Climate change and primary industries

Impacts, adaptation and mitigation in the Nordic countries

Report for Policy Makers

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Nordic Council of Ministers

Ved Stranden 18

DK-1061 Copenhagen K

Phone (+45) 3396 0200

www.norden.org

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Preface

Climate change will have considerable and complicated impacts on the Nordic Primary Industries. The Nordic countries are very much aware that although climate change is a global issue it has local consequences and the impacts need to be addressed locally. The Nordic countries have been among the leaders in addressing adaptation and mitigation of climate change in all its complexity both locally and globally.

In the light of this it is my pleasure to be able to present the final report and policy recommendations of the research programme, *Climate Change Impacts, Adaptation and Mitigation in Nordic Primary Industries*, the first attempt to comprehensively evaluate the impacts of climate change on the Nordic primary industries. The programme was developed and implemented in cooperation with NordForsk and has been active between 2010 and 2014.

The report states that it is expected that climate change will have significant impact on living natural resources on land and in the sea, and thereby have significant impacts on fisheries, agriculture and forestry in the Nordic region. Climate change impacts present serious threats to ecosystems that need to be addressed, but on the other hand the anticipated changes present opportunities for new land and marine based production systems within the framework of the sustainable bioeconomy. The foreseen climate changes furthermore pose serious challenges for political decision making processes and natural resource management.

Climate change challenges the existing knowledge on natural resources in the Nordic region. There is a need to focus on research that supports decision making processes for new policies, new policy instruments. We need new thinking to address these challenges, but we also need to continue

to support better monitoring systems, research strategies and international cooperation.

The report and policy recommendations provide a baseline and a way forward, a focus for the activities that can help the Nordic region to address the threats and opportunities of climate change for our primary production systems.

I would like to thank the extensive Nordic networks that have done the heavy lifting behind this report and policy recommendation.

Dagfinn Høybråten
Secretary General
The Nordic Council of Ministers

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Introduction

Agriculture, forestry and fisheries continue to play a key role in the Nordic economies.

For centuries, the primary industries have been the main source of livelihood in the Nordic countries. With industrialisation and the emergence of the information age and leisure society, the role played by the primary industries in the economy appears to have grown smaller. However, in several Nordic countries these industries continue to be significant for exports. Additionally, they fill several other roles in relation to the economy, rural societies, culture and ecosystem goods and services. Nordic agricultural products are sold across the globe at premium prices. The Nordic region is home to one-third of the forested area in Europe, excluding the Russian Federation, and is a major supplier of forestry products. Moreover, the marine fisheries in the Northern Atlantic are of great importance for European fisheries. Thus the primary industries continue to be of fundamental importance within the Nordic societies.

The global human population is estimated to grow to more than 9 billion by 2050, and at the same

time the global middle class will likely double in size. This will lead to a projected increase in global food consumption of 70–100%, which will test current production and supply systems that are already struggling to meet global food demands. The challenge of meeting demand is being exacerbated by increasing demand for biofuels, which compete with food and feed crops, by excessive waste in the food chain, by inadequate policies for managing natural resources such as fish stocks and soils, and by inadequate management of agricultural and forestry systems leading to productivity gaps. This points to the need to revise policies, governance structures and management regimes to meet future requirements at a reasonable cost to consumers as well as to the consequences for environment and climate.

The primary industries are not merely affected by climate change, they also contribute to the emissions causing global warming. In the Nordic countries, the primary industries are esti-

mated to contribute from about 5% of total national greenhouse gas (GHG) emissions in Iceland to more than 20% in Denmark. Emissions stem not only from use of fossil fuels, but also from biogenic sources such as soils, livestock, manure, etc. In addition, changes in the carbon stock in soils and vegetation contribute greatly (both positively and negatively) to net GHG fluxes.

The Nordic region is located in an area in which climate change may be seen both as a threat to production in some primary industries, and as something that will open up new possibilities for agriculture, forestry and fisheries. Making the best of these new options will require targeted research and innovation, along with flexible governance structures that allow for structural changes in the way primary industries are managed, incentivised and controlled.

Research programme on climate change and the primary industries

Climate change is expected to have a profound impact on natural resources, and thus on the primary industries (agriculture, forestry and fisheries) in the Nordic countries. Climate change induces risks but also creates possibilities for new production systems on land as well as in the ocean. Climatic changes also represent great challenges for policy-making and management regimes.

The current knowledge base on natural resources in the Nordic region needs to be expanded to fully address the impacts of climate change. In particular it is

important to direct more research towards the need for improved policies and new policy instruments. This will in turn require continued support for improved monitoring systems, research strategies and international collaboration.

The research programme *Climate Change Impacts, Adaptation and Mitigation in Nordic Primary Industries* is a coordinated set of thematic research networks initiated by the Nordic Council of Ministers and is part of its Globalisation Initiative launched in 2007.

The programme's overall objective is to create a Nordic knowledge base on climate change impacts in the Nordic region. This knowledge base is intended to contribute to the development of an adaptation and mitigation policy in relevant areas in the Nordic region, and to serve as a source of advice for developing an overarching climate policy for the region as a whole. Thus the programme will inform climate policy at a general level as well.

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Key findings

Key finding 1:

Reducing GHG emissions from primary industries entails opportunities and challenges

The global demand for high-quality foods such as meat and fish is projected to greatly increase as a consequence of a rise in global wealth and a rapidly growing middle class, leading to nearly a doubling of demand by 2050. This will lead to corresponding increases in emissions of biogenic GHG (CO₂, methane and nitrous oxide) from crop and livestock production as well as from fossil fuels used in the primary industries unless new technologies and management schemes

to reduce emissions are developed. This will require new and more energy efficient technologies and greater reliance on renewable energy, as well as new production technologies that can reduce emissions from crop and livestock production.

The biogenic emissions of nitrous oxide and methane from agriculture are closely linked to the carbon and nitrogen flows on which agricultural production depends. Achieving substantial reductions in these emissions

will require research and technological developments beyond the current state-of-the-art. Achieving such reductions will not only require basic research on underlying processes but also incentives to develop innovations and new technologies that deliver emissions reductions without compromising productivity.

Key finding 2:

The Nordic countries are expected to warm at or above the global rate, but with large regional variations

The projected temperature increase towards the end of the 21st century depends greatly on future emissions. With the current trend in emissions, the global mean temperature is projected to increase by 2.6°C to 4.8°C (corresponding to IPCC RCP8.5), and with lower emissions by 1.4°C to 3.1°C (RCP6.0). According to a wide range of climate models, the warming in the Nordic region will be similar to the global mean in the south and west and nearly double this in the

north and east. The increase will be greatest in winter and in areas with a continental climate. More and heavier extreme precipitation events are expected, while change in wind conditions is uncertain. Warm water transported northwards with the North Atlantic Current may decrease by 20–30% by the end of the century, adding uncertainty to sub-regional climate projections.

The warming will also reduce snow and ice cover. It is estimated that by the end of the century

the duration of snow cover will be reduced by 1–3 months throughout the region. The warming will also lead to a substantial decline in the extent and duration of sea ice. In addition, surface salinity of the Nordic Seas will be affected, with reduced salinity in some cases and increased salinity in others.

Key finding 3:

The Nordic region with its dark winters and long summer days faces particular challenges in the context of global warming

The Nordic region is the only place on earth where climatic conditions allow productive agriculture, forestry and fisheries at high latitudes with dark winters. This unique geographical position makes it difficult to transfer knowledge from other parts of the world to the environmental conditions in the Nordic region, where both plants and animals are adapted to survive long, dark and cold winters. In large parts of the region, projected climate change

will mean warmer winters with more variable conditions in terms of rainfall, snow and ice cover. This will pose a challenge to current production systems and require new solutions in terms of management and genotypes for crops and livestock alike.

The high latitudes are projected to warm at a higher rate than the global average. This will lead to winter conditions outside of those currently known and understood. The effects of such changes are

difficult to predict, and there is little research or evidence on which to base assessments of potential effects on the functioning of ecosystems and how this will affect productivity and management in agriculture, forestry and fisheries. Targeted research is called for to explore the consequences of climate change under the unique conditions of the Nordic region.

Key finding 4:

Forests may experience enhanced carbon uptake under climate change, whereas agricultural soils face losses

Soils in the Nordic region generally have carbon contents that are considerably higher than in other parts of Europe. This is due in part to the larger proportion of peatlands, forestry and grasslands in the land use, and in part to the slower decomposition of soil organic matter under the currently cool climatic conditions. The projected temperature increase will enhance decomposition of soil organic matter, which in turn may increase the supply of nitrogen in both agricultural and forest ecosystems. In forestry systems, this enhancement of nutrient turnover, together with a longer growing season and higher treeline, will boost forest growth, timber yield and carbon sequestration. The carbon sequestra-

tion rate in biomass is expected to increase steadily as a consequence of higher atmospheric CO₂ concentrations as well, whereas effects on soil carbon stocks are uncertain.

Grasslands are also expected to benefit from the projected warming, with increased growth and a longer growing season. While this may increase soil carbon in grasslands, in many cases the higher soil carbon contents will be balanced by faster degradation of soil organic matter. Arable soils, on the other hand, will face a significant reduction in soil organic matter contents under warming, thereby leading to increased emissions of CO₂. This effect can be reduced by including cover crops in the rotation and converting some of the arable land into grasslands. Such changes may not only require incentive

schemes such as payment for carbon sequestration, but also new technologies such as biorefineries that allow alternative use of harvested cover crops and biomass from grasslands.

Key finding 5: Climate change will cause spatial shifts in ecosystems and production systems

The most prominent impact of climatic warming in the Nordic region will probably be spatial shifts in ecosystem and species ranges and resultant changes in the suitability of production systems for agriculture, forestry and fisheries.

In the sea, phytoplankton primary production in surface waters is the major driver of the production of fish stocks. This primary production is projected to more than double in the northern seas, as longer ice-free periods and higher sea temperatures will extend

the period of plankton growth. However, phytoplankton production in some areas may be negatively affected by changes in vertical stratification of the water column through reduced nutrient availability. Zooplankton form the link between primary producers and fish, and both zooplankton survival and species distribution will be affected by temperature changes. Climate therefore plays a dominant role in the distribution and production of major marine fish species as well. Different fish species will tend to move northwards at different rates, thereby altering the overlap between

predators, prey and competitors. This will lead to new interactions between species, which will in turn affect stock productivity.

The freshwater fish fauna in the Nordic region currently comprises a limited number of species and is dominated by generalists with some genetic specialisation to suit the specific climatic environments in the Nordic countries. Climate change may affect freshwater fish species in relation to migration and genetic selection pressures. The salmonid

species (Atlantic salmon, brown trout and Arctic char) spend part of their life in the sea and part in freshwater systems. The different species have different temperature preferences, thus climate change will alter their relative abundance.

Agricultural crops and cropping systems depend on suitable temperatures and rainfall.

Changes in both of these climatic elements will therefore determine shifts in crops as well as in associated livestock systems. In the Nordic region, warming will mean a substan-

tial northward expansion of suitability for crop production, leading to an increase in productivity and a wider selection of crops being grown in most areas, provided that the terrain and soils are suitable. This is primarily a consequence of a longer and warmer growing season. Increases in atmospheric CO₂ concentration will also enhance crop productivity.

Forestry will see a shift in the suitability of tree species at higher latitudes and higher elevations in mountainous terrain. The extension of the growing season is also expected to enhance the

growth and productivity of forests in the Nordic region. This increase may help to satisfy not only the need for traditional wood-based products but also the growing demand for bioenergy.

Key finding 6: Climate change poses risks to current production systems

While climate change provides improved conditions for agriculture, forestry and fisheries in the Nordic countries, it will also give rise to new risks associated with biotic and abiotic stresses to plants and animals. In addition to warmer average conditions, climate change will also lead to increased inter-annual variability and higher frequency of extreme weather events such as heat waves, droughts, storms and intense and persistent rainfall. This will mean new and altered threats to production systems. Such changes will result in an overall increase in variability, reduced productivity and increased uncertainty for producers. In agriculture, this will affect not only crops but also livestock production, partly in relation to feed availability and partly as a result of the effects of heat stress on animals. Adapting to these conditions may require

investing in resilience against variability, such as by diversifying crop rotation, improving drainage of agricultural soils, and improving livestock breeds and crop varieties.

In forestry, the risk of fire and damage due to wind and storms are expected to increase. The risk of outbreaks of pests and diseases causing defoliation, growth loss, timber damage and even massive forest dieback may increase as well. Climate change may alter the physiology and possibly weaken the defence mechanisms of trees in boreal forests, making them increasingly susceptible to insect and pathogen attack. It may also dramatically shift or extend the natural habitats of insects and pathogens that can damage vast forest areas.

In freshwater systems, weather extremes, such as floods and droughts, can decrease recruit-

ment and survival of fish. Possible displacement of salmonid and coregonid species by more warm-adapted species would likely have major negative consequences for recreational fisheries.

The warming will not only affect plants and animals on which the primary industries depend, but also the proliferation of pests and diseases that thrive on these. This will in turn affect crop production, making it necessary to cope with new species of weeds, pests and diseases that are better adapted to warmer conditions. In general, the need to control these will call for new approaches in order to avoid increased use of pesticides. In addition, livestock production will need to cope with new and changed vector- and food-borne diseases adapted to the changed climatic conditions. Some of these diseases may also be transmitted between humans and animals, which means close surveillance will be essential.

Key finding 7:

Climate change offers possibilities for new production systems

In the Nordic region, the longer and warmer growing season will open up for cultivation of new crops and trees and farming of new fish species. The northern parts of the region will see an increase in arable crops in general, while the central parts will see an expansion of the growth of autumn-sown crops and the southern parts the adoption of warm season crops such as grain maize. The growth of fruits and berries will be affected by climatic changes as well and will allow new and more productive systems. An example here is the current expansion of grapevine cultivation into Denmark.

In grasslands, the longer growing season will allow more cuts and higher production, particularly in areas that are less affected by summer droughts. This may facilitate

greatly increased production of protein-rich crops by cultivating highly productive grass-clover pastures with little fertiliser and pesticide use. These pastures may be harvested or grazed for production of ruminant livestock such as dairy and beef cattle and sheep. The pastures may also be a new source of sustainable production of protein for monogastric farm animals (pigs and poultry) as well as for farmed fish. This will require the development and implementation of new biorefinery technologies, for which the Nordic region, with its strong tradition of partnerships across sectors, is in an ideal position.

The increased productivity of the primary industries in the Nordic countries may strengthen their global market position in a situation where climate change is negatively affecting food and fibre production systems in other

parts of the world. Exploiting these opportunities, however, will require targeted research, innovation and investment.

Key finding 8: Climate change poses challenges for current schemes for managing natural resources and the environment

Climate change will pose a challenge to current governance schemes in multiple ways, in relation to how current resources are shared between countries, regions and actors, and how the primary industries affect other natural resources and the quality of the environment.

Changes in ocean temperatures affect fish stock productivity, shift distribution and may influence migration patterns, which may have important economic implications. Changes in distribution and migrations of fish stocks may also put pressure on existing agreements on fish stock sharing or necessitate entirely new ones. It should be noted that the ultimate fate of many of the fish species, even under climate change, will depend upon the fisheries and hence fisheries management, which may call for new flexible and adaptive regimes for managing fish stocks.

Land use has a great influence on landscape and ecosystem goods and services. Changes in climatic suitability may lead to major changes in land use, which will affect not only production of goods in agriculture and forestry, but also the quality of nature, the environment, groundwater and freshwater systems. This will challenge current land use planning in the Nordic countries, and will call for a strategic, long-term perspective on land use policy under climate change.

In arable farming systems, warmer temperatures will enhance turnover of soil organic matter and this, in combination with increased and more intense rainfall, will enhance the risk of nitrogen and phosphorus losses to the aquatic environment, thereby threatening the quality of these waters for both recreational use and fish production. New and adapted policy may be needed to manage the environmental impacts of agricultural production. Likewise, the increased need

for pesticide use in agricultural production may be problematic in relation to current pesticide policies in the Nordic countries.

Policies will need to promote active resource management and the utilisation of renewable raw materials as substitutes for metal and oil-based products and fossil fuels. This is essential for sustainable resource management, as well as for mitigating climate change. Resource management of this type will have to take multiple needs into consideration, including:

- 1) provision of biomass for food, feed, bioenergy and biomaterials within the bioeconomy;
- 2) recycling of nutrients and resilient organic matter to the agricultural and forestry systems;
- 3) maintenance of carbon stocks in soils and vegetation; and
- 4) provision of other ecosystem goods and services, such as clean water and air and a diverse natural environment.

Key finding 9: Greater focus on adaptation to climate change is needed

Giving consideration to adaptation is particularly important where there are long lead times before new technologies, materials or management schemes can be implemented or where the involvement of several actors or institutions is required. This is a particular concern in land use planning and management, use of genetic resources for both plants and animals, and management and prevention of plant and animal disease.

Cultivation of agricultural crops requires suitable and well-drained soils. The anticipated increase in winter rainfall throughout large parts of the Nordic region will put additional stresses on current drainage systems. This issue will become increasingly important in areas where agricultural production may expand due to increased suitability. Enhancing drainage of agricultural soils cannot be implemented without ensuring that water can be effectively transported in streams and

rivers. Aligning such drainage needs with the need to protect parts of the landscape from flooding may provoke conflict among actors, and will require new planning at the landscape and catchment level. Similar considerations must be taken into account when preparing for increased risk of summer drought.

The changes in temperature and precipitation and their inter-annual variability as well as increased atmospheric CO₂ concentration mean that plant breeding will face new challenges. Plant breeders will have to deliver cultivars that are more resilient to weather extremes and resistant to new diseases. Plant breeding is a long-term activity, and delivering such cultivars will require early anticipation and planning for new conditions in the development of suitable germplasm. Since the Nordic region is unique in terms of its dark winters and long summer days, breeding will likely need to be specialised and will be dependent on strong public-private partnerships.

In the wake of climate change, the commercial and widespread livestock breeds may exhibit shortcomings, e.g. insufficient resistance to new diseases and lack of heat stress resistance. Minority breeds may have resistance to the new diseases, and in extreme cases the minority breed may have to replace the commercial breed. Adaptation to and mitigation of climate change will require rapid adjustments of the genetics of livestock because many of the consequences of the changing climate cannot be predicted.

In both plant and livestock production there will be a need to integrate adaptation to climate change and reduction of GHG emissions. Breeding should therefore consider how to adapt plants and livestock to climatic change and climatic variability, but also how to help to reduce nitrous oxide emissions from crop production and methane emissions from livestock production.

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Recommendations

The Nordic region, like other parts of the world, will face both general and specific challenges related to climate change. The general challenges are mostly related to reducing the climate footprint of human activities. The sources of GHG and the opportunities for reducing them vary greatly among the agriculture, forestry and fisheries industries, so care must therefore be taken when developing policies and incentive structures for emissions reduction. In the agriculture industry, which generates the largest emissions, there is a particularly pressing need for enhanced knowledge and innovation to reduce emissions from the multiple biogenic sources of CO₂, methane and nitrous oxide.

Specific challenges are associated with the individual primary industries, all of which must deal with changing conditions for managing their resource base. These challenges are in many cases regionally specific across the Nordic countries, although there are also significant commonalities. This means that policies must be flexible enough to allow actors to

efficiently adapt to the changing conditions while ensuring that common ecosystem goods and services are respected.

Lowering greenhouse gas emissions through active climate change policy

1. Research and innovation to reduce GHG emissions from the primary industries should take into account all emissions pathways in the supply chain, including effects of carbon storage and indirect land-use changes.
2. The national GHG accounting and monitoring systems should be further developed to better reflect results of developments and innovations that lower net GHG emissions.
3. New technologies, management measures and supporting governance structures that reduce net GHG emissions should be developed and supported in close collaboration between private and public actors to facilitate efficient implementation.
4. Efficient incentive structures should be developed to drive

innovation towards lowering GHG emissions from supply chains.

Developing adaptive resource policies for the primary industries

5. Resource management policies should be flexible enough to allow for continued changes in suitability in primary production and associated effects on ecosystem services across space:
 - a) Marine fisheries policies will have to take into account large shifts in the spatial range of fish stocks;
 - b) Land management policies will have to take into account changes in suitability for use in agriculture and forestry, i.e. prioritisation of use in land use planning;
 - c) Management of freshwater resources, their ecological quality and their links to land use and management will need to be adapted due to the impact of changing climatic conditions on water and nutrient flows.

6. Policies should support resilience to the impacts of climatic change, enhanced climatic variability and climatic extremes on the primary industries (e.g. through insurance schemes or by land and water infrastructure planning).

Adapting governance structures to climate change-related challenges

7. Research institutions, government institutions and private enterprise should form partnerships to foster innovation and implement new governance schemes to facilitate effective reduction of GHG emissions while enhancing productivity in the primary industries.
8. Institutions and institutional structures should be aligned to deal with major changes in the resource bases for the primary industries to ensure that these are efficiently and sustainably managed under changing climatic conditions.

Managing genetic resources

9. Genetic resources play a special role with regard to both mitigation and adaptation, and effort should therefore be made to maintain and map a diverse gene pool of plant and animal species.
10. Partnerships between public and private actors in research and innovation should be established and maintained to ensure that the genetic resources are effectively used for reducing GHG emissions and facilitating climate change adaptation.

Integrating adaptation and mitigation via the bioeconomy

11. New technologies such as biorefineries based on innovative and/or new sources of biomass should be developed, tested and implemented with the aim of developing agricultural, forestry and marine production systems that deliver food, feed and biomaterials with low or no GHG emissions.

12. Technologies based on the recycling principle should be developed to reduce, reuse and recycle waste and residues in order to lessen reliance on non-renewable resources and promote efficient use of biomasses of all types.

Improving knowledge and awareness

13. Research and innovation should be strengthened to generate new integrated solutions and technologies that reduce GHG emissions, enhance productivity in terms of providing services to meet increasing global demands, and facilitate adaptation to changing climatic conditions.
14. Communication and outreach tools should be developed to provide better information to actors in the primary industries about the challenges relating to GHG emissions reduction and adaptation to changing climatic conditions.

Conclusion

Agriculture, forestry and fisheries have played and will continue to play a fundamental role in the development of the societies in the Nordic region. Climate change will pose new challenges as well as open up new opportunities for these primary industries. Some of the changes will bring benefits, whereas others will have negative effects, at least for some actors.

The challenge for the primary industries is twofold: to reduce their climate footprint and to efficiently adapt to the changing conditions while also ensuring sustainability of the resource base.

With the anticipated growth in the global demand for food, feed, biofuel and biomaterials, the Nordic region may increase its

share in the global market for high-quality products. Research and innovation will provide many opportunities to improve the sustainability of the Nordic primary industries and to turn climate-related changes into competitive advantages. This, however, will require changes in governance schemes and new partnerships between the main actors.

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Nordic Council of Ministers

Ved Stranden 18

DK-1061 Copenhagen K

www.norden.org

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