393.2
1967	-	*160*	-	1 593	770	906.3	-	-	-	1 635	754	453.8
1968	-	*110*	-	468	525	978.7	-	-	-	191	452	436.2
1969	-	-	-	2 117	826	818.4	-	-	-	2 054	635	312.1
1970	-	*230*	*250*	2 065	825	826.9	-	-	-	2 215	862	398.9
1971	-	-	-	1 749	693	1173.0	-	-	-	1 560	611	424.8
1972	-	-	-	2 232	917	993.9	-	-	-	1 924	964	341.0
1973	-	-	-	1 687	696	1165.3	-	-	-	1 890	746	411.7
1974	-	-	-	2 188	873	694.3	-	-	-	2 129	865	415.4
1975	-	-	-	377	466	1452.2	-	-	-	411	501	503.4
1976	-	-	-	1 655	650	786.9	-	-	-	1 777	633	306.4
1977	-	-	-	1 271	578	823.8	-	-	-	**1 716**	580	347.5
1978	-	-	-	1 444	810	966.2	-	-	-	1 654	636	447.7
1979	-	*325*	*380*	1 406	768	684.4	-	-	-	**1 653**	761	365.1
1980	-	-	-	1 626	916	721.1	-	-	-	1 652	750	300.3
1981	-	-	-	1 097	571	808.5	-	-	-	1 094	550	456.8
1982	-	-	-	1 241	537	1102.5	-	-	-	1 102	525	470.3
1983	-	-	-	1 181	712	1176.1	-	-	-	1 345	698	419.5
1984	-	*164*	:	1 562	724	676.9	-	-	:	1 435	700	308.8
1985	-	*352*	:	1 371	779	1073.0	-	-	:	1 074	731	395.2
1986	:	*313*	:	1 445	667	792.5	-	-	:	1 334	677	334.0
1987	-	-	-	1 102	473	888.9	-	-	-	538	471	384.0
1988	-	:	:	1 903	697	1122.3	-	-	-	1 274	786	417.9
1989	-	-	:	1 317	644	1227.5	-	-	-	1 376	769	524.3
1990	-	-	-	1 544	810	1003.8	-	-	-	1 258	767	342.4
1991	-	-	-	1 007	631	1059.4	-	-	-	1 452	677	426.5
1992	-	-	-	1 593	742	1328.2	-	-	-	1 280	713	491.7
1993	-	-	-	1 433	689	1135.2	-	-	-	1 063	600	400.8
1994	-	-	-	1 142	653	1089.7	-	-	-	935	666	327.1
1995	-	-	-	570	616	1182.2	-	-	-	788	630	470.5
1996	-	-	-	1 072	685	920.1	-	-	-	953	643	381.6
1997	-	-	-	1 235	857	1198.5	-	-	-	1 219	805	376.9
1998	-	:	-	1 448	843	872.8	-	-	-	1 289	678	420.1
1999	-	-	-	1 446	689	1181.6	-	-	-	1 243	744	487.5
2000	-	-	-	1 824	692	1280.2	-	-	-	1 151	735	409.7
2001	-	-	-	1 720	778	1145.1	-	-	-	1 227	830	549.3

*Sources: *Statistics Norway; ** Norwegian Meteorological Institutue*
Data in bold = figure calculated using interpolated data
Data in italics = incomplete data, excluded from analysis

Annex 2: Detailed regression output

County / crop			Constant		GS-GDD		Ann-Pre		Time Trend	
	Observations	R²	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Østfold										
Wheat	43	0.65	**420.535**	3.63	-0.067	-0.90	-0.102	-1.79	**5.958**	8.49
Barley	43	0.46	**506.602**	4.61	-0.122	-1.71	**-0.098**	-1.83	**3.704**	5.57
Oats	43	0.46	**475.532**	3.51	-0.129	-1.48	-0.064	-0.96	**4.626**	5.64
Potato	43	0.06	**2819.000**	3.74	-0.281	-0.58	-0.341	-0.92	6.412	1.40
Wheat P1	16	0.79	110.467	0.68	0.086	0.88	-0.041	-0.56	**12.993**	6.04
Barley P1	16	0.47	346.769	1.76	-0.029	-0.24	-0.090	-1.02	**6.384**	2.45
Oats P1	16	0.64	341.646	1.69	-0.050	-0.41	-0.089	-0.99	**10.023**	3.75
Potato P1	16	0.28	2442.532	1.28	0.003	0.00	-0.603	-0.71	40.414	1.61
Wheat P2	15	0.04	367.937	1.68	-0.010	-0.09	0.011	0.08	1.753	0.37
Barley P2	15	0.15	**495.260**	2.52	-0.113	-1.05	0.106	0.87	-2.716	-0.64
Oats P2	15	0.08	**492.571**	1.84	-0.105	-0.72	0.070	0.42	-1.046	-0.18
Potato P2	15	0.16	**3078.539**	2.16	-0.700	-0.90	0.996	1.13	-29.686	-0.96
Wheat P3	12	0.31	**670.946**	2.18	-0.331	-1.67	-0.084	-0.70	8.061	1.20
Barley P3	12	0.22	**769.197**	2.62	-0.230	-1.22	-0.070	-0.61	-0.498	-0.08
Oats P3	12	0.18	526.531	1.45	-0.263	-1.13	-0.002	-0.02	6.153	0.78
Potato P3	12	0.12	1606.259	1.17	0.238	0.27	-0.498	-0.93	22.946	0.77
Akershus & Oslo										
Wheat	44	0.57	**438.737**	3.22	-0.127	-1.41	-0.065	-0.86	**5.655**	7.28
Barley	44	0.47	**459.357**	4.03	-0.128	-1.71	-0.072	-1.14	**3.775**	5.82
Oats	44	0.42	**411.233**	2.99	-0.132	-1.46	-0.016	-0.21	**4.250**	5.43
Potato	44	0.43	712.304	1.05	0.330	0.74	**0.952**	2.53	**18.302**	4.72
Wheat P1	16	0.69	208.541	1.25	0.075	0.81	-0.127	-1.27	**8.754**	3.46
Barley P1	16	0.41	283.689	1.39	0.003	0.03	-0.088	-0.72	**6.293**	2.03
Oats P1	16	0.53	266.847	1.38	0.006	0.06	-0.088	-0.76	**7.811**	2.67
Potato P1	16	0.24	801.484	0.62	0.558	0.78	0.423	0.54	34.888	1.77
Wheat P2	15	0.21	364.396	1.67	-0.078	-0.56	-0.025	-0.17	5.687	1.32
Barley P2	15	0.44	**579.153**	3.40	**-0.252**	-2.30	0.205	1.76	-3.767	-1.12
Oats P2	15	0.29	**599.107**	2.44	-0.275	-1.73	0.182	1.08	-2.260	-0.47
Potato P2	15	0.34	987.290	0.72	-0.158	-0.18	**1.844**	1.96	-0.881	-0.03
Wheat P3	13	0.30	**786.092**	2.10	-0.427	-1.74	0.086	0.45	3.322	0.46
Barley P3	13	0.07	**565.182**	2.04	-0.135	-0.75	-0.053	-0.38	0.586	0.11
Oats P3	13	0.13	308.256	0.85	-0.117	-0.50	0.086	0.47	3.953	0.56
Potato P3	13	0.50	79.881	0.06	0.227	0.27	0.778	1.19	43.284	1.74
Hedmark										
Wheat	41	0.74	**307.340**	2.51	-0.062	-0.79	0.023	0.23	**6.836**	9.89
Barley	41	0.63	**262.052**	2.65	-0.013	-0.21	0.001	0.01	**4.280**	7.69
Oats	41	0.53	**244.141**	2.22	0.007	0.09	-0.009	-0.10	**3.861**	6.22
Potato	41	0.37	544.453	0.74	0.775	1.65	1.068	1.77	**14.016**	3.40
Wheat P1	16	0.58	136.315	0.93	0.024	0.28	0.107	0.85	**8.344**	3.88
Barley P1	16	0.34	142.106	0.70	0.051	0.45	0.042	0.24	**6.655**	2.22
Oats P1	16	0.42	100.608	0.52	0.072	0.65	0.055	0.33	**7.471**	2.62
Potato P1	16	0.24	-365.797	-0.25	0.952	1.16	1.966	1.58	32.463	1.53
Wheat P2	15	0.35	**354.476**	1.81	-0.103	-0.76	0.152	0.83	4.691	1.31
Barley P2	15	0.11	**366.487**	2.96	-0.054	-0.63	0.087	0.76	-0.181	-0.08
Oats P2	15	0.09	**376.344**	2.50	-0.072	-0.69	0.059	0.42	0.619	0.22
Potato P2	15	0.13	1264.622	0.98	0.365	0.40	1.451	1.20	-5.222	-0.22
Wheat P3	10	0.17	230.246	0.46	0.078	0.33	0.373	0.98	-2.620	-0.41
Barley P3	10	0.50	12.602	0.05	0.137	1.06	**0.478**	2.32	-2.485	-0.72
Oats P3	10	0.46	-203.027	-0.53	0.288	1.59	**0.632**	2.18	-4.756	-0.97
Potato P3	10	0.41	-184.553	-0.10	**1.774**	1.97	2.121	1.47	-18.381	-0.76
Oppland										
Wheat	42	0.59	**384.311**	3.16	-0.074	-0.86	-0.037	-0.41	**5.443**	7.35
Barley	42	0.39	**266.007**	2.73	-0.008	-0.11	-0.002	-0.04	**2.875**	4.84
Oats	42	0.30	**306.820**	2.27	-0.032	-0.34	-0.035	-0.35	**3.298**	4.01
Potato	42	0.24	839.194	1.23	0.530	1.09	**1.237**	2.49	**8.098**	1.95
Wheat P1	16	0.68	175.427	1.29	0.004	0.04	0.079	0.67	**10.335**	4.72
Barley P1	16	0.35	110.083	0.68	0.069	0.72	0.067	0.47	**6.043**	2.31
Oats P1	16	0.45	211.122	1.23	0.019	0.18	-0.026	-0.18	**7.282**	2.62
Potato P1	16	0.19	266.849	0.21	0.671	0.87	1.772	1.57	18.048	0.86
Wheat P2	15	0.18	**552.990**	2.38	-0.173	-1.05	0.074	0.45	1.172	0.28
Barley P2	15	0.13	**336.610**	2.05	-0.052	-0.44	0.110	0.95	-0.876	-0.30
Oats P2	15	0.19	**463.605**	1.96	-0.156	-0.92	0.148	0.89	-2.076	-0.49
Potato P2	15	0.19	1231.143	0.78	0.263	0.23	1.684	1.52	-9.852	-0.35
Wheat P3	11	0.00	411.889	1.36	0.018	0.09	0.033	0.16	-0.162	-0.02
Barley P3	11	0.09	**512.271**	1.87	-0.012	-0.06	0.055	0.28	-4.986	-0.81
Oats P3	11	0.04	251.114	0.57	0.138	0.47	-0.043	-0.14	-0.645	-0.06
Potato P3	11	0.27	1492.394	1.35	0.946	1.29	0.897	1.15	-15.895	-0.64

KEY:
Data in bold: t-stat >= 1.8
P1: 1958-1973, P2: 1974-1988, P3: 1989-2001

Table A2-1: Regression output by county

County / crop			Constant		GS-GDD		Ann-Pre		Time Trend	
	Observations	R^2	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Buskerud										
Wheat	44	0.53	**467.927**	3.19	-0.149	-1.60	-0.037	-0.46	**5.596**	6.68
Barley	44	0.35	**438.658**	3.41	-0.124	-1.52	-0.037	-0.52	**3.426**	4.66
Oats	44	0.43	**376.877**	2.59	-0.096	-1.04	-0.030	-0.37	**4.495**	5.41
Potato	44	0.13	**2550.186**	3.16	-0.349	-0.68	-0.052	-0.12	**11.219**	2.43
Wheat P1	16	0.86	171.141	1.32	0.059	0.90	-0.083	-0.92	**12.200**	6.15
Barley P1	16	0.60	**265.168**	1.91	0.037	0.53	-0.115	-1.19	**5.380**	2.53
Oats P1	16	0.78	**255.249**	2.09	0.043	0.70	-0.144	-1.69	**7.613**	4.06
Potato P1	16	0.19	1034.077	0.86	0.253	0.42	0.813	0.97	30.146	1.64
Wheat P2	15	0.30	**645.011**	2.01	-0.297	-1.55	0.185	0.86	0.451	0.07
Barley P2	15	0.49	**738.290**	3.29	**-0.359**	-2.67	**0.280**	1.86	-5.669	-1.23
Oats P2	15	0.34	**747.746**	2.59	**-0.349**	-2.01	0.239	1.24	-5.098	-0.86
Potato P2	15	0.66	1790.157	1.61	-1.046	-1.57	**1.879**	2.53	14.205	0.62
Wheat P3	13	0.23	539.589	1.73	-0.253	-1.25	-0.002	-0.01	6.254	1.07
Barley P3	13	0.04	455.528	1.24	-0.123	-0.51	-0.059	-0.34	3.114	0.45
Oats P3	13	0.19	136.246	0.34	-0.074	-0.28	-0.034	-0.18	9.935	1.31
Potato P3	13	0.55	**3452.009**	2.49	0.346	0.38	**-1.775**	-2.73	-1.969	-0.08
Vestfold										
Wheat	44	0.54	**385.673**	2.61	-0.056	-0.58	-0.072	-1.05	**5.687**	6.86
Barley	44	0.41	**489.148**	3.98	-0.096	-1.21	-0.093	-1.64	**3.565**	5.17
Oats	44	0.42	**510.762**	3.29	-0.144	-1.43	-0.065	-0.91	**4.656**	5.34
Potato	44	0.26	**2971.869**	3.81	-0.483	-0.96	-0.152	-0.42	**16.152**	3.69
Wheat P1	16	0.76	86.570	0.49	0.089	0.92	-0.023	-0.25	**11.842**	5.25
Barley P1	16	0.58	**340.251**	1.86	0.023	0.22	-0.135	-1.43	**6.313**	2.69
Oats P1	16	0.74	**363.453**	2.11	-0.019	-0.20	-0.139	-1.55	**9.600**	4.34
Potato P1	16	0.29	2005.287	1.34	-0.086	-0.10	0.175	0.22	**40.168**	2.08
Wheat P2	15	0.08	**494.882**	2.00	-0.098	-0.68	0.074	0.46	-0.116	-0.02
Barley P2	15	0.31	**609.572**	3.14	**-0.216**	-1.90	0.179	1.43	-4.146	-1.03
Oats P2	15	0.17	**678.968**	2.22	-0.244	-1.37	0.125	0.63	-2.786	-0.44
Potato P2	15	0.45	1705.025	1.18	-0.665	-0.79	1.228	1.31	28.847	0.97
Wheat P3	13	0.24	**771.762**	1.96	-0.330	-1.49	-0.014	-0.12	3.357	0.49
Barley P3	13	0.17	617.106	1.51	-0.216	-0.94	-0.105	-0.83	4.538	0.64
Oats P3	13	0.25	584.101	1.23	-0.324	-1.22	-0.038	-0.26	8.186	1.00
Potato P3	13	0.14	3466.811	1.74	-0.034	-0.03	-0.550	-0.90	-5.108	-0.15
Telemark										
Wheat	32	0.42	219.660	1.39	-0.041	-0.38	0.037	0.46	**5.217**	4.50
Barley	32	0.28	**298.467**	2.13	-0.057	-0.60	0.017	0.24	**3.351**	3.27
Oats	32	0.19	**409.203**	2.73	-0.140	-1.37	0.014	0.18	**2.483**	2.27
Potato	32	0.17	**2395.118**	2.93	-0.685	-1.23	0.726	1.76	-3.378	-0.56
Wheat P1	16	0.74	-174.219	-1.46	**0.264**	3.35	0.021	0.28	**7.376**	4.13
Barley P1	16	0.69	-111.873	-0.81	**0.229**	2.52	0.037	0.43	**8.293**	4.01
Oats P1	16	0.87	-110.622	-1.22	**0.186**	3.13	0.081	1.45	**10.548**	7.78
Potato P1	16	0.40	-105.132	-0.12	**1.120**	1.88	0.780	1.40	**27.838**	2.06
Wheat P2	15	0.33	**649.128**	3.02	**-0.282**	-2.01	0.144	1.05	-2.944	-0.60
Barley P2	15	0.39	**636.209**	3.08	**-0.299**	-2.22	0.170	1.29	-3.246	-0.69
Oats P2	15	0.44	**741.976**	3.66	**-0.368**	-2.78	0.078	0.60	-1.416	-0.31
Potato P2	15	0.61	**4065.881**	4.04	**-2.119**	-3.22	**1.449**	2.26	-23.926	-1.05
Aust-Agder										
Wheat	22	0.05	219.660	1.39	-0.213	-0.79	0.027	0.17	-1.854	-0.46
Barley	44	0.08	**298.467**	2.13	-0.041	-0.50	-0.018	-0.48	**1.144**	1.83
Oats	44	0.04	**409.203**	2.73	-0.043	-0.39	-0.011	-0.23	1.077	1.29
Potato	44	0.16	**2395.118**	2.93	0.351	0.68	-0.119	-0.52	**-10.486**	-2.68
Barley P1	16	0.39	60.139	0.41	0.102	1.03	0.028	0.56	**5.668**	2.45
Oats P1	16	0.33	18.321	0.11	0.119	1.10	0.033	0.61	**5.302**	2.08
Potato P1	16	0.45	-154.192	-0.16	0.936	1.44	**0.647**	1.99	**41.801**	2.74
Wheat P2	15	0.08	511.305	0.85	-0.078	-0.22	-0.179	-0.67	7.393	0.80
Barley P2	15	0.17	404.742	1.59	-0.123	-0.83	-0.037	-0.33	4.051	1.03
Oats P2	15	0.11	**630.031**	1.90	-0.183	-0.95	-0.094	-0.63	-0.554	-0.11
Potato P2	15	0.19	**3228.416**	2.67	-0.893	-1.28	0.324	0.60	-22.959	-1.24
Barley P3	13	0.02	367.801	1.00	0.003	0.01	0.001	0.01	-2.116	-0.38
Oats P3	13	0.03	276.814	0.50	-0.087	-0.24	0.021	0.18	2.686	0.32
Potato P3	13	0.35	-967.087	-0.49	**2.394**	1.84	-0.560	-1.31	6.071	0.20

KEY:

Data in bold: t-stat >= 1.8

P1: 1958-1973, P2: 1974-1988, P3: 1989-2001

Table A2-2: Regression output by county

County / crop			Constant		GS-GDD		Ann-Pre		Time Trend	
	Observations	R^2	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Vest-Agder										
Wheat1	12	0.67	123.686	1.11	0.117	1.48	-0.072	-1.71	**6.825**	3.24
Wheat2	19	0.12	104.151	0.24	0.038	0.11	0.059	0.28	7.835	1.21
Barley	44	0.28	**256.312**	1.98	0.053	0.51	-0.091	-1.76	**2.810**	3.58
Oats	44	0.32	**317.180**	2.16	-0.043	-0.36	-0.029	-0.49	**3.805**	4.28
Potato	44	0.06	**1839.660**	3.13	0.467	0.99	-0.317	-1.35	-1.664	-0.47
Wheat P1	12	0.67	123.686	1.11	0.117	1.48	-0.072	-1.71	**6.825**	3.24
Barley P1	16	0.49	48.918	0.45	**0.156**	1.98	-0.021	-0.55	**3.491**	2.35
Oats P1	16	0.79	86.865	0.70	0.135	1.50	-0.048	-1.09	**9.510**	5.62
Potato P1	16	0.42	-694.517	-0.62	**1.976**	2.45	0.119	0.30	25.334	1.67
Wheat P2	15	0.14	47.187	0.09	0.156	0.45	-0.082	-0.33	11.676	1.32
Barley P2	15	0.30	291.789	0.90	0.140	0.63	**-0.318**	-1.99	8.585	1.49
Oats P2	15	0.10	261.498	0.74	0.033	0.14	-0.114	-0.66	6.609	1.06
Potato P2	15	0.01	2126.762	1.62	-0.183	-0.20	-0.066	-0.10	5.326	0.23
Barley P3	13	0.16	436.274	1.32	-0.199	-0.84	-0.011	-0.13	4.146	0.87
Oats P3	13	0.27	671.182	1.62	-0.450	-1.51	0.126	1.19	3.113	0.52
Potato P3	13	0.28	**2761.331**	2.36	0.114	0.14	-0.446	-1.49	-9.730	-0.58
Rogaland										
Wheat1	14	0.82	**348.063**	3.67	0.073	1.10	**-0.137**	-4.75	**6.102**	3.97
Wheat2	21	0.34	**490.947**	2.47	0.102	0.70	**-0.246**	-2.99	1.662	0.64
Barley	44	0.58	**438.401**	5.12	0.096	1.51	**-0.221**	-6.37	**2.602**	4.95
Oats	44	0.34	**384.630**	3.27	0.134	1.52	**-0.193**	-4.06	**1.580**	2.19
Potato	44	0.29	**1880.336**	2.85	**1.233**	2.51	**-0.804**	-3.01	5.526	1.36
Wheat P1	14	0.82	**348.063**	3.67	0.073	1.10	**-0.137**	-4.75	**6.102**	3.97
Barley P1	16	0.68	**323.103**	2.07	0.135	1.24	**-0.171**	-3.67	**4.200**	2.07
Oats P1	16	0.82	**286.609**	1.98	0.166	1.64	**-0.194**	-4.48	**8.901**	4.74
Potato P1	16	0.41	**4127.854**	2.09	-0.254	-0.18	**-1.478**	-2.50	44.234	1.73
Wheat P2	15	0.52	467.480	1.71	0.134	0.82	**-0.335**	-3.33	5.724	1.27
Barley P2	15	0.70	154.652	0.82	**0.258**	2.29	**-0.285**	-4.10	**10.212**	3.28
Oats P2	15	0.38	236.458	1.06	0.203	1.54	**-0.175**	-2.14	4.612	1.26
Potato P2	15	0.36	1755.915	1.32	1.368	1.72	-0.470	-0.96	-11.066	-0.50
Barley P3	13	0.62	**524.713**	3.31	0.132	0.81	**-0.265**	-3.28	0.222	0.07
Oats P3	13	0.34	314.682	1.00	0.160	0.50	-0.257	-1.61	4.019	0.68
Potato P3	13	0.42	**1734.081**	2.71	0.973	1.48	-0.577	-1.77	9.683	0.81
Hordaland										
Barley	35	0.41	**443.832**	2.84	-0.005	-0.04	**-0.120**	-3.96	**5.051**	4.00
Oats	34	0.15	213.439	1.04	0.121	0.75	-0.060	-1.60	**3.099**	2.08
Potato	44	0.22	**2378.405**	3.06	0.378	0.58	**-0.343**	-2.08	-7.526	-1.46
Barley P1	16	0.68	156.510	1.25	**0.174**	1.91	**-0.072**	-3.06	**6.706**	3.82
Oats P1	16	0.57	175.261	1.02	0.139	1.10	**-0.069**	-2.13	**9.038**	3.72
Potato P1	16	0.46	2512.254	1.31	0.567	0.41	**-0.874**	-2.42	**71.090**	2.63
Barley P2	15	0.53	71.068	0.20	0.192	0.73	**-0.163**	-2.52	**15.328**	2.98
Oats P2	15	0.23	533.612	1.22	0.017	0.05	-0.139	-1.73	-0.354	-0.06
Potato P2	15	0.34	1921.248	1.50	1.065	1.10	-0.381	-1.61	-10.473	-0.56
Potato P3	13	0.24	**2405.011**	2.15	0.927	0.91	-0.131	-0.53	-40.303	-1.62
Sogn and Fjordane										
Barley	35	0.46	**288.050**	2.52	-0.008	-0.09	-0.028	-1.26	**4.859**	4.85
Oats	29	0.07	335.359	1.55	-0.035	-0.21	-0.033	-0.80	2.556	1.38
Potato	44	0.23	**1526.346**	2.18	**1.048**	1.84	**-0.236**	-1.81	-7.238	-1.56
Barley P1	16	0.66	-24.730	-0.18	**0.243**	2.49	-0.014	-0.59	**6.709**	3.63
Oats P1	16	0.48	148.321	0.60	0.143	0.80	-0.064	-1.44	**9.695**	2.87
Potato P1	16	0.43	2457.754	1.34	0.474	0.36	**-0.664**	-2.00	**51.424**	2.04
Barley P2	15	0.30	**404.657**	3.22	-0.113	-1.10	-0.030	-0.98	**4.937**	1.97
Oats P2	13	0.15	550.801	1.57	-0.328	-1.17	0.022	0.29	2.068	0.29
Potato P2	15	0.60	**1963.218**	2.72	**1.538**	2.60	**-0.328**	-1.88	**-41.907**	-2.91
Potato P3	13	0.10	920.793	0.59	-0.254	-0.17	0.144	0.58	28.416	0.92
Møre & Romsdal										
Barley	43	0.10	**280.494**	2.72	0.024	0.26	-0.059	-1.70	1.207	1.71
Oats	34	0.14	259.926	1.40	0.040	0.24	-0.071	-1.23	**3.316**	2.14
Potato	43	0.29	1126.926	1.66	**1.612**	2.66	**-0.563**	-2.47	7.984	1.73
Barley P1	15	0.28	202.780	0.99	0.102	0.59	-0.075	-1.48	1.757	0.59
Oats P1	15	0.36	175.884	0.87	0.140	0.81	-0.086	-1.71	2.781	0.93
Potato P1	15	0.50	**3657.735**	1.95	-0.233	-0.15	**-1.384**	-2.98	47.282	1.72
Barley P2	15	0.35	169.343	0.99	0.093	0.71	-0.065	-1.18	**5.112**	1.97
Oats P2	15	0.07	34.657	0.08	0.175	0.53	-0.015	-0.11	5.138	0.78
Potato P2	15	0.36	1331.990	1.18	**1.589**	1.83	-0.565	-1.54	-1.527	-0.09
Barley P3	13	0.19	-64.950	-0.30	0.133	0.83	0.058	0.77	2.305	0.57
Potato P3	13	0.47	-730.269	-0.68	1.183	1.48	0.533	1.43	27.294	1.36

KEY: Data in bold: t-stat >= 1.8. P1: 1958-1973, P2: 1974-1988, P3: 1989-2001

Table A2-3: Regression output by county

County / crop			**Constant**		**GS-GDD**		**Ann-Pre**	
	Observations	R^2	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Sør-Trøndelag								
Wheat1	13	0.11	103.921	0.38	0.149	0.81	-0.019	-0.13
Wheat2	28	0.37	**303.361**	1.89	0.216	1.56	0.006	0.07
Barley	44	0.41	**163.147**	2.04	**0.144**	2.19	**-0.081**	-2.20
Oats	44	0.29	**182.735**	1.88	**0.157**	1.96	**-0.099**	-2.19
Potato	44	0.45	**1394.896**	2.46	**1.605**	3.44	**-0.783**	-2.98
Wheat P1	13	0.11	103.921	0.38	0.149	0.81	-0.019	-0.13
Barley P1	16	0.36	319.918	1.59	0.054	0.35	**-0.168**	-2.03
Oats P1	16	0.45	**444.136**	1.85	0.010	0.05	**-0.258**	-2.61
Potato P1	16	0.59	1761.191	1.22	1.685	1.52	**-1.468**	-2.46
Wheat P2	15	0.24	105.716	0.52	0.231	1.32	-0.018	-0.18
Barley P2	15	0.44	**225.539**	2.46	0.089	1.14	**-0.081**	-1.87
Oats P2	15	0.25	**273.126**	2.19	0.127	1.19	-0.082	-1.38
Potato P2	15	0.68	**1761.212**	2.83	**1.873**	3.51	**-0.656**	-2.22
Wheat P3	13	0.24	356.385	1.31	-0.086	-0.43	0.159	1.11
Barley P3	13	0.38	-116.090	-0.59	**0.269**	1.85	-0.006	-0.06
Oats P3	13	0.45	-260.093	-1.24	0.229	1.48	0.072	0.65
Potato P3	13	0.54	-516.451	-0.59	-0.052	-0.08	**1.030**	2.25
Nord-Trøndelag								
Wheat	44	0.25	199.965	1.77	0.049	0.55	0.023	0.42
Barley	44	0.38	**173.116**	2.59	**0.125**	2.34	**-0.073**	-2.21
Oats	44	0.21	**181.596**	2.02	0.124	1.74	-0.076	-1.69
Potato	44	0.42	**1579.955**	3.35	1.269	3.38	**-0.732**	-3.13
Wheat P1	16	0.08	**452.693**	1.92	-0.103	-0.58	-0.107	-0.98
Barley P1	16	0.27	263.451	1.52	0.057	0.44	-0.119	-1.48
Oats P1	16	0.40	**390.134**	2.20	-0.011	-0.08	**-0.200**	-2.44
Potato P1	16	0.56	1314.999	1.12	**1.661**	1.89	**-1.060**	-1.94
Wheat P2	15	0.69	**202.729**	2.52	0.047	0.70	-0.067	-1.56
Barley P2	15	0.53	**204.710**	2.67	0.112	1.73	**-0.098**	-2.40
Oats P2	15	0.32	239.383	1.74	0.087	0.75	-0.125	-1.70
Potato P2	15	0.36	**1837.539**	2.13	1.309	1.79	-0.686	-1.49
Wheat P3	13	0.47	-107.354	-0.47	0.033	0.22	**0.292**	2.69
Barley P3	13	0.32	157.078	0.94	**0.209**	1.93	-0.087	-1.09
Oats P3	13	0.29	89.933	0.47	0.220	1.77	0.004	0.04
Potato P3	13	0.13	**2268.755**	3.74	0.420	1.06	-0.173	-0.60
Nordland								
Barley	37	0.55	93.765	1.10	**0.239**	3.55	**-0.083**	-3.23
Oats	26	0.49	101.807	0.77	**0.233**	2.30	**-0.089**	-2.15
Potato	44	0.64	578.412	1.45	**2.051**	5.98	**-0.442**	-3.45
Barley P1	16	0.59	10.771	0.11	**0.257**	3.15	-0.034	-1.11
Oats P1	16	0.57	-41.369	-0.35	**0.308**	3.11	-0.032	-0.88
Potato P1	16	0.70	39.688	0.06	**2.354**	4.01	-0.314	-1.44
Barley P2	15	0.66	194.787	1.09	**0.207**	1.88	**-0.130**	-2.68
Oats P2	10	0.61	545.561	1.62	0.045	0.19	**-0.222**	-1.91
Potato P2	15	0.66	**1990.438**	1.87	**1.235**	1.89	**-0.817**	-2.83
Potato P3	13	0.64	-183.956	-0.22	**2.453**	3.23	-0.618	-1.64
Troms								
Potato	44	0.51	157.064	0.35	**2.290**	5.36	0.054	0.21
Potato P1	16	0.59	-661.821	-0.80	**3.014**	3.98	0.544	1.10
Potato P2	15	0.63	528.527	0.68	**1.694**	2.75	-0.652	-1.75
Potato P3	13	0.38	-1681.857	-1.24	**2.194**	1.88	0.875	1.29
Finnmark								
Potato	44	0.64	253.329	0.61	**2.678**	7.24	-0.982	-1.37
Potato P1	16	0.66	-560.858	-0.53	**3.005**	4.61	0.041	0.02
Potato P2	15	0.74	**1884.200**	2.17	**2.271**	3.45	**-2.474**	-2.07
Potato P3	13	0.44	558.698	0.93	**1.516**	2.08	0.480	0.65

KEY:

Data in bold: t-stat >= 1.8

P1: 1958-1973, P2: 1974-1988, P3: 1989-2001

Table A2-4: Regression output by county

Annex 3: RegClim data and predictions

County	Period	Crop	Average yield (observed)	Estimated yield (model derived)	AVERAGE ANNUAL GDD: 1980-2000 value*	RegClim % change	Estimated coefficient	Predicted change in yield	Predicted % change in yield from RegClim
Østfold	All	Barley	341	592	1 439	0.15			
Aker/Oslo	All	Potato	2 306	1 663	1 370	0.17			
Hedmark	P3	Barley	395	489	1 206	0.18			
	P3	Oats	376	372	1 206	0.18			
	P3	Potato	2 617	2 126	1 206	0.18	1.8	394	19 %
Oppland	All	Potato	2 393	1 844	1 176	0.24			
Buskerud	P2	Potato	2 138	3 444	1 472	0.20			
	P3	Potato	2 504	2 221	1 472	0.20			
Telemark	P1	Wheat	231	356	1 363	0.19	0.3	68	19 %
	P1	Barley	269	371	1 363	0.19	0.2	59	16 %
	P1	Oats	268	314	1 363	0.19	0.2	48	15 %
	P1	Potato	2 137	1 591	1 363	0.19	1.1	290	18 %
Aust-Agder	P1	Potato	2 197	823	1 515	0.20			
	P3	Potato	1 866	2 830	1 515	0.20	2.4	725	26 %
Vest-Agder	P1	Barley	242	449	1 467	0.20	0.2	46	10 %
	P1	Potato	2 057	2 375	1 467	0.20	2.0	580	24 %
	P2	Barley	264	62	1 467	0.20			
Rogaland	All	Oats	355	317	1 437	0.18			
	All	Potato	2 563	2 832	1 437	0.18	1.2	319	11 %
	1958-71	Wheat	323	350	1 437	0.18			
	1974-94	Wheat	365	358	1 437	0.18			
	P1	Barley	327	283	1 437	0.18			
	P2	Barley	367	345	1 437	0.18	0.3	67	19 %
	P3	Barley	371	369	1 437	0.18			
Hordaland	All	Potato	1 956	1 822	1 243	0.21			
	P1	Barley	267	391	1 243	0.21	0.2	45	12 %
	P1	Oats	269	199	1 243	0.21			
Sogn&Fjordane	All	Potato	2 100	2 491	1 213	0.30	1.0	381	15 %
	P1	Barley	268	441	1 213	0.30	0.2	89	20 %
Møre&Romsdal	All	Potato	2 142	2 414	1 174	0.24	1.6	454	19 %
Sør-Trøndelag	All	Barley	278	421	1 143	0.23	0.1	39	9 %
	All	Oats	284	439	1 143	0.23	0.2	42	10 %
	All	Potato	2 087	2 658	1 143	0.23	1.6	431	16 %
Nord-Trøndelag	All	Barley	275	431	1 212	0.23	0.1	35	8 %
	All	Potato	2 435	1 115	1 212	0.23			
	P1	Oats	249	387	1 212	0.23			
	P3	Wheat	339	316	1 212	0.23			
Nordland	All	Barley	203	393	934	0.36	0.2	80	20 %
	All	Oats	206	389	934	0.36	0.2	78	20 %
	All	Potato	1 602	2 165	934	0.36	2.1	689	32 %
Troms	All	Potato	1 492	1 987	724	0.39	2.3	647	33 %
Finnmark	All	Potato	1 375	2 285	695	0.43	2.7	800	35 %

Table based on: model estimates, changes in GDD and precipitation under the RegClim scenario and yield predictions for 2040.
*Note: Average temperature calculation based on available data: Hedmark: 1980-1999; Oppland: 1980-1999; Telemark: 1980-89

Table A3-1: Average annual crop yields for the period 1980-2000

County	Period	Crop	AVERAGE ANNUAL PRECIPITATION 1980-2000 value*	RegClim % change	Estimated coefficient	Predicted change in yield	Predicted % change in yield from RegClim	Predicted % change in yield: Net effect
Østfold	All	Barley	866	0.05	-0.1	-4	-1 %	-1 %
Aker/Oslo	All	Potato	819	0.04	1.0	31	2 %	2 %
Hedmark	P3	Barley	639	0.05	0.5	15	3 %	3 %
	P3	Oats	639	0.05	0.6	19	5 %	5 %
	P3	Potato	639	0.05				19 %
Oppland	All	Potato	674	0.04	1.2	33	2 %	2 %
Buskerud	P2	Potato	789	0.02	1.9	30	1 %	1 %
	P3	Potato	789	0.02	-1.8	-28	-1 %	-1 %
Telemark	P1	Wheat	816	0.02				19 %
	P1	Barley	816	0.02				16 %
	P1	Oats	816	0.02				15 %
	P1	Potato	816	0.02				18 %
Aust-Agder	P1	Potato	1 246	0.05	0.6	40	5 %	5 %
	P3	Potato	1 246	0.05				26 %
Vest-Agder	P1	Barley	1 260	0.08				10 %
	P1	Potato	1 260	0.08				24 %
	P2	Barley	1 260	0.08	-0.3	-32	-52 %	-52 %
Rogaland	All	Oats	1 231	0.18	-0.2	-43	-14 %	-14 %
	All	Potato	1 231	0.18	-0.8	-178	-6 %	5 %
	1958-71	Wheat	1 231	0.18	-0.1	-30	-9 %	-9 %
	1974-94	Wheat	1 231	0.18	-0.2	-55	-15 %	-15 %
	P1	Barley	1 231	0.18	-0.2	-38	-13 %	-13 %
	P2	Barley	1 231	0.18	-0.3	-63	-18 %	1 %
	P3	Barley	1 231	0.18	-0.3	-59	-16 %	-16 %
Hordaland	All	Potato	2 117	0.18	-0.3	-131	-7 %	-7 %
	P1	Barley	2 117	0.18	-0.1	-27	-7 %	5 %
	P1	Oats	2 117	0.18	-0.1	-26	-13 %	-13 %
Sogn&Fjordane	All	Potato	2 023	0.14	-0.2	-67	-3 %	13 %
	P1	Barley	2 023	0.14				20 %
Møre&Romsdal	All	Potato	1 380	0.11	-0.6	-85	-4 %	15 %
Sør-Trøndelag	All	Barley	947	0.10	-0.1	-7	-2 %	7 %
	All	Oats	947	0.10	-0.1	-9	-2 %	8 %
	All	Potato	947	0.10	-0.8	-71	-3 %	14 %
Nord-Trøndelag	All	Barley	868	0.08	-0.1	-5	-1 %	7 %
	All	Potato	868	0.08	-0.7	-51	-5 %	-5 %
	P1	Oats	868	0.08	-0.2	-14	-4 %	-4 %
	P3	Wheat	868	0.08	0.3	20	6 %	6 %
Nordland	All	Barley	1 129	0.08	-0.1	-8	-2 %	18 %
	All	Oats	1 129	0.08	-0.1	-8	-2 %	18 %
	All	Potato	1 129	0.08	-0.4	-40	-2 %	30 %
Troms	All	Potato	1 040	0.06				33 %
Finnmark	All	Potato	407	0.06				35 %

Table based on: model estimates, changes in GDD and precipitation under the RegClim scenario and yield predictions for 2040.
*Note: Average precipitation calculation based on available data: Hedmark: 1980-1998; Telemark: 1980-89

Table A3-2: Average annual crop yields for 1980-2000

Annex 4: Model variants

Annual or growth season data

With respect to temperature, we initially considered annual GDD as an alternative to growth season GDD (defined as April to September in our study). However, given the Norwegian climate, the difference between these two measures would have been minimal, as there are few days where the temperature rises above 5°C between late autumn and early spring. Conversely, in the case of precipitation, we considered growth season data as an alternative to annual data, but an annual precipitation figure seemed more appropriate than a growing season figure, since a significant proportion of precipitation falling outside the growing season is likely to feed crops during it. This is because a large share of precipitation during winter months is likely to be released as water when the snow melts in spring and early summer, even if some water is lost to runoffs to rivers, etc.

Inclusion of CO_2 concentration

Data was obtained at the global level (in parts per million) from the Scripps Institution of Oceanography.[16] Different data formats for CO_2 concentration were explored: atmospheric concentration in ppmv; transformation of atmospheric concentration to a normalized series starting at 0 in 1957 and ending at 56 in 2001; logarithmic transformation of atmospheric concentration; and finally, a quadratic term from a second-order polynomical was fitted to atmospheric concentration through a regression. These data formats were included either alone as part of the regressions, or in addition to the linear trend. It turned out that the simple time trend behaved as well or better in the regressions than the various CO_2 formats, so we chose to only include the former in the main model. The major reason for this finding is the dominating linear part of CO_2 concentration in the atmosphere.

Frost events

Frost events can be harmful to crops, grains in particular. Wheat is especially sensitive to sub-zero conditions during its vegetative period, when germination and leaf growth take place. Cromey et al. (1998) found that a late frost event reduced yields by 13 to 33 % for the affected winter wheat crops in the Southland region of New Zeland [9]. On this background we expected that a weather event, such as a late spring frost episode, would be likely to have negative consequences

[16] Atmospheric CO_2 concentrations (ppmv) were derived from flask and in situ air samples collected at the South Pole. Source: C.D. Keeling, T.P. Whorf and the Carbon Dioxide Research Group, Scripps Institution of Oceanography, University of California, La Jolla, California USA 92093-0444, July 25, 2002; http://cdiac.esd.ornl.gov/trends/co2/sio-spl.htm.

for yield. To capture an element of this vulnerability, a dummy variable was introduced in the model, with '1' indicating the occurrence of one or more 'frost events' during that year in a given county and a '0' representing the absence of one. Given the sensitivity of crops to low temperatures during the early phases of their development, a 'frost event' was said to have taken place when the minimum air temperature during one or more days in May was equal to, or fell below -2°C (or -4°C in a second variant of the model). May was selected as a key month as grains are commonly sown in April in Norway.[17][18] In cases where observations from several weather stations had been used to compile weather data for a particular county, the records of all relevant stations were examined for evidence of frost events. Weather stations were initially chosen due to their proximity to areas of agricultural activity in a county, therefore a frost event occurring at any one of the stations would be likely to have some relevance for at least part of the crop area under cultivation in that county. In terms of our results, we found no evidence to suggest that frost events influence crop yields. This suggests that the model was not well suited to incorporate such a variable.

Fertiliser application to grain production

The limited fertilizer use data that was available at county level was integrated into the model for the brief period, 1989-1996. Sample surveys provided figures for the application of commercial nitrogen and phosphorus fertilisers to grain and oil seeds in the form of average kilograms per decare for most counties.[19] Based on the assumption that farmers used both nitrogen and phosphorus optimally, the sum of the two was calculated and included as a third independent variable in addition to the two central climate variables - GDD during the growing season and annual precipitation. The analyses showed that fertilizer use - for the limited period data was available - did not have any significant positive effects on yield.

Quadratic and logarithmic variables

The use of quadratic and logarithmic forms of the independent variables (GDD and precipitation) did not appear to improve the model's capabilities for the four test counties we selected in our analysis (Akershus/Oslo, Rogaland, Sør-Trøndelag, and Nordland). Results provided fewer significant coefficients than our main model.

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[17] Note that if spring arrivs late sowing can be delayed.

[18] Thirty per cent of wheat in Norway is sown in the autumn.

[19] Resultatkontroll jordbruk, Statistics Norway, 1993, 1995 and 1997. A complete data set for the eight-year period was not available for some Northern and Western counties, i.e. Telemark, Hordaland, Sogn and Fjordane, Nord-Trøndelag, Nordland, Troms and Finnmark.