CICERO Report 2004:03

Towards assessing socioeconomic impacts of climate change in Norway

Sensitivity in the primary sectors: fisheries, agriculture and forestry

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May 2004

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Tittel: Towards assessing socioeconomic impacts of climate change in Norway – Sensitivity in the primary sectors: fisheries, agriculture and forestry

Forfatter(e): Ane Schjolden

CICERO Report 2004:03, 27 sider

Finansieringskilde: Norges forskningsråd

Prosjekt: An assessment of the impacts of climate change in Norway

Prosjektleder: Asbjørn Aaheim

Kvalitetsansvarlig: Asbjørn Aaheim

Nøkkelord: Norge, klimavirkninger, fiskeoppdrett, jordbruk, skogsbruk

Sammendrag:. Denne rapporten sammenholder informasjon om den økonomiske og regionale sammensetningen av de tre primærnæringene fiske (inklusiv fiskeoppdrett), jordbruk og skogbruk og hvordan disse sektorene kan påvirkes av klimaendringer. Tilgjengelig informasjon viser at alle de tre sektorene sannsynligvis vil oppleve både positive og negative endringer som resultat av klimaendringer, men tydeliggjør samtidig at vi mangler et oversiktsbilde over totale virkninger.

Positive virkninger for alle sektorene omfatter for eksempel forventet økning i vekstrater og produktivitet på grunn av høyere temperaturer og større konsentrasjonen av CO_2 i luften. Det er også forventet at et varmere klima kan åpne opp muligheter for dyrking eller fangst av nye arter, og endret arealbruk og geografisk fordeling av økonomiske aktiviteter innen fiske, jordbruk og skogbruk.

På den annen side ventes det også negative virkninger av klimaendringer som for eksempel økte kostnader i forbindelse med skade eller tap etter ekstreme værhendelser, som storm eller frost, eller fra økt forekomst av angrep fra skadedyr og sykdommer. Økt hyppighet av stormer kan øke tapstallene knyttet til rømning innen fiskeoppdrett og skade på utstyr. Storm og frost kan føre til tap i skogbruket knyttet til frostskade og maste-knekk. Høyere temperaturer vil øke problemene med ugress, skadedyr og sopp i jordbruket og barkebiller i skogbruket.

Språk: engelsk

Rapporten kan bestilles fra:
CICERO Senter for klimaforskning
P.B. 1129 Blindern
0318 Oslo

Eller lastes ned fra:
http://www.cicero.uio.no

Title: Towards assessing socioeconomic impacts of climate change in Norway – Sensitivity in the primary sectors: fisheries, agriculture and forestry

Author(s): Ane Schjolden

CICERO Report 2004:03, 27 pages

Financed by: The Research Council of Norway

Project: An assessment of the impacts of climate change in Norway

Project manager: Asbjørn Aaheim

Quality manager: Asbjørn Aaheim

Keywords: Norway, climate impacts, fishing sector, agriculture, forestry

Abstract: This report pulls together existing information that describes the economic composition and regional distribution of the fisheries, agriculture and forestry sectors in Norway and how they might be influenced by climate change. The information collected here demonstrates that all three sectors are likely to simultaneously experience both positive and negative impacts of climate change, but also indicates that the question of overall impacts from climate change to one sector is largely unexamined.

Positive impacts expected include increased growth rates and productivity, due to warmer temperatures and higher concentrations of CO^2. Another element is the increased potential for exploiting new species as well as the geographical expansion of areas suitable for either fishing, agriculture or forestry activities.

However, these positive impacts can partly be outplayed by negative impacts such as increased damage or loss from severe weather events, such as storms and frost, and from increased occurrence of pests/diseases. Increased frequency of storms might lead to higher losses from escapes of fish in aquaculture and storms in combination with more severe frost can increase the forestry sector's problems with frost damage and breakage of trees. Warmer temperatures are expected to lead to more problems of weeds, pests and fungi in agriculture and bark beetles and other pests in forestry.

Language of report: English

The report may be ordered from:
CICERO (Center for International Climate and Environmental Research – Oslo)
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Climate change is expected to heavily influence both the production and potential exploitation of natural resources. Increasing efforts have been put into analyzing the effects that increased temperatures and other place-specific climate factors are expected to have on, e.g., agricultural production. However, in Norway, impacts of climate change is a relatively new research topic, with few clear results for agriculture, forestry and fisheries in place.

The objective of this report is to describe the fishing and aquaculture, agriculture, and forestry sectors in Norway under today's climatic conditions and provide an overview of existing research on impacts of climate change on these sectors. In cases where no such research exists for Norway, data is extrapolated from general climate impact assessments and studies examining these sectors' sensitivity to climate change. The aim is to help achieve an overall assessment of impacts of climate change for these three sectors in Norway that can be used in formulating future research questions and designing methodologies.

Before discussing the sectors in more detail, a general overview of what climate changes we can expect in Norway in the future is presented below. The subsequent discussions of the fisheries and aquaculture, agriculture, and forestry sectors focus on 1) the sector today, its production, value of production, sales, regional distribution, employment, and so forth; 2) how climate and climate change can influence activities in the sector; and 3) how climate change may affect this sector in the Norwegian context.

1.1 Climate change in Norway

The RegClim[1] scenarios for future climate development in Norway have been widely used since they were published in 2000 (RegClim 2000). These scenarios indicate the following changes in temperature and precipitation:

Table 1: Average climate change in Norway, scenarios for the period 2030 – 2050 compared to the period 1980 – 2000

	Norway	Northern Norway	Western Norway	Eastern Norway
Temp. increase ° C				
Yearly average	1.2	1.6	1.0	1.1
Spring	1.1	1.4	0.9	1.0
Summer	0.9	1.2	0.7	0.6
Fall	1.4	1.7	1.1	1.3
Winter	1.6	2.0	1.2	1.3
% increase precipitation				
Yearly average	9.6	7.8	13.5	4.3
Spring	0.1	5.0	1.2	-4.1
Summer	9.5	1.5	18.2	1.7
Fall	17.1	18.2	23.5	6.9
Winter	9.4	5.2	9.3	13.1

Source: (RegClim 2000).

[1] See http://www.nilu.no/regclim

2 Fisheries and aquaculture

In terms of export earnings, fisheries and aquaculture is Norway's second most important sector – second only to petroleum and natural gas, and occasionally sharing second place in the export statistics with the metal industry (table 365, SSB 2002)

The data available for this sector is usually divided into fisheries and aquaculture, therefore the presentation of this sector is also in two parts: First fisheries (section 2.1), then aquaculture (section 2.2). The fish processing industry is covered in section 2.3 and some common issues like employment are discussed in section 2.4.

2.1 Norwegian fisheries today

2.1.1 Production

In 2001, 2.68 million tons of fish were caught by Norwegian fishing vessels (table 419, SSB 2002). As much as 93% of this catch comprised eight groups of fish: herring, blue whiting, capelin, cod/haddock, mackerel, pollack, small sand eel, and shrimp.

Table 2: Catch by Norwegian fishing vessels 2001, tons and percent

Fish species (Norwegian name)	**Tons**	**Percent**
Herring (sild*)	581,100	21.7
Blue whiting (kolmule)	573,686	21.4
Capelin (lode)	482,834	18.0
Cod and haddock (torsk og hyse)	259,486	9.7
Small sand eel (småsil/tobis)	187,459	7.0
Coalfish/pollack (sei)	169,577	6.3
Mackerel (makrell**)	180,602	6.7
Shrimp (reke)	62,873	2.3
TOTAL, 8 major species		93.15

*) includes the species: 'fjordsild', 'feitsild' and 'nordsjøsild', but not brisling

**) includes 'pir', but not 'hestmakrell'

Source: Tables 418 and 419, SSB 2002

As can be seen in table 2 above, herring and blue whiting are the most important species when measuring in quantity, each accounting for approximately 22 % of the total catch.

2.1.2 Value

Since there is great variation in value of the various fish species, quantity measures alone are not a good indicator of the production in the fisheries sector; one also needs to look at the value of the catch. In 2001, the total value of fish catches – including shrimp, crustaceans and shellfish – amounted to NOK 11. 4 billion, distributed among the same eight fish varieties as shown in the previous table.

Table 3: Value of the catch in 2001, NOK 1000 and percent

Fish species (Norwegian name)	NOK 1000 *	Percent
TOTAL value of catch	11,399,771	100
Herring (sild*)	2,245,433	19.70
Blue whiting (kolmule)	400,869	3.52
Capelin (lode)	535,185	4.69
Cod and haddock (torsk og hyse)	3,520,225	30.88
Small sand eel (småsil/tobis)	146,960	1.29
Coalfish/pollack (sei)	822,771	7.22
Mackerel (makrell**)	1,336,644	11.73
Shrimp (reke)	839,110	7.36
Other species	1,552,571	13.6

*) Ex-farm value /price offered to the fishermen when they deliver their catch

Source: SSB 2002

From the table above one can see that the *cod fishes* are most important in terms of value (accounting for 30% of the value of total catch, even though cod accounts for only 9.7% of the catch in quantity). Herring, the most important in quantity (22% of the catch) is almost equally important in terms of value, accounting for 20% of the total value of the catch.

On the other hand, the second biggest catch in quantity – that of blue whiting – accounts for 21 % in quantity and only 3.5 % of the value.

2.1.3 Regional distribution

Most of the cod is taken ashore in the three northernmost counties of Finnmark, Troms and Nordland, but with some also in the western county of Møre og Romsdal. Herring is mostly taken to the shore in Sogn og Fjordane, Møre og Romsdal, but also Nordland (tables 419 and 420, SSB 2002). The overall distribution of the total catch (all species) to the seven most important counties (receiving almost 90% of all catch) is described in table 4 below.

Table 4: The counties to which most of the fish is shipped, 2001 – quantity in percent

Møre og Romsdal	23.5
Rogaland	18.4
Sogn og Fjordane	13.3
Nordland	11.4
Troms	7.7
Finnmark	6.9
Hordaland	6.5
Total 7 most important counties	87.7

Source: table 419, SSB 2002

2.1.4 Structural changes in the fisheries

According to Album, Wiik et al. (2001), there has been a gradual shift in investments away from smaller boats in the coast fleet, towards the fishing fleet operating at sea. Today, 80% of the investments go towards the latter. This has resulted in fewer smaller boats in the coastal fleet and arguably a reduced flexibility in the sector. The shift in investments towards the larger vessels of the coast fleet is partly explained by changes in government incentives.

In the past decade, a quota system per fishing vessel has been introduced. The quotas can be traded, and a rough estimate of the quota price is NOK 4-6 per kilo.

2.2 Aquaculture

2.2.1 Production

Traditionally, fish farming in Norway has concentrated on salmon and trout. However, over the past ten years fish farming of cod, halibut, oysters, scallops, mussels and sea urchins has been introduced. In 2000, 490,278 tons of farmed fish were raised, the value corresponding to NOK 12.1 billion (ex-farm value). Table 5 below shows that the production of salmon accounts for 90% both in quantity and value, and the farming of trout accounts for almost 10%. The other fish species, including cod, account for only 0.3% of quantity of the total production. A total of 170 tons of cod were sold in 2000, valued at NOK 3.4 million. (The largest annual quantity ever sold of Norwegian-raised farmed cod was in 1994, amounting to 569 tons) (NOU 2000).

Table 5: Aquaculture production in Norway, 2000

	Tons	%	Value in NOK	%
Salmon	440,061	89.8	10,907,028	89.8
Trout	48,778	9.9	1,172,049	9.7
Other	1,439	0.3	64,344	0.5
TOTAL	490,278	100	12,143,421	100

Source: (NOU 2000)

Also included in the 'other' category is halibut farming. In 2000, 562 tons were sold. This production was valued at NOK 39.7 million. The shellfish production amounted to about NOK 8.1 million, most of it being mussels (Fiskeridirektoratet 2000).

In aquaculture, there is always a loss or wastage of units. For salmon, loss and wastage amounted to 6.1 % of stocks (including new supplies) in 2000, totalling as many as 17.2 million salmon. For trout the loss was 4.9%, numbering 2.5 million trout (table 2.7, (NOU 2000). The leading cause of loss is disease (where the major cause is salmon lice) in the net cages, true also for the farming of trout. A total of 7.1 million salmon and 858,000 trout were lost due to disease (table 2.8, NOU 2000). Infested farmed fish suffer reduced growth and quality, and the annual loss to aquaculture due to salmon lice is estimated to be NOK 300-500 million (NOU 2000). Another important cause is escaping. In 2000, 276,000 salmon and 75,000 trout escaped from fish farms. Damage or wreckage in bad weather is the chief cause of major escapes.

Even with these losses, overall profit before tax for the companies in aquaculture was about NOK 3.6 billion in 2000, leaving the producers with an operating margin of 28.7 %. Year 2000 was a better year compared to 1999, when the overall profit was NOK 2 billion, with an operating margin of 20.9 %. The increased profitability can be explained by better prices for salmon and trout, combined with lower production costs per kilogram of fish produced (NOU 2000).

2.2.2 Value of aquaculture

Even though most salmon is reared, the value of trout and salmon is almost the same. In 2000 the ex-farm value of salmon was NOK 10.9 billion, an average ex-farm price of NOK 24.79 per kilo (440 061 tons) (NOU 2000). For trout, the ex-farm value was NOK 1.17 billion, equalling NOK 24.03 per kilo (48 778 tons) (NOU 2000).

2.2.3 Regional differentiation

When it comes to the regional distribution of the production in aquaculture, the counties of Hordaland and Nordland are the two most important, accounting for approximately 20% and 17% of the total production, respectively (see table 6 below). The third most important is the county of Møre og Romsdal (14%), followed by Sør Trøndelag (11%) and Sogn og Fjordane (10%).

Table 6: Aquaculture, produced quantity in tons, value in NOK and percentage per county, 2000.

	Tons	%	NOK million	%
Rogaland	27,036	5.5	761,069	6.3
Hordaland	102,184	20.8	2,537,194	20.9
Sogn og Fjordane	51,390	10.5	1,240,523	10.2
Møre og Romsdal	68,682	14.0	1,760,627	14.5
Sør-Trøndelag	54,304	11.1	1,260,059	10.4
Nord-Trøndelag	32,870	6.7	820,870	6.8
Nordland	85,588	17.5	2,102,236	17.3
Troms	40,049	8.2	915,081	7.5
Finnmark	21,159	4.3	549,856	4.5

Source: SSB 2002, table 427.

2.3 Fish processing industry

The processing of fish in Norway has been increasing over the past decade, in 1999 its gross value of production was NOK 23.6 billion and it employed 12,690 people. (NOS 2002) The total gross value of production was concentrated in freezing of fish (43.9%), salting, drying and smoking of fish (31.5%) and the manufacture of fish oil, fish meal and other fish products (22.6%). Canning only accounted for 2% of the gross value of production in 1999. The importance of the various activities is slightly different if measured by gross investment, then the manufacture of fish oil, fish meal and other products is the largest, accounting for 41.6%, the freezing for 32.1% and the salting etc. for 24.5%.

2.4 Export

In 2000, Norway exported fish and fish products equivalent to the value of NOK 31.5 billion, (NOS 2002, table 42). Most of this (31%) comes from farmed salmon, either fresh or frozen. The second largest export category ‘other frozen fish’ accounts for 15% (excluding fillets, a lot of this being reared trout sold whole) and the third ‘frozen fillets of fish’ (excluding herring) accounts for 12.1%. See table 7 for more details.

Table 7: Export value of the most important fish products, NOK million and percent

Total	31510.8	100%
Salmon (farm raised)	9808.5	31.1
Other frozen fish, excluding fillets	4738.7	15.0
Frozen fillets of fish, excluding herring	3799.2	12.1
Klipfish (salted and dried)	2753.4	8.7
Herring and sprat, fresh, chilled or frozen, including fillets	2236.2	7.1
Other fresh or chilled fish, including fillets	2314.3	7.3

Source: NOS 2002, table 42

The fish products resulting from aquaculture are obviously very important to the export earnings from this sector. As much as 70% of the aquaculture production is exported. In 2000, this consisted of almost 371,000 tons of salmon and trout to a total value of NOK 13.25 billion. The income from fish export comes primarily from trade with countries within the EU (58%), but also with Japan (13.4%), USA (4.4%) and Russia (3.7%) (table 42). The concentrations of the trade with EU countries is even stronger if one only considers export from aquaculture (67%) (NOS 2000).

The table also shows that the selling of whole fish is the most common, but that there is some processing of fillets. In 2000 the export value of whole salmon, fresh and frozen amounted to 79.9 % of the total value of salmon exported. Only 20.1 % of the export value was processed products (NOS 2000).

2.5 Employment and consequences for settlement

The total number of people depending on the various marine sector activities amounts to almost 50,000 – of which 50% are in fishing and aquaculture, 20% are in the processing industry and export, and 33% are in fodder production and other contractors/suppliers (Nafstad, Bergesen et al. 2002). In some more detail, the fisheries sector employed 13,773 people full time and 5,452 part time, distributed on 11,940 boats/vessels in 2001 (table 417, SSB 2002). A total of 12,690 people in 1999 were employed in the fish processing industry[2] (table 40, NOS 2002), and approximately 3,600 in aquaculture (in 2000), corresponding to 4.8 million man hours (SSB 2002, table 429; NOU 2000, table 2.1). The report from The Directorate of Fisheries (Fiskeridirektoratet 2000) shows a higher number of 4000, including also the employment in the production of shellfish and research and development (see also table 2.3, NOU 2000).

This employment is regionally distributed along the coastal communities with a concentration on the western and northern part of the country. Fish processing is concentrated in the counties of Møre og Romsdal, Finnmark, and Nordland. Aquaculture is most significant in the counties Hordaland, Nordland and Møre og Romsdal as can be seen from table 8 below.

[2] As from 1993 Standard Industrial Classification (NACE).

Table 8: Number of people employed in aquaculture* in Norway, most important counties, 2000

Hordaland	822
Sogn og Fjordane	345
Møre og Romsdal	520
Sør-Trøndelag	389
Nord-Trøndelag	250
Nordland	564
Troms	308
Finnmark	189

*) Accounting both the production of fish for food and the hatcheries/fingerling production. Salmon and trout

Source: SSB 2002, table 429; NOU 2000,table 2.1.

The Norwegian coastline is more than 57,000 kilometers long, and 40% (1.8 million) of the population live within one kilometer from the coast (Nafstad, Bergesen et al. 2002). The fisheries sector has been the most important provider of employment opportunities in many coastal communities in Norway, particularly in the northern part of the country. The Norwegian fisheries policies have been an important vehicle for maintaining a dispersed population settlement pattern. As the sector has become more efficient through technological development (Krovnin and Rodionov 1992) over the years, the same catch can be maintained employing fewer people, and it has proved more difficult to maintain the settlements.

In total, the labor force in fisheries has been reduced from 115,000 people in 1945 to only 14000 in 2000 (Album, Wiik et al. 2001) and even less in 2001, according to numbers from the *Statistical Yearbook 2002* as presented above.

The reduction in both number of fishing vessels and establishments in the processing industry has been regionally uneven in Norway. In the period 1987 to 1992, buyers of fish have been reduced by 59% in Finnmark and 25% in Lofoten, whereas in Nord-Møre the number is kept stable. As much as 80% of the total investments in the fishing fleet were carried out in Nord-Møre, and they are filling the same share of the fishing quota as 20 years ago. Finnmark, however, has reduced their share of the quota by 44 percentage points over the same period (i.e. their catch has remained the same in absolute terms, while total catch has increased from 400,000 tons 20 years ago to 700,000 tons today) (Album, Wiik et al. 2001).

The dependency on fisheries and related activities also varies at the regional scale in Norway. In several municipalities in the northernmost county of Finnmark, as much as 20% of the population is employed on fishing vessels or in the fish industry. In many of these municipalities the population numbers no more than 1,000–1,500 people, and during the past thirty years there has been a reduction in the population size of as much as 20% in many municipalities (Album, Wiik et al. 2001).

2.6 How can climate change influence fisheries and aquaculture?

Because the recruitment and growth of fish populations depends on a number of factors – such as availability of food, sea temperatures and currents and, not to forget, human interference – climate change can influence the production in fisheries and aquaculture both directly and indirectly through various processes. All in all, the system of fisheries is extremely complex and the way weather influences life in the oceans is still largely undocumented.

However, there have been attempts at identifying at least some relevant climatic parameters for fisheries and estimating how fisheries can be sensitive to climate change. Relevant climate features include temperature, wind (speed and direction) and the shifting of streams and currents (important to the creation of upwelling), sea level rise, availability of sunlight, and occurrence of storms (IPCC 2001, section 6.3; Cushing 1982; Laevastu 1993; Glantz 1992). In addition, climate warming can increase rainfall and hence also freshwater runoff affecting the availability of nutrients and iron in the ocean. The oceans can also influence climate change in return because of the organisms' ability to absorb and release carbon dioxide (IPCC 2001).

These weather elements can induce death of a population, change the recruitment to the population or influence the year-class strength. The growth of fish depends primarily upon the availability of foods, but also gross differences in temperatures (Cushing 1982). Another important element is that the sea temperatures will affect the geographical distribution of the various fish species. With such distributional changes, patterns of predators and prey is also likely to change (IPCC 2001). Cushing (1982) more concretely points to the northward migration of species.

In the UN's Intergovernmental Panel on Climate Change (IPCC)'s Third Assessment Report (TAR), aquaculture is pointed to as a possible way of compensating for the potential reductions in ocean fish. However, the success of aquaculture could be affected by a change in the availability of herring, anchovies and other species used to provide fodder for the cultured fish. Aquaculture also depends on fisheries for their supplies of fish meal and fish oil (also for fodder). Thus the impacts of climate change on fisheries will have second order impacts on aquaculture. Another possible impact relates to the potential higher ocean temperatures. This can make the rearing of different fish species possible at higher latitudes, as well as increase growth rates and the growing season for fish farming. However, higher temperatures can also lead to decreased oxygen levels, enrichment of organic matter and outbreaks of algal blooms that spread diseases to the fish and deteriorate the conditions for fish farming. Increasing frequency and/or magnitude of storms and floods can also have negative impacts on aquaculture as the damage to infrastructure might increase, as well as fish escapes (IPCC 2001).

2.7 Potential impacts of climate change on Norwegian fisheries and aquaculture

With climate change one expects increased sea temperatures, and this can have both a positive and a negative effect on Norwegian fisheries, distributed over different fishing grounds in the North Sea, the Norwegian Sea and the Barents Sea. For example, for the North Sea, Toresen (2001) expects a temperature increase of 1-2 ^{o}C for the next decades. This higher temperature can mean increased growth of fish, but it can also mean more parasites and algae problems for aquaculture. With warmer sea water, researchers foresee a shift towards increased catches of anchovies and sardines, but reduced catches of herring and cod. However, because of northward migration, the recruitment of herring and cod will improve in the Norwegian Sea. In the Barents Sea, the ice is expected to move north and the conditions for plankton production will deteriorate. Hence cod, haddock, herring and capelin will move eastwards (Glantz 1992). An eastward shift can bring an economic loss to Norway as the fish might move across the 'border' to Russian fishing grounds. Another element of climate change can be that more extreme weather might cause more accidents for fishing fleets. There is also much discussion about potential changes in the Gulf Stream. Even though it is not certain how climate change will influence the Gulf Stream, it is true that any severe change will have detrimental effects for overall living in Northern Europe, including fisheries (Glantz 1992).

When it comes to work on specific species, Krovnin and Rodionov (1992) have found that warming is likely to be favorable for the Atlanto-Scandian herring fishery, as correlation is shown between warmer temperatures and more frequent appearances of rich year classes of Atlanto-Scandian herring. They also show that the fish move according to water temperatures. In years with warmer water, herring go into the northern and northeastern parts of the Norwegian Sea and in the Barents Sea. In colder years, herring is concentrated in the coastal waters of southern and central Norway.

For **aquaculture,** Nafstad, Bergesen et al. (2002) have found that one can expect an increase in the growth of fish by about 10 percent per degree (Celcius) of temperature increase. In the long term, farming of turbot (piggvar) might become possible. However, increased temperatures may increase illness and the occurrence of poisonous algae and parasites. They point to negative effects also if there is an increased frequency of extreme weather events which will mean more days with operational problems and added costs for securing equipment properly (Nafstad, Bergesen et al. 2002).

2.8 Climate change and fisheries: a complex relationship

> The relationship between climate change and fisheries will not be easy to define and most likely will have to depend … on generalizations derived from case by case assessments of past and present experiences. Such assessments can provide 'guesstimates' about how fisheries might respond to climate related environmental stress … (Glantz 1992, p. 4)

As stated in almost all the sources used for this compilation of data on fisheries and aquaculture, it is difficult to separate the impact of climate from that of other factors that influence the marine ecosystem, as for example increased harvesting. "Interactions within the marine environment are acknowledged to be extremely complex" (Glantz 1992, p.4). Climate change is only one factor among many that influences the stock size and availability of fish. The many factors operate simultaneously and in different directions, and it is hard to separate out the impacts of only one factor such as climate change on fisheries /changes in stock sizes and catches (Laevastu 1993).

2.9 Summarizing fisheries and aquaculture

As was shown in 2.1, the fisheries provide a very important source of income for Norway as a whole, and for the small settlements along the coast in particular. The most valuable are the catches of cod and herring, accounting for 2.2 billion NOK and 3.5 billion NOK yearly, respectively. In addition, aquaculture of salmon alone equals the value of the production of fisheries (about NOK 11 billion). The value connected to the fish processing industry is twice this, about NOK 24 billion.

Guessing at the socio-economic consequences of climate change is almost impossible given the complex relationship between climate and other variables influencing the growth and catch of fish. It is possible, however to summarize some of the issues that are thought to be affected by warmer temperatures and more variable weather bringing more extreme events.

Fish species are sensitive to water temperature, which in many cases will determine the geographical dispersal of where the fish can be found. For cod, the effects of climate change can prove to be negative for Norway if the species migrates as far north east as to enter the Russian part of the Barents Sea. Cod is Norway's most valuable catch. This loss might be somewhat compensated by catching more herring (the second most valuable catch today), as warmer water temperatures can bring this fish species farther north and even east into the Barents Sea. This is also the case for fish species like anchovies and sardines that have their northern limit in southern Norway today (Toresen 2001). Effects of warmer water can also mean stronger year-classes of fish (better recruitment).

When it comes to aquaculture, the positive effects of warmer climate are expected to be rapid growth, resulting in a higher turnover, and there might also be a potential for the cultivation of new and maybe more valuable species. The negative effects concern the loss of fish to parasites and escapes. These are already the major reasons for loss in this sector. With warmer temperatures more outbreaks of pests can be expected. More variable weather such as a higher frequency of storms can also be expected, something that can lead to increased loss due to escape of fish because of weather damaged equipment. Increased losses will reduce the profit margin of the industry.

3 Agriculture

3.1 Agriculture in Norway

The agricultural sector in Norway is diverse in terms of both activities and location, hence also to exposure to climate change and variability.

Table 9: Land use, percent per county, 1999

Use Area/county	Grass production (including pastures)	Grains and oilseeds	Potatoes	Other field and crop area	Surface cultivated area	Total
Total Norway	47.0	32.2	1.4	4.8	14.6	100.0
Østfold	10.3	82.6	1.3	3.1	2.8	100.0
Oslo and Akershus[a]	12.6	80.2	0.7	2.7	3.8	100.0
Hedmark	30.9	55.2	4.5	4.7	4.7	100.0
Oppland	53.9	24.6	1.6	6.0	13.9	100.0
Buskerud	31.9	51.9	0.9	5.6	9.8	100.0
Vestfold	12.3	71.5	3.5	10.4	2.3	100.0
Telemark	44.1	37.1	1.2	6.4	11.3	100.0
Aust-Agder	70.2	10.5	2.0	7.9	9.5	100.0
Vest-Agder	70.8	3.8	0.5	3.5	21.4	100.0
Rogaland	47.7	3.8	0.9	6.3	41.3	100.0
Hordaland	56.8	0.1	0.1	3.5	39.5	100.0
Sogn og Fjordane	63.1	0.2	0.3	2.5	33.8	100.0
Møre og Romsdal	78.4	2.7	0.4	1.6	16.9	100.0
Sør-Trøndelag	65.6	20.0	0.5	3.9	10.0	100.0
Nord-Trøndelag	53.1	33.0	1.8	6.0	6.0	100.0
Nordland	78.1	0.5	0.8	4.1	16.5	100.0
Troms	81.0	0.0	1.1	7.1	10.9	100.0
Finnmark	78.7	0.0	0.3	7.6	13.4	100.0

a) Since Oslo is a small county consisting of only one municipality and dominated by the capital city, it is often counted in the statistics together with the neighboring county Akershus
Source: http://www.ssb.no/jt1999/tab-2001-04-03-02.html

As in any economic sector, productivity/output depends on a relationship between resources, capital and labor. In resources, climatic factors such as rainfall, temperature, wind, and frequency and magnitude of extreme events (such as floods and storms) are important, as well as agro-ecological characteristics such as soil quality and slope.

3.2 How can climate change influence agriculture?

Agriculture is intimately linked to climate (Kandlikar and Risbey 2000) and world agricultural production varies from year to year, largely as a result of weather conditions and inter-annual climatic variability in many regions (Feenstra, Burton et al., 1998). Climatic change will affect agriculture, resulting in costs and benefits at all scales, ranging from individual plant/animals to global trade (IPCC 2001).

Many hundred assessments of impacts of climatic change on agriculture have already been undertaken, most of them focusing either on specific crops or regions (Tol 2002). Many studies have included crop yield modeling (see for example Harrison, Butterfield et al. (1995), and since 1995 there have also been studies that try to link the estimates of crop yield change to estimation of production and welfare impacts by using economic models (IPCC 2001). In addition, the consequences of climatic change to agriculture have also been explored in wide-ranging studies such as the IPCC report (IPCC 2001) and the European ACACIA project (Parry 2000). The assessments differ in their objectives and targeted users. Objectives range from evaluation of output, management, or adaptation options, to identification of gaps in knowledge or increased public awareness (Feenstra, Burton et al., 1998).

From the impacts studies already undertaken, we can derive that there are some basic mechanisms and processes that regulate the sensitivity of agriculture to climate change.

For Europe, the ACACIA report (Parry 2000) mentions temperature, incoming radiation, water and nutrient availability as the most important factors determining agricultural production. Plants are affected directly through the process of photosynthesis. Animal husbandry is affected directly through the temperature; heat and cold stresses cause lower food intake and higher water intake which results in lower performance. Indirectly, climatic factors influence the production of fodder.

The question of interaction between climatic change and enhanced CO_2 concentrations has also been considered important, as increased concentrations of CO_2 will lead to an increased rate of photosynthesis, which again leads to larger and more vigorous plants and higher yields. Also, consumption of water is reduced because of decreased transpiration. Experiments where CO_2 concentrations have been doubled show an increase of harvestable dry matter by 21 to 34 percent, depending on species. Also studies of smaller changes in CO_2 concentration have shown an increase in grain yield of wheat. With respect to water use efficiency, a study of wheat indicates that a doubling of CO_2 concentration increases efficiency by as much as 50-60% (Parry 2000).

On the issues of spatial change of crops and varieties, a study from Finland has found that with a one degree increase in temperature (annual mean), there will be a northward shift of 120-150 km for spring cereals. Similar results were also found for maize in Finland. The largest changes will be at the current margins for specific crops. Associated processing industries will be likely to move with the species because of high transportation costs of the raw material (Parry 2000).

There are few studies of impact of climate change on the quality of produce; this seems to be very crop-specific (Parry 2000).

In addition to looking at the mean seasonal temperature to measure the consequences for the yield of annual crops, Wheeler, Craufurd et al. (2000) argue that it is important to look at the variability in temperature. Seed yields in particular are sensitive to brief episodes of hot temperatures. For example, if hot periods coincide with the time of flowering, the number of seeds or grains that develop can be less.

In the northern countries, the length of the growing season limits the productivity of crops. Night frost in late spring and early autumn produces a risk (Parry 2000).

3.3 Potential impacts of climate change on agriculture in Norway

Sygna and O'Brien (2001) find the following climate parameters to be relevant when assessing the impacts on agriculture: winter-, summer-, and average temperature, frost/thawing, length of growing season, distribution and intensity of rainfall, extreme weather events, radiation, and humidity. Most likely there will be both positive and negative impacts. Positive impacts include a longer growing season (which makes harvesting twice per year possible). In mid-Norway (Stjørdal) an experiment has shown that the growth season has been extended by 10 days compared to 1963. Other positive potential impacts might include increased plant productivity due to increased CO_2 uptake and warmer temperatures as well as the potential for new species (with higher market value). Negative impacts include increased erosion and discharge of nitrogen depending on pattern of rainfall (seasonal and quantity), presence or absence of permafrost, as well as soil type and usage. More frequent problems with pests and diseases are also expected.

None of the above-mentioned factors of potential impact from climate change have been surveyed for Norway. The most comprehensive study of climate impacts on Norwegian agriculture was undertaken in 1990 (NILF 1990). This study calculates the effects of increased CO_2 concentrations (a concentration of 450 ppm will give an average increase of 15% on yield), as well as higher temperatures and therefore also an extended growing season. These factors are considered the most important to explain changes in yield, which in most cases will be positive. In addition, factors such as increased erosion and use of pesticides/herbicides are also known to influence yield, however the quantification remains a problem.

The research undertaken by NILF is based on a climate scenario that is substantially warmer than the scenario now provided by RegClim (see table 1, this report). In NILF (1990), the calculations of the impacts are based on the following climate scenario for 2030 (referred to as the ‘most likely’ scenario in the report):

Table 10: Climate change in Norway by 2030

	Inland	**Coast**[A]
Temp. increase º C		
Summer	2	1.5
Winter	3.5	3.0
% increase precipitation [B]		
Spring	10	15
Summer	10	10
Fall	5	5
Winter	5	5

A) Coast= all the counties from vest-Agder and west/north bound to Finnmark. All the other counties (Øst-Agder, Telemark, Vestfold, Buskerud, Oslo/Akershus, Hedmark, Oppland, Østfold) are considered inland (even though they also have coastline).
B) Depending on when the rain falls and how much that comes as showers, the rainfall will have differential effect on agriculture. Estimations indicate that the deficit of rainfall in May, June and sometimes also July, will be reduced by 4-6mm per month, and that the surplus in August and September (sometimes also July) will increase by 4-8 mm per month.

Source: NILF (1990).

3.3.1 Climatic zones in Norway

The NILF-report (NILF 1990) uses a division of 8 climatic zones according to temperature (table 3.2 page 22). Today, Norway has area only in zones 3 – 8. With the most likely scenario for climatic change, the area will be in zones 1-6.

The total area that will be in the most productive zones (1 and 2) will be 4.000 square kilometers (1 km^2 = 0,3861 square miles, 1 decare (mål) = 0.249 acres). This equals 46 percent of the total area. For the other zones there will be an increase from 14 to 27 percent in zone 3, and a decrease in the remaining zones from 38 to 10 percent for zone 4, from 27 to 11 percent in zone 5 and from 9 to 6 percent in zone 6. Zones 7 and 8, in which we have 9 and 3 percent, respectively, of our total agricultural area with today's climate, will probably not be used for agriculture.

3.3.2 Overall economic consequences

The increased yield in the NILF report is calculated to be a 20% increase in production of fruit, a 30% increase for berries, an increase of grain production by 35%, and fodder grain production by 300 million fodder-units. Under the assumptions of optimal localization of production, this increased production can still be sustained using less area, (1.8 million acres), than today (2.5 million acres). Large areas with low temperatures and yields in northern Norway, as well as in Oppland and Hedmark counties, will be left unused.

Since employment in agriculture is related to both area under cultivation and yield, the effect is calculated to be a decrease in demand for labor, at approximately 7200 man-labor years (NILF 1990, p. 76). Effects of employment were not calculated on the county level, but we can assume that the areas with reduced area under cultivation will also experience reduced demand for labor.

With increased volume, production costs would increase by 800 million NOK. However, NOK 550 million will be saved as a result of reduced need for imported goods. Hence, the net increase in production costs is only NOK 250 million (NILF 1990).

3.3.3 Increased yields per crop and crop-group.

The NILF report presents yield data for specific species in different climatic zones (p. 29). We can hold this together with information on which climatic zones will be predominant in each county with climatic changes (ibid, tables, pp. 92-105), and compare this with today's distribution of area use per county (see table 9, this report). For the calculations of yield change for fruit, berries and vegetables, county level data on current yield are taken from the SSB agricultural statistics of 2000.

Grass

The cultivation of grass takes up 47% of the area under cultivation in Norway (1999). According to (NILF 1990), the risk of frost damage will be reduced for large areas. Most (50.7%) of the grass-growing area ("eng" in the statistics) is found in the counties of Oppland, Sør-Trøndelag, Nord-Trøndelag, Rogaland, and Møre-og Romsdal. The four first counties will experience a shift from a concentration of their arable land in climatic zones 4-5 to 2-3. Yield will go up from an average of 720 kg/decare to approximately 1150 kg/decare, an increase of 60%.

The economic significance of climate change for grass cultivation is hard to determine because most of the grass grown is usually used on the farm for animal keeping, and this is not recorded in bookkeeping with monetary values. This is illustrated by the low value registered as income from grass production in year 2000, a mere NOK 101 million (table 8.16 NOS 2001b[3]).

Grain and oilseeds

The cultivation of grain and oil seeds takes up 32% of the area under cultivation in Norway (1999, see table 9). The estimated yield increase for grains is 35% (oat, barley, wheat). Grains account for 85.5% (based on area) of the category 'Grain and oilseeds' (NILF 1990). Grains and oil-crop production are concentrated in the counties of Østfold, Oslo og Akershus and Hedmark, accounting for 57% of the national production. The income from grain and oilseed production in 2000 reached NOK 2.3 billion (table 8.16, NOS 2001b).

Fruit, berries and vegetables

The cultivation of fruit, berries and vegetables is included in the statistics as "other field and garden area", which occupies 4.8 % of area under cultivation (1999). In this category 63% of the area is actually used for fodder crops, and the remaining 37% of the category covers vegetables, fruit, berries and "other plants" (*hagebruksvekster*) (table 1.8, NOS 2001b[4]). Even though these crops are insignificant in terms of occupied area, (only 1.6% of total cultivated area in Norway), these crops are significant in rendering value for the farmer, more than 10% of the total income from plant production comes from vegetables, fruit and berries.

The NILF report estimates the overall yield increase for fruit and berries to be of 20%. If one tries to disaggregate this number using sources as mentioned above on climatic zones change and crops yield, the picture is more varied.

For **fruit**, the counties of Hordaland, Telemark, Buskerud, Sogn og Fjordane and Vestfold are the major producers. The NILF report does not include zone changes for Hordaland and Sogn og Fjordane. In the case of Vestfold, Buskerud, and Telemark the zones will change from 3-4 to 1-2, and mean yields will go up from 150 kilos to 250 kilos per 10 trees, an increase of 66%.

When it comes to **berries,** Hedmark, Buskerud, Oppland and Sogn og Fjordane are the major producers. The areas of Hedmark and Oppland will be in climate zones 2-3, compared to today's zones 4-5. The mean yield for red currants and gooseberries (*stikkelsbær*) will go up from around 30 kilos per decare to 60, a 100% increase. Strawberries and raspberries will go from an average of 600 kilos per decare to 950. In the case of Buskerud county, the zones will be 1-2 (today 3-4). Here, mean yield for red currants and gooseberries from around 50 kilos per decare to 70, and strawberries and raspberries from an average of 850 kilos per decare to 1000.

For **vegetables**, the largest producers are Vestfold, Rogaland, Hedmark, Østfold, Oppland Buskerud. In Vestfold, Østfold and Buskerud the zones will change from 3-4 to 1-2, and the mean yield increase by approximately 200 kilos per decare in zones 4, 3, and 2, but many varieties will experience either decreasing or stagnant yields for zone 1. This is also the case of the counties Rogaland, Hedmark, Oppland, where the zones will shift from 4-5 to 2-3. Changes in yields will be crop and zone specific, with a maximum of 200% increase. The largest increase in yields will be from zones with a higher number, e.g. 5 to 4.[5]

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[3] See NOS (2001b), table 8.16: Aggregate account of agriculture/ Totalrekneskap for jordbruket

[4] See NOS (2001b), table 1.8 Agricultural area, by use/ Jordbruksareal, etter bruken

[5] Table 2.6 NOS (2001b) and table 4.2, p. 33 and annex 1, p. 92-102 in NILF (1990).

The income from the production of fruit, berries and vegetables (and flowers) in 2000 reached NOK 2.8 billion (table 8.16, NOS 2001b).

Potato

The cultivation of potatoes occupies 1.4% of the area under cultivation (1999). The NILF report highlights that the longer growing season will give better quality produce and increased yields, but it does not quantify. It also states that there will be fewer mechanical injuries and a hence also a reduction of damage during the following storage. However, potato rot will become a larger problem, and may be handled with increased spraying. Most (55%) of the potato area is in Hedmark, Oppland and Nord Trøndelag counties. Here the climatic zones will be 2 and 3 (compared to 4 and 5 today), and the mean yield will increase from 24.5 to 31.5 tons per hectare, an increase of 28%. Vestfold county is another important potato producer in the country, account ting for 10.2% of the area used for potatoes in Norway. The zones here will change from 3-4 to 1-2, and the mean yield can be expected to increase by from 27.5 to 33.0 tons per hectare, an increase of 20%.

The income from potato production in 2000 reached NOK 445 million (NOS 2001b).

3.3.4 Increased use of herbicides, pesticides and fungicides

With a warmer and wetter climate, the impacts assessment undertaken by NILF estimates the needs for spraying against weeds, pests and fungi to increase by 50% to 200%, depending on type of chemical. For herbicides the expected increase is between 50 and 100%, and for pesticides 100%. The need to spray grains against fungi is estimated to increase by 100-200%, and for vegetables and tubers like potato crops the need is expected to increase by 100%. For fruit and berries a 100-200% increase is estimated.

Table 11: Trading in chemicals, tons active component, 2001[6]

Fungicide	Herbicide	Pesticide	Others	Sum
119.9	377.2	8.5	13.1	518.7

Source: Mattilsynet (2004).

In 2002 the cost of these chemicals reached NOK 219 million (NILF 2003). According to Bye (2002)[7], the share going to the agricultural sector account for 92% of this number, about NOK 201.5 million.

If we calculate an average change in the consumption of these chemicals of a 100%, the cost of chemical use with climate change is NOK 403 million.

3.3.5 Use of fertilizer, increased erosion and loss of nutrients by runoff

An increased use of fertilizer is expected because of increased erosion and loss of nutrients by runoff, and because higher temperatures speed up the natural decomposition and other soil processes (Parry 2000). The increased demand for fertilizer is not quantified, either in amount or in value (NILF 1990). In 2000, the agricultural sector in Norway consumed 171215 tons of chemical fertilizer (table 397, SSB 2002). Accounting data from the sector calculates the expenditure to be NOK 939 million (table 401, SSB 2002).

[6] The numbers from 2001 are considered to be representative after three years of steep increases and decreases in the trading reflecting changes in tax regulations for these chemicals as of Jan. 1. 1999 Bye, A. S. and S. E. Stave (2001). *Resultatkontroll jordbruk 2001. Jordbruk og miljø.* 2001/19. Oslo, SSB.
[7] Bye, A. S. Personal communication (e-mail) with A. Schjolden, 23.7.2002.

3.3.6 Impacts on cattle

The IPCC and the ACACIA report (Parry 2000) states that cattle will be affected both directly through warmer temperatures and indirectly through the production of fodder connected to climate change. The Norwegian impacts assessment emphasizes that milk production can increase from 6000 to 7000 liters per cow when the animals are given more concentrated feed. Under the assumption of stable milk consumption, the number of cows can be reduced by 14%. Employment would be reduced by 4% (almost 3000 man years). The total production cost would be down 2% (NOK 531 million).[8]

3.4 Summarizing agriculture

Again, as was the case with fisheries and aquaculture, the way climate change is likely to affect agriculture is a complex picture with both positive and negative elements. Here also, climate change does not occur in a vacuum but along with other global changes such as economic growth, urbanization, migration, changes in land use and resource degradation, processes that will also affect the agricultural sector. In addition, social, economic and technological change will transform the setting in which climate change interacts with agricultural processes.

For Norwegian agriculture, climate change is generally expected to bring a longer growing season and increased productivity because of increased CO_2 uptake and warmer temperatures. The NILF report calculates the following increases in yield: a 20% increase in fruit production, a 30% increase for berries, and an increase of grain production by 35%. A productivity increase is also expected for grass, which most often means increased self-sustained fodder capacity for raising animals, and decreased expenditure on fodder (however, not quantified in the calculations). For vegetables, the increased productivity will be specific to crop and area where planted. For potatoes, increased productivity is estimated at 28% for the counties where the majority of the potato fields are located – however, with increasing problems and economic damage from potato rot. With these increases in productivity, the same amounts of produce as in 1990 can be produced using less area and labor. The report estimates that large areas with low temperatures and yields in northern Norway as well as in Oppland and Hedmark counties will be left unused, and that there will be a decrease in the demand for labor, by approximately 7200 man-labor years.

Other negative impacts include increased erosion and discharge of nitrogen due to increased runoff from more summer rains combined with heavier use of fertilizer. More frequent problems with pests and diseases are also expected, and hence an increased need for use of pesticides, herbicides, or fungicides. Future increased erosion and fertilizer use under a changed climate have not been quantified in terms of either amounts or monetary value. To combat the increasing problems with pests and diseases, the estimates range between a 50% and a 100% increase, depending on the chemical.

All these results presented from the NILF study need to be approached with caution, however, because the analyses are based on an average warming of 2 °C (inland) and 1.5 ° C (coast) during the summer, almost twice as warm compared to the summer average projected by the RegClim scenario for Norway (0.9° C). Hence the results are likely to be overestimated, but it is not possible to say by how much unless repeating the whole NILF study under the assumption of a less warm climate scenario.

[8] Assumption: to keep up the meat production, you need more sheep when you reduce the amount of cows; hence, the production cost is not reduced by more than 2% because of the increased cost in sheep. Most of the saved cost is accounted for by the reduced demand for labour.

4 Forestry

4.1 The forestry sector in Norway

At the national scale, an average of 23% of Norway's total area is used for productive forestry (data from 1989), equal to 70,000 square kilometers (NOS 2001, table 2.1).

4.1.1 Characteristics and productivity of the forest sector

The ownership structure of the forest properties in Norway is made up of many small units. When looking at the number of properties, almost 58% are smaller than 250 decares, and almost 90% of the properties are smaller than 1000 decares (see table 12 below).

Table 12: Number of forest properties according to size in decares

	Total[1]	25-99	100-249	250-499	500-999	1000-1999	2000-4999	5000-9999	10000-19999	20000 and over
	125,522	37,683	34,802	23,515	16,489	8189	3628	717	275	224
%	100	30.02	27.73	18.73	13.14	6.52	2.89	0.57	0.22	0.18

1) Counting properties with at least 25 decares of productive forest area
Source: table 404, Statistical Yearbook 2003 (Based on data from 1989)

However, when looking at the distribution of the productive forested area in properties in table 13 below, 61% of the productive area is held in properties larger than 1000 decares, 16% between 500 and 599 decares, and 19% between 100 and 499 decares.

Table 13: Distribution of productive forest area on property size groups

	Total[1]	Size groups, decares				
		25-99	100-499	500-999	1 000-4 999	5 000-
Decares	701,22,254	2,068,656	13,709,048	11,276,965	21,491,353	21,576,232
%	100	2.95	19.55	16.08	30.65	30.77

1) Counting properties with at least 25 decares of productive forest area
Source: table 2.3, NOS (2001) (Based on data from 1989)

Only 2.8% of the properties are smaller than 100 decares. The average size of forest properties is 571 decares. Only 1 % of the properties was larger than 5 000 decares.

Most of this area is covered by coniferous forest (in total 55%) or forest where conifers dominate in mixed forests (17%). For more detailed information on species composition, see table 14 below.

Table 14: Productive forest area[1] by species of tree. Square kilometers and percent

	Total	Spruce forest	Pine forest	Mixed coniferous forest	Conifer-dominated mixed forest	Broadleaf dominated mixed forest	Broad-leaf forest
Km²	70,966	19,025	15,455	4815	12,081	4364	15,227
%	100	26.8	21.8	6.8	17.0	6.1	21.5

1)Excluding area under regeneration
Source: table 2.7 (NOS 2001).

The total growing stock, as measured in cubic meters, amounted to 697 million m3 in 2000, with an annual increment for all species of 23 million m3 (table 2.5 (NOS 2001).
This increment is distributed unevenly on the various species, as seen in table 15 below.

Table 15: Growing stock inside bark, 2000. Million m3 and percent

Spruce	Pine	Deciduous (broadleaf) trees
308.6	233.9	155.4
44%	34%	22%

Source: table 2.5 (NOS 2001).

4.1.2 Regional distribution

The productive forested area is concentrated in the counties of Hedmark (18%), Oppland (10%), Nord Trøndelag (8.3%), Buskerud (7.7%) and Telemark (7%) (Table 2.3, NOS 2001).

Table 16: Regional distribution of productive forest area by species of tree. Square kilometers and percent

Groups of counties	Total	Spruce forest	Pine forest	Mixed coniferous forest	Conifer-dominated mixed forest	Broadleaf dominated mixed forest	Broadleaf forest
Østfold, Akershus, Hedmark, Oslo Km2	18427	5371	5473	2163	3498	773	1150
%	100	29.15	29.70	11.74	18.98	4.19	6.24
Oppland, Buskerud and Vestfold Km2	13694	5563	2238	983	2417	1044	1449
%	100	40.62	16.34	7.18	17.65	7.62	10.58
Telemark, Aust-Agder and Vest-Agder Km2	10692	2016	3542	737	2016	860	1522
%	100	18.86	33.13	6.89	18.86	8.04	14.23
Rogaland, Hordaland, Sogn og Fjordane and Møre og Romsdal Km2	8427	1108	2560	179	869	559	3153
%	100	13.15	30.38	2.12	10.31	6.63	37.42
Sør- and Nord Trøndelag Km2	10059	3682	1224	677	2359	770	1346
%	100	36.60	12.17	6.73	23.45	7.65	13.38
Nordland and Troms Km2	9666	1285	418	76	922	358	6607
%	100	13.29	4.32	0.79	9.54	3.70	68.35

Source: table 2.7 (NOS 2001).

There is also great variation in species composition between the different regions of Norway. While the coniferous forests are concentrated in the south-eastern and central parts of Norway, (three first rows in the table below), the broad-leaved species are more prominent on the west coast and in the northern parts of the country.

4.1.3 Distribution of forest in relation to altitude

The large majority of the forested areas are below 1000 meters above sea level in southern Norway and below 800 meters in Western and Northern Norway. The tree line has both a north-south and east-west gradient related to exposure to climatic features such as temperature and wind. With a warmer climate there is a potential for increasing the area of productive forest land.

Table 17: Distribution of forest in relation to altitude

Regions and altitude	Total area, excl. lakes[a] Square km	Productive forest areas Square km	Percent of productive forest areas %
NORTH NORWAY			
b/w 1000-1199	4,232.33	9.39	0.22
b/w 800-999	8,738.66	68.73	0.79
b/w 600-799	15,172.46	431.67	2.85
SOUTH NORWAY			
b/w 1000-1199	20,432.04	242.12	1.19
b/w 800-999	29,507.05	3,191.82	10.82
b/w 600-799	32,808.57	10,786.72	32.88
ALL NORWAY			
b/w 1000-1199	24,664.37	251.51	1.02
b/w 800-999	38,245.71	3,260.55	8.53
b/w 600-799	47,981.03	11,218.39	23.38

a) Total area excluding lakes. Calculated using 4 groups: 1- Productive Forest, 2- Other woodlands, 3- Populated areas and areas above coniferous forest, 4- Agricultural areas.

Source: CICERO's GIS covers: DTED: Elevation Norway and DMK N1000: Norway 1:1.000.000, Themes: Land use (Data uses a total of productive forested areas of 87832 square kilometers, compared to the above data from SSB of 70000).

4.2 Removal, sale and value of wood products

A total of 8.1 million cubic meters of lumber were removed for sale in 2000, equaling a value of NOK 2.56 billion, or NOK 314 per m3 (table 412, Statistical yearbook 2002 and table 5.1, NOS 2001). As much as 91 % of the removals in 2000 were softwood lumber (71% spruce and 20% pine), only 0.7% was hard wood lumber, and 8.3% was wood for fuel. The softwood lumber was sold to sawmills and wood industries and mechanical and chemical pulp industries, as shown in table 18 below.

Table 18: Commercial removal, by buyer group. Thousand cubic meters solid wood

Year	Total	Softwood lumber by purchase				Hardwood lumber	Wood
		Total	Sawmills and wood industries	Mechanical and chemical pulp industries	Other buyers		
2000	8 156	7 417	4 119	2 708	589	61	678
%	100	91	51	33	7	1	8

Source: table 412, Statistical yearbook 2002

In 2001, a somewhat larger quantity of 8.4 million cubic meters of lumber was sold, equaling a value of NOK 2.56 billion, or 327 per m3 (http://www.ssb.no/emner/10/04/20/skogav/).

4.2.1 Regional distribution

Also when looking at removals, Hedmark is the most important forestry county. As much as 28 % of Norway's total removal in 2001 was in Hedmark. This was more than twice the size of the second largest removal, which was in Oppland county and accounted for 13% of the total removal in Norway that year. http://www.ssb.no/emner/10/04/20/skogav/

4.2.2 Sale and production in wood industries

As pointed out in table 16 above, more than 50% of the lumber removed was bought by sawmills and wood industries, and more than 30% by mechanical and chemical pulp industries. The quantities of the most valuable wood, paper and pulp products and the value created from this production are shown in table 19 below. The total value of these commodities was NOK 19.5 billion.

Table 19: Quantity sold and value of commodities, 2001

	Quantity	Value (thousand NOK)
Sawn wood [a]	1,752,705 m3	2,190,449
Planed wood	1,015,305 m3	2,053,141
Particle boards	3,876,065 m3	1,168,006
Pulpwood and pulp of other cellulosic material	728,428,000 kg 90% sdt	2,829,580
Paper and paperboard	2,321,204,870 kg	11,230,035
Total		**19,471,211**

a) numbers from 2000
Source: table 5.10, SSB (2001).

4.2.3 Foreign trade

In 2001, Norway exported wood and paper products totaling a value of 8.5 billion NOK. The commodities that raised the largest values were paper and paper board (4.5 billion), cellulose (875 million), pulp wood (728 million), sawn wood (590 million), and mechanical pulpwood (502 million). Paper and paperboard is also the largest export commodity in terms of quantity (2 million tons), followed by newsprint paper (804 thousand tons) and writing and printing paper (646 thousand tons). At the same time Norway imports almost 2 million m^3 of pulpwood (1.8 in 2001), indicating that the industries producing pulp and paper have a larger capacity than the Norwegian forest stands can provide material for (table 5.11 and 5.12 , NOS (2001).

4.2.4 Employment

Forestry is an important sector in the counties of Hedmark, Oppland and Buskerud (Sygna and O'Brien 2001). A total of 43% of the productive forestlands in Norway are owned by people who are also farmers (http://www.ssb.no/emner/10/04/20/skogav/)

4.3 Potential impacts of climate change on forestry

Forests provide many goods and services, such as timber, food, biodiversity, medicines, recreation, and so on, that society values. Changes in the global climate are likely to affect forests and hence also the goods and services and the socioeconomic system. However, it is difficult to distinguish the impacts of climate change on these goods and services from impacts caused by other global changes such as atmospheric changes or land-use changes (IPCC 2001). Still, it is possible to point to several climatic features that are likely to be relevant to the growth and health of forest and hence also the productivity of the sector.

Forests are sensitive to climate change as climate drives both forest growth and the health of the forest through the existence of pests (such as insects and fungi) (Solberg 2002). Forests, in turn, are the basis for the economic activity of forestry, thus climate change will affect this sector indirectly (UNEP 1998). However, estimating exactly how climate change will affect the production in forestry is a very difficult task, as the impacts will be geographically place-specific, and depend on other factors influencing forest growth and productivity, such as management and nitrogen deposition in the soil, as explored in Mund, Kummetz et al. (2002). There is also a difference in the influence of mean conditions of climate change and climate variability (Bugmann and Pfister 2000). Many studies have assessed the remarkable forest growth for the past 50 years (see list in Mund, Kummetz et al., 2002), and many have also documented that climate variation is a major driving force behind growth variation and tree mortality (see list in Mäkinen, Nöjda et al. 2002).

There are a number of climate change parameters that are relevant to the growth and health of forest. Along with higher temperatures, which are likely to increase growth pace, increasing CO^2 concentrations and other chemicals in the atmosphere has also been the subject of many studies. A variety of evidence indicate that forest productivity increases with the fertilizing effect of atmospheric CO^2, but that these increases are strongly tempered by local conditions such as moisture stress and nutrient availability. In addition, other components of environmental change, such as nitrogen deposition and ground-level ozone concentrations, also affect forest processes. Modeling has shown a synergistic fertilization response between CO^2 and nitrogen enrichment, leading to further increases in productivity. Ozone, however, can suppress these gains. In forests in the Northeast of USA, current ozone levels have likely decreased production by 10% (NAST 2001).

Other mechanisms through which climate change can affect forests are natural disturbances such as insects, disease, introduced species, fires, droughts, frosts, hurricanes, landslides, wind storms and ice storms. Climate change can alter the nature of these disturbances, which will again affect the forests. For example, the risk of more frequent or severe fires might increase in a warmer climate – e.g., in the US about 10% over the next century. The interactions between climate change and hurricanes, landslides, ice storms, wind storms, insects, disease, and introduced species are difficult to predict but very plausible (NAST 2001). Parry (2000) specifically points to how increased wind damage may more frequently result in imbalances in orderly harvesting procedures with increased costs and disturbed timber markets.

A changing climate is also likely to bring changes in the composition of species in the forests, as well as a change in total forested area (UNEP 1998). These changes will have consequences for related sectors, such as the wood processing industry and agriculture. Parry (2000) points to how increased productivity provides new opportunities for the wood processing industry to expand its capacity. Another issue can be increasing competition for land areas between forestry and agriculture as more land becomes feasible for agriculture. The US assessment also focuses on similar features. With more potential forest inventory to harvest, the costs of wood and paper products to consumers are likely to decrease, as are the returns to owners of timberland. The changes in climate and consequent impact on forests are likely to change market incentives to harvest and plant trees, and shift land uses between agriculture and forestry (NAST 2001).

Are there any evidence of how climate change will affect forests and the forestry sector in Norway? Before answering that, it is necessary to look at the sensitivity of the Norwegian forestry sector.

4.4 Potential impacts in boreal areas such as Norway

In the boreal region, researchers expect an increase in timber production and a change in the composition of the forests. Several existing tree species will probably grow faster and consequently experience enhanced turnover of tree populations. Most likely, there will be an increasing dominance of deciduous species and a larger supply of hardwood timber. On the other hand, increased precipitation, cloudiness, more rain days and reduced duration of snow cover and soil frost can lower the profitability of forest production because these factors adversely affect forest work (Parry 2000).

In Norway, several areas are likely to experience reduced snow accumulation in the future, for example in the western edges of the boreal forest. This may lead to a reduction in soil moisture on shallow soils in early spring and early summer, causing problems for *picea abies* (Norway spruce) and other shallow rooted tree species (Parry 2000). *Picea abies* is the most common tree species in Norway.

Changes in natural disturbances are also likely to occur in Norway. Based on downscaled climate scenarios, Solberg (2002) believes we will experience more spring frost damage, more drought stress in the early summer (particularly in south-eastern Norway), and perhaps less fall frost damage. In addition, increased storm frequency and strength is likely to lead to more uprooting and damage from salt along the coast. Increased winter precipitation can lead to more breakage from weight of snow in the alpine forest. With an increase in average temperature, Norway is likely to experience an increase in forested areas, with the future tree line at a higher elevation. Warmer temperatures will also most likely change the composition of species in the forest towards more deciduous trees.

In the 1990s, a unique project on impacts of climate change on the forest was carried out in Norway. The CLIMEX experiment surveyed the effects of increased CO^2 concentrations (560 ppm) and temperature (3-5ºC warmer) in an enclosed, forested area of 860 m^2 in the southern limits of the boreal forests. In this large-scale greenhouse, the chemical composition of soil changed towards higher levels of nitrogen, and the runoff contained higher levels of inorganic nitrogen. With higher levels of nitrogen, increased plant growth can be sustained. However, the longer term effects of increased nitrogen availability is uncertain; it might for instance lead to a shift in plant species adapted to higher levels of nitrogen in the soil (van Breemen, Jenkins et al. 1998).

4.4.1 Shifting forest boundaries

According to a study by NIJOS (Norsk Institutt for Jord- og Skogkartlegging/ Norwegian Institute of Land Inventory) that surveyed the potential areas for forest growth with a warmer climate, 116,303 square kilometers of Norway's total area lie above today's tree limit (Strand 2002). As an average for the whole of Norway, the study estimates that with a 0.5 °C degree warming, one can expect about 31,557 square kilometers, or about 27.1%, of this area to become forested. If the temperature increase is of 1°C, one can expect that another 23,880 square kilometers (or 20.5% of the total current area) can be forested. The total will then be 55,437 square kilometers (or 47.6% of today's area above the tree limit) as seen in the 'Cumulative' column of table 20 below.

Table 20: Increase of forested area in Norway per temperature interval and cumulative.

Temperature increase	Area		Cumulative	
	km^2	%	Area (km^2)	%
0.0-0.5°C	31,557	27.1	31,557	27.1
0.5-1.0°C	23,880	20.5	55,437	47.6
1.0-1.5°C	17,758	15.3	73,195	62.9
1.5-2.0°C	13,243	11.4	86,438	74.3
2.0-2.5°C	9,787	8.4	96,225	82.7
2.5-3.0°C	7,033	6.1	103,258	88.8
Rest area	13,045	11.2	116,303	100.0
Total	116,303	100.0	-	-

Source: Strand (2002)

The NIJOS report also calculates the potential for forested areas with the different intervals of temperature increase at the county level. Only four counties are excluded because all of their area is within today's tree limit. (These are Akershus, Oslo, Vestfold and Østfold).

As one might guess, the temperature increase will have the largest effect of forested area on the three northernmost counties of Finnmark, Nordland and Troms. Here, a temperature increase of 0.5°C will increase forested area by 6572, 3501 and 2405 square kilometers respectively. In comparison, for the counties that have the largest productive forested area today, Hedmark and Oppland, the increase with the same warming is expected to be 2238 and 1880 square kilometers, respectively. For tables with data for all counties, see Strand (2002).

An increase in productive forest area will undoubtedly affect the economics of forestry in Norway. However, research has not yet shown *how*.

4.4.2 Climate change impacts on the socio-cultural value of forests

Aside from the economic impacts of climate change on forests and forestry, climate change is likely to affect also the recreational and cultural significance of forests. Parry (2000) points out that with changes in rainy days, cloudiness and snow cover, species composition and growth rates, one might expect there will be a decrease in the value for use of forests in conservation, recreation, landscaping and reindeer herding. In the case of Norway, this is very significant, as most people use the forests for recreational activities such as hiking, skiing, camping, canoeing, as well as berry and mushroom picking. To place an economic value on this is almost impossible, but reduced snow cover for example will be a loss for the skiers and the cabins in the forest who run food and beverage services.

4.5 Summarizing forestry

The forestry sector is an important part of the Norwegian economy, as it yields an income of NOK 2.56 billion from the sale of lumber and 19.5 billion from the sale of the most valuable wood, paper and pulp products. The sector also generates foreign income, as wood and paper products totaling a value of NOK 8.5 billion are exported (all numbers from 2001). Its importance is also geographical, as almost one quarter of Norway's total area is used for productive forestry, with a concentration in the central parts of the country. Most forest properties are smaller (less than 1000 decares) and owned and operated by farmers.

Several climatic features are relevant to the growth and health of forests, and hence also the productivity of the forestry sector. First of all, higher temperatures are thought to induce more rapid growth. However, the impacts of a temperature increase will be place specific, as other elements such as moisture stress and nutrient availability influence forest growth also. In the case of Norway, a reduced snow cover in the winter and increased drought stress during early summer may reduce the availability of moisture and hence limit the tree growth. However, increased precipitation other times of the year, along with cloudiness, more rain days and reduced duration of snow cover and soil frost can lower the profitability of forest production. One also expects increased damage to the forest from wind storms and frost, as well as attacks from insects and pests.

With a warmer climate there is a potential for increasing the area of productive forest land. In Norway this will be both in terms of altitude – the tree line would go at a higher elevation than today – as well as forest expansion northward and westward. According to the NIJOS study, if the temperature increase is of 1°C, one can expect that another 55,437 square kilometers will be forested (equivalent to 47.6% of today's area above the tree limit). It is possible, however, with a warmer climate, that some of the area that is now forested may be converted to agricultural use. Another change expected with a warmer climate is an increased rate of hardwood to softwood trees. The effect of this might not be particularly strong in the forest related industry, however, because both softwood and hardwood are used mainly for the production of pulp.

Even though there are indications of how climate change is likely to affect forests and indirectly the forestry sector, there has not been any study of forestry in Norway that tries to quantify these impacts, in terms of either biological growth rates or economic values of derived forest products.

5 Summary

This paper has compiled available information from other studies on the fisheries, agriculture and forestry sectors in Norway, and how these sectors might be influenced by climatic change. All three sectors are important economically or socially, influencing settlement and occupational patterns in Norway. Climate change is likely to have both positive and negative impacts in all three sectors.

Positive impacts include expected increased growth rates and productivity. For example, stronger year classes of fish and more rapid growth of fish in aquaculture, about 10% per degree Celsius, are expected. For agriculture, the study from 1990 by NILF estimates between 20 and 35% increase in yield, depending on species and place (NILF 1990). For forestry, the expectation is increased productivity, but it has not yet been quantified. Another element that is often mentioned in the various studies is the increased potential for exploiting new species as well as the geographical expansion of areas suitable for either fishing, agriculture or forestry activities. In fisheries, herring might become a more valuable resource further north in Norway, and it might be possible to get larger catches of anchovies and begin fish farming of turbot. On the other hand, migration of fish species according to water temperatures might lead to a reduction in income from cod fishing for Norway, as this species might move farther east into the Russian part of the Barents Sea. In agriculture, the areas that are now under cultivation will "move up" one or two climate zones, meaning improved conditions for most species that are grown today and the potential for introducing southern species such as corn (maize). For forestry, the expectations are of more hardwood trees and an expansion of the forested area by 55,437 square kilometers with a 1°C increase in temperature.

The positive impacts can partly be outplayed by negative impacts, such as increased damage or loss from severe weather events such as storms and frost, and from increased occurrence of pests or diseases. For fisheries, there might be more damage to the fishing fleet, or loss of income from an increase in the number of days where the weather makes fishing impossible, as well as damage to equipment used for aquaculture. Even today, most escapes from the fish farming nets are caused by extreme weather events. The total loss of farming of salmon (accounting for 90% of total aquaculture in Norway) was about 6% of total stocks in 2000, the most severe loss coming from pests or disease (41%). For agriculture, increasing problems of weeds, pests and fungi are thought to increase spraying needs: 50–100% for herbicides and 100% for pesticides The need to spray grains against fungi is estimated to increase by 100-200%, and for vegetables and tubers like potato crops the need is expected to increase by 100%. For fruit and berries the estimates are for a 100-200% increase. Today the agricultural sector spends NOK 196.9 million on these chemicals. The forestry sector can also be heavily influenced by increased risk of frost damage and breakage of trees due to wind storms. A warmer climate also increases the likelihood of problems with bark beetles and other pests.

As has been shown throughout this paper, the information that exists on impacts of climate change on the sectors of fisheries and aquaculture, agriculture and forestry is only to some extent quantified, not nearly enough to make an overall assessment of the socio-economic impacts of climatic change for these three sectors in Norway. The information is scattered, results coming from many different studies that use different climate change scenarios and assumptions. For instance, the results that are quantified for the impacts of climate change on the Norwegian agricultural sector are based on a climate change scenario almost twice as warm as the now most widely used scenario, downscaled from global climate scenarios by RegClim. Also, in some cases, research has not yet been undertaken in the case of Norway, so the information is drawn from other cases judged to have similar characteristics to the particular sector in question in Norway. Another challenge to conducting a socio-economic impacts assessment of climate change in Norway is that some of the impacts are of more social than economic character, such as consequences for changes in settlement of the Norwegian population, or changes in the cultural value of forest use. These are still impacts, but cannot be easily measured by monetary terms alone, and it is difficult to compare these impacts to those that are quantified in monetary value.

In addition, the studies vary to which extent they consider other factors that influence change in these three sectors, such as social, economic and technological change, be it economic growth, urbanization, migration, or changes in land use and resource degradation. It is obvious to all that climate change does not occur in a vacuum but along with other global changes. However, how to account for these future changes and how they will interact with climate change to produce impacts on fisheries, agriculture and forestry are still nuts to crack.

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