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# **CLIMATE CHANGE IMPACTS ON CROP RISKS AND AGRICULTURAL PRODUCTION IN FINLAND**

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# CLIMATE CHANGE IMPACTS ON CROP RISKS AND AGRICULTURAL PRODUCTION IN FINLAND

*Heikki Lehtonen and Sanna Kujala*

## **Abstract**

Climate Change is expected to improve crop production conditions significantly in northern Europe. In some studies a significant increase in agricultural production is expected in northern Europe while drought is becoming gradually more severe in Southern Europe and France due to climate change. Our analysis provides one of the first steps in evaluating the possible scale of changes in agricultural production and use of farm land in Finland, so far one of the least favoured agricultural areas in Europe.

Drought in early summer and low temperature sum during growing period are currently the main growth limiting factors in Finland. Even though the early part of the growing period is likely to be dry also in the future, both mean and variance of crop yields are expected to increase in Finland. However the changes are likely to be very different for different crops. We use mean-variance analysis and a sector level, regionally disaggregated, optimisation-based economic model in evaluating the likely impacts increasing mean and variance of crop yields on agricultural production and land use in Finland. Our sector level analysis takes into account important supply-demand conditions, e.g. changes in feed crop use, limited domestic demand, and imperfect substitution. Sector models including risk are relatively few in recent literature of agricultural economics. In our first analysis we use mean-variance approach in including crop yield risk and risk aversion explicitly in our dynamic recursive sector model.

Increasing mean and variability of crop yields change the relative profitability of crops. For example, increasing feed crop yields may drive up animal production, especially if export prices of meat remain strong. On the other hand, if the demand is relatively inelastic, land area of some less competitive crops may clearly decrease despite increasing yields. Consequently, climate change may trigger changes on the production structure of agriculture. Farm income is relatively little affected by higher crop yields, on the average, while income may increase significantly on some individual farms. Our preliminary analysis also shows that policy measures aimed at reducing crop risks may be relatively efficient in increasing or sustaining production of many crops. Even if policy measures for reducing risks are commonly perceived less production-linked compared to price and area based subsidies, we show that their impact on production volume will most likely increase in on-going climate change. However in further research we need to test alternative approaches for better representation and modelling of crop risks. Albeit simple, we consider optimisation and risk aversion necessary techniques and assumptions in producing consistent evaluations of economic behaviour in long-term economic adaptations and risks.

## **Keywords**

Climate change, agriculture, risk aversion, mean-variance analysis, sector models, optimization, crop production, Finland

## 1 Introduction

In some studies a significant increase in agricultural production is expected in northern Europe due to much temperate climate while drought is becoming gradually more severe in Southern Europe and France. Many of the predicted changes will profit agriculture in Finland but the speed of the change, the considerable variability of the weather and the negative factors related to the climate change raise number of uncertainties. Full advantage of the longer growth season and the increased yield potential requires risk and uncertainty factors to be observed and anticipated. It has to be noticed that in the areas where the current climate corresponds to the future climate in Finland, the length of the day and the amount of the light per day may greatly differ from our circumstances. Also the changes in the annual precipitation, the circumstances of the overwintering and populations of the plant pests are crucial in structuring the projections for the future.

Problems with drought, floods and ground water and the rise of the sea level in Central and Southern Europe and more severe drought in USA and Latin America may weaken the global supply of agricultural products. Therefore long continued decrease of real prices may stop and turn up. At the same time the focus of agricultural production will gradually move from current major export countries elsewhere. Continuing economic growth in Asia and in many developing countries will increase demand and trade of meat and milk products as well as grains and gardening products. However the price trends of different products depend not only on the climate change but also on the liberalization of the world trade, changes in the agricultural policy and the changing structure of world food demand.

Our study is related to a larger research project which examines the climate change adaptation potential of the Finnish agriculture and food economy in perspective of crop production, environmental effects, food supply and market conditions<sup>1</sup>. The aim is to assess the potential and relative competitiveness of the Finnish agriculture in different scenarios of the climate change and in different states of the global and European food markets. We need a consistent socio-economic scenarios and arguments how climate change and its implications propagate as price signals and opportunities to Finnish agriculture through world food markets.

Our target is to assess changes in spatial allocation of crops and animal production in Finland on the basis of global and European food market scenarios and the research output from soil and plant scientists. Such research outputs are prone to many sources of uncertainty, but may be helpful in evaluating long-term adaptation strategies and the role of autonomous and planned adaptation in Finnish agriculture. However we need a solid but relatively simple analytical framework used in deriving likely impacts of climate change and food market scenarios on agricultural production and land use in Finland. There is a demand for such an analytical framework in evaluating effectiveness and economic consequences of different adaptation options, including those of risk management.

In the country-specific analysis concerning Finland and its different areas we use mean-variance approach in including crop yield risk explicitly in our dynamic recursive sector model DREMFIA (for a description and one of the recent applications of the model, see Lehtonen 2001, Lehtonen et. al. 2006). We implemented a simple linear mean-variance – approach to DREMFIA in order to compute land use changes in a number of global and EU

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<sup>1</sup> Ilmasopu –project of MTT Agrifood Research Finland is divided into five work packages that cover climate scenarios and data, adaptation of agricultural production, risks and their anticipation, alternative scenarios for production systems, environmental effects, economy and markets and adaptation and mitigation.

food market scenarios. Just (2003) emphasizes the importance of addressing risk averse behaviour explicitly.

DREMFIA sector model, where also animal production and use of feed is included, provides agricultural production, foreign trade of agricultural products, land use and farm income as outputs in different climate change scenarios. These outputs are consistent at the level of agricultural sector, its product markets and competition of the land area.

Recent policy developments have brought risk management in the policy discussions. All support measures designed to reduce risk have some impact on production decisions of a risk-averse farmer. There also seems to be a strong correlation for risk and production effects of the instruments designed to reduce risk (OECD, 2005:24). In Finland, farmers' access to futures markets has been rather limited and the role of risk reducing instruments in farm risk management has been small. Instead excessive production-linked farm subsidies have been paid for production because of the high production costs (MTT, 2007:52). However, our preliminary analysis shows that crop insurance scheme can have a considerable risk reducing effect in Finland, especially in the northern areas, even with modest governmental costs. OECD (2005) has concluded crop insurance to be most effective instrument to reduce farm risk. Since yield risk is the dominant part of the revenue risk in Finland, crop insurance can be expected to be a relatively effective instrument as well. According to the results of Liu & Pietola (2005) yield volatility in Finland is large and it dominates the price volatility in the optimal hedging decisions of the Finnish wheat producers.

This paper proceeds as follows. Section 2 discusses the crop insurance as one (possibly subsidized) risk reducing instrument. Section 3 presents the classical mean-variance-approach used to include risk aversion in the optimization model. In section 4 data is described with yield trends of some of the major crops in Finland presented in Annex 1 and regional variance-covariance matrixes of the crop contribution margins in Annex 2. Scenarios and policy options including increased mean yields, increased variance yields and crop insurance are presented in section 5. Section 6 presents the results of the study. Section 7 is for discussion and conclusions.

## **2 Crop insurance as a risk reducing instrument**

Crop insurance could ease farmer's adaptation to the climate change because yield variability is predicted to increase. It is still difficult to predict the variability of crop prices since the development of food markets are subject to a large number of socio-economic issues. However the predicted increase in crop yield variability can be inferred directly from the increased climate variability, especially at the local scale. Several studies (e.g. Parry et al. 2004, Fisher et al. 2005, Audsley et al. 2006) have predicted mean yields to increase in Finland and other northern and eastern areas of Europe due to the climate change, but they have also shown that variance of yields is very likely to grow with climate change induced by more frequent and intense extreme events, such as droughts or heavy rainfalls.

We focus on crop insurance because yield risk has been observed to be more dominant than price risk for cereals. Since production costs are high in Finland, crop insurance is interesting also because in addition to risk-reduction effect it has potentially large subsidy effects. In the crop insurance scheme farmer decides the area he will be insuring given the conditions provided by the scheme. The crop insurance contract fixes a minimum yield guaranteed for

the insured hectares and eliminates the worst outcomes in exchange for the premium payment, making a crop less risky and potentially more desirable in the crop mix. The availability of subsidized crop insurance affects farmer's current crop decisions by creating a direct incentive to expand production. With no land constraint, the farmer would likely alter each crop's share of acreage in accordance with the effect of insurance on relative net returns (Young et al. 2001).

Impacts of crop insurance schemes on production have been excessively studied in the literature. Young et al. (2001) have studied production and price impacts of crop insurance programs in U.S. The study concluded that crop insurance influences production decisions and therefore prices. The overall acreage impacts are small with total planted acreage to major field crops to be about 0.4 % higher with government subsidized crop insurance than in the absence of any insurance program. The increased plantings are concentrated in certain areas and with certain crops e.g. wheat and cotton. Prices for wheat and cotton are about 3 % lower, whereas feed grain prices decrease 0.5 %. Market returns to farmers from expanded acreage and higher production will be reduced due to the inelastic demand for the major crops.

OECD (2005) has reviewed the crop and revenue insurance literature and draws conclusions that crop insurance is the most effective instrument in reducing risk, with an 11 % reduction in the coefficient of variation of profits, measured with a USD 300 subsidy obtained with crop insurance. According to OECD (2005), crop insurance is an effective instrument because it is targeted to yields which are the main source of the variability in the crop production. Price hedging is the second effective instrument. They both are voluntary market schemes with less potential for crowding out market strategies compared to other risk reducing instruments. Crop insurance and price hedging also induce the largest production effects. However, the highest risk reduction is obtained with the highest production effects and the lowest level of profits. (OECD, 2005: 26)

OECD (2005) has concluded that for most examples of policy interventions low levels of subsidy would reduce variability. However, there could be a threshold beyond which further subsidy would contribute to increased variability. This could be a case if a farmer is clearly over-compensated by the government's risk reducing subsidies, e.g. high subsidies for revenue or crop insurance may then work as a production subsidy. In general, it is found that market mechanisms are better suited for reducing the risk of farmers. Hence government decisions must also take into account impacts on production and profits. Area payments are found to be more transfer efficient in terms of profits, but are less efficient in reducing risk than other risk reducing policies. In general, the impact on farmer's welfare of the different measures depends on trade-offs between income and income variability that are defined by the farmer's degree of risk aversion. (OECD, 2005:5)

In Finland the risk reducing instruments for farmers have traditionally related to the subvention of high production costs. Also the farm size structure dominated by small farms which have relatively large transaction costs relative to any market based risk reducing instruments, such as forwards markets, explain the crop insurance scheme are not very familiar in Finland. However the relatively large crop yield variability, which is likely to increase further due to climate change, may be a good reason to use risk reducing instruments, so far largely neglected in Finland. However instruments widely used in farm management in other countries may become in higher demand when larger farms become more common. In that case also government may become interested in subsidising some risk reducing instruments.

### 3 Model

Ignoring risk-averse behaviour in farm planning models often leads to results that bear little relation to the decisions farmer actually makes (Hazell & Norton, 1986: 80). In studying climate change impacts on agricultural production it is essential to implement risk into the optimization models, rather than operate them assuming risk neutrality. Furthermore, including risk in optimisation models is relatively straightforward technically.

Several techniques have been developed to incorporating risk-averse behaviour in mathematical programming models. We adopted the mean-variance analysis with dynamic recursive sector model to explicitly include crop risks into estimates of land use changes in Finland. In classical mean-variance-model we maximize the utility function with positive risk aversion coefficient. If  $X$  is a vector of the different activities (amount of  $n$ ), the vector of the land use of different crops is  $(x_1, x_2, \dots, x_n)$  and  $P$  is vector of the prices of different crops  $(p_1, p_2, \dots, p_n)$ .

The model maximizes the utility function:

$$\text{Max } u = E[PQ] - cX - \Phi V[PQ]^{1/2}, \quad (1)$$

where  $E[PQ]$  is the expected profit (price vector multiplied with quantity vector  $Q$ ),  $c$  is the unit cost of the activity (e.g. euros/ha),  $\Phi$  is the positive risk averse parameter and  $V$  the variance operator. This can be written:

$$\text{Max } u = P^* E[y]X - cX - \Phi[X' \Omega X]^{1/2}, \quad (2)$$

where  $P^*$  is the expected price,  $y$  yield,  $\Omega$  is covariance matrix between profits of the different activities. The target function  $u$  is maximized with resource constraint as matrix  $A$  contains the resource use, like availability of land and working ours at peak working period:

$$AX \leq b \quad (3)$$

If the expected return per hectare is denoted:

$$r^* = P^* E[y] \quad (4)$$

we have:

$$\text{Max } u = r^*X - cX - \Phi[X' \Omega X]^{1/2} \quad (4)$$

In the optimum, the utility gained from the additional unit of activity equals with marginal costs. For a risk-averse farmer the possibility for the lower profits than expected is the additional cost. Increasing the activity produces additional costs determined by the risk parameter. These costs are positive if the profit of the activity correlates positively with the profits of the other activities and negative if the profit of the activity correlates negatively

with the profits of the other activities. For example if the profit of certain crop correlates negatively with the profits of other crops, the variance of the total profit decreases.

The empirical estimation of the risk attitude parameters is difficult. Quadratic utility functions can't be summed up, so we are not able to calculate the mean value of the risk attitude parameters measured from different entrepreneurs and the groups of entrepreneurs. In addition the values of the risk attitude parameters depend substantially on definition of the optimization model and the mean prices. In empirical work the values of the risk attitude parameters are often calibrated so that the resulting model outcome is close to the realized production. The problem is that realized situation in a certain year or mean of the several years may not necessarily represent the economical equilibrium (Hardaker & Huirne, 1997:187-189; Coyle, 1992).

#### **4 Data**

The variance-covariance matrixes of the crop contribution margins are calculated for spring wheat, winter wheat, rye, barley, malt barley, oats, mixed grain, oilseeds and greenfallow, the most important crops cultivated in Finland. In the appendix 1 trend yields for winter wheat, rye, barley and oilseeds are presented at the country-level. The trend yields show that yields of winter wheat and barley have been increasing from the 1970's. However there has been hardly any trend in wheat and barley yields in the last 15 years. Increase of rye yields has been very modest. The yields of oilseeds have even decreased. Crop yields have considerable regional variability as the low temperature sum and short growing period are limiting the cultivation of the most risky crops towards the north.

The variance-covariance matrixes of the crop contribution margins are calculated on the regional basis since there are 18 production regions in the DREMFA model. We have used the regional data of crop yields from 1995 - 2006, product and input prices and agricultural subsidies from the official statistics. The use of inputs per hectare in different regions is already defined and validated to farm taxation data and farm level production costs calculations made by rural advisory services<sup>2</sup>. Hence the variance-covariance matrices we have produced fit the DREMFA –model specifications but may not be usable in a context of some other input specification and aggregations. For example, we have fully included labour costs of farm family to production costs, which is more appropriate in long-term analysis than in short-term analysis. In the appendix 2 the matrices for Uusimaa, Satakunta, Southern Ostrobothnia, North Savo and Northern Ostrobothnia are represented in order to show the considerable differences in yield levels and their variation. Uusimaa and Satakunta situating in the south of Finland are the most crop cultivation intensive areas in Finland.

The data of regional crop yields includes two years of crop failures in 1998 and 1999. The time series of crop yields in appendix 1 reveals that 2 clear crop failures per decennium have been rather typical in Finland. On the cost side, all variable costs are taken into account in the calculations. Farm subsidies have a great significance in the farm profits of Finland. The subsidies of Common Agricultural Policy of European union (29% of total farm subsidies in 2007), subsidies of Finland's environmental administration (18%) and LFA (payments for less favoured area; 22% ), together with national farm payments (30%) are taken into account.

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<sup>2</sup> We have used input specification and aggregation of Pro Agria –organisation ([www.proagria.fi](http://www.proagria.fi)) which is a central coordinating body of rural advisory services in Finland.



The calculation of matrixes shows that wheat, rye, malt barley and oilseeds have higher own variances than barley, oats and mixed grain which are mainly cultivated for feed use. The variances of wheat, rye, malt barley and oilseeds further grow towards the north. These crops of high variances also correlate positively with each other. There are few negatively correlating crops in the northern areas, but areas under these crops are quite insignificant.

## **5 Scenarios and policy options**

In all scenarios we assume product prices and farm subsidies at 2006 level but assume inflation of input prices by 1.8% per year, on the average, until 2020. Hence we do not include any socio-economic scenarios and their impacts on product and input prices. We only assume different levels of crop yields and/or their variability. However the production and income effects of these very simple scenarios are not trivial but subject to structural characteristics of food demand and production.

In fact our preliminary analysis here is to show what might happen if climate change, technological change, and/or change in risk averse behaviour, as assumed in the scenarios below, would take place already before 2020, at current production structures and consumer behaviour. Large socio-economic changes globally, partly dependent or independent of climate change, may have relatively larger impacts on agriculture than mere climate change. This may be particularly true for Finland and other northern European countries since predicted increases in mean temperature and precipitation may not be harmful for agriculture, even the contrary. Hence we simply evaluate how opportunities and challenges, as well as subsequent adaptation options and policies (such as crop insurance), of climate change through crop yield means and variances affects Finnish agriculture. It is technically an easy task of taking into account different future states of global food markets and input and output prices in the sector model we use. However we need to evaluate the role of crop means and risks, and their appropriate modelling, before we shift to any more complex scenarios of many dimensions.

### **5.1. Increased mean yields**

We assume yields increased of 20 % for each crop 2010-2013 which relates to the possible climate change benefits in the temperate areas concluded in the several studies of the agricultural impacts of the climate change.

### **5.2. Increased yield variance**

We assume increase of crop revenue variance of 100% for each crop which relates to the climate change induced changes in the variability of the yields.

### **5.3. Increased crop yield means and increased variance**

We assume both the mean yield to increase by 20% 2010-2013 and the increased variance of crop revenues.

## 5.4. Crop insurance

Crop insurance program is simulated with the minimum yield level for winter wheat, rye and oilseeds which are the crops with highest variances in Finland. The level of the minimum yield is calculated on the national basis based on the national room for the manoeuvre of CAP subsidies (at maximum, 10% of CAP area support can be used in such production linked subsidies) which was 5,8 million euros in 2006.

If the same amount of money was paid for farmers through the crop insurance program it would result in lower variances and growing average contribution margins. That would be the consequence particularly for winter wheat, rye and oilseeds, whose yield and revenue variability is the greatest among all crops, especially in the north. The crop insurance induced responses in variance-covariance matrixes are presented in appendix 2.

We have selected only winter wheat, rye and oilseeds to be eligible for the crop insurance program in our scenario since they are the most interesting crops in terms of climate change adaptation, both in terms of increasing crop yield potential and in the sense of mitigating yield risk with certain adaptation measures. The yield development of rye and oilseeds have been poor in the last decades while recent sharp price fluctuations of oilseeds at the world market make the risk management of oilseeds interesting even in Finland.

## 6 Results

We simulate the land use changes in 2020 in Finland. The baseline assumes product prices and farm subsidies at 2006 level but assumes inflation of input prices by 1.8% per year, on the average, until 2020.

*In the first scenario (CIY)* we use to the same risk aversion parameter as in the baseline but we assume 20% increase of yield for each crop until 2013 to correspond the possible benefits from the climate change in temperate regions concluded in the several studies.

*In the second scenario (C2)* we assume increase of the risk aversion parameter by 100% implying the increase of the total covariance of crop contribution margins by 100 % to simulate the increased variability of the yields due to climate change (or risk increasing risk averse behaviour of farmers).

*In the third scenario (C2Y)* we assume both the increase of the total covariance of crop contribution margins by 100 % and the increase of crop yields by 20 %.

*We construct the fourth scenario (INS)* on the top of the second scenario C2. In the fourth scenario we assume the crop insurance program simulated with the minimum yield level for winter wheat, rye and oilseeds which are the most risky crops to product in Finland, especially in the northern areas. Even this kind of political instrument with modest cost effects can have essential impact on the variances of the contribution margins and expected profits of winter cereals and oilseeds (appendix 2).

In table 1 we have collected the production volumes of main products and the level of farm income as model outcomes in the different scenarios. We can see that most production lines,

such as milk and beef production are almost invariant to our scenarios. This is partly because of the milk quota system is still in place in our simulation until 2020 (while there exists only a decision to continue quotas up to 2015). However the milk quota system is not considerably restricting the milk and beef production except at the very last years before 2020 in scenarios where crop yields increase by 20%. The reason for this is that the CAP reform is challenging for dairy sector dominated by small scale dairy farms and the need of structural change and growth of farms in the context of high production costs. This imply that reductions in milk prices and decoupling of the compensatory milk payments provides significant incentives for increasing set-aside (253,000 ha in 2006 increasing up to 500,000 ha in the baseline until 2020), not for dairy or beef production investments endogenous in the DREMFA model.

**Table 1. Country-level changes in total cereal area (1000 hectares), milk production, pigmeat production (million kg) and farm income (Eur million) in 2020.**

	Base: C1	C1Y	C2	C2Y	INS
Cereals total	807	952	720	884	763
Grasslands	657	573	655	582	651
Set-aside	533	508	606	551	570
Milk prod.	2341	2398	2317	2398	2316
Beef	75	77	75	77	74
Pigmeat	171	287	169	242	169
Poultry meat	84	87	84	87	84
Farm income	771	906	769	883	765

Source: Own calculations.

However pig sector is able to utilise the increasing crop yields. Rapid structural change in the Finnish pig sector seems to make it possible to produce more value added and improve profitability by producing more barley, oats, and pigmeat, if crop yields increase. Even though the increased crop yield level increases profit per hectare relatively more in the case of wheat, rye and oilseeds, calculated at producer prices of crops, increasing profitability of exports of pigmeat due to cheaper feed grain makes feed grain relatively more competitive at the sector level. Revenues per hectare of feed grain are relatively less variable than revenues per hectare of wheat, rye or oilseeds. Even though the crop insurance decreases the revenue variability significantly for these crops they cannot compete with feed grain (Table 2).

One could expect a larger increase in farm income following 20% increase in the yield of each and every crop, assuming unchanged EU price level. However the increased production volume (only area allocations are presented in tables 1-2: production volumes increase in scenarios) decreases the domestic prices of most crops, especially those of food and starch potatoes due to very inelastic demand. For this reason the price reductions of crops and pigmeat slow down the increase in farm income. Nevertheless the most important reason why only few production lines are able to increase their production and exports is the high level of production costs relative to the 2006 EU prices. Hence only pig sector can significantly benefit from the sizable 20% yield increase.

**Table 2. Country-level land use changes (1000 hectares) in 2020.**

	Baseline	C1Y	C2	C2Y	INS
Spring wheat	14.0	46.1	15.9	37.4	13.6
Winter wheat	87.5	60.3	84.5	53.5	86.1
Rye	2.9	30.8	4.0	30.8	25.4
Barley	300.3	273.7	294.0	270.9	300.3
Malt barley	50.7	48.6	50.5	42.9	50.4
Oats	326.2	472.0	245.3	427.6	262.3
Mixed grain	25.1	21.0	25.9	20.9	24.9
Oilseeds	77.2	68.1	77.0	66.6	75.6
Potatoes	31.9	26.8	32.0	26.8	32.0
Cultivated land, total	1592.1	1640.5	1503.5	1578.5	1540.4
Set-aside	533.1	508.1	606.1	550.9	569.6
Unused land <sup>*)</sup>	68.3	44.9	83.8	64.1	83.5

\*) In the Dremfia model the land rent may become negative in some region which implies that land is not used

1,835 million euros was spent on farm subsidies in Finland in 2006 (MTT 2007). Total farmland area is appr. 2.3 million hectares. Actively cultivated area was 1,966,000 hectares, excluding set-aside. This makes 919 euros per hectare of cultivated land. Paid subsidies per hectare of cereals was appr. 600 euros/ha, on the average. Considering the 5.8 million euros invested in crop insurance and the resulting increase in cereal area by 43,000 hectares in the equilibrium solution of scenario 4, one hectare increase of cultivated land area cost 134 eur. Implementing the same crop insurance on the baseline scenario would increase cereals area by 37,000 ha. What is remarkable, however, is that the area under winter wheat and oilseeds did not increase due to the insurance, but only rye area, and areas under oats and barley (feed grains). This effect is due to the high variance of contribution margins of oilseeds and winter wheat, and due to low covariance between feed grains and rye. Hence decreased variability of rye, winter wheat and oilseeds yields decreases the total variance of feed grains as well.

If the target is to maintain and develop agricultural production in a less favoured area such as Finland under climate change, crop insurance is increasingly competitive in terms of production effect. However such a production linked character of any farm support is questionable from the trade liberalisation point of view. In limited extent with no overcompensation, however, the production effects of risk reducing policies are relatively smaller than price supports or crop specific area payments currently dominating the national supports in Finnish agriculture.

## 7 Discussion and conclusions

This study evaluated effects of increasing crop yields and their variability on agricultural production and farm income in a less favoured northern area such as Finland. The increasing mean of feed crop yields may increase both crop and animal production, especially if domestic meat production, and related meat processing industry, is competitive and export prices of meat remain strong. On the other hand, in the case of some other crops, such as potatoes or oilseeds, whose demand is relatively inelastic, land area may clearly decrease

despite increasing yields. Increasing yields may not outweigh the implicit cost of high variance and hence some crops remain relatively unprofitable.

Crops such as oilseeds, rye and winter wheat have relatively high variance and hence yields of these crops and/or their variance should decrease significantly before these crops may take more land area from the dominant feed crops in Finland. It seems that a very significant crop insurance scheme for these crops is not enough to significantly increase their competitive position to feed grains. Hence one can conclude that increasing mean and variance of crop yields, triggered by climate change, for example, may increase production of only few crops in Finland. Consequently, increasing crop yields due to technological change or climate change may result in increased specialisation of production and trigger major changes on the production structure of agriculture.

Farm income is relatively little affected by higher crop yields, on the average, while income may increase significantly on some individual farms. Profits would increase most in pig farms. However there would be increase in profits due to cost savings on crop farms as well since more output could be produced on a smaller area. Since the initial level of production costs are high in Finland the cost savings would not materialise in any significant increase in farm income, but the main part of the increased profit to agriculture would be earned in export markets of pigmeat, if demand there remains strong.

Our preliminary analysis also shows that appropriate policy measures aimed at reducing crop risks are not production neutral but even relatively efficient in increasing or sustaining production of many crops. Even if policy measures for reducing risks are commonly perceived less production-linked compared to price and area based subsidies, we show that their impact on production volume is not negligible even in less favoured areas such as Finland, and these impacts will most likely increase in on-going climate change.

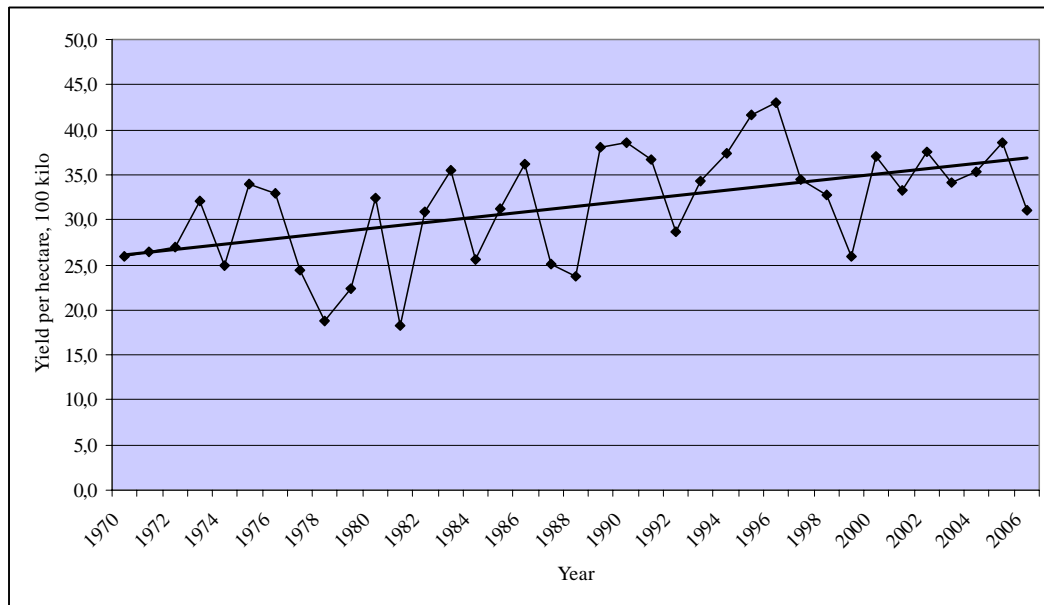
In further research we need to test alternative approaches for better representation and modelling of crop risks. Our simple mean-variance approach, embedded in a multi-regional sector model of agriculture, is not likely to be adequate for weather related crop risks. Historical time series on regional crop yields and the calculated variance-covariance –matrix of the contribution margins, may not provide a true picture of the pattern of crop risks, especially if magnified in a straightforward manner in climate change scenarios. Another starting point for crop yield variability could be crop specific theoretical yield models constructed by crop scientists. Adopting a simulated series of crop yield variability, observed yield data from regions (such as northern Germany) whose production conditions in terms of temperature and rainfall have been similar to those in Finland in climate change projections, may provide different alternative starting points. However the differences in soil types, pests, sunlight radiation conditions etc. makes it necessary to conduct economic crop risk analysis in cooperation with crop scientists. Nevertheless we feel that the optimisation and risk aversion are the techniques and assumptions necessary in capturing rational economic behaviour in the climate risk assessment frameworks.

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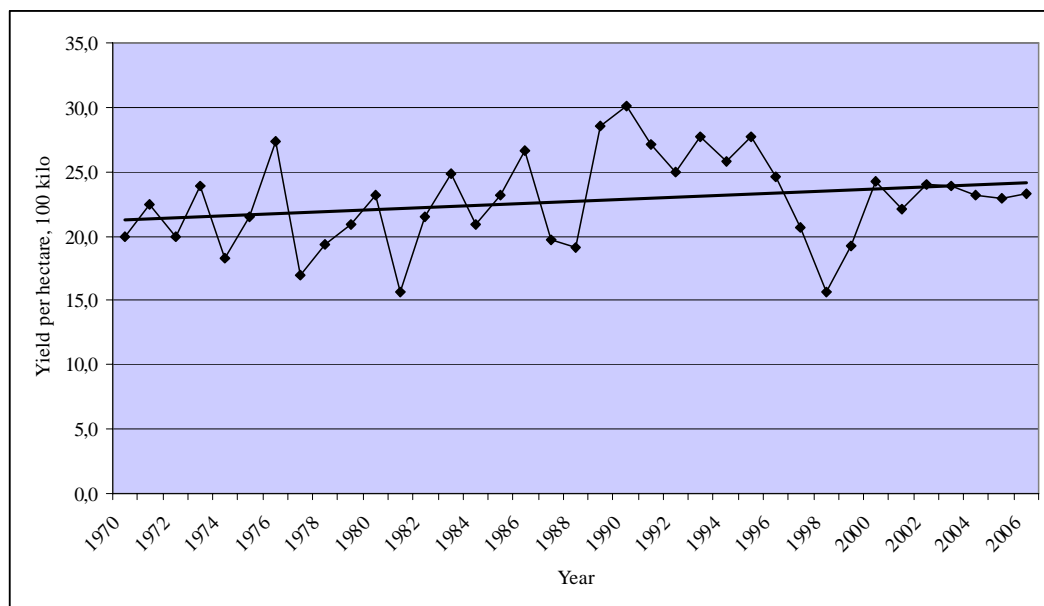
## Annex 1

**Figure 1: Yields of winter wheat in 1970-2006.**



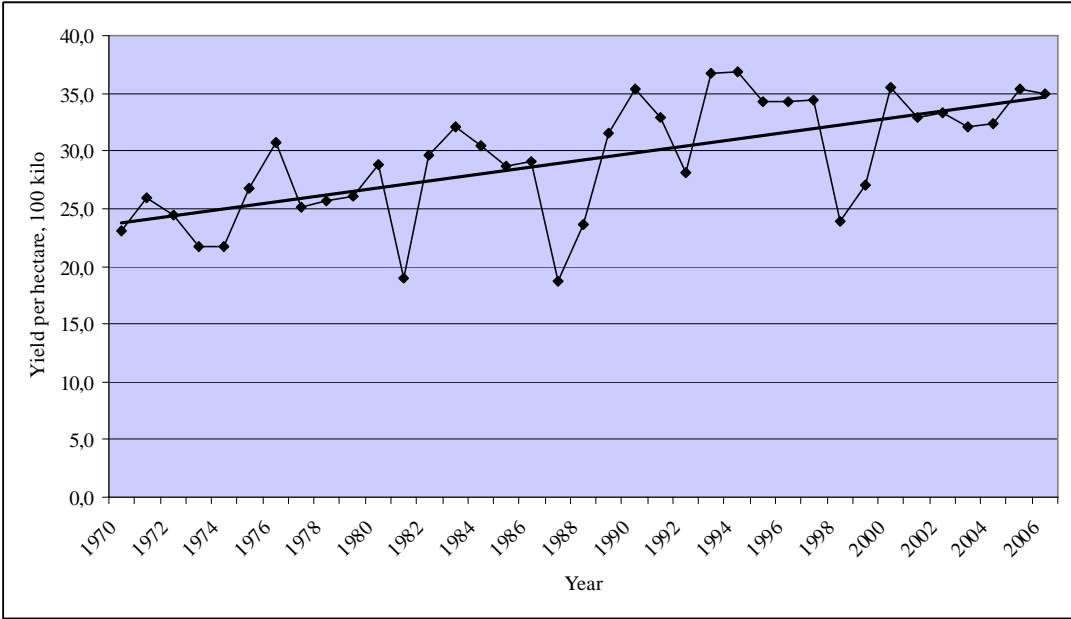
Source: MTT, 2007.

**Figure 2: Yields of rye in 1970-2006.**



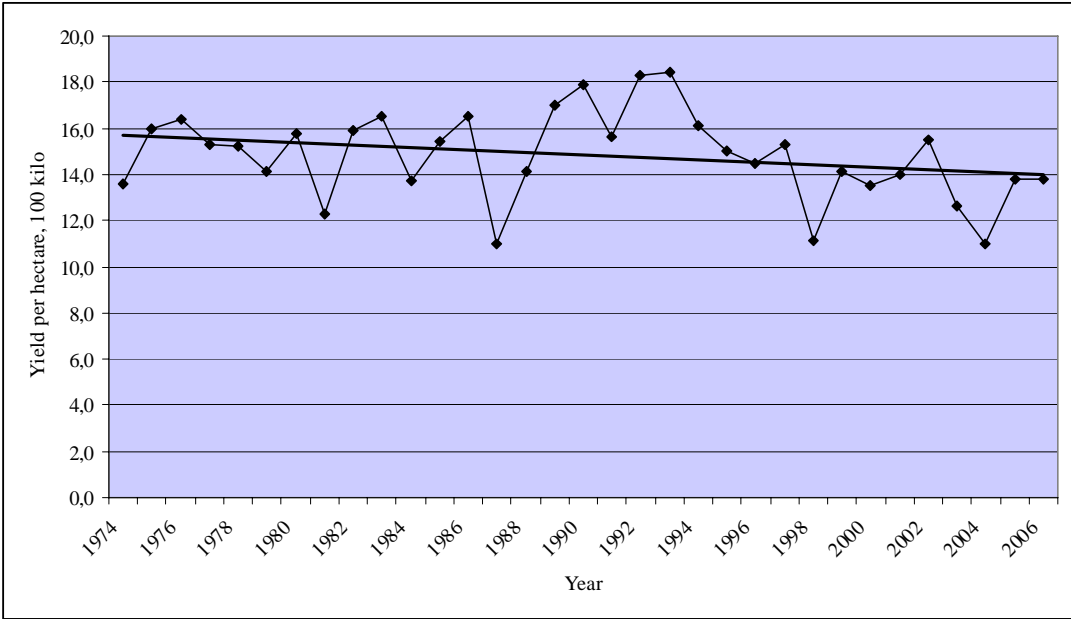
Source: MTT, 2007.

**Figure 3: Yields of barley in 1970-2006.**



Source: MTT, 2007.

**Figure 4: Yields of oilseeds in 1974-2006.**



Source: MTT, 2007.



## Annex 2

**Table 1: Variance-covariance matrix of the crop contribution margins in Uusimaa.**

Uusimaa	Spring wheat	Winter wheat	Rye	Barley	Malt barley	Oats	Mixed grain	Oilseeds	Greenfal
S.wheat	9021.7								
W.wheat	7478.4	10502.3							
Rye	1821.7	2883.0	8063.2						
Barley	3690.2	3186.9	1398.0	3167.1					
M. barley	7624.8	6350.0	2897.5	4413.7	9383.3				
Oats	6677.9	6372.1	1019.8	2675.5	5566.0	6364.3			
M. grain	6737.3	6418.0	853.9	2745.0	5650.2	5928.2	6611.4		
Oilseeds	8457.0	7895.8	7119.7	5050.1	9455.9	6283.3	6164.9	16393.9	
Greenfal	210.1	223.9	534.4	146.6	227.0	70.6	7.6	908.9	176.0
Aver.cont. margin*)	515.6	543.3	440.4	385.1	469.1	412.0	425.9	571.6	233.3
Aver.land use**)	44800.0	4725.0	4717.0	14940.0	22680.0	23117.0	550.0	11400.0	21373.0

\*) Average contribution margin of different crops in 1995-2006.

\*\*) Average land use of different crops in 1995-2006.

Source: Own calculations.

**Table 2: Variance-covariance matrix of the crop contribution margins in Satakunta.**

Uusimaa	Spring wheat	Winter wheat	Rye	Barley	Malt barley	Oats	Mixed grain	Oilseeds	Greenfal
S.wheat	6212.7								
W.wheat	4057.6	5179.5							
Rye	2838.2	3755.1	4572.3						
Barley	3094.7	1859.2	1610.8	3041.0					
M. barley	6577.3	4526.6	3498.0	3642.9	9671.3				
Oats	2424.5	1155.7	705.6	1884.6	2592.8	2211.3			
M. grain	2687.8	1433.9	903.3	2256.4	3236.7	1989.4	3041.0		
Oilseeds	5345.7	5350.7	5078.3	2298.1	6628.8	1840.3	1940.0	9376.7	
Greenfal	-300.4	-263.5	-317.1	-170.1	-508.0	-126.3	-205.0	-371.2	94.0
Aver.cont. margin *)	532.7	543.8	428.8	418.9	486.2	426.9	437.1	533.7	232.5
Aver. land use**)	4050.0	900.0	2533.0	43280.0	11720.0	43442.0	700.0	4608.0	13350.0

\*) Average contribution margin of different crops in 1995-2006.

\*\*) Average land use of different crops in 1995-2006.

Source: Own calculations.

**Table 3: Variance-covariance matrix of the crop contribution margins in Southern Ostrobothnia.**

Uusimaa	Spring wheat	Winter wheat	Rye	Barley	Malt barley	Oats	Mixed grain	Oilseeds	Greenfal
S.wheat	8167.2								
W.wheat	9632.6	47090.6							
Rye	2568.8	12425.8	12578.2						
Barley	3833.3	8088.1	3674.3	3636.2					
M. barley	4077.5	14730.8	9284.1	4085.5	12725.9				
Oats	4010.5	9318.2	3738.6	3014.2	4545.5	3818.9			
M. grain	3789.9	8049.5	4418.9	3036.2	5112.2	3414.9	3938.3		
Oilseeds	3303.2	9787.5	3954.8	2674.3	3777.3	3253.6	3159.5	4657.2	
Greenfal	-302.6	-8.4	30.6	-68.8	-135.4	-65.6	-90.4	68.7	53.6
Aver.cont. margin*)	530.1	479.2	424.4	429.1	502.4	430.4	439.3	436.8	242.5
Aver. land use **)	3922.0	190.0	1450.0	62067.0	4600.0	57833.0	2050.0	10308.0	21880.0

\*) Average contribution margin of different crops in 1995-2006.

\*\*) Average land use of different crops in 1995-2006.

Source: Own calculations.

**Table 4: Variance-covariance matrix of the crop contribution margins in North Savo.**

Uusimaa	Spring wheat	Winter wheat	Rye	Barley	Malt barley	Oats	Mixed grain	Oilseeds	Greenfal
S.wheat	14787.3								
W.wheat	12665.3	58733.1							
Rye	9299.4	12540.4	12116.5						
Barley	6817.1	8667.8	4297.1	5232.3					
M. barley	6831.1	-352.2	-336.3	2975.9	20166.6				
Oats	6413.6	6879.8	3627.9	3977.7	4270.0	4117.3			
M. grain	6050.4	7575.7	3054.2	4176.3	4573.7	3926.7	4681.6		
Oilseeds	3462.1	5972.7	2360.9	3664.3	339.6	2897.1	3395.2	5680.6	
Greenfal	-41.3	80.2	-72.6	74.7	-325.3	17.0	22.8	173.5	39.2
Aver.cont. margin*)	422.2	407.9	327.9	362.2	436.8	385.4	404.9	424.0	204.2
Aver. land use **)	808.0	100.0	617.0	26225.0	100.0	15567.0	358.0	642.0	7000.0

\*) Average contribution margin of different crops in 1995-2006.

\*\*) Average land use of different crops in 1995-2006.

Source: Own calculations.

**Table 5: Variance-covariance matrix of the crop contribution margins in Northern Ostrobothnia.**

Uusimaa	Spring wheat	Winter wheat	Rye	Barley	Malt barley	Oats	Mixed grain	Oilseeds	Greenfal
S.wheat	62109.3								
W.wheat	19926.4	76243.2							
Rye	10349.1	12544.9	5390.4						
Barley	14680.2	5594.0	3343.0	5137.8					
M. barley	21927.3	11198.6	1505.2	3227.2	34036.7				
Oats	16469.4	2032.8	2809.8	4808.0	4303.7	6257.7			
M. grain	16715.5	2430.5	2891.5	4884.7	4494.9	5810.3	6425.8		
Oilseeds	18646.3	4026.0	3369.0	6013.5	1277.4	6266.9	6322.3	11297.6	
Greenfal	-46.5	-90.1	92.7	76.7	-858.9	59.4	57.3	184.1	39.2
Aver.cont. margin*)	519.8	389.4	306.0	387.4	480.8	409.9	425.0	402.0	204.2
Aver. land use**)	2044.0	200.0	950.0	52950.0	120.0	25925.0	3600.0	1550.0	14660.0

\*) Average contribution margin of different crops in 1995-2006.

\*\*) Average land use of different crops in 1995-2006.

Source: Own calculations.

**Table 6: Variance-covariance matrix of the crop contribution margins in Uusimaa under the crop insurance program.**

Uusimaa	Spring wheat	Winter wheat	Rye	Barley	Malt barley	Oats	Mixed grain	Oilseeds	Greenfal
S.wheat	9021.7								
W.wheat	5276.2	7438.9							
Rye	1990.6	2932.1	7586.1						
Barley	3690.2	2548.4	1687.7	3167.1					
M. barley	7624.8	4666.4	3164.9	4413.7	9383.3				
Oats	6677.9	4454.6	1089.2	2675.5	5566.0	6364.3			
M. grain	6737.3	4499.1	927.1	2745.0	5650.2	5928.2	6611.4		
Oilseeds	7781.1	5282.2	7359.2	4785.9	9095.6	5655.4	5542.9	15545.9	
Greenfal	210.1	120.3	590.7	146.6	227.0	70.6	7.6	856.1	176.0
Aver.cont. margin*)	515.6	551.7	446.5	385.1	469.1	412.0	425.9	508.5	233.3
Aver.land use**)	44800.0	4725.0	4717.0	14940.0	22680.0	23117.0	550.0	11400.0	21373.0

\*) Average contribution margin of different crops in 1995-2006.

\*\*) Average land use of different crops in 1995-2006.

Source: Own calculations.

**Table 7: Variance-covariance matrix of the crop contribution margins in Satakunta under the crop insurance program.**

Uusimaa	Spring wheat	Winter wheat	Rye	Barley	Malt barley	Oats	Mixed grain	Oilseeds	Greenfal
S.wheat	6212.7								
W.wheat	3418.5	3746.7							
Rye	1619.5	2436.8	2943.0						
Barley	3094.7	1392.7	501.6	3041.0					
M. barley	6577.3	4018.9	2337.5	3642.9	9671.3				
Oats	2424.5	925.4	-118.0	1884.6	2592.8	2211.3			
M. grain	2687.8	1252.2	137.6	2256.4	3236.7	1989.4	3041.0		
Oilseeds	4700.7	4174.5	3455.6	1694.9	6094.4	1353.5	1495.1	7789.7	
Greenfal	-300.4	-283.8	-253.6	-170.1	-508.0	-126.3	-205.0	-355.5	94.0
Aver.cont. margin*)	532.7	549.5	437.2	418.9	486.2	426.9	437.1	540.9	232.5
Aver.land use**)	4050.0	900.0	2533.0	43280.0	11720.0	43442.0	700.0	4608.0	13350.0

\*) Average contribution margin of different crops in 1995-2006.

\*\*) Average land use of different crops in 1995-2006.

Source: Own calculations.

**Table 8: Variance-covariance matrix of the crop contribution margins in Southern Ostrobothnia under crop insurance program.**

Uusimaa	Spring wheat	Winter wheat	Rye	Barley	Malt barley	Oats	Mixed grain	Oilseeds	Greenfal
S.wheat	8167.2								
W.wheat	3382.9	4396.7							
Rye	259.3	930.3	8413.6						
Barley	3833.3	1524.5	1566.0	3636.2					
M. barley	4077.5	2147.1	6417.1	4085.5	12725.9				
Oats	4010.5	2133.7	1756.4	3014.2	4545.5	3818.9			
M. grain	3789.9	1524.4	2521.4	3036.2	5112.2	3414.9	3938.3		
Oilseeds	2635.9	2392.0	2231.9	2143.9	3748.2	2614.6	2589.0	3533.5	
Greenfal	-302.6	-35.4	37.1	-68.8	-135.4	-65.6	-90.4	68.7	53.6
Aver.cont. margin*)	530.1	495.5	439.7	429.1	502.4	430.4	439.3	448.5	242.5
Aver. land use**)	3922.0	190.0	1450.0	62067.0	4600.0	57833.0	2050.0	10308.0	21880.0

\*) Average contribution margin of different crops in 1995-2006.

\*\*) Average land use of different crops in 1995-2006.

Source: Own calculations.

**Table 9: Variance-covariance matrix of the crop contribution margins in North Savo under crop insurance program.**

Uusimaa	Spring wheat	Winter wheat	Rye	Barley	Malt barley	Oats	Mixed grain	Oilseeds	Greenfal
S.wheat	14787.3								
W.wheat	6082.8	4495.7							
Rye	7189.1	3907.2	7773.0						
Barley	6817.1	2809.5	3150.8	5232.3					
M. barley	6831.1	3584.4	-825.3	2975.9	20166.6				
Oats	6413.6	2571.3	2388.4	3977.7	4270.0	4117.3			
M. grain	6050.4	2418.4	1842.7	4176.3	4573.7	3926.7	4681.6		
Oilseeds	3110.5	1542.4	1508.7	3251.5	-165.7	2490.8	2926.9	4417.7	
Greenfal	-41.3	-130.1	9.9	74.7	-325.3	17.0	22.8	173.5	39.2
Aver.cont. margin*)	422.2	456.6	389.9	362.2	436.8	385.4	404.9	437.8	204.2
Aver. land use**)	808.0	100.0	617.0	26225.0	100.0	15567.0	358.0	642.0	7000.0

\*) Average contribution margin of different crops in 1995-2006.

\*\*) Average land use of different crops in 1995-2006.

Source: Own calculations.

**Table 10: Variance-covariance matrix of the crop contribution margins in Northern Ostrobothnia under crop insurance program.**

Uusimaa	Spring wheat	Winter wheat	Rye	Barley	Malt barley	Oats	Mixed grain	Oilseeds	Greenfal
S.wheat	62109.3								
W.wheat	9217.7	7614.9							
Rye	3707.1	3359.1	3929.0						
Barley	14680.2	2213.2	995.2	5137.8					
M. barley	21927.3	9437.0	885.4	3227.2	34036.7				
Oats	16469.4	1857.7	267.7	4808.0	4303.7	6257.7			
M. grain	16715.5	2029.7	317.7	4884.7	4494.9	5810.3	6425.8		
Oilseeds	12531.1	-94.8	-301.4	3565.2	1264.7	3938.8	3970.8	6110.0	
Greenfal	-46.5	-184.8	27.6	76.7	-858.9	59.4	57.3	116.2	39.2
Aver.cont. margin*)	519.8	421.1	347.4	387.4	480.8	409.9	429.9	402.0	204.2
Aver. land use**)	2044.0	200.0	950.0	52950.0	120.0	25925.0	3600.0	1550.0	14660.0

\*) Average contribution margin of different crops in 1995-2006.

\*\*) Average land use of different crops in 1995-2006.

Source: Own calculations

**Table 11: Regional increases in the expected crop contribution margins due to the crop insurance scheme.**

	Uusimaa	Satakunta	South.Ostroboth.	North Savo	North.Ostroboth.
Spring wheat	1	1	1	1	1
Winter wheat	1.021	1.016	1.045	1.159	1.096
Rye	1.017	1.022	1.048	1.273	1.160
Barley	1	1	1	1	1
Malt barley	1	1	1	1	1
Oats	1	1	1	1	1
Mixed grain	1	1	1	1	1
Oilseeds	1.026	1.003	1.034	1.041	1.088
Greenfal	1	1	1	1	1

Source: Own calculations