Finnish Environment Institute Mimeographs

335

The practice and process of adaptation in Finnish agriculture

Mikael Hildén, Heikki Lehtonen, Ilona Bärlund, Kaija Hakala,
Timo Kaukoranta, Sirkka Tattari

FINADAPT Working Paper 5

FINNISH ENVIRONMENT INSTITUTE

THE PRACTICE AND PROCESS OF ADAPTATION IN FINNISH AGRICULTURE

Mikael Hildén[1], Heikki Lehtonen[2], Ilona Bärlund[1], Kaija Hakala[3], Timo Kaukoranta[3], Sirkka Tattari[1]

FINADAPT WORKING PAPER 5

[1] Finnish Environment Institute (SYKE), Box 140, FIN-00251, Helsinki, Finland
[2] MTT Agrifood Research Finland, Economic Research, 00410 Helsinki
[3] MTT Agrifood Research Finland, Plant Production Research, 31600 Jokioinen

This publication should be cited as:

Hildén, M., Lehtonen, H., Bärlund, I., Hakala, K., Kaukoranta, T. and Tattari, S. 2005. The practice and process of adaptation in Finnish agriculture. FINADAPT Working Paper 5, *Finnish Environment Institute Mimeographs 335*, Helsinki, 28 pp.

Preface

The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities"[1]. The IPCC lists two reasons why adaptation is important in the climate change issue. First, an understanding of expected adaptation is fundamental in evaluating the costs or risks of climate change. Second, adaptation is a key response option or strategy, along with mitigation. Even with reductions in greenhouse gas emissions, some climate change is regarded as inevitable, and it will be necessary to develop planned adaptation strategies to deal with the associated risks as a complement to mitigation actions.

In Finland, there has been substantial progress during the past decade in investigating the potential impacts of climate change on natural and human systems. In contrast, there has been much less attention paid to adaptation. This was recognised by the Finnish Parliament as early as 2001, when it recommended that a separate programme for adaptation to climate change be initiated. As a result, a task force co-ordinated by the Ministry of Agriculture and Forestry completed Finland’s first National Strategy for Adaptation to Climate Change in 2005.[2]

At about the same time as the Strategy document was being drafted, a research consortium named FINADAPT also began its work. The goal of the consortium, involving 11 partner institutions co-ordinated by the Finnish Environment Institute, was to undertake an in-depth study of the capacity of the Finnish environment and society to adapt to the potential impacts of climate change. FINADAPT was funded for the period 2004-2005 as part of the Finnish Environmental Cluster Research Programme, co-ordinated by the Ministry of the Environment. It comprised 14 work packages (WP) covering: 1) co-ordination, 2) climate data and scenarios, 3) biodiversity, 4) forests, 5) agriculture, 6) water resources, 7) human health, 8) the built environment, 9) transport, 10) energy infrastructure, 11) tourism and recreation, 12) economic assessment, 13) urban planning, and 14) a stakeholder questionnaire. The primary objective of FINADAPT was to produce a scoping report based on literature reviews, interactions with stakeholders, seminars, and targeted research.

This report addresses the potential role of climate change in affecting the development of Finnish agriculture during future decades. Agricultural activities are directly exposed to climatic variability on a year-to-year basis, but the current pattern of agricultural production in Finland is strongly influenced by socio-economic policies originating in Brussels. This work package 5 study attempts to disentangle the roles of environment, policy, economics and farm-level decision-making in influencing the present and future adaptive capacity of the sector under a changing climate.

Timothy Carter, Consortium Leader
Helsinki, December 2005

---

[1] IPCC, 2001. *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken, and K.S. White (eds)]. Cambridge University Press, Cambridge and New York, p. 982.
[2] MMM, 2005. *Ilmastomuutoksen kansallinen sopeutumisstrategia* (Finland's National Strategy for Adaptation to Climate Change) [Marttila, V., Granholm, H., Laanikari, J., Yrjölä, T., Aalto, A., Heikinheimo, P., Honkatuki, J., Järvinen, H., Liski, J., Merivirta, R. and Paunio, M. (eds)], Ministry of Agriculture and Forestry, Helsinki (available in Finnish, 276 pp., Swedish 212 pp. and English, 280 pp.) http://www.mmm.fi/sopeutumisstrategia/

Table of contents

Preface .... **i**

Table of contents .... **iii**

Executive Summary **1**

1. Introduction **5**

2. Scenarios and assumptions **5**

3. Impacts of climate change **6**
3.1. Biophysical changes 7
3.2. Economic impacts: a simplified preliminary economic analysis of climate change impacts on Finnish agriculture 9
3.2.1. Method for analysing economic factors 10
3.2.2. The results of the economic analysis 10
3.3. Environmental impacts of agriculture under climate change 12

4. Adaptation in agriculture **14**
4.1. Adaptation and coping capacity 14
4.2. Key factors affecting adaptation in agriculture 15
4.3. Rationales for interventions in the adaptation process 18
4.4. Consequences of adaptation in agriculture 18
4.4.1. Expanding or contracting agriculture? 18
4.4.2. Greater or smaller environmental impacts? 20
4.5. Planning for adaptation 20

5. Research needs and priorities **22**
5.1. Impacts 22
5.2. Adaptation 22

6. Conclusions **23**

7. Acknowledgements **23**

8. References **24**

THE PRACTICE AND PROCESS OF ADAPTATION IN FINNISH AGRICULTURE

Mikael Hildén[1]*, Heikki Lehtonen[2], Ilona Bärlund[1], Kaija Hakala[3], Timo Kaukoranta[3] and Sirkka Tattari[1]

[1]Finnish Environment Institute (SYKE), Box 140, 00251 Helsinki
[2]MTT Agrifood Research Finland, Economics Research, 00410 Helsinki
[3]MTT Agrifood Research Finland, Plant Production Research, 31600 Jokioinen

*Corresponding author: mikael.hilden@ymparisto.fi

Executive Summary

Adaptation in agriculture has to be seen in a wider context

The agriculture sector in Finland is accustomed to adapting to external changes and pressures and can also be expected to adapt in the future. In a medium term perspective, the Common Agricultural Policy (CAP) and its measures, as well as other economic factors, are forceful drivers that are likely to have more significant impacts on agriculture in Finland than climate change. In the more distant future (> 20 years) climate change related impacts can become important, but they will not operate in isolation. When climate change and economic driving forces have synergies, rapid adaptation may occur. For example, when the development of agricultural practices that either attenuate negative effects of climate change or reinforce positive effects coincide with increased demand for crops that benefit from climate change, rates of adaptation will be high.

The present climate change scenarios do not appear to threaten agriculture in Finland. Under the most favourable circumstances, climate change might even increase yields in Finland. However, the expected impacts of climate change are not sufficient to relieve Finnish agriculture from other natural handicaps such as small and scattered field plots, the need for winter proof buildings and equipment, a long housing period in animal production, the seasonal nature of farm work and long distances to export markets from small domestic markets. For this reason a simple increase or decrease in yield alone is not very significant and will not, according to preliminary model-based analysis, have major structural effects on Finnish agriculture. There are complex interactions that come into play. For example, if an increased yield causes export of cereals to increase, the long distances to export markets and high per unit transport costs compared to current prices for cereals reduces the extra income for the agricultural sector considerably. The main conclusion is that even in the most favourable circumstances the climate change offers little *net* advantage, unless there are major changes in demand and prices of agricultural products. Therefore changes in e.g. the Asian consumption patterns and global food markets as well as demands for energy crops in export-oriented production areas are likely to be very significant.

Areas of slow adaptation in the agricultural sector

Despite the strong role of other external factors, there are certain parts, within the agricultural sector, where a spontaneous adaptation is likely to be too slow for avoiding adverse effects of climate change. Parts or aspects that are prone to insufficient spontaneous adaptation are:

- water management and drainage of fields
- agricultural infrastructure, including buildings
- agricultural technology
- long term plant breeding
- management of externalities such as measures against leaching of nutrients
- development of proper monitoring and measuring systems, and
- agricultural policy.

The challenge for agricultural policy-making is to adapt not only to climate change as such, but in particular to various forms of spontaneous adaptation that will occur within the agricultural sector. The driving forces behind spontaneous adaptation processes include, among others, general economic changes on the world market for agricultural products as well as national climate policy related changes, such as added emphasis on biofuels. If the agricultural policy, including the CAP, is too rigid, it may deter farmers from experimenting, which may slow down spontaneous adaptation or even in some cases lead to maladaptation.

For example, the current legislation in Finland restricts the land tenancy period to ten years only, while in many other EU countries such short tenancy periods are exceptional. The short tenancy period in Finland results in land tenure insecurity and provides little incentives for investments in drainage systems of fields or in improving soil quality. While the proportion under lease farming has increased up to 35% in Finland in the last ten years, the investments in drainage systems, as well as lime application on land, have decreased. The projected increase in annual precipitation by 30-40%, and an increasing probability of heavy rainfall and storms due to climate change require efficient drainage systems. Hence, farmers need appropriate economic incentives and a suitable institutional setting for making investments in drainage systems whose operating time is typically 50-100 years, if properly installed. This means that investing in insufficient drainage systems - i.e. in those systems which have worked well in history but may have problems in cases of heavy rainfalls - may already start to become costly for farmers during the next 20-30 years.

Information and research needs

It is important to recognize that adaptation is not only a technical but also a societal process, or rather an intricate joint process of technical and societal change interacting with each other. Thus one should evaluate which kind of institutional settings of land markets and policy measures are necessary to foster appropriate land management under changing climatic conditions. Farmers do not operate in isolation when planning measures to cope with weather-related effects. For example, the planning of drainage systems is dependent on the existence and state of water courses adjacent to fields and on the actions of other farmers. It might be necessary to evaluate whether the capacities of major waterways, which collect the run-off from field parcels, are sufficient to cope with more frequent heavy rainfall events. This could become important if large numbers of farmers simultaneously renovate their drainage systems, most typically built in the 1970s and 1980s. Any major bottleneck may cause economic losses and environmental harm. It may also be worthwhile to consider how much production is concentrated in areas very prone to flooding, such as those along rivers in Ostrobothnia. Since agricultural investments are made on a long-term basis and have many social and environmental consequences, it is important to understand how different incentives affect the development and to avoid incentives that may lead to maladaptation.

One key research challenge is to develop the use of information from other sectors in order to understand the broader context of change and adaptation in the agricultural sector. This means developing and using macro-models for the analysis of economic incentives, and integration of different policy objectives as a background for agricultural policy development both at the EU and the national levels. It also means bottom-up approaches, analyzing events and policy implications at the farm level, in order to understand the factors influencing the effectiveness of policy instruments and measures in reaching a broad, probably partly conflicting, set of goals. Studies of the production base, including the water management of fields, measures against nutrient leaching, etc. and the likelihood of success and risks associated with different crops, provide material for farm level analysis. The management of adaptation processes under a changing climate will require addressing farm-level issues such as land use, suitable crop species and varieties, consequences of extreme weather events, water management, protein self sufficiency, innovative use of set aside areas, and methodological development.

The Finnish National Adaptation Strategy (Marttila et al. 2005) has identified a set of research needs for the agricultural sector. The results of this study endorse these research topics, but there is also a need to identify specific knowledge gaps in order to initiate research projects.

A specific set of research tasks are related to ways of benefiting from climate change through adaptation. These include

- Planning for long term breeding and testing of winter hardiness in perennial horticultural crops to meet increasing demand for high-price products.
- Mapping of the capabilities of annual crops for adapting to longer growing seasons, especially in the spring - to utilize an earlier start of growth under long-daylight conditions.
- Identification of those crops and production systems, which are most likely to gain from climate change, and examination of incentive systems needed for making such crops attractive at farm level.
- Identification of cropping systems and land use practises to preserve and increase biodiversity in agricultural areas and on the fields.
- Compiling a comprehensive examination of short term changes (< 30 years) in biological productivity of field crops – in order to provide a basis for several other analyses, including bio-economic modelling.
- Research on how to create incentives that support innovations for adaptation.

Another set would specifically address need for adaptation to avoid potential adverse consequences of climate change, and also the environmental consequences of the spontaneous adaptation to climate change. These include

- Monitoring of changes in migratory pest and pathogen occurrence. Some of these changes may be a direct consequence of climate change affecting the geographical dispersion of pests and pathogens; others may be related to changes in the susceptibility of crops, cultivation areas or cultivation techniques.

- Analyses of alternative actions and costs for pest and pathogen management.
- Planning for cultivation and crop rotation methods that minimize losses of soil carbon, deterioration of soil structure, and leaching of nutrients and pesticides under changing climatic conditions.
- Adaptation to extreme weather events and their environmental consequences at different scales, varying from fields to watersheds.
- The consequences of changes in demand and subsidies that arise due to climate mitigation measures. For example, expanding biofuel production may within some areas compete for land use with food crops causing structural changes also in the food industry.

The overall conclusion of the study is that the agricultural sector has adapted to many different kinds of changes in the course of history. Climate change, in comparison with many rather sudden shifts in policy, is likely to be a slow process.

The actual form and extent of adaptation will be determined jointly by the external climatic changes, internal changes within the agricultural sector, including agricultural innovations, and external decisions that specify agricultural policies.

Research can support adaptation by demonstrating how agricultural and other policies create incentives or disincentives for innovative adaptation. The environmental impacts of alternative adaptive processes within the agricultural sector are also important to explore. Research is further needed to fill the substantial gaps concerning impacts of climate change.

Adaptation can under favourable conditions also meet other societal objectives, such as improving the sustainability and profitability of the agricultural sector. Feedback loops are of particular importance because they may accelerate or slow down adaptive processes. For example rigid systems of subsidies that are fixed to particular cultivars or agricultural practices will tend to slow down adaptation whereas systems that support innovativeness may speed it up.

1. Introduction

In Finland temperature is a major limiting factor for agricultural production along with nutrient levels and the water balance (Marttila et al. 2005). The most important projected changes affecting agriculture in Finland are: 1) increase in ambient temperatures, 2) increase in the atmospheric concentration of CO_2 and 3) increase in precipitation (Carter et al. 1996a; Mela et al. 1996; Marttila et al. 2005). In the absence of other confounding factors, these changes in climate alone would be expected to have significant effects on Finnish agriculture. Some impacts are expected to be beneficial, whereas others, such as an increasing prevalence of pathogens and proliferation of pests, can affect agriculture adversely.

Adaptation is defined as the process of adjusting to occurred and expected changes by exploiting advantages or minimizing adverse effects. Adaptation is not limited to coping with changes in climate. The agriculture sector in Finland is accustomed to adapting to all kinds of external changes and pressures. In a medium term perspective the Common Agricultural Policy (CAP) and its measures, as well as other economic factors, are forceful drivers that are likely to have greater impact on agriculture in Finland than climate change. In the more distant future (> 20 years) climate change related impacts can become important, but they will not operate in isolation.

This report will explore some of the likely key processes and possible feedbacks in Finnish agriculture under a changing climate. We will provide examples of the pressures requiring adaptation, and analyse the preconditions for successful adaptation, including their societal context. In addition we will examine the possible wider consequences of adaptation in terms of environmental effects. We will show that adaptation in agriculture is strongly dependent on economic and institutional factors and on the interaction between spontaneous adaptation and policy instruments.

The report has been developed as a co-operative effort between researchers from SYKE and MTT. In addition the report and its conclusion build on a seminar that the project organised on 7 September 2005, with 26 participants from the Ministry of Agriculture and Forestry, the Ministry of Environment, the food and fertilizer industry, university research, NGO, and the research institutes SYKE and MTT. Preliminary findings were presented and discussed at the seminar, where the main focus was on identifying research needs.

2. Scenarios and assumptions

In order to provide a context for research into adaptation to climate change in Finland in the FINADAPT project, three scenarios for the 21st century have been developed (Carter et al. 2005). The scenarios are labelled: Global Markets, assuming low greenhouse gas levels, high economic growth with rapid technological development (related to SRES A1T); Sustainability, assuming low greenhouse gas levels, sustainability goals with slower economic growth than Global Markets and rapid technological development (related to SRES B1); and Retrenchment, assuming high global greenhouse gas emissions, a world in blocs with unbalanced wealth, rapid population growth and obstacles to technological proliferation and trade (related to SRES A2).

The scenarios span four time frames (climatological averaging periods in brackets): present-day (1971-2000), near-term (1991-2020), mid-term (2021-2050), and long-term (2071-2100), and the requirements for adaptation are then treated as if they apply in 2005 (present-day), 2020, 2050 and 2100. Quantitative scenario information on population/demography, socio-economic development, climate, nitrogen deposition and land cover has been provided.

In order to examine adaptation and adaptation processes in Finnish agriculture it is necessary to view the general scenarios through agricultural lenses. This was achieved by examining which features of the scenarios were likely to have effects on agriculture, and through which mechanisms such effects may arise. The collective expertise of the authors and the insights presented in the seminar of September 7, 2005, provided a broad view of the scenarios.

The most relevant biophysical aspects of the FINADAPT scenarios concerning agriculture are related to climate (see also Ruosteenoja et al. 2005) and land cover. Climate scenarios indicate a rise in temperature and a shift in the precipitation pattern. The land cover scenarios, which discriminate between cropland, grassland and biofuel production areas, were developed using a methodology that is based on a qualitative interpretation of the SRES storylines for the European region, an estimation of the aggregate totals of land use change using various land use change models and the allocation of these aggregate quantities in space using spatially-explicit rules (Rounsevell et al. 2005). It can be assumed that changes in N deposition will not have an effect on fertilised agricultural land.

As argued above, adaptation in agriculture will also be affected by economic factors. In the *Global Markets scenario* (A1T) changes are assumed in EU agricultural policies and textile policies, causing textile and food prices to fall behind average inflation up to 2015. For agriculture in Finland this means adapting to world market prices and international trade in agricultural commodities. Non-food production may expand with increasing demands for energy.

In the *Sustainability scenario* (B1) sustainability criteria in trade and production are emphasised, implying less reduction in food, clothing and textile prices. The sustainability criteria may offer an additional competitive advantage for Finnish agriculture, provided that the need for control of pests and pathogens remains at or near present low levels compared to other regions. This may create incentives to find new profitable crops where this competitive advantage can be fully exploited, e.g. in herbs or spices.

In the *Retrenchment scenario* (A2) protectionist trade policies mean that prices of foodstuffs, textiles and clothing also diminish less in this scenario, whilst the larger global population growth causes more tensions for the markets of these products after 2015. For Finnish agriculture this could mean higher prices for products, but also for production factors. It is likely to stress a conservative approach with minimal efforts to make innovative changes in agricultural production, but a continued demand to reduce costs and increase productivity within existing structures.

3. Impacts of climate change

This section compiles knowledge from previous research on the impacts of climate change in three dimensions – biophysical factors, economics and environmental impact. The aim is to provide a general overview of how the impacts of climate change can be approached in the agricultural sector. It provides a basis for examining the adaptation processes in later sections.

3.1. Biophysical changes

The impacts of biophysical changes on agriculture were examined in detail during the Finnish Research Programme on Climate Change (SILMU) in the early 1990s and subsequently in various EU-funded projects (e.g. Carter et al. 1996a; Mela et al. 1996; Kleemola and Karvonen 1996; Carter et al. 2000; and summarised in Marttila et al. 2005). In these studies combinations of experimental work and comparisons with analogue regions were used. The analogue regions were chosen to reflect conditions that could arise also in Finland as a consequence of climate change.

A starting point is that the increase in ambient temperatures extends the growing season. A longer growing season allows cultivation of crop types and varieties with higher crop potential. Most of the cereal yield increase attributed to climate change in Finland results from this. Under most climate projections, by the second half of this century new crop plant species such as grain maize could become viable and might be taken into cultivation. On the other hand, with higher growing season temperatures the development of determinate crop plants, such as cereals, is accelerated, leading to lower yield of present-day cultivars. This effect is compensated by the positive effects on growth and water use of higher atmospheric CO_2 levels (see an example for spring wheat in Figure 1).

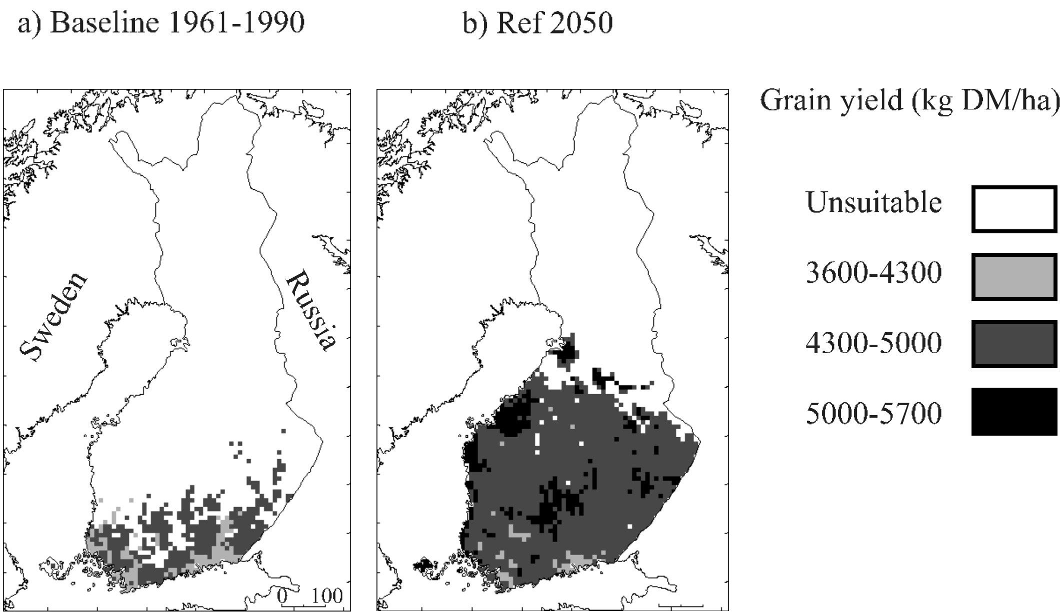


Figure 1 Simulated 30-year mean spring wheat yields: (a) baseline, 1961-1990; pCO_2 = 353 ppm and (b) GCM-based scenario for 2050 ; 515 ppm. Source: Carter et al. (2000).

Long spells of drought, estimated in some scenarios to occur during the growing season, perhaps together with heavy rainfall, could also be detrimental for many crops. Because of this, plants with an indeterminate growth habit such as grasses, potato and root crops, would probably benefit most from climate change. For example, under a growing season scenario of warming of about 2ºC, increased precipitation by 8% and CO_2 concentration of 515 ppm (similar to conditions projected for 2050 in all three FINADAPT scenarios), modelled tuber yields of potato were estimated to increase by over 50% on average nationally in Finland (Carter et al. 2000; Figure 2). Gains were substantially greater in the north than the south, where moisture stress becomes a constraint on growth in some years. Moreover, the coefficient of variation of modelled yields was halved, implying more reliable as well as higher yields.

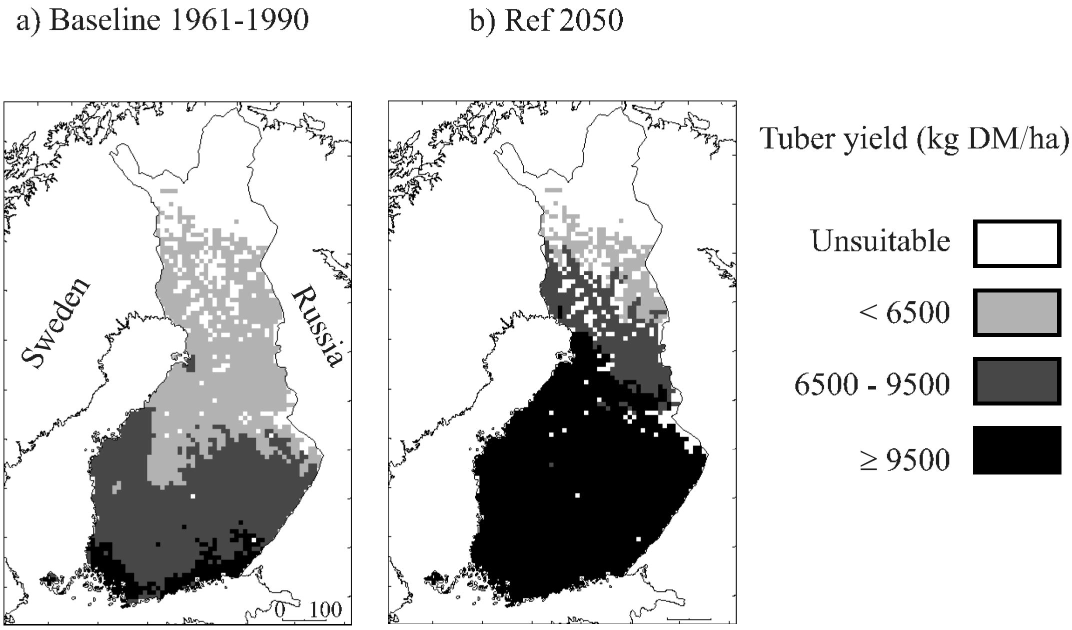


Figure 2 Simulated 30-year mean potato yields: (a) baseline, 1961-1990; CO_2 concentration = 353 ppm and (b) GCM-based scenario for 2050; CO_2 concentration = 515 ppm. Source: Carter et al. (2000).

Overwintering plants could also benefit from the high radiation levels of the spring, if the growing season starts earlier in the season. Fruit trees and bushes, as well as landscaping trees and bushes etc. will also benefit from climate change mainly because of milder winters and longer growing seasons. Warmer winters, again, may cause problems in overwintering through increases in winter pathogens, or disturbances in the dormancy of plants.

Both simple indices and detailed mathematical models have been utilised in Finland to assess the effects of climate change on crop growth. The research work includes estimates of the length of the thermal growing season, which has been observed to lengthen by about 10 days in southern Finland during the 20th century (Carter 1998), and model based analysis of biomass development and nutrient management of specific crops like spring barley (Kleemola and Karvonen 1996) or spring and winter wheat (Saarikko 1999).

An increase in atmospheric CO_2 concentrations promotes photosynthesis and biomass accumulation. Higher CO_2 also ameliorates the effects of drought, because the stomata of plants close partially at high CO_2, resulting in less water loss by the leaves. Increase in levels of O_3 will reduce the benefits gained by increases in the levels of CO_2. On the other hand, the partial closure of stomata in higher CO_2 concentrations, together with other possible interactions between CO_2 and O_3 are shown to reduce the damages caused by O_3 (Rao et al. 1995, McKee et al. 1997). In addition, e.g. with potato, the marked yield increase caused by higher CO_2 concentrations has shown to more than compensate for the less marked decrease in yield in higher O_3 concentrations (Craigon et al. 2002).

Higher temperatures accelerate microbial activity in the soil, resulting in increased mineralization, leaching of nutrients and combustion of organic matter. The effects will depend on cultivation practises and are counteracted by increased carbon and nutrient assimilation. With higher rainfall in the winter, problems with leaching of nutrients, diminishing organic matter and soil structure will increase, unless measures are taken to reduce the problems. Field work in wet conditions also would increase soil compaction. If ground frosts disappear, soil granular structure will suffer, especially in the clay soil regions typical of Finland.

The most significant problems created by climate change for crop production are pests, pathogens and weeds (Kaukoranta 1996; Carter et al. 1996b). With longer growing seasons and higher winter temperatures, pests would be able to produce more generations each year, and thus reproduce at a higher rate. Pathogens favour wet and warm conditions as well. With higher autumn temperatures, snow might fall on unfrozen soil, providing the pathogens with ideal conditions to proliferate. With no snowfall at all, the pathogen situation might be better, but overwintering plants would be exposed to lower temperatures than at present, or to alternations of melting and freezing of surface water, which would challenge their frost resistance and tolerance of anoxic conditions. With milder winters and longer growing seasons, new weeds may find suitable conditions to thrive.

Climate change would probably not affect animal production as much as plant production. There would of course be indirect effects, as cattle food consists mainly of plant-derived products. High temperatures could also affect some breeds of animals negatively. A longer pasture season would bring economic benefits for farmers with fields suitable for pasture.

One important aspect of climate change are the effects on the variability of conditions for production and the risks of yield failure. Milder winters and spring seasons may reduce the risks associated with early seeding, but extreme events during the growing and harvest seasons may increase the risks of yield failure. The magnitude and changes of these risks will depend on the choice of crops, the cultivation technology and the state of the soils, including drainage.

3.2. Economic impacts: a simplified preliminary economic analysis of climate change impacts on Finnish agriculture

Two highly simplified climate change scenarios can be used in order to obtain an indicative picture of how agricultural production in Finland responds to climate change. Let us assume that yields of all crops increase by either 20% (CC20%-scenario) or 10% (CC10%-scenario) by 2010 and then stabilise at these levels. Such rough assumptions are made for analytical purposes only, there are no *a priori* reasons for a crop yield gain of exactly 20% or 10% for each and every crop. However, an assumption that these increases would occur by 2010 saves us from building different scenarios of future agricultural policy reforms and other factors relevant for long-term agricultural development. Such factors need to be taken into account in a proper treatment of agricultural adaptation to climate change. These simplistic scenarios are meant to show that agricultural markets and relative profitability between agricultural products play a role in determining the effects of climate change, and that any analysis assuming observed static production structure is likely to be misleading.

While demand and prices of agricultural products are assumed to be unchanged in the EU the main question is how the markets will react to this supply shock in the long-term, i.e. which products are relatively more favoured and experience a sustained increase in production compared to the 2003-2004 situation. On the other hand, it is likely that increases in production of some other crops are not absorbed by the market at prices which cover long-term production costs and production linked agricultural support payments. Production of such products will decrease. Besides effects on animal production and land use, changes in farm income need to be evaluated.

Development of agricultural production under the CC20% and CC10% -scenarios are compared to the development of production in baseline scenario which assumes no climate change. It should be noted that the baseline scenario, as well as the two climate change scenarios, already include the 2003 CAP reform

3.2.1. Method for analysing economic factors

These effects are evaluated using a dynamic regional sector model of Finnish agriculture (DREMFIA) (Lehtonen 2001, 2004). DREMFIA is a dynamic recursive model for simulating agricultural production and markets from 1995 up to 2020. The model consists of two main parts: (1) a technology diffusion model which determines sector level investments in different production technologies; (2) an optimisation routine simulating annual production decisions (within the limits of fixed factors) and price changes, *i.e.* supply and demand reactions, by maximising producer and consumer surplus subject to regional product balance and resource (such as land and capital) constraints as well as certain constraints of animal biology. Production activities include number of different animals, hectares under different crops and set-aside, feed diet composition, chemical and manure fertilizer use and the resulting crop yield level.

3.2.2. The results of the economic analysis

The numerical results from the model are compared to a baseline (no climate change) in which there are some changes in production technology and regional location of production within Finland but only small changes in the overall volume of agricultural production nationally up to 2025. The results (Table 1) are also compared with the 2004 production levels since the baseline takes into account the production changes due to CAP reform and other factors.

Table 1 Production development under baseline and simplified climate change scenarios relative to actual production levels in 2004.

	Actual 2004	Baseline 2025[a]	CC10% 2025 – yields +10%[b]	CC20% 2025 – yields +20%[b]
Wheat (1000 ha)	225	122 (-45%)	119 (-2%)	160 (+31%)
Rye (1000 ha)	31	0 (-100%)	0	0
Other cereals (1000 ha)	965	880 (-9%)	931 (+6%)	980 (+11%)
Cereals total area (1000 ha)	1221	1000 (-18%)	1050 (+5%)	1140 (+14%)
Oilseeds (1000 ha)	75	60 (-20%)	54 (-10%)	55 (-8%)
Sugarbeet (1000 ha)	29	24 (-17%)	25 (+4%)	25 (+4%)
Grass (1000 ha)	618	500 (-19%)	480 (-4%)	450 (-10%)
Potatoes (1000 ha)	29	28 (-3%)	27 (-4%)	25 (-11%)
Set-aside (1000 ha)	220	580 (+163%)	560 (-3%)	500 (-14%)
Milk (million litres)	2304	2320 (+0.1%)	2386 (+3%)	2397 (+3%)
Beef (million kg)	91	73 (-20%)	74 (+1%)	74 (+1%)
Pork (million kg)	198	175 (-12%)	264 (+51%)	282 (+61%)
Poultry meat (million kg)	87	86 (-1%)	88 (+2%)	89 (+3%)
Eggs (million kg)	57	55 (-4%)	55 (+0%)	55 (+0%)
Farm income (million euros)	941	990 (+5%)	1096 (+11%)	1181 (+19%)

a Percentage changes are relative to 2004; b percentage changes are relative to 2025 baseline

The results indicate an increase in the production volume of cereals, though by less than 20%. This is because increased production lowers prices in Finland. Prices of crop products typically decrease by 5-15%, and potato prices, in particular, decrease relatively more than the production expands. Domestic prices in Finland decrease regardless of the common EU markets because transportation costs of crop products, especially those of cereals, are large relative to the value of the product.

The main contributor to the projected increase in farm income under the simplistic climate change scenarios is efficient pig meat production, which expands rapidly when cheaper feed grain becomes available. It seems that the increased yield level is utilised for the production of the most competitive product on the exports markets. In both climate change scenarios the most competitive export product seems to be pig meat. This result, however, is conditional on the assumption (prevalent in the baseline and in both climate change scenarios) that significant investment support for animal farms will continue to be paid in the future. If not, the increase in farm income will be significantly less than 10%. Exporting cereals is not very profitable because of the high transportation costs relative to the product value.

The effect of a higher grass yield level has some positive effects on dairy production, which is nevertheless constrained by a quota system that is assumed to stay in place in the scenarios. However, in the baseline scenario the aggregate production falls well below the national quota, whereas under the climate change scenarios the quota is reached in almost all 18 production regions in the model. The higher crop yield level, however, is not enough to increase suckler cow production and hence the beef production gradually falls because of decreasing dairy cow numbers and increasing milk yields per dairy cow. The development of milk yield per dairy cow is assumed to be independent of climate change.

Animal production, especially pig and poultry production, concentrates more and more in the south-western part of Finland. Dairy production concentrates in the regions of Ostrobothnia and northern Savo. However, there are areas of concentrated dairy production scattered across all parts of the country. The concentration of production is somewhat exacerbated by the climate change, since higher crop yields facilitate sufficient feed production and higher animal density per hectare. For example, dairy and beef cattle farms need sufficient roughage production at a reasonable distance to a farm. Higher crop yields generally imply slightly higher land prices, especially in areas of concentrated production, but more concentrated production due to climate change may imply stable or even decreasing land prices in areas where production is decreasing. Nevertheless, even marginal land will not be abandoned or converted to forests as long as agricultural policies require that land be maintained in a good condition. The current value of support payments per hectare is far greater than the potential value of increasing crop yield due to climate change.

The conclusion of the numerical analysis is that production tends to increase in sub-sectors that are already relatively more competitive, such as pork. If there is no increase in demand or in product prices, crop yields alone do not provide any rapid increase in farm income. Farm income can increase only gradually as more capacity is built in the most competitive sectors. This, in turn, is dependent on the agricultural policies in the EU, i.e. the level of investment support available. It may be that support will be cut if production expands, which means that the increase of pork production and farm income (mainly on pig farms) predicted due to climate change can be seen to be a rather optimistic development path

Another conclusion is that higher crop yields do not have much effect on other natural handicaps in Finnish agriculture such as long distance to markets, fragmented fields, and need for costly infrastructure due to winter conditions. Hence stronger demand and higher market prices are necessary for any production expansion on most sub-sectors in Finnish agriculture. This increase in demand is more likely to arise in the *Global Markets* and *Sustainability* scenarios than in the *Retrenchment* scenario, because one driver for the expansion of the markets is the increasing wealth in Asia. However, the supply-demand conditions and potential for agricultural exports from Nordic countries, including Finland, also depend on the specific assumptions of trade policy in the Retrenchment scenario.

3.3. Environmental impacts of agriculture under climate change

Assessments of how climate change affects the environmental impacts of agriculture are relatively few. One relevant question is how erosion and nutrient losses are affected. Another set of questions is related to the impacts on biological diversity.

Studies of nutrients and soils have generally been specific to a given site or crop-soil combination. The results indicate that climate change may significantly increase the loss of soil and nutrients from agricultural land (e.g. Porter 1989, Favis-Mortlock 1994). Climate change may thus change agricultural soil quality by affecting soil carbon content, nutrient leaching and runoff. The increase of erosion of agricultural soils is closely connected to extreme climatic events, such as drought and flooding (Lemmen et al., 1999). Warmer winters may result in a decrease of protective snow cover which would enchance wind and water erosion and nutrient leaching (Lemmen & Warren, 1999). A recent study in Finland (Puustinen et al. 2005, submitted) confirms that warmer winters produce distinctively higher sediment and nutrient concentrations in the runoff water compared to "normal" winters (Figure 3).

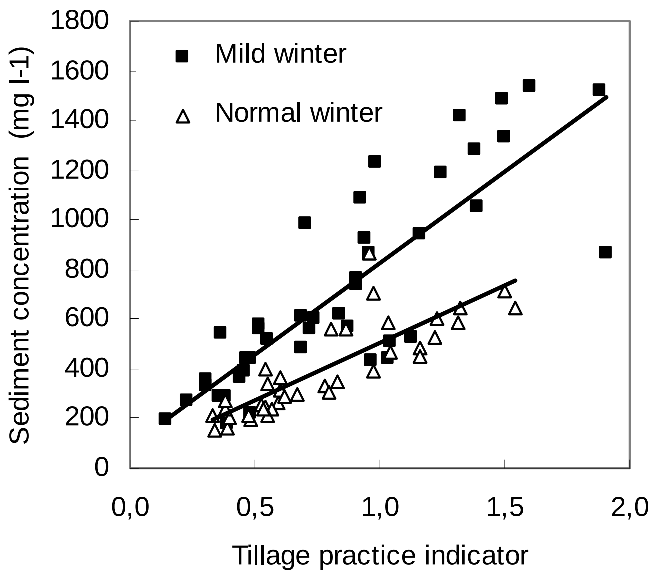


Figure 3 Sediment concentration in runoff grouped according to the type of winter. The x-axis indicates tillage practice: 0=permanent grass cover, 2=normal ploughing, 0-2: cultivation practices with increasing plant coverage such as winter wheat, stubble and direct drilling (Puustinen et al. 2005, submitted).

Typical combinations of slopes, soils, crops and climatic regions in Finland were analysed in a SILMU study on nitrate and particulate phosphorus losses using a modelling approach

(Kallio et al. 1997). The analysis assumed constant cropping patterns and cultivars. A possible increase in yields was only partly taken into account.

The results indicate that projected increases in precipitation and temperature are likely to increase the nitrogen loss from agricultural areas to surface waters, whereas particulate phosphorous losses would decrease. Nitrogen loss was predicted to increase particularly in south-western Finland. The main reasons for the increase are an acceleration of organic matter mineralization in agricultural soils and increased water flow through the soil column. At the same time particulate phosphorus losses decrease due to the shorter period of frozen soil and reduced snowfall, which both reduce surface runoff. Further results of the Water-SILMU research work are summarized by Lepistö et al. (Finadapt/WP 6: Water resources, Chapter 3).

The effects of climate change on the water quality of European rivers were explored within the EU project CHESS "Climate, Hydrochemistry and Economics of Surface-water Systems Water quantity" (contract ENV4-CT97-0440, CHESS Summary Report, 2001) using models operating at different scales. The climate scenarios used were: CSIRO-Mk2, ECHAM4, CGCM1 and HadCM2. Results show that some impacts can be large, e.g. the loss of the spring snowmelt causing high flows. Seasonal changes in nutrient losses can be significant, even if the annual change is small. The seasonal distribution of the flows in the baseline scenario is dominated by a flow peak due to the snow melting in March and April. This peak completely disappears in the future for all scenarios, as melting will take place during the whole winter. Consequently, the flows will increase by 40 to 80% from November to February. This is reinforced by a significant increase in the precipitation, especially for the ECHAM and CGCM scenarios. Summer flows remain largely unaffected by the climate change.

The hydrological changes have implications for agricultural land; fields with no crop cover between autumn ploughing and spring time sowing would be especially affected. The starting point is that in Europe nitrogen and phosphorus plant uptake tend to be dominated by a peak in May. Under the climate change scenarios, uptake after May decreases as a reduction in soil water limits plant growth. Overall plant uptake is nevertheless likely to increase due to the extended growing season.

At present, snow melt is the main cause of losses of dissolved and particulate nutrients. Under all climate change scenarios from 2050s onwards, the peaks in nutrient losses are reduced and move to the winter months. Overall nutrient losses can increase because higher soil temperatures will lead to additional mineralization of organic nitrogen in the soil. However, the final outcome in terms of nutrient losses will depend on how agricultural practices adapt to climate change.

Loss of biodiversity is one of the major impacts of Finnish agriculture (Hildén et al. 2005). This impact is the result of a loss of specific habitats such as meadows, pastures and landscape features such as open ditches. Climate change may on one hand improve conditions for species that live near their northern limit. For example, a significant number of butterfly species have returned to Finland during the recent period of warm climate (Toivonen et al. 2005). Also agricultural pests are likely to benefit from the change. Ultimately, however, the influence of climate change on the way agriculture affects biodiversity will depend on how agriculture adapts to the climate change.

4. Adaptation in agriculture

4.1. Adaptation and coping capacity

Adaptation is defined as the process of adjusting to changes that have already occurred or are expected to occur, by exploiting advantages or minimizing adverse effects. The adaptive capacity of Finnish agriculture has been considered to be rather high due to the generally short production time and the fairly broad tolerance to different weather conditions that characterise crops used in Finnish agriculture (Marttila et al. 2005).

In principle agriculture adapts to climate change just as it does to any other external change. At the farm level the objective is to maintain and preferably increase the viability and profitability of the farm. At a regional and national level the objective of adaptation will be to maintain a successful agricultural sector and to meet other societal goals such as those related to food security, rural livelihoods and biological diversity. At the national policy level the challenge is not only to adapt to climate change but also to adapt to the spontaneous adaptation that occurs in agriculture and to the changes that take place in the general increasingly globally operating environment. One can argue that the adaptive capacity has been empirically proven in the context of great agricultural policy changes in the last ten years due to EU integration. The complexity of the adaptive processes is depicted in Figure 4.

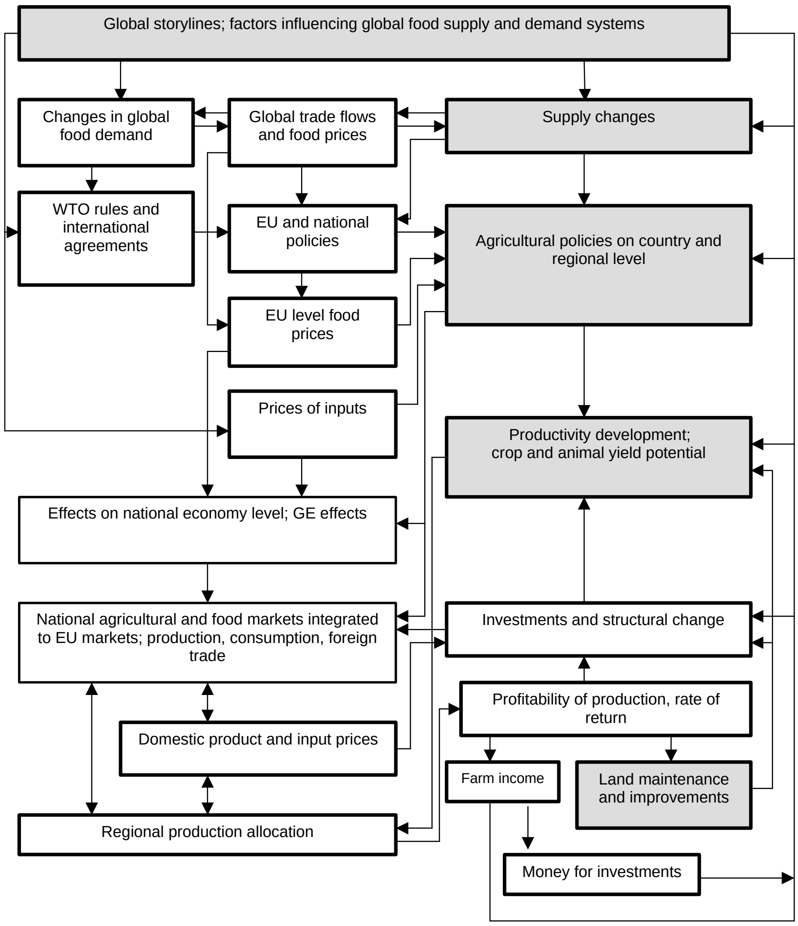


Figure 4 Drivers of agricultural production, food markets and policies, and some causal linkages. Areas where climate change and adaptation are likely to be dealt with explicitly are shown in grey. The adaptation process is complex because different levels and types of external signals that create incentives and needs to adapt are transmitted through many different pathways and linkages.

4.2. Key factors affecting adaptation in agriculture

A fundamental question is: *to what exactly will Finnish agriculture have to adapt?* As shown in section 3, the need will arise from a combination and interaction of bio-physical changes and economic and political changes. Some major options resulting from these combinations can be summarised as follows:

1. Severe drought in major grain producing areas in the world → increasing grain prices → increasing meat consumption→ opportunities for increasing grain and meat production in Finland
2. Improved crop varieties and cultivation practices improve quantity and quality of yields significantly in major production areas in the world → low grain and meat prices despite increasing food consumption → even lower prices if agricultural trade is considerably liberalised → pressure to decrease production in Finland despite increased crop yield levels.
3. Climate change and various adaptation measures make it possible to cultivate new plants and plant varieties in Finland → changes in relative profitability of crops and feed stuffs → possibly significant changes in land use and production volumes
4. Increasing meat consumption in Asia → increasing meat and grain prices → opportunities for increasing meat exports and production in Finland.

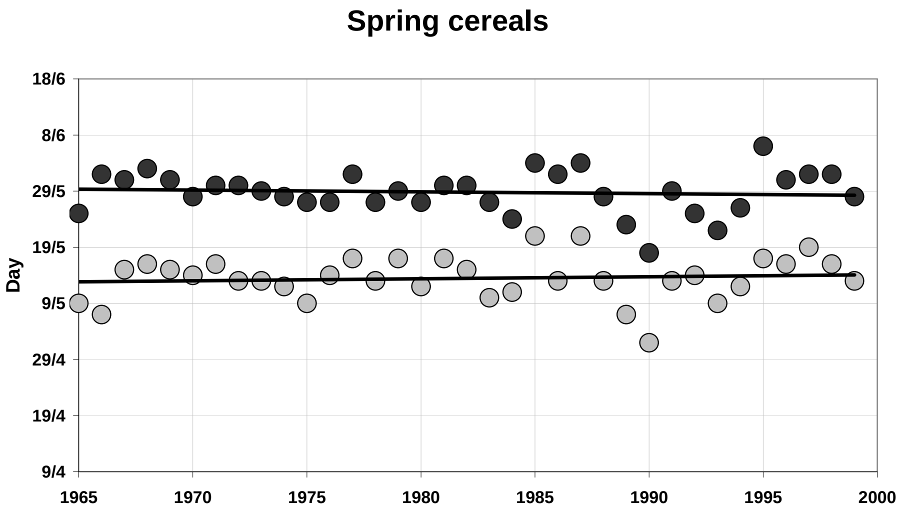
It is worth noting that the relevance of the options varies with the scenarios of global socio-economic development (cf. the different scenarios introduced in section 2). In addition, there is a set of natural conditions that creates an economic burden on agriculture in Finland and which therefore partly reduces the adaptive capacity and the resources available for adaptation. These include (Puurunen et al. 2004):

(i) The need for winter proof building and equipment solutions
(ii) The seasonal nature of farming work
(iii) The feeding of livestock (i.e. long housing period and high work load compared to outdoor grazing)
(iv) Long distances, small market (i.e. high per unit transportation costs, long distance to export markets)
(v) Small size of field parcels, fragmented field parcels and distances between field parcels

Many of these natural handicaps are not much relieved by the climate change. For example, climate change cannot improve the small size and fragmented structure of field parcels (v) which imply high labour use and hence high production costs per hectare. Also long distances (iv) are not affected by climate change. However, natural handicaps (i)-(iii) are partly relieved, but only marginally since basic building and equipment conditions must be in place even in slightly milder winter temperatures, and there will still be winter in Finland, even though a milder one. Overall, some cost reductions can nevertheless be obtained in points (i)-(iii).

Changes in agricultural policy and markets imply important changes in incentives for agricultural production and incentives to develop production. These changes are in many cases more fundamental and more deterministic by nature than the biophysical risks and potential benefits of climate change. Changes in the Common Agricultural Policy (CAP) and its measures, as well as in other economic factors, are also forceful drivers in the short-term and intermediate term that are likely to generate greater adaptation challenges for agriculture in Finland than climate change. Over a longer time span (> 20 years) climate related changes can become important for adaptation, but they are conditional on changes in agricultural policy and food markets.

For farmers, adaptation to climate change includes e.g. adaptation to a longer growing season and earlier start of the growing season. Generally farmers start to work in the fields as soon as they are in a suitable condition for tilling and cultivation. During the last four decades, however, the sowing dates of cereals haven't changed much despite warming of climate during this time. In contrast, sowing dates of potato have become earlier with time (Figure 5). This may be due to risks connected with earlier sowing of cereals (night frosts), while technology of potato cultivation has developed so that these risks can be controlled (e.g. growth under gauze), and perhaps also because of the additional profit that can be made with early yielding potatos. It is likely that similar processes will apply also in the future, adaptation to changing conditions will take place if investment in new technology and any other addtional work is paid off by a worthwhile return.



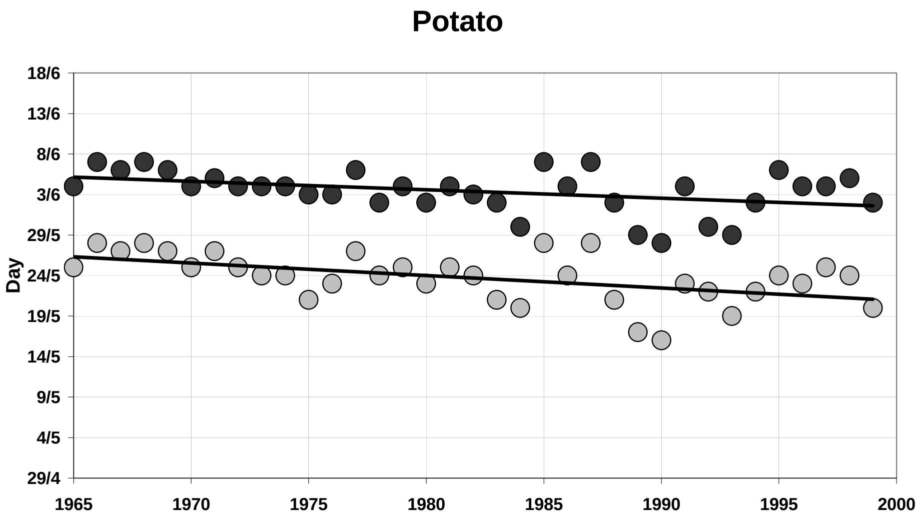


Figure 5 Average date of beginning and end of sowing of spring cereals (top) and potato (bottom) in Finland from 1965 to 1999. Upper trend lines are fitted through the latest sowings; lower trend lines the earliest sowings. Source: Information Centre of the Ministry of Agriculture and Forestry.

A longer growing season and changing weather conditions will also steer farmers' choice of crops and planning of land use. There will always be farmers that are more inclined to try a new promising crop than other farmers. Depending on the outcomes, the early adopter will or will not be followed by others. Mostly farmers’ decisions are outcome-driven. If new production possibilities provide better income prospects they will be readily accepted. Extension organizations or seed retailers and processing factories have a major role in encouraging farmers to step into the cultivation of new crops, when it becomes possible in the Finnish climate. An example of farmers' ability to adjust was the eager acceptance of a totally new crop, Camelina, in 2005, once it had been offered as a contract crop by a major milling and processing company.

A general hypothesis is that when biophysical and economic driving forces have synergies, rapid adaptation may occur. For example, crops and agricultural practices which benefit from climate change, and which are supported by the CAP, or are otherwise profitable, will spread rapidly. By contrast, a simple increase in yield alone may not be very significant if the market prospects are poor, the processing industry is not interested in product development and marketing, and agricultural supports are de-coupled from production. The value of increasing productivity in agriculture, whether induced by climate change or by technological innovations, is conditional on national and EU wide markets and agricultural policies.

Currently, the on-going and forthcoming agricultural policy changes until 2007 influence greatly the economic viability of many crops in Finland. For example, the cultivation of sugar beet, rye and oilseeds is sensitive to production-linked agricultural supports. One should realise that the market prices for these products do not even cover variable production costs in Finland. This means that elimination of all production-linked supports would make production of these crops commercially unattractive while the decrease in domestic production can be easily compensated by imports. Decreasing diversity of crop production in Finland means that knowledge and skills related to the cultivation and food processing of some specific crops may vanish which makes it difficult to utilise improving crop yield potential in the future. How the diversity of Finnish agriculture will be maintained until the positive effects of the climate change can be utilised depends, however, on the agricultural policy setting. If agricultural policy changes further de-couple support from production and lower import tariffs outside the EU, the profitability of some special crops will decline significantly and production may be replaced by imports. In other words, the agricultural policy decisions of the next 10 years may be very important for Finnish agriculture in terms of adaptation to climate change.

Assuming unchanged product prices and production technology and increased costs of protection against pests and pathogens, the net gain, if any, of climate change is likely to be relatively modest. However, the long time span of climate change makes it possible to develop new crop varieties, which can more efficiently exploit the increasing crop yield and quality potential. Then, if product prices increase due to large changes in the world and the EU food markets, the increased productivity potential may be valuable and provide market opportunities for Finnish agriculture.

One core aspect in agricultural adaptation is the relative profitability of food crop and bio-fuel crop production on agricultural land, since the two major lines of production compete on the same land resource. The increase in biomass yield potential due to climate change and possible high energy prices may make bio-fuel production relatively more profitable than food crops. Considering the abundance of agricultural land in Finland and the likely increase of set-aside land, the land available for bio-fuel production is likely to increase considerably. Long day conditions during the growing season make Finland an excellent potential producer of biomass for energy. A lengthening of the growing season, especially at the beginning of the season, will increase the growth potential even more. However, further analysis of how climate change will alter the relative position of Finland in bio-fuel production internationally requires more research.

4.3. Rationales for interventions in the adaptation process

From a policy point of view it is important to identify areas where spontaneous adaptation is likely to be too slow, to avoid adverse effects of climate change. These include the water management and drainage of fields, the infrastructure of agriculture including buildings, agricultural technology, long term plant breeding, management of externalities such as measures against leaching of nutrients, development of proper monitoring and measuring systems and agricultural policy itself. The challenge of agricultural policy is to adapt not only to climate change as such, but in particular to various forms of spontaneous adaptation that will occur within the agricultural sector. The reasons behind these other adaptation processes include general economic changes on the world market for agricultural products, and also parallel national climate policy related changes with the emphasis on e.g. biofuels. If agricultural policy, including the CAP, is too rigid, it may deter farmers from experimenting, which may slow down spontaneous adaptation or even in some cases lead to maladaptation.

For example, the current legislation in Finland restricts the land tenancy period to ten years only while in many other EU countries such short tenancy periods are exceptional. The short tenancy period in Finland results in land tenure insecurity and provides little incentives for investments in drainage systems of fields or in improving soil quality. While the proportion under lease farming has increased up to 35% in Finland, investments in drainage systems, as well as lime application on land have decreased in Finland in the last ten years. The projected increase in annual precipitation by 30-40%, and an increasing probability of heavy rainfall and storms due to climate change require efficient drainage systems. Hence, farmers need appropriate economic incentives and a suitable institutional setting for making investments in drainage systems whose operating time is typically 50-100 years, if properly installed. This means that investing in insufficient drainage systems – i.e. in those systems which have worked well in history but may have problems in cases of heavy rainfall - may already start to become costly for farmers during the next 20-30 years.

4.4. Consequences of adaptation in agriculture

4.4.1. Expanding or contracting agriculture?

According to various research results (Fischer et al. 2002; Fischer 2005, Rosenzweig and Parry 1994, Parry et al. 2004) conditions for crop cultivation will become more favourable in industrialised countries but will deteriorate in less-developed countries. The deterioration of production conditions may be severe in Africa and many parts of Latin America (Parry et al. 2004, Pingali 2004, Royal Society 2005). Furthermore, production conditions improve relatively more in northern Europe than elsewhere in Europe (Olesen and Bindi 2002). In western and central Europe climate change is expected to bring no significant changes, *in relative terms*, in crop yield levels. In southern Europe crop yield levels may deteriorate significantly due to increasing probability of serious droughts. This development would mean that the relative competitive position of northern Europe on food markets may improve considerably. At the first glance this might mean that agricultural production in northern Europe would expand significantly up to 2050 or 2080 and thus compensate for the decline of production in southern Europe. However, if there is any significant increase in crop productivity in western and central Europe independent of climate change the competitive position of Finnish agriculture may not improve at all.

Climate change is only one of the many factors influencing crop productivity. Ewert et al. (2005) point out that field crop yield levels have roughly doubled during 1961-2000 (see also Edmonds and Rosenberg 2005; Parry et al. 2004). During that period there were no significant changes in climatic conditions, at least comparable to the expected climate change up to 2050 and 2080. Although an increase in CO_2 concentration over the past few decades may have contributed to the yield increases (Jones and Carter 1992; Carter et al. 2000), technological change, i.e. new varieties, use of fertilisers and pesticides as well as improved cultivation practices, appear to explain most of the increases in field crop yields across Europe. However, these yield trends seem to be linear, which means decreasing relative yield growth over time. Simple extrapolation of the linear yield trends into the future means that the absolute annual gain in field crop yield level in western and central Europe *will remain* higher than in Finland. Hence the increase in crop revenues per hectare due to the yield trend will be lower in Finland compared to countries in western and central Europe. If the forecasted linear crop yield trend (calculated by Ewert et al. 2005) continues and technological change still dominates over climate change, the competitive position of Finland does not improve as a result.

The second reason for a lack of increase in Finnish agricultural production might be the relatively lower productivity potential in case of future price changes of agricultural products. Linear development of field crop yields in major producer countries in Europe, due to the dominance of technological change in crop yield development, implies an unchanging competitive position for Finnish agriculture. If Finnish agriculture is unable to gain any significant relative advantage in terms of crop yields, increase in food prices may stimulate production in central and western Europe relatively more than in Finland. Nevertheless, the very long-term supply response of central and western European agriculture depends on the relative attractiveness of non-agricultural land use.

Urban expansion and other related uses of land, and expansion of bio-energy crop cultivation are likely to occupy farm lands not needed in agricultural production. If competition for land becomes strong and land prices rise, then agricultural production may decrease in western and central Europe and hence agricultural production in Finland and other northern European countries could expand, especially in the case of higher food prices. Hence starting from the assumptions of linear crop yield development of Ewert et al. (2005) one may argue that the competitive position of Finland on food markets will improve only if prices of agricultural products increase due to climate change, and if land prices increase considerably in western and central Europe. The abundance of agricultural land in Finland relative to current production volume provides considerable potential for production expansion in such favourable climatic and market conditions.

An analysis of food markets in different climate change scenarios would provide wide range of development perspectives for Finnish agriculture. A coherent and detailed scenario analysis combined with economic analysis of food markets and agricultural production in each scenario would provide insights how Finnish agriculture could develop its agriculture and its responsiveness to changing demand and price conditions.

4.4.2. Greater or smaller environmental impacts?

An adaptation process that changes little in the crop properties (utilisation of fertilisers, biomass production) or in the timing of cultivation practices (e.g. a one week change in sowing or harvesting dates) will probably have little influence on nutrient leaching. The largest impacts can be expected if new cultivars are introduced that differ substantially from the traditional cereal and root crop production with respect to fertilization, use of biocides or irrigation needs. A substantial expansion of the area of special crops can have implications at a local level.

The largest effects on nutrient leaching can be expected if adaptation leads to an expansion of the permanent crop cover, which minimises the field area that is left bare during the winter period. In this way the area that otherwise would be subject to increased surface and subsurface leaching is reduced.

Since climate change is likely to increase the number and prevalence of agricultural pests, an increased use of biocides is a probable adaptive reaction. Other things remaining equal, this kind of adaptation would increase the environmental impacts caused by agriculture. If, on the other hand, the adaptation causes a shift to more pest resistant crops or farming practices that require less biocides, impacts may decrease. Agricultural policies will play a significant role in providing incentives for different directions in the adaptation process.

The biodiversity impacts of adaptation are also indeterminate. Adaption that leads to more extensive agriculture, or to greater diversity in terms of farming practices, will facilitate the safeguarding of biodiversity. By contrast, adaptation that leads to highly standardised intensive farming practices, which remove habitat variability in agricultural landscapes, would accelerate the loss of biodiversity. The development of agricultural policies is likely to have a crucial effect on the biodiversity impacts of adapation in the agricultural sector. If the agricultural policies favour a single model of effective agriculture, the impacts are probably negative at all levels of biodiversity, from landscapes to genetic diversity.

4.5. Planning for adaptation

Our study has shown that adaptation is a not only a technical but also a societal process. Thus one should evaluate which kind of institutional settings of land markets and coordination systems are necessary to foster proper land management in the face of adaptation to climate change. Farmers do not operate in isolation when planning measures to cope with weather-related effects. For example, the planning of drainage systems is dependent on the existence and state of water courses adjacent to fields and on the actions of other farmers. It might be necessary to evaluate whether the capacities of major waterways, which collect the run-off from field parcels, are sufficient to cope with more frequent heavy rainfall events. This could become important if large numbers of farmers simultaneously renovate their drainage systems, most typically built in the 1970s and 1980s.. Any major bottleneck may cause economic losses and environmental harm. It may also be worthwhile to consider how much production is concentrated in areas very prone to flooding, such as those along rivers in Ostrobothnia. Since agricultural investments are made on a long-term basis and have many social and environmental consequences, it is important to understand how different incentives affect the development and to avoid incentives that may lead to maladaptation.

In developing agricultural policies it is useful to aim for flexibility that can react to and support innovative spontaneous adaptation. It is also necessary to develop instruments that can react to changes in agriculture that may increase adverse externalities in the form of leaching of nutrients and pesticides or loss of biodiversity. It should further be noted that, for example, biofuel crop cultivation on agricultural lands competes with food crop production. If considerable public support is given for energy crops they may even replace food crops in relatively favoured agricultural areas. That may cause problems for the food industry. This means that it is necessary to consider not only agricultural policies, but also the adaptation of agriculture to other policy areas and policy measures, and to consider reactions in agriculture, when developing climate related policies in other sectors.

One key research challenge is to develop the use of information from other sectors in order to understand the broader context of change and adaptation in the agricultural sector. This means developing and using macro-models for the analysis of economic incentives, and integration of different policy objectives as a background for agricultural policy development both at the EU and the national levels. It also means bottom-up approaches, analyzing events and policy implications at the farm level, in order to understand the factors influencing the effectiveness of policy instruments and measures in reaching a broad, probably partly conflicting, set of goals. Analysis of the production base, including the water management of fields, measures against nutrient leaching, etc. and the likelihood of success and risks associated with different crops, provides material for farm level analysis. The management of adaptation processes under a changing climate will require addressing farm-level issues such as land use, suitable crop species and varieties, consequences of extreme weather events , water management, protein self sufficiency, innovative use of set aside areas, and methodological development.

Some public policy measures, such as support for crop insurance, for example, could be used as instruments in encouraging farmers to cultivate riskier crops. Such policy measures are also less coupled to production and more WTO-compatible than the product specific policy measures which may become relatively scarce due to trade liberalization. The role of advisory organizations is crucial in encouraging farmers to adopt new crop species and varieties and new cultivation practises. Whatever the desired change is, farmers will readily adopt it, providing it can be shown to produce profit for the farm.

When utilizing potential benefits of climate change in the food sector it is crucial to identify the crops and production systems most likely to gain from climate change, and long-term development of varieties, cultivation practices and incentive systems needed for making such crops attractive at the farm level. If both spontaneous and assisted adaptation is properly considered, the additional costs due to adaptation are likely to be modest. Such costs may arise in the need to develop drainage and irrigation, in setting up schemes for pest management and in ensuring that the agricultural infrastructure is able to cope with extreme climatic events of a realistic magnitude. There are risks of "over-adaptation" by large investments into costly structures and there are risks of maladaptation, especially if the agricultural policy is rigid. Flexibility and support for innovations are therefore major challenges.

5. Research needs and priorities

5.1. Impacts

In order to understand the basis of the adaptation and its consequences some further analyses of the impacts of climate change should be explored:

- A further analysis of the links between the climate change scenarios and the global supply and demand for agricultural products, and the effects of subsidies on these.
- The land cover scenarios based on European-wide GIS data and modelling work have to be tested against regional assessment in order to develop reliable methods for producing European wide scenarios of impacts of climate change. (see ATEAM and ACCELERATES scenario work, e.g. Rounsevell et al. 2005; Schröter et al. 2005).
- In order to estimate the environmental effects of agriculture as modified by climate change there is a need to develop further models that can quantify scenarios at the level of crop and animal production, and the environmental pressures of agriculture.

The climate scenario approach used within the CHESS project is outdated. The effect of up-to-date and properly downscaled climate scenarios should be systematically tested with a wide range of different hydrological and chemical field scale and catchment scale models. This is necessary in order to explore the processes within the soil-plant system as well as the processes (leaching, gaseous losses) that govern the transport out of this system to the atmosphere or water bodies coherently. The approach should include both water and chemicals (nutrients, pesticides, heavy metals) and various scales (fields, small catchments and river basins). Before any credible climate change impact modelling can be performed, the hydrological and chemical models have to be tested and validated against years/seasons with different climatic conditions (warm, cold, dry, wet) in order to prove coherent reaction of the modelled system to what has been observed in field trials or catchment monitoring systems (e.g. see the work of Puustinen et al. 2005, submitted and Tattari et al. 2005, submitted). This systematic model validation work has not taken place in Finland yet.

5.2. Adaptation

An overview of the adaptation processes in agriculture could be obtained by developing scenarios and scenario tools for the agricultural sector that can deal explicitly with markets of agricultural products, agricultural policies and policy measures. The issue could be approached using economic general equilibrium modelling.

A specific set of research tasks are related to ways of benefiting from climate change through adaptation. These include

- Planning for long term breeding and testing of winter hardiness in perennial horticultural crops to meet increasing demand for high-price products.
- Mapping of potential in annual crops for adapting to longer growing season, especially in the spring - to utilize earlier start of growth under long-day conditions.
- Identification of the crops and production systems most likely to gain from climate change, and examine incentive systems needed for making such crops attractive at farm level.
- Identification of cropping systems and land use practises to preserve and increase biodiversity in agricultural areas and on the fields.

- Creating a general future prediction of short term changes (< 30 years) in biological productivity of field crops - to provide a basis for several other analyses, including bio-economic modelling.
- Research on how to create incentives that support innovations for adaptation.

Another set would specifically address need for adaptation to avoid potential adverse consequences of climate change, and also the environmental consequences of the spontaneous adaptation to climate change. These include

- Monitoring of changes in migratory pest and pathogen occurrence. Some of these changes may be a direct consequence of climate change affecting the geographical dispersion of pests and pathogens, others may be related to changes in crops, cultivation areas or cultivation techniques.
- Analyses of alternative actions and costs for pest and pathogen management.
- Planning for cultivation and crop rotation methods that minimize losses of soil carbon, deterioration of soil structure, and leaching of nutrients and pesticides under changing climatic conditions.
- Adaptation to extreme weather events and their environmental consequences at different scales from fields to watersheds.
- The consequences of adaptation to changes in demand and subsidies. For example, adaptation to biofuel production may within some areas compete for land use with food crops causing structural changes also in the food industry.

6. Conclusions

The overall conclusion of the study is that the agricultural sector has adapted to many different kinds of changes in the course of history. Climate change, in comparison with many rather sudden shifts in policy, is likely to be a slow process. The actual form and extent of the adaptation will be determined jointly by the external climatic changes, internal changes within the agricultural sector, including agricultural innovations, and external decisions that specify agricultural policies.

Research can support adaptation by demonstrating how agricultural and other policies create incentives or disincentives for innovative adaptation that also meets other societal objectives, such as improving the sustainability and profitability of the agricultural sector. Feedback loops are of particular importance because they may accelerate or slow down adaptive processes. The environmental impacts of alternative adaptive processes within the agricultural sector are also important to explore.

7. Acknowledgements

The authors are very grateful for the valuable guidance and comments provided by Adriaan Perrels, Tim Carter and Markku Puustinen. The participants of the seminar also contributed with useful insights. Tim Carter’s careful reading improved the English significantly.

8. References

Carter, T.R. 1998. Changes in the thermal growing season in Nordic countries during the past century and prospects for the future. Agricultural and Food Science in Finland 7: 161-179.

Carter, T.R., Hakala, K., Kaukoranta, T., Kleemola, J., Laurila, H., Mela, T., Pehu, E., Saarikko, R., Tiilikkala, K. 1996a. Maatalous. In: Ilmastonmuutos ja Suomi. Esko Kuusisto, Lea Kauppi ja Pirkko Heikinheimo (eds.). p. 127-143. ISBN 951-570-296-8.

Carter, T.R., Saarikko, R.A. & Niemi, K.J. 1996b. Assessing the risks and uncertainties of regional crop potential under a changing climate in Finland. Agricultural and Food Science in Finland 5: 329-350.

Carter, T.R., Saarikko, R.A. and Joukainen, S.K.H. 2000. Modelling climate change impacts on wheat and potato in Finland. Chapter 16 in: T.E. Downing, P.A. Harrison, R.E. Butterfield and K.G. Lonsdale (Eds). Climate Change, Climatic Variability and Agriculture in Europe: An Integrated Assessment. Research Report No. 21, Environmental Change Unit, University of Oxford, Oxford, UK, pp. 289-312.

Carter, T.R., Jylhä, K., Perrels, A., Fronzek, S. and Kankaanpää, S. 2005. FINADAPT scenarios for the 21st century: alternative futures for considering adaptation to climate change in Finland. FINADAPT Working Paper 2, *Finnish Environment Institute Mimeographs*, Helsinki, 42 p

CHESS (Climate, Hydrochemistry and Economics of Surface-Water Systems). 2001. Summary Report by CEH Wallingford for the EC Environment and Climate Research Programme. [Available at: http://www.nwl.ac.uk/ih/www/research/bchess.html.]

Craigon, J., Fangmeier, A., Jones, M., Donnelly, A., Bindi, M., De Temmerman, L., Persson, K. & Ojanpera, K. Growth and marketable-yield responses of potato to increased CO_2 and ozone. European Journal of Agronomy 17: 273-289.

Edmonds, J.A. and Rosenberg, N.J. 2005. Climate Change Impacts for the Conterminous USA: An Integrated Assessment Summary. Climatic Change 69: 151-162.

Ewert, F. , Rounsevell, M.D.A., Reginster, I., Metzger, M.J. & Leemans, R. 2005. Future scenarios of European agricultural land use I. Estimating changes in crop productivity. Agriculture, Ecosystems and Environment 107: 101-116.

Favis-Mortlock, D.1994. Modelling soil erosion on UK agricultural land under a changed climate. In: Rounsevell, M.D.A., Loveland, P.J. (eds) Soil responses to climate change. NATO ASI series 1: Global Environmental Change, vol. 23, Springer Verlag, Berlin Heidelberg.

Fischer, G. 2005. Climate Change Impacts on Agriculture: An Integrated Assessment. Presentation in Informal Meeting of EU Agricultural and Environment Ministers September 11 2005, hosted and chaired by the UK Secretary of State for Environment, Food and Rural Affairs as part of the UK's Presidency of the EU. Slides. http://www.iiasa.ac.at/docs/HOTP/Sep05/EU_Fischer_v7.pdf

Fischer, G., Shah, M. and van Velthuizen, H. 2002: Climate Change and Agricultural Vulnerability, International Institute for Applied Systems Analysis, Laxenburg, 152 pp.

Hildén, M., Auvinen, A.-P. and Primmer, E. (eds.) 2005. Suomen biodiversiteettiohjelman arviointi. Suomen ympäristö 770.

Jones, M.B. and Carter, T.R. 1992. European grassland production in a changing climate. In: Proceedings of the 14th General Meeting of the European Grassland Federation, Lahti. pp. 97-110.

Kallio, K., Rekolainen, S., Ekholm, P., Granlund, K., Laine, Y., Johnsson, H. & Hoffman, M. 1997. Impacts of climatic change on agricultural nutrient losses in Finland. Boreal Environmental Research 2: 33-52.

Kaukoranta, T. 1996. Impact of global warming on potato late blight: risk, yield loss and control. Agricultural and Food Science in Finland 5: 311-327.

Kleemola, J. and Karvonen, T. 1996. Modelling growth and nitrogen balance of barley under ambient and future conditions. Agricultural and Food Science in Finland 5: 299-310.

Lehtonen, H. 2001. Principles, structure and application of dynamic regional sector model of Finnish agriculture. Maa- ja elintarviketalouden tutkimuskeskus (MTT), Taloustutkimus (MTTL), Julkaisuja 98. Helsinki. 265 p.

Lehtonen, H. 2004. Impacts of de-coupling agricultural support on dairy investments and milk production volume in Finland. Acta Agriculturae Scandinavica Vol 1 (1), 46-62. Section C: Food Economics.
Lemmen, D.S., Vance, R.C., Campbell, I.A., David, P.P., Pennock, D.J., Sauchyn, D.J. and Wolfe, S.A. 1998. Geomorphic systems of the Palliser Triangle, southern Canadian Prairies: description and response to changing climate. Geological Survey of Canada, Bulletin 521, 72p.
Lemmen, D.S. and Warren, F.J. (editors) 1999. Climate change impacts and adaptation: Canadien prespective. Natural Resources Canada, 174p.
Marttila, H., Granholm, H., Laanikari, J., Yrjölä, T., Aalto, A., Heikinheimo, P., Honkatukia, J., Järvinen, H., Liski, J., Merivirta, R. & Paunio, M. 2005. Finland’s National Strategy for Adaptation to Climate Change. Publications of the Ministry of Agriculture and Forestry 1/2005. Vammalan kirjapaino, Vammala. 276 p.
McKee, I.F., Bullimore, J.F. & Long, S.P. 1997. Will elevated CO_2 concentrations protect the yield of wheat from O_3 damage? Plant, Cell and Environment 20: 77-84.
Mela, T., Carter, T., Hakala, K., Hannukkala, A., Kaukoranta , T., Laurila, H., Niemi, K., Saarikko, R., Tiilikkala, K. 1996. The effects of climatic change on crop production: results of a five-year research project. The Finnish Research Programme on Climate Change : Final report. Jaana Roos (ed.). Publications of the Academy of Finland 4/96: 324-336. ISBN 951-37-1961-8.
Olesen, J.E. and Bindi, M. 2002. Consequences of climate change for European agricultural productivity, land use and policy. European Journal of Agronomy 16:239-262.
Parry, M.L., Rosenzweig, C., Iglesias, A., Livermore, M. & Fischer,G. 2004. Effects of climate change on global food production under SRES emissions and socio-economic scenarios. Global Environmental Change 14: 53-67.
Pingali, Prabhu 2004. Climate change and food systems. Paper presented in Global Forum on Sustainable Development in OECD headquarters, Paris 11-12 November 2004. Unclassified document ENV/EPOC/GF/SD/RD(2004)11/FINAL.
Porter, J.R. 1989. Interactions between climate change and nitrate leaching using the AFRC model of winter wheat growth. In: Bennett, R.M. (Ed.) The Greenhouse effect and UK agriculture. Centre for Agricultural Strategy, University of Reading, Paper 19.
Puurunen, M., Turunen, H., Knuutila, K., Uusitalo, P., Turtola, E., Lemola, R., Laitinen, P., Ylivainio, K., Risku-Norja, H., Jansson, H., Karhu, E., Grönroos, J., Mattila, P., Pyykkönen, S., Ekholm, P., Granlund, K., Rankinen, K., Räike, A., Heliölä, J., Kuussaari, M., Pykälä, J., Schulman, A., Hietala-Koivu, R. 2004. Horisontaalisen maaseudun kehittämisohjelman väliarviointi : Manner-Suomi. MMM:n julkaisuja 1/2004: 272, [28] p.
http://www.mmm.fi/julkaisut/julkaisusarja/MMMjulkaisu2004_1.pdf
Puustinen, M., Tattari, S., Koskiaho, J. & Linjama, J. 2005. Influence of seasonal and annual hydrological variations on erosion and phosphorus transport from arable areas. Submitted manuscript.
Rao, M.V., Hale, B.A. & Ormrod, D.P. 1995. Amelioration of ozone-induced oxidative damage in wheat plants grown under high carbon dioxide (role of antioxidant enzymes). Plant Physiology 109: 421-432.
Rosenzweig, C. and Parry, M.L., 1994. Potential impact of climate change on world food supply. *Nature* 367, 133–138.
Rounsevell, M.D.A., Ewert, F., Reginster, I., Leemans, R. and Carter, T.R., 2005. Future scenarios of agricultural land use in Europe. II: Estimating changes in land use and regional allocation. Agriculture, Ecosystems & Environment 107, 117-135.
Royal Society 2005. Food crops in a changing climate: Report of a Royal Society Discussion Meeting held in April 2005. Policy document 10/05. June 2005. ISBN 0 85403 615 6. www.royalsoc.ac.uk
Ruosteenoja, K., Jylhä, K. and Tuomenvirta, H. 2005. Climate scenarios for FINADAPT studies of climate change adaptation. *FINADAPT Working Paper 15*, Finnish Environment Institute Mimeographs, Helsinki (in press).
Saarikko, R.A. 1999. Climate change and crop potential in Finland: Regional assessment of spring wheat. University of Helsinki, Department of Plant Production, Section of Crop Husbandry. Publication no. 55, 60 p.

Schröter, D., Cramer, W., Leemans, R., Prentice, I.C., Araújo, M.B., Arnell, N.W., Bondeau, A., Bugmann, H., Carter, T.R., Garcia, C.A., de la Vega-Leinert, A.C., Erhard, M., Ewert, F., Glendining, M., House, J.I., Kankaanpää, S., Klein, R.J.T., Lavorel, S., Lindner, M., Metzger, M.J., Meyer, J., Mitchell, T.D., Reginster, I., Rounsevell, M., Sabaté, S., Sitch, S., Smith, B., Smith, J., Smith, P., Sykes, M.T., Thonicke, K., Thuiller, W., Tuck, G., Zaehle, S. and Zierl, B. 2005. Ecosystem service supply and vulnerability to global change in Europe. Science, 310, 1333-1337.

Tattari, S., Reuna, M., Puustinen, M., Linjama, J. and Koskiaho, J. 2005. Classification of erosion and phosphorus load events based on long-term snow water equivalent data. Submitted manuscript.

Toivonen, H., Kaipiainen, H., Söderman, G., Mannerkoski, I., Kemppainen, E., Mikkola-Roos, M., Mäkelä, K. Ryttäri, T. and Syrjänen, K. 2005. Lajien uhanalaisuuden ja kantojen kehitys eri elinympäristöissä. in Hildén, M. Auvinen, A.-P. and Primmer, E. (eds.) 2005. Suomen biodiversiteettiohjelman arviointi. Suomen ympäristö 770. p. 93-97.

Documentation page

Publisher	Finnish Environment Institute	Date December 2005
Author(s)	Mikael Hildén, Heikki Lehtonen, Ilona Bärlund, Kaija Hakala, Timo Kaukoranta, Sirkka Tattari	
Title of publication	The practice and process of adaptation in Finnish agriculture	
Parts of publication/ other project publications		
Abstract	The starting point for the analysis has been that economic factors and agricultural policies significantly affect agriculture. When climate change and economic driving forces have synergies, rapid adaptation may occur. The present climate change scenarios do not appear to threaten agriculture in Finland. Under the most favourable circumstances, climate change might even increase yields in Finland. However, the net advantage remains small, unless there are major changes in demand and prices of agricultural products. Therefore changes in e.g. the Asian consumption patterns and global food markets as well as demands for energy crops in export-oriented production areas are likely to be very significant. In some cases a spontaneous adaptation is likely to be too slow for avoiding adverse effects of climate change. Such areas are water management and drainage of fields, agricultural infrastructure, agricultural technology, long term plant breeding, management of externalities such as measures against leaching of nutrients, development of proper monitoring and measuring systems, and agricultural policy. The challenge for agricultural policies is to adapt not only to climate change as such, but in particular to various forms of spontaneous adaptation that will occur within the agricultural sector. Adaptation also creates needs for new research. Research can support adaptation by demonstrating how agricultural and other policies create incentives or disincentives for innovative adaptation. The environmental impacts of alternative adaptive processes within the agricultural sector are also important to explore. Feedback loops are of particular importance because they may accelerate or slow down adaptive processes. For example rigid systems of subsidies that are fixed to particular cultivars or agricultural practices will tend to slow down adaptation whereas systems that support innovativeness may speed up adaptation.	
Keywords	Agriculture, adaptation, climate change, research needs	
Publication series and number	Finnish Environment Institute Mimeographs 335	
Theme of publication		
Project name and number, if any	FINADAPT A01025	
Financier/ commissioner	Finnish Environmental Cluster Research Programme	
Project organization		
	ISSN 1455-0792	ISBN 952-11-2106-8 952-11-2107-6 (PDF)
	No. of pages 34	Language English
	Restrictions public	Price
For sale at/ distributor		
Financier of publication	Finnish Environment Institute, PO Box 140, FIN-00251 Helsinki, Finland	
Printing place and year	Edita Prima Ltd, Helsinki 2005	
Other information		

Kuvailulehti

Julkaisija	Suomen ympäristökeskus Julkaisuaika: joulukuu 2005
Tekijä(t)	Mikael Hildén, Heikki Lehtonen, Ilona Bärlund, Kaija Hakala, Timo Kaukoranta, Sirkka Tattari
Julkaisun nimi	Sopeutumisen prosessit ja käytännöt Suomen maataloudessa
Julkaisun osat/ muut saman projektin tuottamat julkaisut	
Tiivistelmä	Tarkastelun lähtökohtana on ollut, että maatalouden sopeutumiseen vaikuttaa monet taloudelliset ja maatalouspoliittiset tekijät. Kun ilmastonmuutos ja taloudelliset tekijät vaikuttavat samansuuntaisesti, sopeutuminen voi olla nopeaa. Tähänastisten skenaarioiden perusteella ilmastonmuutos ei näytä uhkaavan Suomen maataloutta. Myönteisimmillään ilmastonmuutos voi jopa lisätä satoja Suomessa, mutta hyöty jää verrattain pieneksi, jos maataloustuotteiden kysyntä ja maailmanmarkkinahinta eivät nouse merkittävästi. Aasian markkinoilla tapahtuvat muutokset sekä bioenergian kysyntä voivat siten vaikuttaa merkittävästi Suomen maatalouteen. Joissakin tapauksissa luonnollinen sopeutuminen voi olla liian hidasta ilmastonmuutoksen kielteisten vaikutusten välttämiseksi. Tällaisia alueita ovat maatalouden vesitalous ja peltojen kuivatus, maatalouden infrastruktuuri, maatalousteknologian kehitys, pitkäjänteinen kasvinjalostus, maatalouden ulkoisvaikutusten vähentäminen, kuten ravinnekuormituksen supistaminen, seuranta- ja arviointijärjestelmien kehittäminen sekä maatalouspolitiikka. Maatalouspolitiikan haasteena ei ole vain sopeutua ilmastonmuutokseen, vaan erityisesti niihin eri sopeutumisen muotoihin, jotka toteutuvat itsestään maataloussektorilla. Sopeutuminen luo myös uusia tiedon tarpeita. Tutkimus voi tukea sopeutumista osoittamalla kuinka maatalouspolitiikka ja muut politiikka-alueet luovat kannustimia tai asettavat esteitä innovatiiviselle sopeutumiselle. Tutkimuksen tulee myös tarkastella vaihtoehtoisten sopeutumistapojen ympäristövaikutuksia. Takaisinkytkennät ovat erityisen tärkeitä, koska ne voivat jarruttaa tai nopeuttaa sopeutumisprosesseja.
Asiasanat	Maatalous, sopeutuminen, ilmaston muutos, tutkimustarpeet
Julkaisusarjan nimi ja numero	Suomen ympäristökeskuksen moniste 335
Julkaisun teema	
Projektihankkeen nimi ja projektinumero	FINADAPT A01025
Rahoittaja/ toimeksiantaja	Ympäristöklusterin tutkimusohjelma
Projektiryhmään kuuluvat organisaatiot	
	ISSN: 1455-0792 ISBN: 952-11-2106-8, 952-11-2107-6 (PDF)
	Sivuja: 34 Kieli: englanti
	Luottamuksellisuus: julkinen Hinta:
Julkaisun myynti/ jakaja	
Julkaisun kustantaja	Suomen ympäristökeskus, PL 140, 00251 Helsinki
Painopaikka ja -aika	Edita Prima Oy, Helsinki 2005
Muut tiedot	

ISBN 952-11-2106-8
ISBN 952-11-2107-6 (PDF)
ISSN 1455-0792

This report examines the capacity and opportunities for adaptation in Finnish agriculture. In Finland agriculture is accustomed to adapting to external changes and pressures and it can also be expected to adapt in the future. In a medium term perspective, the Common Agricultural Policy (CAP) and its measures, as well as other economic factors, are forceful drivers that are likely to have more signifi-cant impacts on agriculture in Finland than climate change. The present climate change scenarios do not appear to threaten agriculture in Finland. Under the most favourable circumstances, climate change might even increase yields in Finland. The challenge for agricultural policy-making is to adapt not only to climate change as such, but in particular to various forms of spontaneous adapta-tion that will occur within the agricultural sector. The actual form and extent of adaptation will be determined jointly by the external climatic changes, internal changes within the agricultural sector, including agricultural innovations, and external decisions that specify agricultural policies. The report also identifies research topics. Feed back mecahanisms are particularly important to analyse, because they may speed up or slow down adaptation processes.

Raportissa on tarkasteltu Suomen maatalouden kykyä ja mahdollisuuksia sopeutua ilmastonmuu-tokseen. Suomen maatalous on tottunut sopeutumaan ulkoisiin paineisiin ja muutoksiin ja sopeutu-nee myös tulevaisuudessa. Lyhyellä ja keskipitkällä aikavälillä muutokset maataloustuotteiden kan-sainvälisillä markkinoilla, EU:n yhteinen maatalouspolitiikka ja muut taloudelliset tekijät vaikutta-vat maatalouteen todennäköisesti voimakkaammin kuin ilmastonmuutos. Esitettyjen skenaarioiden perusteella ilmastonmuutos ei näytä uhkaavan Suomen maataloutta. Myönteisimmillään ilmaston-muutos voi jopa lisätä satoja Suomessa. Maatalouspolitiikan haasteena ei ole vain sopeutua ilmas-tonmuutokseen, vaan erityisesti niihin eri sopeutumisen muotoihin, jotka toteutuvat itsestään maata-loussektorilla. Maatalouden sopeutuminen määräytyy lopulta ilmastonmuutoksen, maatalouden oman dynamiikan ja maatalouteen vaikuttavien ulkoisten taloudellisten ja poliittisten tekijöiden yhteisvaikutuksen tuloksena. Raportissa on myös tunnistettu tutkimustarpeita. Erityisen tärkeää on selvittää erilaisia takaisinkytkentöjä, jotka voivat jarruttaa tai nopeuttaa sopeutumisprosesseja.

This report is also available at the FINADAPT Web site:
http://www.ymparisto.fi/syke/finadapt or from www.environment.fi/publications
Finnish Environment Institute, Box 140, 00251 Helsinki, Finland, tel: +358 9 40 300

FINADAPT (Assessing the adaptive capacity of the Finnish environment and society under a changing climate) is a consortium co-ordinated at the Finnish Environment Institute (SYKE). It is part of the Finnish Environmental Cluster Research Programme, co-ordinated by the Ministry of the Environment.

MTT

SYKE

Finnish Environmental Cluster
Research Programme