Emissions and removals of greenhouse gases from land use, land-use change and forestry in Norway

CICERO
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Statistisk sentralbyrå
Statistics Norway

NIJOS
Norsk institutt for jord- og skogkartlegging

NIJOS Report 11/2005

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NIJOS report 11/2005
ISBN 82-7464-352-6

<table>
<tr><td colspan="2">Tittel:
Emissions and removals of greenhouse gases from land use, land-use change and forestry in Norway</td><td>NIJOS nummer:

11 / 2005</td></tr>
<tr><td colspan="2">Forfatter(e):
Rypdal, K., Bloch, V.V.H., Flugsrud, K., Gobakken, T., Hoem, B., Tomter, S.M. & Aalde, H.</td><td>ISBN nummer:

82-7464-352-6</td></tr>
<tr><td colspan="2">Oppdragsgiver:
Norwegian Pollution Control Authority (Statens Forurensningstilsyn)
Ministry of Agriculture and Food (Landbruks- og matdepartementet)</td><td>Dato:
September 2005</td></tr>
<tr><td colspan="3">Prosjekt/Program:
Norsk oppfølging av IPCC-rapporten Good Practice Guidance for Land Use, Land-use Change and Forestry (GPG-LULUCF).</td></tr>
<tr><td colspan="3">Relatert informasjon/Andre publikasjoner fra prosjektet:</td></tr>
<tr><td colspan="3">Utdrag:
FN's klimapanel (IPCC) avsluttet i 2004 arbeidet med retningslinjer for god praksis i forbindelse med estimering av utslipp og opptak av klimagasser som følge av arealbruksendringer og endringer i skog. Foreliggende rapport beskriver datagrunnlaget og metodene som er benyttet for å framskaffe slike estimater for Norge for perioden fra 1990. Endring i arealbruk fører til endring i karbonlagre og derfor indirekte til utslipp og opptak av CO_2. Opptak av CO_2 i Norge som skyldes endringer i arealbruk er imidlertid forholdsvis små i forhold til binding i eksisterende skog. For 2003 er netto-opptaket av CO_2 fra denne sektoren beregnet til 21 millioner tonn. Dette tilsvarer ca. 38% av de totale menneskeskapte utslippene av klimagasser. Netto-opptaket (bindingen) av klimagasser har økt med ca. 60% fra 1990 til 2003.</td></tr>
<tr><td colspan="3">Abstract:
Intergovernmental Panel on Climate Change under the UN finalised in 2004 the report "Good Practice Guidance for Estimating and Reporting of Emissions and Removals from Land Use, Land-use Change and Forestry". The present report describes the data material and the methods used to provide such estimates for Norway for the period from 1990. Land-use changes cause changes in carbon storage, thus indirectly emissions and removals of CO_2. Removals of CO_2 in Norway due to land-use change are relatively insignificant compared to sequestration in existing forest. For 2003, the net sequestration of CO_2 from this sector has been estimated at 21 million tonnes. That would correspond to about 38% of the total anthropogenic greenhouse gas emissions. The net sequestration increased by approximately 60 per cent from 1990 to 2003.</td></tr>
<tr><td>Emneord:
Arealbruk, arealinngrep, klimagasser, avskoging, skogreisning, biomasse</td><td>Keywords:
Land use, land-use change, greenhouse gases, deforestation, afforestation, biomass</td><td>Sideantall: 104</td></tr>
<tr><td colspan="2">Geografisk sted:
Ås/Oslo</td><td>Pris kr:
Pris S/H :</td></tr>
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1 Introduction

The IPCC report “Good Practice Guidance for Estimating and Reporting of Emissions and Removals from Land use, Land-use Change and Forestry” was finalised in 2004 (IPCC (2004), here called GPG 2004), and the methodologies have been accepted by the Conference of the Parties of the United Framework Convention on Climate Change (UNFCCC) to be used for annual reporting. This report also gives guidance on methodologies and principles for reporting under the Kyoto Protocol. The Kyoto Protocol reporting differs from the reporting under UNFCCC in that the UNFCCC reporting includes all emissions and removals from managed land and land under land-use changes, while the Kyoto Protocol reporting includes certain activities as defined in the Protocol and as elaborated in the Marrakesh accords[1]. Some of the Kyoto Protocol activities are mandatory to include for the Parties, while other activities are eligible.

The aim of this report is to provide documentation of the implementation of the IPCC good practice guidance for LULUCF for Norway. For each category of emissions and removals the methodological choice, availability of data and recommendations for use of data is discussed. National data have been used if available, otherwise default data from GPG2004 are applied. The underlying assumptions are also discussed. The report provides estimates of emissions and removals as reported in 2005. For the Kyoto Protocol reporting the report suggests which sources and sinks that are relevant for each activity, suggests initial geographical boundaries and proposes how appropriate reporting can be achieved if activities are elected. The report presents estimates for all sources of emissions and removals to ensure completeness of reporting. When using the report it is, however, important to bear in mind that forest is the most important managed land use in Norway and also involves the largest changes in carbon stocks.

To complete this work the following project team was established:

Harald Aalde (Norwegian Institute of Land Inventory[2], later the Ministry of Agriculture and Food)
Stein Tomter (Norwegian Institute of Land Inventory, Project leader)
Terje Gobakken (Norwegian Institute of Land Inventory)
Ketil Flugsrud, Vilni Verner Holst Bloch and Britta Hoem (Statistics Norway)
Kristin Rypdal (CICERO, Editor of this report)

The project team has been in contact with national and Nordic experts to complete specific parts of this report. The following persons have in particular contributed: Heleen de Wit (Norwegian Institute for Water Research: forest soil carbon), Bal Ram Singh (Norwegian University of Life Sciences: agriculture management and soil carbon), Arne Grønlund (Norwegian Centre for Soil and Environmental Research[3]: soil carbon in agriculture land and peat land) and Gro Hylen (Norwegian Institute of Land Inventory: carbon in forest biomass).

The project team would also like to thank Marit Viktoria Pettersen (Norwegian Pollution Control Authority and Ministry of Environment) for useful comments and suggestions.

The work has been supervised by a steering group: Audun Rosland (Norwegian Pollution Control Authority), Arne-Ivar Sletnes (Ministry of Agriculture and Food) and Håvar Thoresen (Ministry of Environment).

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[1] Annex to Decision 11/CP.7 and attached draft COP/MOP decision, FCCC/CP/2001/13/Add.1.

[2] Abbreviated NIJOS.

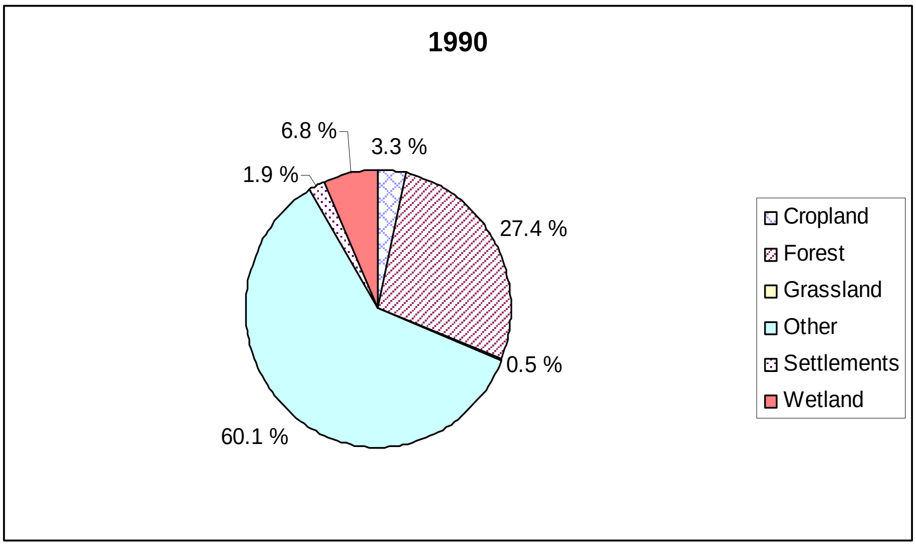
[3] Abbreviated Jordforsk.

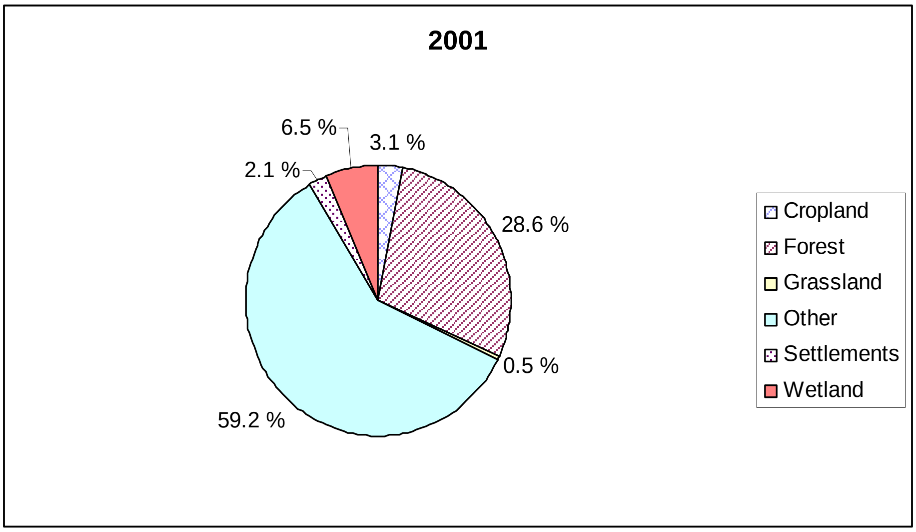
2 Summary

The average annual net sequestration from the land use, land-use change and forestry sector was about 13 Tg of CO_2 per year for the period 1990-1996, and about 21 Tg per year from 1997 to 2003. In 2003 the net sequestration of 21.0 Tg of CO_2, would offset 38 per cent of the total anthropogenic greenhouse gas emissions in Norway. The net sequestration increased by approximately 60 per cent from 1990 to 2003. In 2003 the land-use category forest land remaining forest land was the single largest contributor to the total amount of sequestration with 23.4 Tg CO_2. All other land-use categories showed net emissions, which amounted to 2.5 Tg CO_2. Of these, the most important category was grassland remaining grassland (including farmed organic soils for grass production) with total emissions of 1.9 Tg of CO_2; while land converted to settlements (deforestation) was the second most important category with 0.3 Tg of CO_2. The results are summarized in Table 2.1 and 2.2.

Changes in land use
Changes in land use from 1990 to 2001 have been quite small (Figure 2.1), the forest area is increasing and the agriculture area decreasing. Areas of grassland and settlement have also increased. The forest land category covers around one fourth of the mainland area of Norway and is the most important managed land-use category.

Figure 2.1 Fraction of land area by category in 1990 and 2001





Changes in forest biomass pools
The total removal in forest living biomass was 58.5 Tg C for the period 1990-2003, or in average 15.3 Tg CO_2 annually. Changes in soil carbon have not been estimates previously. The removal is 10% of the removal in living biomass, around 0.5 Tg annually. The carbon stock change in dead organic matter is slightly higher, about 0.7 Tg sequestered annually. Figure 2.2 shows the calculated carbon stock changes in forest land from 1990 to 2003. The annual stock change has been increasing for soils and living biomass, but has been decreasing for dead organic matter. The changes in all pools can be explained by changes in management (e.g. reduced grazing and harvest since 1990), but also to some extent by natural factors. The abrupt change in removals from 1996 to 1997 is due to the data collection cycle of the National Forest Inventory (five year intervals). We will in future reporting years interpolate the different data sets in order to better represent the more realistic gradual changes that have taken place.

We find that the total net removal in forest living biomass for the period 1990-2002 calculated here deviates only by about 6 per cent from the sequestration reported previously to UNFCCC using a lower tier method based on annual increment, losses and biomass expansion factors; see Figure 2.3.

Figure 2.2 Carbon stock changes in forest living biomass, dead organic matter and soil. 1990-2003.

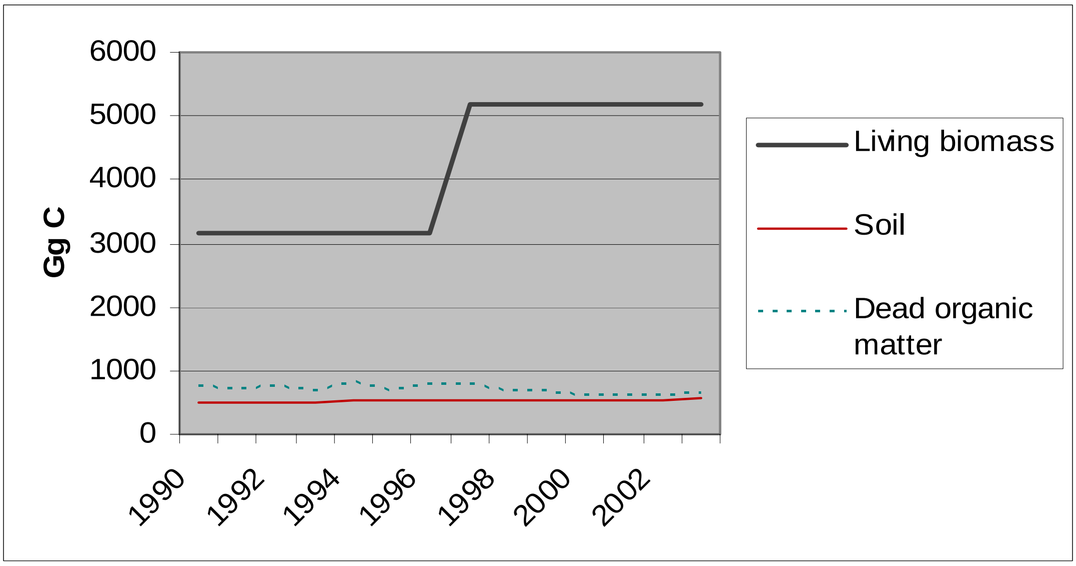
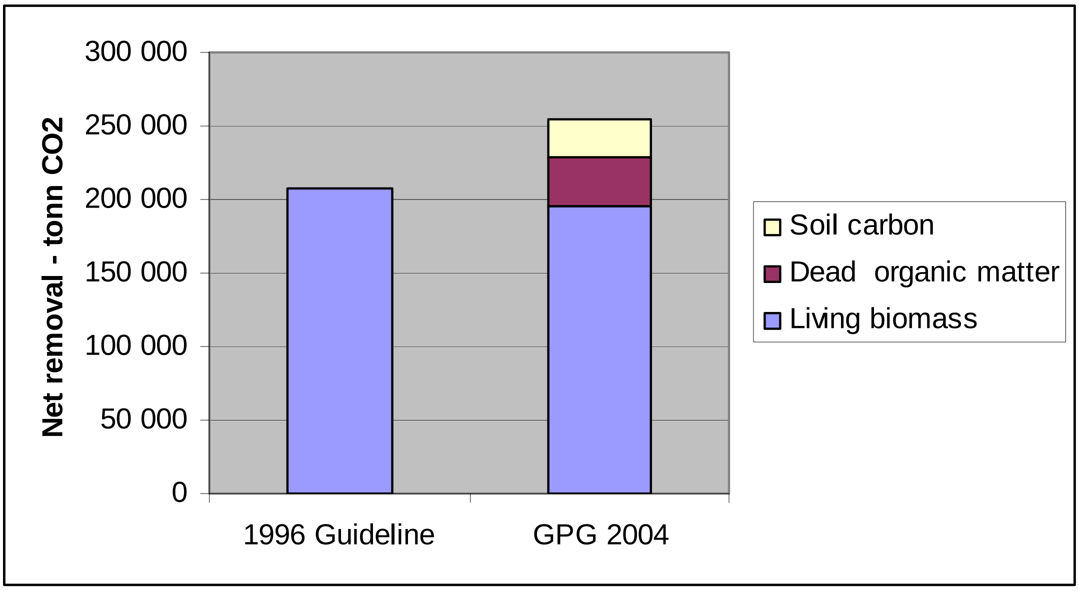


Figure 2.3 Accumulated net CO_2 removals in the Norwegian forest 1990-2002 previously reported to UNFCC using IPCC 1996 Guidelines compared to the accumulation estimated according to IPCC (GPG 2004).



Changes in other pools and emissions of non-CO_2 gases
Figure 2.4 shows all emissions and removals from the LULUCF sector on a common scale. Farmed organic soils (mostly for grass production) contribute with relatively large CO_2 emissions (2 Tg CO_2). The uncertainties are large (more than a factor of 2). Emissions factors should be reconsidered in light of a comprehensive Finnish research project which will conclude late 2005. The estimate has been kept constant because annual data are missing, but large annual changes are not likely given that very little new organic soils are farmed at present. CO_2 emissions from agricultural mineral soils are small due to small new areas cleared for agriculture. Erosion control (in particular spring-till only) contribute with a small removal. Emissions of non-CO_2 gases are very small.

Key category analysis and uncertainty assessment
A key category analysis has been compiled including non-LULUCF sources as calculated in the national inventory and the estimates for LULUCF provided in this report. LULUCF key categories identified using Tier 2 of GPG2004 (all CO_2) include:

- 5A Forest land remaining Forest land - Living biomass
- 5C Grassland remaining Grassland – Soil (farmed organic soils)
- 5A Forest land remaining Forest land - Dead organic matter
- 5A Forest land remaining Forest land - Soil
- 5A Forest land remaining Forest land - Drained organic soils
- 5B Cropland remaining Cropland - Soil (farmed organic soils)

Tier 1 additionally identifies forest land converted for settlements, but does not identify forest drained organic soil and cropland farmed organic soils.

For forest land remaining forest land – living biomass, which constitutes the largest removal of the inventory (Figure 2.4), the estimates are determined with a relatively high accuracy. A Tier 3 method has been used based on the stock data from the National Forest Inventory and reasonably accurate conversion factors. The study has, however, identified several large uncertainties in estimates for other categories. The uncertainties are particularly large for emissions of non-CO_2 gases and CO_2 from soil (except mineral forest soil). For these categories of emissions and removals, also the activity data are often uncertain. Nevertheless, we are able to conclude that emissions of non-CO_2 gases are small. Changes in soil organic carbon are difficult to monitor due to upscaling problems, lack of time-series and lack of management data. Also lack of knowledge of the history of a piece of land causes problems. More measurements and more use of models could contribute to reductions in these uncertainties. Uncertainties are also large for other wooded land (tree covered land that does not meet the forest definition) and for Finnmark county which is not included in the National Forest Inventory. Changes in carbon stocks are, however, expected to be relatively small. Also reservoirs should be further investigated due to the importance of dams in Norway (hydroelectric power stations). Estimates for these have not been included in the present study as they are not mandatory under present guidelines.

National Forest Inventory
In light of the importance of the forest sector and lack of sources of statistical information that can be used to monitor all land-use changes on an annual basis, data from the National Forest Inventory (NFI) has been used as the most important source of information to establish total area of forest, cropland, wetland, settlements and other land and land-use transitions between these. Annual data have been derived using extrapolations and interpolations. The data from the National Forest Inventory have been complemented with other statistical and administrative data, in particular for agriculture. These other data are less suited to derive exact land-use transitions. The study has pointed out several needs for improvements in the National Forest Inventory in order to improve the estimates. These include measures to avoid misclassification during the field work, better interpretation of multiple land uses of plots, more frequent assessment of plots on non-forested areas and the establishment of permanent sample plots in Finnmark county and on other wooded land. The largest costs are associated with the last point on the list.

Completeness
The NFI does not provide data to facilitate estimates of dead organic matter and soil organic carbon for areas classified as non-forest. These have consequently not been estimated, except when other sources of data were available. This error is, however, considered to be very small, as the relevant categories are small compared to forest land. There is nevertheless a goal to try to enhance completeness in future reporting years. The data from the NFI at present has difficulty to fully separate "land converted to forest land" from "forest remaining forest", when sample plots appear as forest, after previously having been considered outside the surveyable area. This problem will be solved in the future due to the extension of the surveyable area and increase in number of permanent sample plots of the NFI. Emissions from the forest in Finnmark county and in wooded land not meeting the forest definition have not been estimated. It is likely that the forest in Finnmark is stable. The area of other wooded land is most likely increasing, although there is currently incomplete data to verify this.

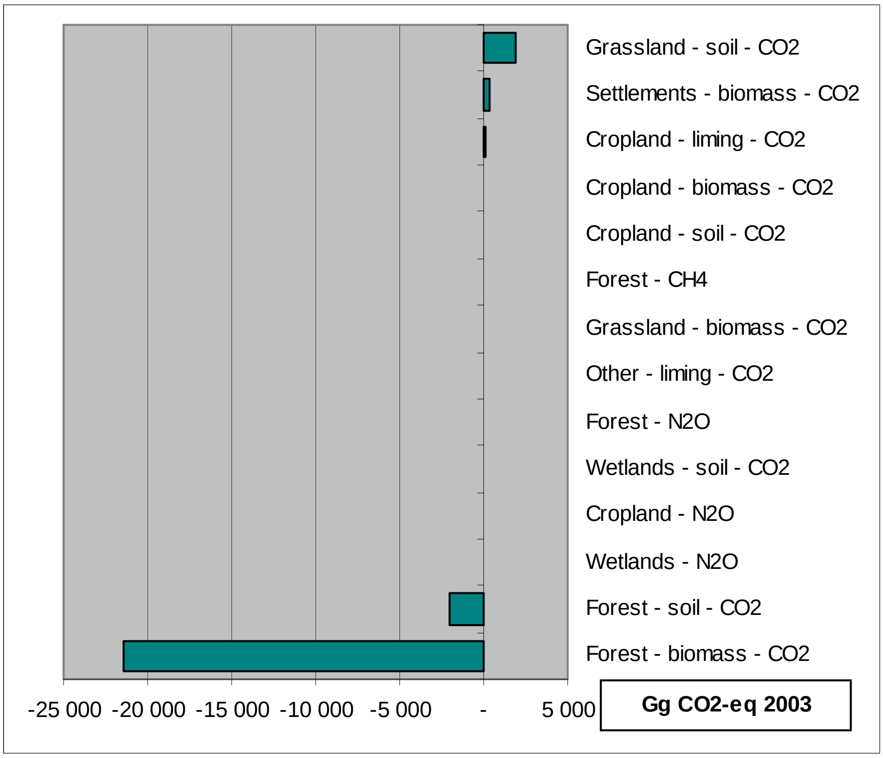
Kyoto Protocol reporting
The project team recommends as far as possible to use the same methods and data for the Kyoto Protocol reporting as for the UNFCCC reporting. However, there is a need to improve the allocation to correct categories and geographical boundaries. The estimation methods used in this report are only appropriate as a basis for reporting emissions and removals from forest (afforestation, reforestation, deforestation and forest management). If Norway would elect cropland management, grassland management or revegetation the estimation methods would need major development. Complete spatial information is not available to facilitate reporting fully in accordance with IPCC good practice. Therefore, there is a need to consider developments of the NFI and include additional sources of data for estimation and verification of the Kyoto protocol reporting.

We propose to divide Norway into 5 parts and use these as geographical boundaries. In the case Norway elects several 3.4 activities and sources and sinks fall within the definition of more than one activity, forest management followed by cropland management should have precedence.

Responsibilities
It is proposed that NIJOS will be responsible for preparing the LULUCF reporting in the future, including the responsibility for documentation, quality assurance/quality control and archiving of data. Statistics Norway will provide estimates of data based on other activity data than area statistics and will integrate the LULUCF results into the non-LULUCF inventory.

Figure 2.4 Emissions and removals in the LULUCF sector in 2003. Gg CO_2-equivalents

a) Full scale



b) Detailed scale

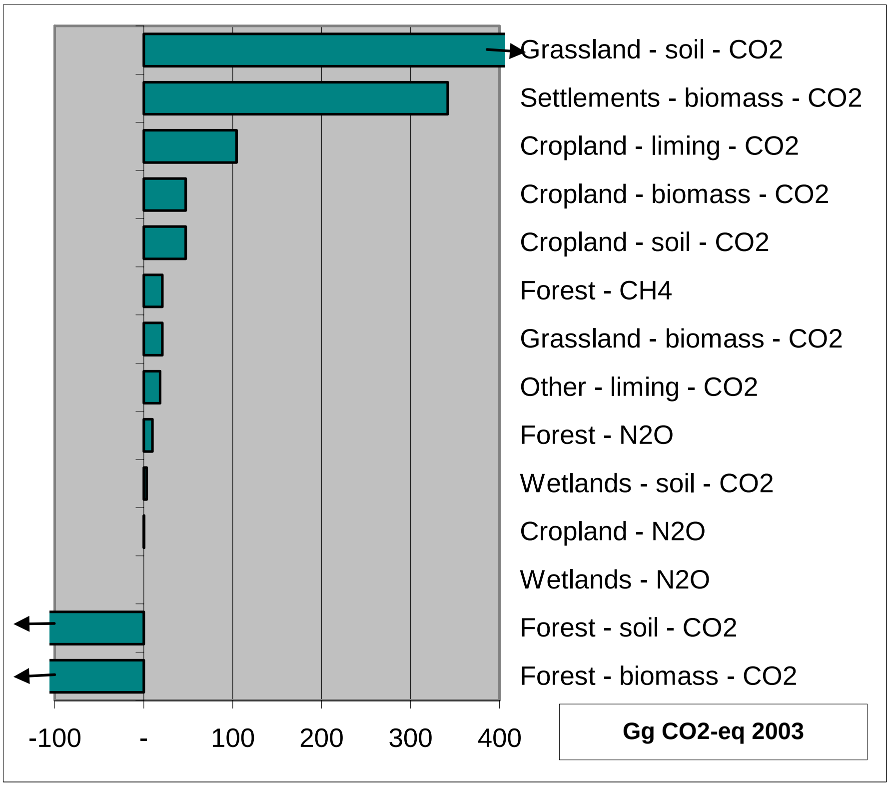


Table 2.1 CO_2 emissions and removals from LULUCF. Gg C

	1990	1995	1997	1998	1999	2000	2001	2002	2003
Forest land remaining forest land	4415.8	4361.0	6494.6	6402.0	6398.0	6351.7	6358.9	6367.3	6388.1
- Living biomass	3158.0	3158.0	5196.3	5196.3	5196.3	5196.3	5196.3	5196.3	5196.3
- Dead organic matter	753.4	680.0	768.0	670.7	663.0	612.0	616.9	621.1	639.2
- Soils	504.3	522.9	530.3	535.0	538.7	543.4	545.7	549.9	552.7
Land converted to forest land	IE	IE	IE	IE	IE	IE	IE	IE	IE
Cropland remaining cropland	-52.90	-34.17	-32.39	-31.26	-28.28	-14.18	-13.78	-8.20	-13.27
- Living biomass	3.76	3.26	3.06	2.96	2.86	1.11	-1.27	4.31	-0.42
- Dead organic matter	NE	NE	NE	NE	NE	NE	NE	NE	NE
- Soils	-56.67	-37.43	-35.46	-34.22	-31.14	-15.29	-12.51	-12.51	-12.84
Land converted to cropland	-22.8	-13.8	-11.9	-12.0	-12.1	-12.2	-12.3	-12.4	-12.4
- Living biomass	-22.8	-13.8	-11.9	-12.0	-12.1	-12.2	-12.3	-12.4	-12.4
- Dead organic matter	NE	NE	NE	NE	NE	NE	NE	NE	NE
- Soils	IE	IE	IE	IE	IE	IE	IE	IE	IE
Grassland remaining grassland	-510.0	-510.0	-510.0	-510.0	-510.0	-510.0	-510.0	-510.0	-510.0
- Living biomass	NE	NE	NE	NE	NE	NE	NE	NE	NE
- Dead organic matter	NE	NE	NE	NE	NE	NE	NE	NE	NE
- Soils	-510.0	-510.0	-510.0	-510.0	-510.0	-510.0	-510.0	-510.0	-510.0
Land converted to grassland	0.0	-3.0	-3.0	-3.0	-3.0	-4.6	-6.8	-1.1	-5.7
- Living biomass	0.0	-3.0	-3.0	-3.0	-3.0	-4.6	-6.8	-1.1	-5.7
- Dead organic matter	NE	NE	NE	NE	NE	NE	NE	NE	NE
- Soils	NE	NE	NE	NE	NE	NE	NE	NE	NE
Wetlands remaining wetland	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9
- Living biomass	NA	NA	NA	NA	NA	NA	NA	NA	NA
- Dead organic matter	NA	NA	NA	NA	NA	NA	NA	NA	NA
- Soils	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9
Land converted to wetland	NO	NO	NO	NO	NO	NO	NO	NO	NO
Settlements remaining settlements	NE	NE	NE	NE	NE	NE	NE	NE	NE
Land converted to settlements	-96.0	-90.1	-89.5	-90.1	-90.8	-91.4	-92.0	-92.6	-93.2
- Living biomass	-96.0	-90.1	-89.5	-90.1	-90.8	-91.4	-92.0	-92.6	-93.2
- Dead organic matter	NE	NE	NE	NE	NE	NE	NE	NE	NE
- Soils	NE	NE	NE	NE	NE	NE	NE	NE	NE
Other land remaining other land	NE	NE	NE	NE	NE	NE	NE	NE	NE
Land converted to other land	NE	NE	NE	NE	NE	NE	NE	NE	NE

Table 2.2 Emissions of non-CO_2 gases and CO_2 from liming in the LULUCF sector. Gg

Source	**Gas**	1990	1995	1999	2000	2001	2002	2003
Direct N_2O emissions from N fertilization	N_2O	0.004	0.004	0.004	0.003	0.002	0.003	0.003
N_2O emissions from drainage of soils (forest)	N_2O	0.04	0.04	0.04	0.04	0.04	0.04	0.04
N_2O emissions from drainage of soils (wetlands)	N_2O	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
N_2O emissions from disturbance associated with land-use conversion to cropland (mineral soils)	N_2O	0.006	0.005	0.004	0.003	0.003	0.003	0.003
Carbon emissions from agricultural lime application (cropland)	CO_2 as C	59.1	46.6	35.3	29.5	30.9	31.6	28.5
Carbon emissions from agricultural lime application (lakes and rivers)	CO_2 as C	2.8	5.1	7.1	7.2	6.5	5.0	5.0
Biomass Burning (wildfires)	CH_4	0.8	0.1	0.1	0.2	0.005	0.2	0.7
Biomass Burning (wildfires)	N_2O	0.006	0.0007	0.0005	0.001	0.00003	0.001	0.005

3 Definitions of land-use classes

Six broad categories of land are described in GPG2004, these are Forest land, Cropland, Grassland, Wetlands, Settlements and Other land. The categories are not defined in detail, giving each country the possibility to adapt their own land-use definitions to the broad categories. Further subdivision may be necessary in order to separate managed land from unmanaged land and to distinguish sub-categories of land use. Carbon stock changes and greenhouse emissions are not reported for unmanaged lands, unless it is subject to land-use conversion to or from managed land. The category "Other land" is to ensure that the total area identified equals the total area of the country. In this way all land-use transfers are included in the reporting. According to the present guidelines, reporting is not necessary for settlements and managed wetlands (for example reservoirs and drained peatlands), but emissions and removals should nevertheless be reported for conversions to and from these categories.

3.1 Forest land

The definition of forest land is consistent with FAO definitions:

Land with tree crown cover of more than 10 per cent and area of more than 0.5 ha. The trees should be able to reach a minimum height of 5 m at maturity in situ. Young natural stands and all plantations established for forestry purposes which have yet to reach a crown density of 10 per cent or tree height of 5 m are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention or forest fires but which are expected to revert to forest.

Areas satisfying the tree cover requirements, and with land utilization of either forestry, military training field, protected or recreational area, will be considered forest. However, areas designated for holiday cabins may meet the tree cover requirement, but will be considered settlements. Also forest patches smaller than 0.5 ha should be excluded from "forest", in order to make this definition consistent with the FAO definition. All areas meeting the forest definition will be considered managed, in that management does not only include management for wood supply, but also for protection, recreation, collection of non-wood forest products etc. Practically all forest in Norway will be used either for wood harvesting, or to a greater or smaller extent for hunting, picking berries, hiking etc.

3.2 Cropland

All lands where the soil is regularly cultivated, and where annual or perennial crops are grown. This category includes temporarily grazed lands that regularly are being cultivated.

Unmanaged cropland is operationalised as cropland where economic subsidies are not applied for. Abandoned cropland may be used at a later stage for cropland or grassland, or undergo a transformation to vegetated "other land" or forest in the longer run. Unmanaged cropland is not spatially determined and it is not known whether abandonment is permanent or not.

Cropland also includes areas for meadows and pastures close to the farm[4]. These are areas included in the agriculture statistics.

[4] The carbon calculations of these areas are for practical reasons presented under grassland (in Section 7.3).

3.3 Grassland

Grassland can be identified as *areas utilized for grazing on an annual basis, but which are not mechanically harvested*.

More than 50% of the area should be covered with grasses. The soil is not cultivated, and may partly be covered with trees, bushes, stumps, rocks etc. Land with tree cover may be classified as grassland if grazing is considered more important than forestry. Meadows and pasture within the farm area are included under cropland, which is consistent with the agricultural statistics.

All grassland is considered managed, because grassland left unmanaged over time will be converted to forest or vegetated “other land”.

3.4 Wetlands

All areas regularly covered or saturated by water for at least some time of the year. The category includes swamps, mires, lakes and rivers. Possible tree cover of swamps and mires must not allow the area to be included as “forest”.

Lands used for peat extraction and reservoirs (dams) are considered managed wetlands.

3.5 Settlements

Settlements include all types of built-up land; houses, gardens, villages, towns and cities. This category also includes areas where infrastructure is predominant, industrial areas, gravel pits and mines. Included are also areas designated for sports or intensive recreational use (for example parks, golf courses and sport recreation areas. The area under power lines are also considered as settlements.

All areas assigned to settlements are considered managed.

3.6 Other lands

Other lands comprise lands that are not covered under any of the other classes. The major part consists of low-productive areas with bare rocks, shallow soil or particularly unfavourable climatic conditions. This category will also include e.g. Calluna heath in western Norway (potential forest land but currently unused land without tree cover). Also the group “other wooded land” (land with sparse tree cover) on mineral soil is assigned to other lands.

According to GPG2004 “other land” is “typically unmanaged”. However, most “other wooded land” in Norway is influenced by some management like grazing, hunting and recreation (and to some extent smaller scale fuel wood production).

4 Key category assessments

The assessment of key categories should have consequences for methodological choice according to the decision trees of GPG2004. As far as possible higher tier methods should be used for the key categories. Key categories are defined according to the level and trend. For this purpose the assessment is made taking into account also the size and change in non-LULUCF sources of emissions.

The key categories identified are summarized in Table 4.1.The detailed results of the Tier 1 and 2 key category analysis performed as described in GPG2004[5] are shown in Annex 5. Uncertainties used for Tier 2 were not determined by a rigid analysis, see Section 10.2. There are some differences between the two tiers, Tier 1 level analysis identifies forest land converted for settlements, but not forest drained organic soil and cropland histosols (farmed organic soils). The reason is that the two latter categories have large uncertainties. For the trend analysis there are small difference between the two tiers with respect to the LULUCF categories identified, and the trend analysis do not identify any additional LULUCF categories to those identified in the level analysis. Including LULUCF also influences other key categories identified. However, according to GPG2004 the LULUCF key categories are additional to those identified analyzing the inventory excluding LULUCF. In both analysis, forest land remaining forest land (all three pools) are among the top key categories.

Table 4.1 Summary of identified key categories

IPCC	**Source category**	**Gas**	**Level assessment, Tier 2**		**Trend assessment, Tier 2**
			1990	2003	2003
5A1	Forest land remaining forest land, Living biomass	CO_2	6.80 %	10.53 %	20.03 %
5C1	Grassland remaining grassland, Histosols, Soil	CO_2	8.04 %	7.57 %	2.56 %
5A1	Forest land remaining forest land, Dead organic matter	CO_2	4.39 %	3.50 %	1.31 %
5A1	Forest land remaining forest land, Soil, Other[a]	CO_2	1.94 %	2.00 %	1.35 %
5A1	Forest land remaining forest land, Soil, Drained organic soils	CO_2	1.23 %	1.22 %	0.67 %
5B1	Cropland remaining cropland, Histosols, Soil	CO_2	0.89 %	0.85 %	
5E1	Forest land converted to settlements, Living biomass	CO_2	*Tier 1 only*		

[a] "Other" refers to all areas excluding Finnmark county and drained organic soils.

[5] Tier 1 is based on only the size of emissions/removals and estimates their contribution to the level and trend. In the Tier 2 method the contribution is also multiplied with the relative uncertainty (two standard deviations divided by the mean).

5 Statistical systems for land use, land-use change and forestry in Norway

Different demands for accuracy with respect to delineation and demands to richness in details is a great and ongoing challenge for official area statistics. The demand for higher accuracy increases with the number of classes in a classification system, and the demands for spatial data have been set by the reporting requirements of the UNFCCC and the Kyoto inventory.

The main problem encountered in Norway is the low population density, which implies that mapping and maintenance of maps are relatively costly, especially for less inhabited areas. In the subsequent sections we will review existing sources of information. There are a number of existing sources of data on land use. Most of them, however, do only show the current situation, and are not capable of presenting exact information on changes, e.g. area categories converted into other categories at an appropriate scale.

5.1 The National Forest Inventory (NFI) of Norway

The National Forest Inventory (NFI) is a sample plot inventory with the aim of providing data on natural resources and environment for forest land in Norway. The NFI is the only system that can present area changes and current area distribution based on a georeferenced sample of field plots for a large part of the country.

The Norwegian Institute of Land Inventory (NIJOS) conducts the NFI. Results are mainly published at the county, regional and national level. Inventory work was started in 1919, with the different inventory cycles having taken place during the following years:

1. 1919-30
2. 1937-56
3. 1957-64
4. 1964-76
5. 1980-86
6. 1986-93
7. 1994-98
8. 1999-03

The inventory comprises all types of land below the coniferous forest limit, but a more comprehensive description is made only for forest land. Each inventory cycle has covered the most important forest districts, while inventories in western and northern Norway have been carried out less frequently and sometimes incompletely. During the three most recent periods (since 1986), all counties except Finnmark (the far northern county) have been surveyed.

The sampling design has changed considerably over the years. The first two cycles were carried out as strip sampling inventories. A system of parallel strips was established throughout the area of interest, and measurements were taken within these strips. In the mid - 1950s, the strip sampling was replaced by a systematic sample plot inventory, a method which has also been used later. However, minor alterations concerning sampling design have been made several times. The sampling design is now based on a systematic grid of sample plots with 3 x 3 km spacing.

An important difference between the period 1986-93 and the previous inventory cycles was the introduction of permanent sample plots. A sub-sample of the established plots was marked, in order to be able to re-measure the exact same area in future inventories. This provides possibilities for detecting changes both in land-use and forest situation. When remeasuring the permanent plots, this has been done according to a specific pattern. All plots corresponding with the 3 x 3 km grid are surveyed every 5th year, and provides national as well as regional statistics of forest resources. The remeasurement is carried out in such a way that 20% of the plots are surveyed every year, thus the cycle will be completed in 5 years. After 5 years, the procedure will start all over again. To obtain reliable data for individual counties, data from permanent plots are supplemented with data from temporary plots, which will not be described in further detail in this report.

The original sample grid was based on the former Norwegian adaptation of a Gauss-Krüger projection (named NGO) with 8 meridian axes and a grid for each zone with reference to UTM zone 32-36. GPS readings have later on been taken in each plot centre for exact georeferencing of the plots.

Highly conspicuous markings are avoided to prevent the location of the plots from being too obvious to passersby. The permanent plots should represent a random sample of the forests in Norway, and they should not be treated differently from the rest of the forests. Totally, approximately 16,500 permanent sample plots have been established, of which about 11,000 are located on productive forest and other woodlands below the coniferous forest limit. On the average, the sampled area comprises about 3×10^{-5} of the surveyable area.

An extensive number of attributes concerning forest conditions are being recorded. Some of these describe the area. Parameters which characterize level of development and species composition of the vegetation, certain aspects on biodiversity, utilization and yield capacity of the land, forest treatment, relations concerning forest operations, etc., are being measured or estimated.

One of the main tasks of the NFI has been an assessment of timber resources. Data are being collected so that the volume can be computed for different tree species and size classes. Number of trees and annual increment are also calculated.

The NFI has so far had certain limitations in providing a complete overview of all forests and all land-use types, due to the fact that areas above the coniferous forest limit and in Finnmark county have been excluded from the inventory. The boundary towards the coniferous forest limit has also been more or less subjectively assessed. To be able to obtain more consistent results, the possibilities of introducing a simplified inventory procedure in mountain areas and in Finnmark will be explored from 2005. Furthermore, the uncertainties are substantially higher for all other land-use classes, compared to forest.

Figure 5.1 Forest land and other wooded land. 1950-2000. km^2 (Source: NIJOS)

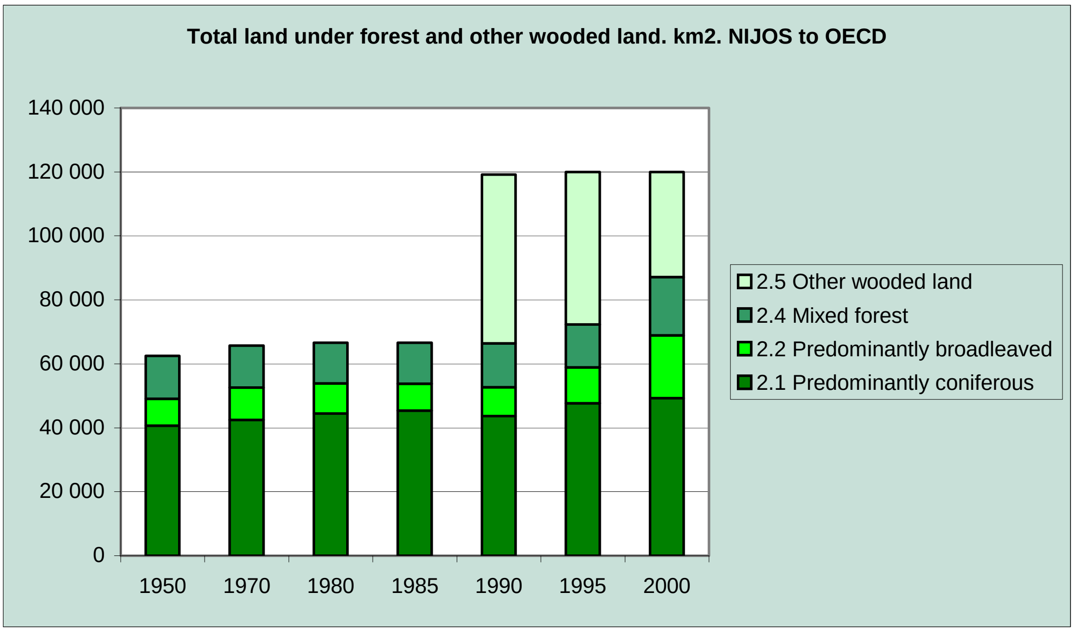


Figure 5.1 shows the development of forest and other wooded land, as reported to OECD at different occasions. The trend shown in the figure may, however, be somewhat misleading, due to the inconsistency in limitation of the forest area. Also, the area given for year 2000 applies to forest according to FAO definition, while for the previous years the national definition has been used. The decrease of other wooded land is probably an artificial semblance, in that there has been no update of total area of woodlands, therefore an increase in forest land implies a decrease in other wooded land.

5.2 Agricultural census

Censuses of agriculture have been held at intervals of approximately 10 years from 1907 to 1969. Combined censuses of agriculture and forestry were held in 1979 and 1989. A separate Census of Agriculture was carried out in 1999. The census in 1999 included all units with at least 0.5 hectares of agricultural area in use and comprised 70 700 respondents.

Sample surveys of agriculture and forestry
In the periods between complete censuses, agricultural statistics are collected by annual sample surveys. The samples consist of about 11 500 - 13 000 units, which are drawn from the Farm register administered by the Norwegian Agricultural Authority. The samples are drawn on the basis of agricultural area in use and productive forest area. The structural variation between different counties is also taken into consideration, and the relative size of the samples differs both by county and by size of holding.

The sample surveys of agriculture and forestry provide figures for number of holdings and the size of agricultural area in use. Data concerning soil preparation are collected regularly, likewise information about labour force and working time on holdings.

Yield of agricultural crops
The statistics on yield of potatoes and coarse fodder are also based on sample surveys. The sample includes about 3 200 units registered with agricultural activity in the Farm register.

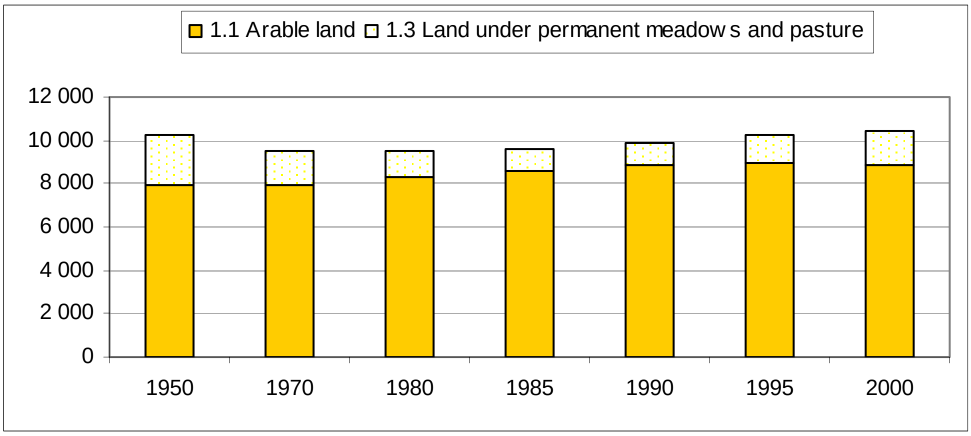
Statistics based on administrative registers
Since 1984 the annual statistics concerning *utilization of agricultural area and number of livestock* are based on information given by holders applying for governmental grants. For previous years these figures were based on sample surveys in agriculture.

Figures concerning *sales of concentrated feed, area subsidized for change of tillage, agricultural area transferred to non-agricultural use and producer prices* on certain agricultural products are given by Norwegian Agricultural Authority.

Statistics on *consumption of fertilizers* are based on data from the National Agricultural Inspection Service.

Area figures in Statistics Norway's agricultural statistics are more up to date than any other source, but do not have spatial coverage because of lacks in georeferencing (although most data are available at the municipality level). This means that the overall data for agricultural areas are of high quality, but they cannot be used to determine transitions between different land categories.

Figure 5.2 Agricultural land based upon the agricultural censuses. km^2 (Statistics Norway).



5.3 Other sources of data

5.3.1 Maps

The main map series N50 (scale 1:50 000), covering the whole country, is another potential source of area statistics. The problem is, however, that the maintenance of the map series is quite variable. In some areas the data are about 20-30 years old, which means that determining reference year based upon N50 is difficult. It is not likely that one in foreseeable future will have updated map coverage of the whole country for one single year. Making land cover/use change statistics based upon this source would be a great challenge.

With regard to the land cover map N5 (Economic Map Series) the paradox is that the older the map data are, the better is the starting point for assessing *changes* in the form of a land-use budget. On the other hand, both processing would be easier and the newest status would have higher quality if the N5 maps were maintained on a regular and frequent basis. This concerns especially areas in and near agricultural areas, where considerable changes in land use often take place. At the moment it seems unlikely that this map will undergo annual updates that could give a statistical data on land use and land-use change.

A digital road map exists for all of Norway and covers all roads of more than 50 meters length. The road map is updated annually, and a data field for date of opening of road exists according to the Road Authorities (Statens vegvesen) for the last 12 years. There is, however, probably a timelag between the construction of roads and registering in the road map database.

5.3.2 Images

Satellite images have often been pointed out as the solution to maintenance of maps and hence a potential source of area statistics. The resolution of satellite images is steadily increasing, but still costly, and has difficulties in covering the country with scenes free of clouds in one year, affecting the possibility of making a good area classification. The main problem with using satellite images is, however, the relatively low accuracy on land classification.

Orthophotos are increasingly being used and do have a high accuracy with respect to land classification. At the moment the coverage of orthophotos is quite low and non-random, resulting in being a biased source for area statistics. Figure 5.3 shows an example from vegetation mapping from satellite by NORUT. CORINE Land Cover is intended to provide consistent localized geographical information on the land cover in Europe. CORINE Land Cover is established with 44 item classes covering artificial surfaces, agriculture, forest, wetland and water bodies. The minimum mapping unit size is 25 hectares. In Norway this dataset will be established by generalization of existing land cover datasets and by satellite interpretation. The work is planned to run from 2005 through 2007.

Resource Account Grid
This is a point sampling grid dating from 1979. The point grid has not been used in later sampling surveys. Statistics Norway is in charge of this grid. Numerous variables (40-50) where interpreted from aerial photos and maps. The grid consists of different levels or distances between sampling sites, with higher concentrations in urban settlements (100x100m) and gradually larger distances between grid points through agricultural areas, forest areas and mountain areas (3, 6 and 12 km). The grid consists of 6230 points at country level, and 157 289 points for urban settlements. The grid is based upon the NGO-system with different axis for projections but has been transformed to UTM 33 WGS84. Figure 5.4 shows some area statistics from this sampling. The data could be interpreted as a picture of the situation at about 1970. The different sources of information may stem from a time span between 1960 and 1980.

Agricultural Landscape Monitoring
The National Program for Monitoring the Norwegian Agricultural Landscape (3Q) (managed by NIJOS) is based on mapping and statistical analyses of a representative sample of 1 x 1 km squares at 3 x 3 km intervals. Results are presented as a set of indicators describing among others land use and land cover. The survey is repeated at 5 years intervals. Figure 5.5 shows an example of the stages and results in such mapping.

Figure 5.3 Example from vegetation mapping from satellite by NORUT.

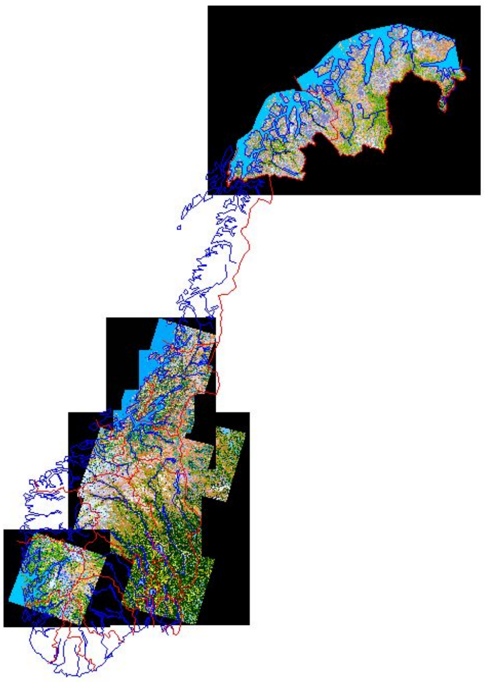


Figure 5.4 Land cover statistics from Resource account grid.

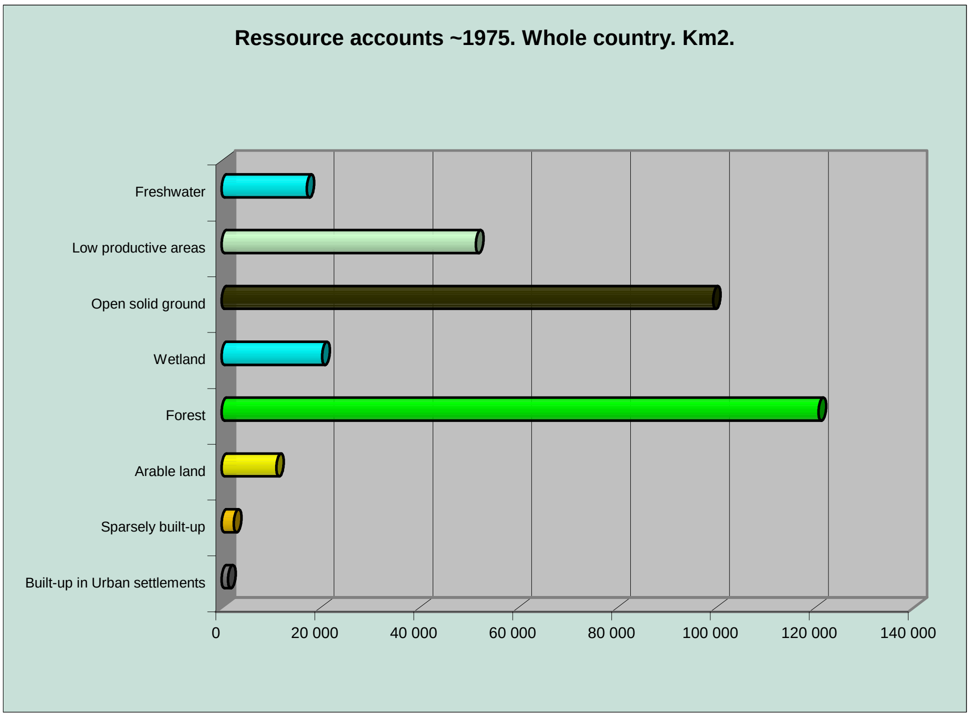
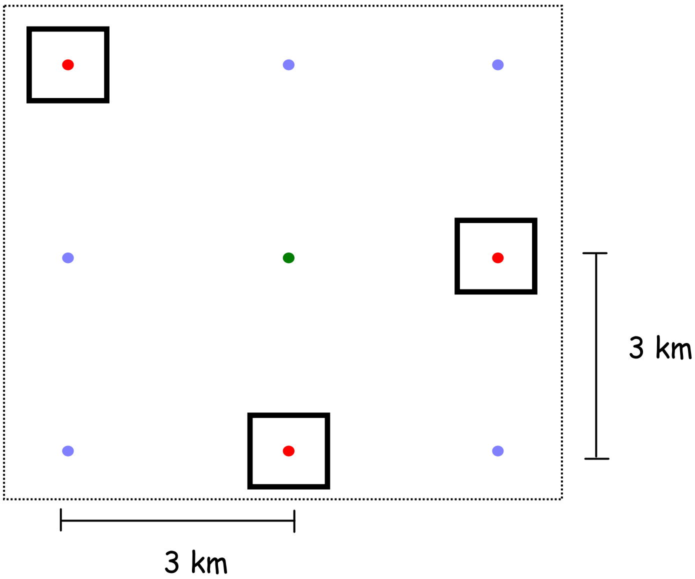
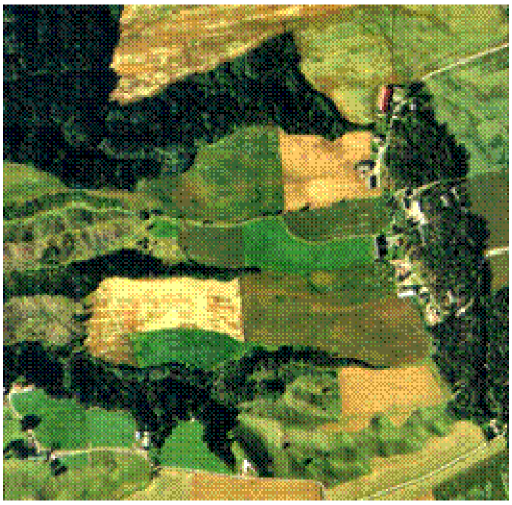
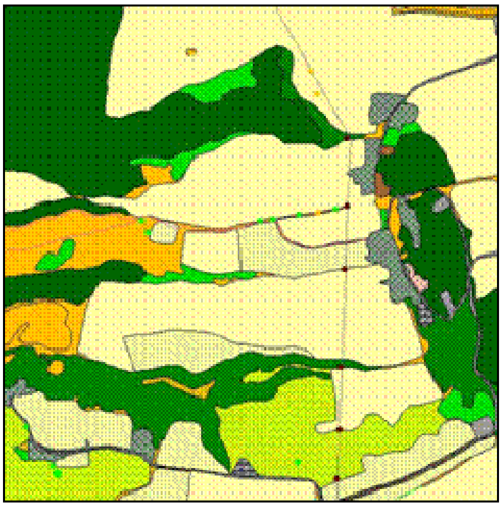


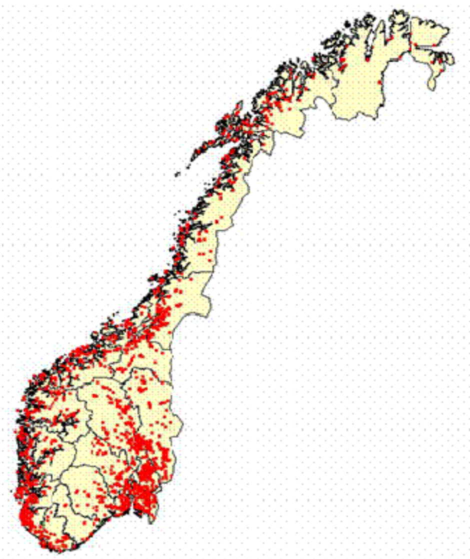
Figure 5.5 Examples of stages and results of 3Q mapping



A grid with 3 km between the intersections, horizontally and vertically is the starting point for selection of 3Q areas. If the intersection falls on an agricultural area (●) a 1km^2 sized square is defined with the intersection as a centre. If the intersection is on a forested area (●) or urban area (●) no 3Q areas is defined.







5.3.3 Miscellaneous administrative data

There exists several administrative registers with relevance to area statistics. Most of them do, however, have drawbacks with regard to lack of systematizing, lack of time stamps, lack of delineation of physical features, incomplete coverage etc. Another problem for this application is that they normally are not able to track the initial land use of a conversion. They may, however, to some extent still be useful for verification purposes. Only the most relevant registers are covered here. Data on reservoirs and dams are for example not available in a format that can be used for this project. Also information about parks and "green lungs" in urban settlements are lacking in a format that is relevant to the project.

Total land occupied by roads, railways, airports and buildings can be estimated by use of administrative registers (Table 5.1).

Table 5.1 Settlements by 1.1.2004

	Area (1000 ha)
Total	421.2
Roads	208.7
Railways	5.7
Buildings	41.6
Airports	1.4
Other urban settlements	163.8

There are, however, some limitations when it comes to estimating the previous land use or land cover. The previous land cover often has no digital maps, or the historical information has not been archived. For buildings, time stamps are given from 1984 and onwards, but with variable quality. Roads managed by the road authority do have time stamps from 1988, but data are currently not easily accessible. Railways and airports lack time stamps, but play a minor role for land use and land-use change.

There are also some difficulties in concluding when a land-use change has taken place. This is either because of lack of time stamps in the registers, or that the registers are not properly systemized. With a new National Road Database and enhancing of building register with census data from 2001, it will by the end of 2005 be possible to give a better description of historical land-use change to settlements.

Given that nearly 90 per cent of physically built-up land outside present Urban Settlements consists of land take by road, one could assume that the statistics for new forest roads gives an indication of the amount of land converted from forest to settlements. According to the statistics about 1910 ha were converted in the period from 1990 to 2000 (Figure 5.6 and 5.7). However, also new main roads built may be in a forested area, and as mentioned this information is more difficult to extract.

Total settlements in 2004 amounts to about 1.3 per cent of total land area according to the administrative registers, and about 2.1 according to NFI (see Table 5.1). This difference, 0.8 per cent or 259 000 ha, may be explained by differences in operationalisation. Urban settlements" are defined by Statistics Norway by a combination of criterias for density in built-up areas and a minimum number of 200 inhabitants within an area. "Other settlement" in table 5.1 refers to areas within urban settlements which are not physically built-up. Settlement figures from NIJOS also include gardens and other surrounding areas of physically built-up areas, and areas in a zone below power lines.

The ground property register probably have information on land use for all properties established after 1983. These properties are, however, not representative for the whole country, neither by land classification, region nor time. There are work going on by the National Mapping Authority (NMA) to have a one-to-one relationship between the ground property register and digital cadastre maps. This will, however, not be finished before the end of 2005 at the earliest.

Figure 5.6 Land converted to forest roads. km^2

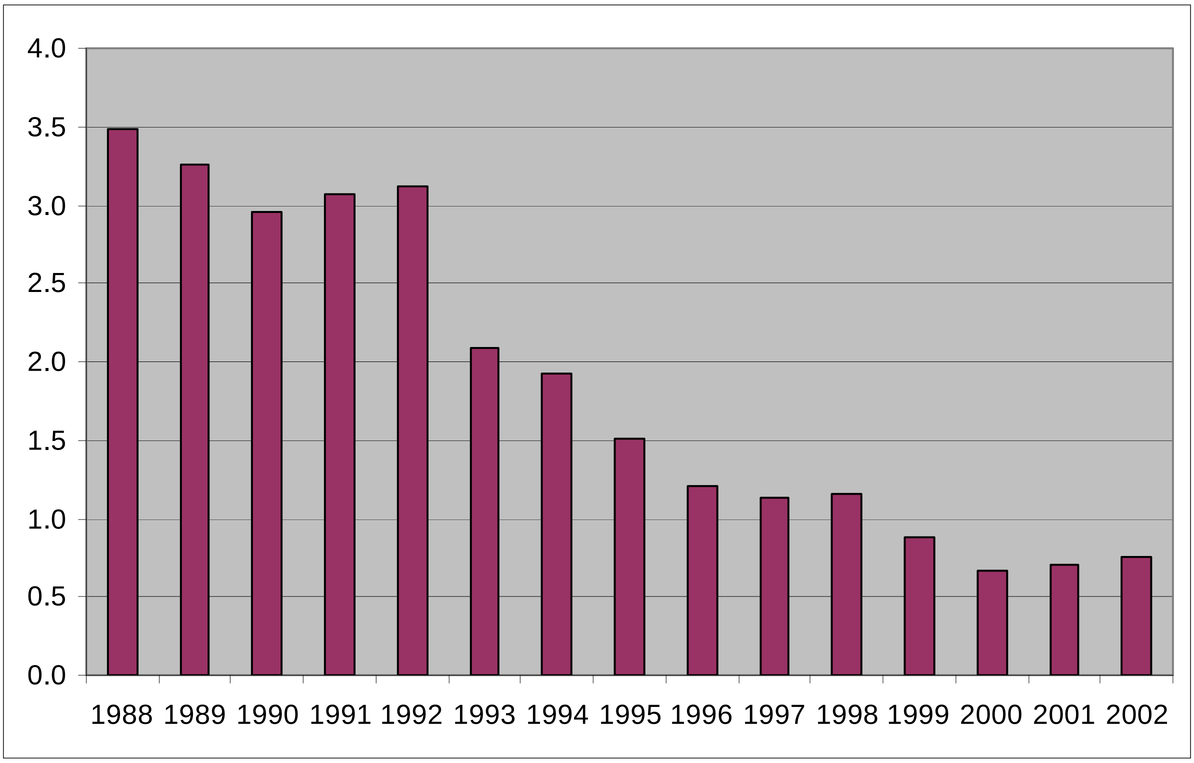
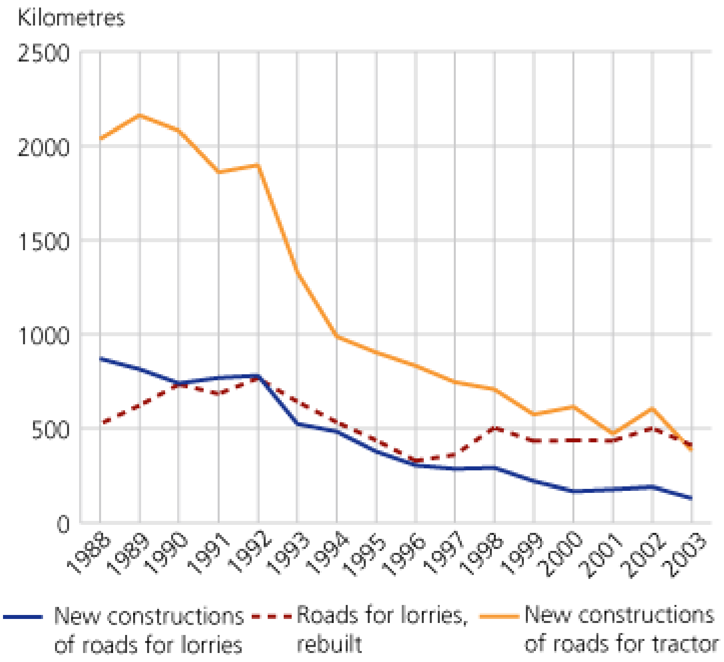


Figure 5.7 Constructions of forest roads (1988-2003)

Construction of forest roads. 1988-2003. Kilometres



6 Proposal for land area statistics and transitions

There exists no system covering all of Norway that could be used for an at situ representation. The use of overall mapping seems not to be feasible, neither by technical nor economical terms. The approach for representing land areas will therefore be based on a combination of existing sources of data, with emphasis on data from the National Forest Inventory.

The ideas for an area database that could improve the basis for spatial data on land use and land-use change are presented in Appendix 1.

6.1 Choosing data according to IPCC Good practice

The framework to estimate emissions and removals from LULUCF activities requires knowledge of areas of different land use and the transition between them. The required main land-use types and their transitions are forest, grassland, cropland, wetland, settlements and other land and all transitions between these categories.

There are several reasons for primarily relying on the National Forest Inventory. First, forest covers 40 % of the mainland area of Norway and also is the most important area type with respect to carbon stock changes (see summary, Section 2). Second, although the National Forest Inventory is not equally accurate for non-forest land it is the only source of information that can track land-use changes from initial to final end use. The administrative data sources like road construction statistics and agriculture statistics normally only give information on final land use, not the initial. The National Forest Inventory (NFI) gives information about initial and final land use for the given categories.

Chapter 2 of GPG2004 (Basis for consistent representation of land areas) introduces three approaches for representing land areas. Because the data from the National Forest Inventory has not full spatial coverage, but gives transitions of land from one category to another use of these data corresponds to *Approach 2*. However, as discussed below and in individual chapters administrative data are used to complement, detail or verify the data from the NFI for use for reporting under the UNFCCC and the Kyoto Protocol. In the next section we will discuss in more detail the application of the NFI data for estimating emissions and removals.

6.2 Area distribution and land-use transfers

The 6th National Forest inventory was carried out from 1986 to 1993. The NFI was progressed by regions of counties until 1993 and this makes it difficult to point out area estimates for a single year, e.g. for year 1990. Thus, *the figures from the period 1986 to 1993 have to be used as the best estimate for the 1990 situation*. From 1994 the NFI design was changed in such a way that a fraction of the field plots is measured in the entire country each year, and thus, single year estimates can be made. Data for 1991-1993 are based on linear interpolations of the 1990 data and 1994. For this project "annual" data were available until 2003 (only suited to give representative data for 2001) and extrapolations of the trends were used to obtain data for 2002 and 2003.

Even for the 7th NFI, from 1994 to 1999, and the 8th NFI, from 2000 to 2004, the areas in Finnmark county and above the coniferous forest limit in the mountains were not covered. These areas are now classified as "Other land" even if a smaller part in principle might be included in the other classes. The forest areas in Finnmark have been reported under forest land. The changes in the forest in Finnmark are discussed in paragraph 6.2.4.

It is technically difficult to handle permanent plots that have undergone changes between periods regarding how they are divided into different land-use classes, i.e. this problem may occur for plots that are located on the boundaries between different land-use classes. Plots may also have been assigned to different classes at different points of time although no real change has occurred. This is due to the fact that different surveyors may have come to different conclusions regarding how land-use on a plot should be classified. Thus, some areas might be missing from the NFI land-use assessment due to misclassification etc. In a plot represents a large share of the area, such a misclassification can influence the assessment of area changes. *If a NFI sample plot has been found misclassified, the correct classification has been used for successive inventories and no land-use changes were assumed.*

The total land area of Norway has been divided into the six categories: forest land, cropland, grassland, wetlands, settlements, and other land as shown in table 6.1 to 6.3 (based on the NFI). The figures from the national land-use classification categories have been reclassified to meet the requirements of the GPG2004. The category “Other land” is to ensure that the total land area identified equals the total area of the country, see discussion below concerning “other land”.

The six land-use categories are consistent with the national definitions applied in 7th and 8th NFI. However, in the 6th NFI the crown cover percentage was not recorded, and also the category “Grassland” had not been defined in the land-use classification. Crown cover is used for Forest land classification. Due to the missing assessment of the crown cover parameter and the area of “Grassland”, the values from the 7th NFI were used as estimates of crown cover and grassland in the 6th NFI. Areas classified as grassland in the 7th inventory were assumed grassland also in the 6th. Consequently, no land-use transfers from “Grassland” were assumed. The reason for not using extrapolations was that it is expected that parts of the changes observed from the 7th to the 8th inventory partly may be due to reclassifications. In this study, exclusively plots which are assigned to only one land-use class have been used. The plots with more than one land-use class (on the boundary between two classes) were not used in order to avoid problems with misclassification.

6.2.1 National data

The land area calculations were made by the Norwegian Mapping Authority and Statistics Norway. The total land area at county level is from (http://www.ssb.no/aarbok/tab/t-010101-021.html) and at municipality level is from (http://www.ssb.no/kommuner/region.cgi?nr=18). Below the land areas for the reference years are presented, and the changes between them. To get a better overview of the significance of the changes we also show the number of plots represented by each land area and each of the transitions.

Table 6.1. Land-use classification in the 6th NFI (used to represent 1990).

	Land use 6th inventory	
Classes	Area (ha)	%
Cropland	1 079 606	3.3
Forest land	8 870 372	27.4
Grassland	154 629	0.5
Other land	19 449 628	60.1
Settlements	629 154	1.9
Wetland	2 196 811	6.8
Sum 6th	32 380 200	100.0

Table 6.2 Land-use classification in the 7th NFI (representing 1996)

	Land use 7th inventory	
Classes	Area (ha)	%
Cropland	1 051 656	3.2
Forest land	8 798 242	27.2
Grassland	154 629	0.5
Other land	19 501 922	60.2
Settlements	643 580	2.0
Wetland	2 230 171	6.9
Sum 7th	32 380 200	100.0

Table 6.3 Land-use classification at 8th National Forest Inventory (representing 2001)

Classes	Land use 8th inventory Area (ha)	%
Cropland	1 019 197	3.1
Forest land	9 251 760	28.6
Grassland	170 858	0.5
Other land	19 162 911	59.2
Settlements	667 023	2.1
Wetland	2 108 451	6.5
Sum 8th	32 380 200	100.0

Table 6.4 Number of sample plots by land-use transfer groups between 6th and 7th National forest inventory

Land-use classes 6th inventory	Land-use classes 7th inventory						
	Cropland	Forest land	Grassland	Other land	Settlements	Wetland	Sum 6th
Cropland	1 158	16	0	3	18	2	1 197
Forest land	5	9 671	0	95	28	35	9 834
Grassland	0	0	171	0	0	0	171
Other land	1	43	0	21 501	2	16	21 563
Settlements	1	11	0	17	664	5	698
Wetland	1	13	0	5	2	2 414	2 435
Sum 7th	1 166	9 754	171	21 621	714	2 472	35 898

Table 6.5 Land-use transfer matrix between the 6th and the 7th National forest inventory, relative values (%)

Land-use classes 6th inventory	Land-use classes 7th inventory						
	Cropland	Forest land	Grassland	Other land	Settlements	Wetland	Sum 6th
Cropland	99.3	0.2	0.0	0.0	2.5	0.1	3.3
Forest land	0.4	99.1	0.0	0.4	3.9	1.4	27.4
Grassland	0.0	0.0	100.0	0.0	0.0	0.0	0.5
Other land	0.1	0.4	0.0	99.4	0.3	0.6	60.1
Settlements	0.1	0.1	0.0	0.1	93.0	0.2	1.9
Wetland	0.1	0.1	0.0	0.0	0.3	97.7	6.8
Sum 7th	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.6 Number of sample plots by land-use transfer groups between 7th and 8th National forest inventory

Land-use classes 7th inventory	Land-use classes 8th inventory						
	Cropland	Forest land	Grassland	Other land	Settlements	Wetland	Sum (7th)
Cropland	1 125	15	17	1	6	2	1 166
Forest land	2	9 625	4	75	20	28	9 754
Grassland	1	5	163	1	1	0	171
Other land	0	444	1	21 151	11	14	21 621
Settlements	1	5	2	5	701	0	714
Wetland	1	163	2	12	1	2 294	2 472
Sum (8th)	1 130	10 257	189	21 245	739	2 338	35 898

Table 6.7 Land-use transfer matrix between the 7th and the 8th National forest inventory, relative values (%)

Land-use classes 7th inventory	Land-use classes 8th inventory						
	Cropland	Forest land	Grassland	Other land	Settlements	Wetland	Sum (7th)
Cropland	99.6	0.1	9.0	0.0	0.8	0.1	3.2
Forest land	0.2	93.8	2.1	0.4	2.7	1.2	27.2
Grassland	0.1	0.0	86.3	0.0	0.1	0.0	0.5
Other land	0.0	4.3	0.5	99.6	1.5	0.6	60.2
Settlements	0.1	0.0	1.1	0.0	94.7	0.0	2.0
Wetland	0.1	1.6	1.1	0.1	0.1	98.1	6.9
Sum (8th)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

A key finding from these data is that changes in land use from 1990 to 2001 are quite small; the forest area is increasing and the agriculture area decreasing. Grassland and settlement areas have also increased.

Below we will discuss all land-use transitions in order to conclude which are real and which can only be explained as changes in classifications. In the cases where the changes cannot be considered real, we will also discuss how this is suggested treated in the calculations. We also address to what extent changes are human induced, as this is relevant for the reporting under the Kyoto Protocol. It is important to bear in mind that not all the changes discussed in the end are important for the carbon stock changes calculated as described in the next chapter.

Conversions between cropland and forest land:
The (direct) conversions between these categories are small. Such a conversion is expected, however, due to abandonment of marginal agriculture land. An explanation may be that the transition goes via other land or grassland.

These area changes can be considered human induced.

Conversions between cropland and grassland:
Some conversion from cropland to grassland has been detected. The lack of transformations between the 6th and 7th are an artifact because grassland was not recorded separately in the 6th inventory. In the data used in the calculations, the data in the 6th inventory have been corrected and assumed that the area is equal to the 7th inventory.

A considerable amount of conversion from cropland to grassland has been detected between the 7th and 8th inventory. The data itself has been checked to be correct, however, it is rather unlikely that substantial transitions of this kind actually have taken place (some change may be real due to abandonment of marginal agriculture area). The most probable explanation is that there was an additional correction of the data that for some reason had not been reassigned between 6th and 7th inventory. Because this change does not affect the estimates of emissions and removals substantially, we propose nevertheless using the data as they are reported in the calculations. To the extent that the changes are real, they would be human induced.

Conversions between cropland and settlements:
There is some conversion from cropland to settlements. These changes are considered to be real, given that the total cropland area has been decreasing and urban area increasing also according to administrative records. The changes are human induced.

Conversions between cropland and wetland:
The conversions between these categories are negligible. There are, however, additional administrative records that can be used to conclude about drainage of wetland for agriculture (also historically). These changes are small today and would nevertheless not be possible to identify through the NFI. The changes are human induced.

Conversions between cropland and other land:
The conversions between these categories are negligible.

Conversions between forest land and grassland:
In the 6th inventory, grassland was not a valid option and therefore all plots classified as grassland in the 7th inventory have been expected to belong to the same land-use class also in the previous cycle. The inventory data indicates some transition from forest to grassland between the 7th and the 8th inventory. It is likely that this can be explained in the same way as for cropland-grassland transitions. All sample plots may not be adequately reclassified in the 7th inventory and therefore the remaining plots on grassland were not reassigned until next time the plots were visited in the field.

In these cases we assume that the change is not real, because forest cleared for grazing is not current practice. *We assume these areas were grassland also in previous years*.

The data shows no conversion from grassland to forest. Such a transition would not have been unlikely, because there has been a reduction in animal grazing in many rural districts. However, the process of reforestation is slow, and the revision of sample plots on grassland may also have been incomplete, since inventory of non-forested plots traditionally have not been given very high priority by the NFI.

Conversions between grassland and forest would be human induced.

Conversions between forest land and settlements:
There has been a rather large conversion from forest land to settlements between the forest inventories. These changes are in line with independent administrative records and human induced. They are interpreted in this project as *deforestation*.

Conversions between forest land and wetland:
There has both been recorded a conversion from forest land to wetland and from wetland to forest land. Some of these differences can be explained by difficulties in classifying areas with tree cover on wetland. However, there may also be some actual changes from wetland to forest land. The limit for classifying as mire is < 10 % crown cover. *In this situation we will assume that the last inventory is the most correct, and we will use the last year's classification also for earlier years.* The actual changes are probably not directly human induced.

Conversions between forest land and other land:
There has been a conversion from other land to forest land (7th and 8th). These conversions are most likely in areas close to the timberline. Changes from other land to forest land are real and are partly human induced (changes in grazing). Some changes can also be due to a warmer climate. The explanations for increases in forest around the timberline has been discussed by Hofgaard (1997a;b), who claims that most of the expansion of the mountain birch forests in Scandinavia after the mid-20 Century, is due to change of land use as a result of diminished grazing pressure. The expansion that has been detected for the first part of the last century is expected to be mainly climatically induced.

The change from forest land to other land is difficult to explain. In the calculations we assume that this "other" is vegetated and the consequences for the biomass calculations are consequently small.

Conversions between grassland and settlements:
A case of change from settlements to grassland has been observed. This change is not significant (assessed in one plot only). This conversion does, however, not have any major practical consequences for the estimates of emissions and removals.

Conversions between grassland and wetland:
There has been some conversion between wetland and grassland. Parts of this can be due to new areas used for grazing, but parts may be reclassifications. The changes are, however, small.

Conversions between grassland and other land:
There is some conversion from "other" to "grassland". The large increase between the 6th and 7th inventory can be explained by the lack of a "grassland" category in the 7th inventory so that the "other" category has been used more frequently. The changes are, however, small.

Conversions between settlements and wetland:
Conversions between settlements and wetland are small. These apparent conversions may have been caused by subjective differences in classification of lands. However, these apparent conversions do not have any major consequences for the calculations of emissions and removals, as the result would be rather negligible.

Conversions between settlements and other land:
There has been some conversion from "other" to "settlements". This can be explained for example by road constructions. We assume that in these situations the "other" is vegetated. The changes are human induced.

Conversions between wetland and other land:
There has been an apparent conversion from "other" to "wetland". This conversion is hard to explain and is probably caused by differences in judgement of classification. However, these apparent conversions do not have any major consequences for the calculations of emissions and removals and we assume that "other" is not vegetated in this situation.

6.2.2 Use of administrative data to detail the categories

As already mentioned, the NFI data are not sufficiently detailed to estimate carbon emissions and removals for some of the transitions where more detailed information is needed to estimate emissions and removals. For this reason a further split of the "agriculture" category has been made for all years. We also discuss a split of the "other land" category.

Cropland

Agriculture statistics gives annual data on area used for different agriculture activities. For this project we have made the following split:

- Grain and oil seeds
- Root crops
- Meadows
- Horticulture
- Grassland

Grassland as defined here differs from grassland in the NFI tables in that it only includes pasture and meadow (that sometimes will be harvested) close to the farm. This type of grassland is classified as "agriculture" in the NFI.

The data are shown in Annex 2. Figure 6.1 illustrates the changes in these categories since 1989 and the country data are summarized in Table 6.8. There has been a reduction in areas used for potatoes (roots), grains and horticulture since 1989. This has, however, been compensated by an increase in meadows (grass production). Also agricultural grassland has increased a lot.

Figure 6.1 Agriculture practices. 1969-2002 (Statistics Norway)

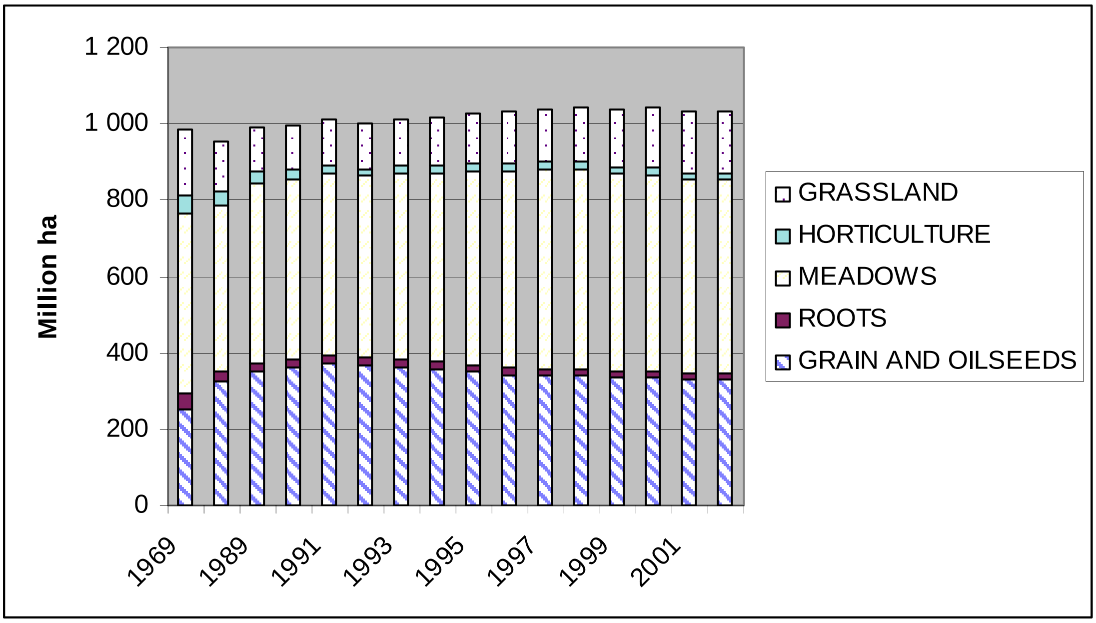


Table 6.8 Agriculture practices. 1969-2002. 1000 ha (Statistics Norway)

	Grain and oilseeds	Roots	Meadows	Horticulture	Grassland	Total agriculture	Total including grassland
1969	252.4	41.6	468.8	51.8	171.7	814.6	986.3
1979	325.2	24.4	434.9	36.0	133.0	820.6	953.5
1989	353.0	21.5	471.1	31.6	113.9	877.2	991.1
1990	361.9	21.0	473.3	23.9	113.9	880.2	994.1
1991	373.4	20.1	476.8	22.2	117.8	892.5	1010.3
1992	365.2	20.8	477.6	18.4	120.2	882.1	1002.3
1993	361.4	19.7	489.5	18.2	123.3	888.8	1012.1
1994	358.5	18.3	495.1	18.9	127.6	890.8	1018.4
1995	349.2	19.0	506.9	20.4	130.0	895.5	1025.5
1996	341.8	18.9	516.9	21.0	132.6	898.6	1031.2
1997	339.7	18.6	523.7	19.9	136.4	902.0	1038.3
1998	338.5	16.8	524.8	18.9	143.6	899.0	1042.6
1999	334.5	15.2	518.3	18.9	151.1	886.9	1037.9
2000	337.0	15.5	514.3	18.5	158.3	885.3	1043.6
2001	331.9	15.5	507.3	17.8	158.7	872.5	1031.2
2002	332.0	15.1	506.5	17.0	161.9	870.6	1032.5

One challenge in using these data is to combine them with the data from the National Forest Inventory (Table 6.9). The sum of cropland and grassland area of the NFI is slightly higher than in the agriculture statistics (difference was around 9 % in 1989, but only 2.5 % in 2002). One explanation is that the NIJOS data will record agricultural land as such also for some time after it has been abandoned. It also appears that some abandoned land again will be in use after a while. The data on the agriculture statistics are expected to be very accurate because agriculture production is highly controlled in Norway due to reliance of economic subsidies. Consequently, the agriculture statistics can be interpretated as managed agriculture land (including certain pastures and meadows), and the difference from the area classified by NIJOS as unmanaged. The explanation of the apparent decrease in "unmanaged" agriculture land can be revegetation in certain areas.

Table 6.9 Agriculture area in the NFI

"1990" (NFI)	Land use 6th inventory	
Classes	Area (ha)	%
Cropland	1 079 606	3.3
Grassland	137 498	0.4
"2000" (NFI)	Land use 8th inventory	
Classes	Area (ha)	%
Cropland	1 019 197	3.1
Grassland	170 858	0.5

Other land

The other land category will under Norwegian conditions consist mainly of "other wooded land" (shrubland or land with some forest characteristics, but not meeting the forest definition) or barren land, especially in high altitude areas and far north. Thus, it is obvious that the biomass may vary between the different sub-types. To be able to assess the importance of different nature conditions, estimates of the wooded part of "other" land have been derived and are presented in table 6.10. The estimates have been obtained by subtracting the forest area assessed by the NFI from the total area of woodlands obtained from topographic maps. However, as the maps are sometimes 20-30 years old, these areas may be more or less underestimated. This land category plays a role in land-use changes, as other wooded land area is expected to increase due to reduced grazing. As discussed in section 7.6, the carbon stock changes are nevertheless expected to be minor compared to the stock changes on land meeting the forest definition.

Table 6.10 Estimates of total wooded land area, forest, other land and “other land” with tree cover (ha). The regions are defined in Section 6.2.3.

Region	Wooded land area (forest + “other land” with tree cover)	Forest	Other land (total)	“Other land" with tree cover	Percentage of “other land” with tree cover
1	5 883 199	5 264 050	3 991 763	619 149	15.5
2	1 564 500	1 159 130	3 915 918	405 370	10.4
3	2 074 747	1 716 515	3 357 285	358 232	10.7
4	1 231 916	1 076 090	3 071 013	155 826	5.1
Total	10 754 362	9 215 785	14 335 979	1 538 577	10.7

6.2.3 Regional data

The land-use status and the transfer matrices have been described for four separate regions, in addition to the whole country. With reference to reporting under the Kyoto Protocol, it is recommended to stratify the entire country and to define and report the geographic boundaries of these land areas (see Chapter 9 on supplementary reporting for the Kyoto Protocol). Criteria for stratification of the country could include statistical considerations for the sampling intensity or sampling approaches, considerations of the type and amount of land-use change activities and selected activities, as well as ecological or administrative considerations.

It is proposed to divide the country into four regions, which can easily be identified and reported on using the NFI data. At the same time, the ecological conditions and forestry activities have a high degree of similarity within each individual region. These regions are:

1. **Østlandet + Sørlandet (Southeast and south Norway).** Comprises the counties Østfold, Akershus, Oslo, Hedmark, Oppland, Buskerud, Vestfold, Telemark, Aust-Agder and Vest-Agder.
2. **Vestlandet (West Norway).** Comprises Rogaland, Hordaland, Sogn og Fjordane and Møre and Romsdal.
3. **Trøndelag og sørlige del av Nordland (Central Norway).** Comprises Sør-Trøndelag, Nord-Trøndelag and southern part of Nordland county.
4. **Nord-Norge (North Norway).** Comprises northern part of Nordland county, in addition to Troms. Finnmark county is not included here due to lack of data, see Section 6.2.4.

The area data for these regions are presented in Annex 3. The agriculture data are presented at the country level (Annex 2) and can be combined with these data as described for the country.

6.2.4 Finnmark county

Finnmark county (the northernmost county of Norway) has so far never been subject to any comprehensive forest inventory. A number of times the forests of commercial interest have been surveyed for management purposes. However, the inventories have not been set up in such a way that it is possible to detect changes in land use over time. Data on “productive forest land” has repeatedly been reported by the forest owners to Statistics Norway’s Census of Agriculture and Forestry. Some information is also available from the Norwegian Mapping Authority, based on calculations from standard topographic maps. The data on settlements is taken from Statistics Norway (2004). Thus, an approximate land-use distribution can be established as shown in Table 6.11.

Table 6.11 Land use in Finnmark county (ha)

Classes	Area (ha)	%
Cropland	9 980	0.2
Forest land	83 100	1.7
Grassland	-	-
Other land	4 177 230	85.9
Settlements	3 990	0.1
Wetland	589 400	12.1
Sum	4 863 700	100

It is likely that the forest area shown in the table is underestimated, in that the total wooded area has been reported as high as 1,250,000 ha, and that the productive forest area usually is considerably lower than forest according to the international definition. Also, a larger forest area has previously been reported, according to older censuses of agriculture and forestry. Taking into account the figures listed in the table, 1,166,400 ha of the "other" category will have some kind of tree cover, comprising about 28% of this category. Most of this area will not meet the definition of forest applied in this project, but it is likely that a minor part could be assigned to this category. Taking into account the changes that have taken place in the adjacent county, the low population density and the fact that the human impact is generally very low (annual harvest is only around 14 000 m^3 annually according to Statistics Norway), it is highly probable that the forest area of Finnmark is increasing, or at least stable. The only aspect to consider would be the rather intensive reindeer grazing taking place in some areas. However, mostly lichens on low-productive soils are subject to browsing, and it is not very likely that the forest would be affected to any substantial degree.

6.2.5 Land-use changes prior to 1990

According to the Good Practice Guidance, it has been recommended that, when a piece of land changes use, then it is followed in that 'changed status' for 20 years, with each year 1/20 of the CO_2 and non- CO_2 effects reported. Tier 3 modeling approaches may utilize different assumptions, but still with a conversion category of 20 years. That means, land-use changes that have taken place after 1970 may still have an impact on soil organic matter in 1990. There was no forest inventory intended to assess land-use changes in 1970, and the forest inventory at that time was not covering the whole country. To be able to make a rough indication of the overall trend in forest area, the areas of "productive forest" according to national classification has been presented in Table 6.12. The data are taken from the Census of Agriculture and Forestry 1967, 1979 and 1989. Because no data from permanent sample plots exists before 1986 and relatively small changes has been detected in total forest land, we have chosen not to take into account changes that may have occurred prior to 1990. This implies that stock changes in lands converted to forest are underestimated, but the biomass changes are included in the reporting category for "forest land remaining forest land".

Table 6.12 Estimates of productive forest land 1967-1989 (ha)

Region	1967	1979	1989
1	4 166 102	4 085 300	4 288 900
2	689 422	770 500	894 700
3	1 021 125	975 600[a]	1 255 200
4	522 110	744 000[b]	514 300
Total	6 398 759	6 659 800	6 953 100

[a] Trøndelag only
[b] Includes all of Nordland

6.2.6 Precision of estimates

About 17 000 permanent plots are available from the NFI. These plots will be revisited during each 5 year period. Estimates for the specific period are likely to be made based on data obtained as 5 year averages.

With the number of plots, the precision of the estimates (in relative terms) will be high for the common land-use classes. Although the NFI is carried out as a systematic sampling of plot clusters, the formulas for simple random sampling can be used to provide approximate values for the precision of the area estimates. The standard error of an area estimate with simple random sampling is:

$$std(\hat{A}_c) = A\sqrt{\frac{p(1-p)}{n}}$$

Where $\hat{A}_c$ is the area of a specific land-use category or transfer class, A is the total area of Norway (32,380,200 ha), p is the proportion of the land-use class, and n is the number of sample plots. In table 6.13, some examples of standard errors are given for various cases, differentiated on proportion of the land-use category and the number of sample plots used.

Table 6.13 Examples of standard errors of area estimates, using a certain number (n) of sample plots in the calculations.

Proportion of area (p)	Corresponding area	Standard error n=5000 (ha)	(%)	n=10000 (ha)	(%)	n=17000 (ha)	(%)
0.001	32 380	14 474	45	10 234	32	7 849	24
0.01	323 802	45 563	14	32 218	10	24 710	8
0.1	3 238 020	137 378	4	97 141	3	74 503	2
0.5	16 190 100	228 963	1	161 901	1	124 172	1

Table 6.13 shows that the relative errors of the uncommon categories will be rather high. On the other hand, once a certain category becomes more frequent, the relative precision of its assessment will be higher. Thus, by using the permanent plots of NFI as a basis for the area estimation, the uncommon classes will be assessed with low accuracy. The system is sensible to the number of permanent plots. For sparse categories the current number of plots may be considered being close to a minimum.

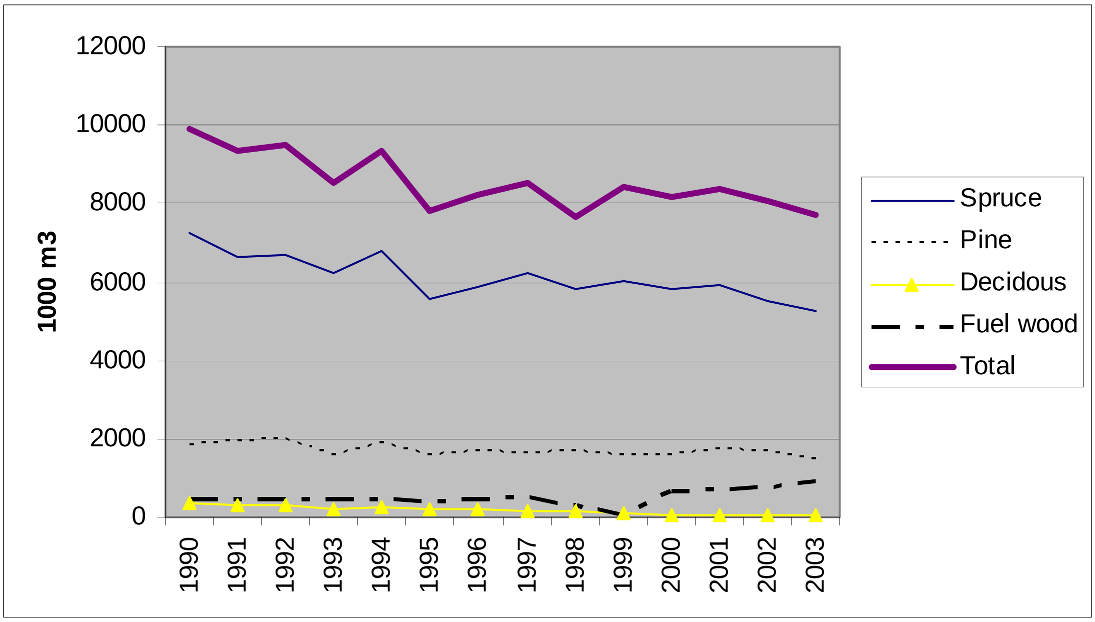
7 Estimating emissions and removals of CO_2 from the LULUCF sector

7.1 *Forest land*

Forest is the most important land cover type with respect to biomass sequestration in Norway and changes in biomass pools under forest land remaining forest land have been identified as a key category. The details of the biomass calculations will be described in Section 7.1.1, but the same data will also be used to estimate losses of C when forest is converted to other land use or removals when the forest area is increasing (Section 7.1.2).

In addition to changes between land categories and other land management, the carbon stock changes are also influenced by changes in harvest. The harvest of all species have decreased since 1990, Figure 7.1.[6]

Figure 7.1 Forest harvest 1990-2003 (Statistics Norway, Forestry Statistics)



7.1.1 Forest land remaining forest land

Change in carbon stock in living biomass

The method implemented corresponds to Tier 3 of GPG2004; a combination of national forest inventory data and models to estimate changes in biomass. Tier 1 may in the future be used to estimate emissions and removals in the forest of Finnmark and in "other wooded land".

Materials and methods

[6] Figures for fuel wood production only include production for sale as registered. The real harvest is higher, therefore the figures differ from those used to estimate emissions from fuel wood combustion.

One method for estimating the total biomass of forest trees, is to use a set of equations developed in Sweden (Marklund, 1988) for single tree biomass of Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*) and birch (*Betula pubecens*). These equations provide biomass estimates for Norway spruce and Scots pine for the various tree biomass components; stem, stem bark, living branches, dead branches, needles, stump, roots larger than 5 cm in diameter and roots less than 5 cm in diameter. For birch, the biomass equations are available only for stem, stem bark, living branches and dead branches.

For the calculations, tree and stand attributes from the permanent NFI sample plots located throughout Norway have been used, except from Finnmark county. Sample plots located on forest and other wooded land were used in the calculations.

The biomass of deciduous trees foliage was calculated by assuming it to be 2.2 % of the stem volume, with a dry weight of 0.520 Mg m^{-3} (Lethonen et al. 2004). Woody biomass for below ground components such as coarse roots larger than and less than 5 cm in diameter were calculated for deciduous trees by assuming the components' volume to be 8% of the stem volume, with a dry weight of 0.520 Mg m^{-3} (Lethonen et al. 2004). The stem volumes were calculated by using volume equations for Norway spruce, Scots pine and birch (Braastad 1966, Brantseg 1967, Vestjordet 1967). The biomass of fine roots, both for coniferous and deciduous trees, was assumed to be 20% of their respective foliage biomass (Vanninen et al. 1996).

The biomass for trees larger than 10 cm diameter at breast height was calculated from diameter and height for the basal area mean tree. For trees between 5 and 10 cm the biomass was calculated by means of biomass equations based only on diameter at breast height. The volume of coniferous and deciduous trees in young forest was calculated on the basis of observed mean height, estimated mean diameter and the number of coniferous and deciduous trees on the NFI plot. Mean diameter was calculated by using a simple equation:

$$D\ (cm) = 1.4xH\ (m) - 1.8$$

where H is the observed mean height.

This equation is based on the assumption that young trees have a linear growth ten years after reaching breast height (Tomter 1998, unpubl.). Trees with a height less then 1.3 meter were excluded from the calculations because this is negligible. Stem volume under bark of coniferous and deciduous trees was calculated by using equations (Seip 1964). The biomass of these young trees was calculated by converting stem volume into biomass by using biomass expansion factors (BEF) for whole trees at a stand age of 10-19 years (Lethonen et al. 2004). The BEF used for Norway spruce, Scots pine and deciduous trees were, respectively, 0.862 Mg m^{-3}, 0.697 Mg m^{-3} and 0.544 Mg m^{-3}. The BEF for birch/deciduous trees accounts for aboveground biomass, only excluding foliage. Therefore, the same assumptions and calculations as described earlier were used for foliage and below ground woody biomass.

Table 7.1 Total biomass for deciduous trees, Norway spruce and Scots pine.

	8th inventory		7th inventory		6th inventory	
Species	Total biomass (Gg)	Biomass (Mg/ha)	Total biomass (Gg)	Biomass (Mg/ha)	Total biomass (Gg)	Biomass (Mg/ha)
Norway spruce	295631	31.95	273364	31.07	262949	29.63
Scots Pine	181936	19.67	167409	19.03	151304	17.05
Deciduous	151916	16.42	136749	15.54	125373	14.13
Total	629483	68.04	577521	65.65	539626	60.81
Area (ha)	9251760		8797521		8873347	

Another alternative to the calculations above is to apply only simple expansion factors for all components of the trees, based on total stem volume. Such a procedure has e.g. been described in the publication "The forest resources of the ECE region" (1985). Overbark and underbark volume from the NFI were used as a starting point.

Total volume of tree biomass was calculated in the following way:

1. $V = V_1 + a + b$
2. $a = K_1 \times V_2$
3. $b = K_2 \times V_2$

where
V = total volume of tree biomass
V_1= volume of wood overbark
V_2= volume of wood underbark
a = other above-ground biomass
b = volume of stumps and roots
K_1 , K_2 = constants

	coniferous	deciduous
K_1	0.25	0.25
K_2	0.25	0.20

and
$M = K \times V$

where
M = oven-dry tree biomass
K = constant, oven-dry density (g/m^3)
V = volume

Values of K:	Stemwood	Bark	Branches	Stumps and roots
Coniferous	0.40	0.31	0.48	0.42
Deciduous	0.52	0.50	0.55	0.53

Calculations based on these expansion factors are very easy and do not require detailed data at the tree or plot level. However, the accuracy must be expected to be somewhat lower than those obtained from individual tree biomass functions. In some cases it is, however, unavoidable that some simplified methods will have to be used. That is for trees outside the forest where no actual inventory data is available, but where there may exist a rough estimate of standing volume. The method can also be suited for QA/QC purposes. The total biomass for deciduous trees, Norway spruce and Scots pine calculated by means of biomass expansion factors shown in table 7.2 below is based on the same data as table 7.2 above. This method gives lower estimates of biomass than the method described above. Tier 3 is based on more detailed and measured data than Tier 1, and is therefore considered more accurate.

Table 7.2 Total biomass for deciduous trees, Norway spruce and Scots pine calculated by means of biomass expansion factors.

	8th inventory		7th inventory		6th inventory	
	Total biomass	Biomass	Total biomass	Biomass	Total biomass	Biomass
Species	(Gg)	(Mg/ha)	(Gg)	(Mg/ha)	(Gg)	(Mg/ha)
Norway spruce	213199	23.04	196680	22.36	190170	21.43
Scots Pine	156488	16.91	141809	16.12	128999	14.54
Deciduous	104024	11.24	94446	10.74	87146	9.82
Total	473710	51.20	432934	49.21	406315	45.79
Area (ha)	9251760		8797521		8873347	

These data illustrates a substantial removal of carbon seen in relation to total annual CO_2 emissions from fossil fuels in Norway. Reduced harvest (Figure 7.1) has contributed to the increase in these removals since 1990. Note that the data in Table 7.2 and 7.3 also includes the sequestration due to increased forest area. To obtain annual data for reporting, the average for each inventory has been assigned to the reference year. Then an interpolation has been carried out in order to assess the annual change until the next reference year.

The biomass in forest in Finnmark has been estimated using the Tier 1 method of GPG2004, Table 7.3. Data from approximately 1989 were used for all years and consequently no changes in biomass pools were assumed.

Table 7.3 Total biomass in Finnmark county land of coniferous and deciduous trees calculated by means of biomass expansion factors.

Species	Total biomass (Gg)	Biomass (Mg/ha)
Coniferous	1213.40	14.60
Deciduous	443.64	5.34
Total	1657.04	19.94
Area (ha)	83 000	

Change in carbon stock in dead organic matter

Change in carbon stock in dead organic matter due to harvest residues and stumps and roots from harvested trees and natural mortality have been calculated from annual harvest volume using the YASSO-model (Liski et al. 2004). Fractions of harvested trees are calculated by means of the biomass expansion factors ("The forest resources of the ECE region" (1985) and (Lethonen et al. 2004)). The decrease in harvest from 1990 (Figure 7.1) influence the amount of harvest waste and therefore also the estimate of "dead organic matter". Therefore "dead organic matter" has decreased since 1990.

Table 7.4 Total remaining biomass in harvest residues and stumps and roots from harvested coniferous and deciduous trees.

	Annual harvest (m^3)			Total biomass (Mg)		
Year	Conifers	Deciduous	Sum	Conifers	Deciduous	Sum
1990	10080618	1269693	11350311	21513993	3829605	25343598
1991	9554399	1204219	10758618	21615841	3865241	25481082
1992	9725168	1210702	10935870	21718208	3895448	25613656
1993	8811162	1078636	9889798	21596153	3882062	25478215
1994	9648118	1116357	10764475	21649526	3886170	25535696
1995	8073829	1054197	9128026	21352330	3846401	25198731
1996	8447156	1113575	9560731	21140397	3825909	24966306
1997	8837010	1082437	9919447	21037547	3812657	24850204
1998	8444524	1080867	9525391	20869521	3792789	24662310
1999	8628946	1166997	9795943	20762283	3799838	24562121
2000	8416910	1091750	9508660	20626334	3788314	24414648
2001	8416910*	1091750*	9508660	20506594	3778138	24284732
2002	8416910*	1091750*	9508660	20403034	3769705	24172739
2003	8416910*	1091750*	9508660	20314475	3763023	24077498

* 2000 data have been used.

Table 7.5 Total remaining biomass in dead wood from natural mortality for coniferous and deciduous trees.

	Dead wood (natural mortality. m^3)			Total biomass (Mg)		
Year	Conifers	Deciduous	Sum	Conifers	Deciduous	Sum
1990	1 120 000	799 000	1 919 000	9 129 536	8 073 624	17 203 160
1991	1 142 000	815 000	1 957 000	9 209 203	8 142 929	17 352 132
1992	1 166 000	831 000	1 997 000	9 299 152	8 220 568	17 519 720
1993	1 190 000	847 000	2 037 000	9 398 651	8 305 875	17 704 526
1994	1 214 000	863 000	2 077 000	9 506 989	8 398 245	17 905 234
1995	1 245 000	885 000	2 130 000	9 627 859	8 501 663	18 129 522
1996	1 288 000	912 000	2 200 000	9 768 128	8 619 363	18 387 491
1997	1 288 000	912 000	2 200 000	9 900 164	8 730 417	18 630 581
1998	1 288 000	912 000	2 200 000	10 022 894	8 834 022	18 856 916
1999	1 288 000	912 000	2 200 000	10 136 109	8 930 025	19 066 134
2000	1 288 000	912 000	2 200 000	10 240 082	9 018 616	19 258 698
2001	1 288 000	912 000	2 200 000	10 335 331	9 100 170	19 435 501
2002	1 288 000	912 000	2 200 000	10 422 491	9 175 140	19 597 631
2003	1 288 000	912 000	2 200 000	10 502 222	9 244 019	19 746 241

The data on natural mortality have been kept constant due to lack of annual measurement data. In addition, biomass from annual litter fall from living trees is calculated and added to carbon stock in dead organic matter.

Change in carbon stocks in soils

Data and calculation method for soil C in forest soils
Forest soil C estimates presented here are based on a reanalysis of data reported in De Wit and Kvindesland (1999) by Strand and De Wit (in prep) and by De Wit (pers.comm). Carbon stocks were estimated for a total number of 1033 soil profiles in productive and non-productive forest including wooded mire, and on organic and mineral soil types. The location of the profiles was a grid of 9x9 km, i.e. the grid of the national forest health monitoring (ICP forests, level 1 plots). Sampling was carried out from 1988-1992. Roughly 75% of the soil profiles were in productive forest and less than 10% were under wooded mire. 15% of all soil profiles were on organic soils and 85% on mineral soil types (classified according to the Canadian System of Soil Classification).

Soil C stocks per profile (Mg C ha^{-1}) were calculated for soil layers of 10 cm thickness and then summed to gain a C stock per profile. More details and equations are given below. Carbon stocks per profile for a given depth were calculated by summing the C stock per horizon, and where the given depth cut a horizon in two, it was assumed that the C stock for this horizon was evenly distributed, so that only the relevant part of the horizon was taken. In addition, sums were calculated for the forest floor where this was present and for mineral soils down to ≥ 30cm, ≥ 50 cm, ≥ 100 cm. The C densities were calculated according to the following equation:

Horizon/Soil layer:

$$C_{density} = BD * C_{content.} * T * CF_{coarse}$$

Profile:

$$C_{density}\ \text{profile} = (C_{density,\ horizon\ 1} + C_{density,\ horizon\ 2} + \ldots + C_{density,\ horizon\ n})$$

Where:

BD = bulk density (kg/m^3)
C_{cont} = organic carbon (kg/kg)
T = thickness of horizon (m)
CF_{coarse} = correction factor for stone and gravel content = 1- (gravel% + stone%)/100

Distribution of forest area between mineral and organic soil types
There are no direct estimates for area of forest on mineral and organic soil types, and the estimate must be therefore be derived from other available data. Here, we use the share of organic soil types and mineral soil types in the soil database and assume that it is representative for Norway. In this way, it can be assumed that 15% of all forested area is on organic soil types, whereas 85% is on mineral soil types.

Soil C stocks in forest
Soil type - mineral soil or organic soil - is a better explanation factor for the size of the C stock than the productivity class of the forest. Additionally, soil C stocks are not normally distributed around a mean value (Strand and de Wit (in prep.)). By contrast, the distribution is skewed, and median values lower than mean values. Therefore, median soil C stocks for mineral soils are used as ‘typical’ values for forest. In agreement with GPG2004, C stocks down to a depth of 30 cm are given (counted from the division between humus layer and top of the mineral soil, for mineral soil types; from the top of the soil for organic soil types) (Table 7.7). For comparison, C stocks for 1 m depth are also given. Similarly, median values were used to characterise organic soils.

Wooded mire is a separate category which is attributed to the land category ‘wetlands’ or forest in the land categorisation. The soil C stocks estimated here cannot be taken as typical for wetlands, because wetlands in general are too moist for tree growth, and moisture is a controlling factor for accumulation of organic matter. Most likely, C stores in wetlands are higher than the stocks that were found in wooded mire. The soil profiles under wooded mire were included in the sampling because forest monitoring plots were located here. Ideally, other data regarding wetlands should be included in order to produce a default value for C stocks in wetlands. The distinction between mineral soils and organic soils is based on the thickness of the humus layer. However, mineral soils under wooded mire had generally a very thick humus layer which lead to relatively similar values of C stocks in mineral soils and organic soils down to 30 cm soil depth. For wooded mire, no distinction was made for organic soils and mineral soils, see Table 7.8 for estimates of total stock.

Table 7.6 Mean and median soil C densities under forest. Standard deviation and number of profiles given.

		mean	Median	stdev	n
30 cm depth	Mineral	132	116	71	851
100 cm depth	Mineral	162	141	95	851
30 cm depth	Organic	132	107	59	108
100 cm depth	Organic	287	214	197	108

Table 7.7 Soil C stocks (until 30 cm and 100 cm depth) in forest and wooded mire in kg C/m^2 for mineral and organic soil types. Number of profiles (n), mean and median values, standard deviation and standard error are given.

	Soil type	N	Cstock30 Mean	Cstock30 median	Cstock30 st.dev	Cstock30 st.error	Cstock100 Mean	Cstock100 median
Productive forest	Mineral	681	13.1	11.4	7.2	0.3	16.2	14.2
Non-productive forest	Mineral	169	12.6	10.8	7.8	0.6	14.7	12.5
Productive forest	Organic	112	11.2	9.6	6.3	0.6	22.9	17.3
Non-productive forest (wooded mire)	Org/mineral	65	17.3	17.9	7.7	1.0	32.6	31.3

Table 7.8 Total soil C stocks in forest in Norway

Soil type	Area 1000 ha	Soil carbon Mg C/ha	Total soil C Tg C
Mineral	10 618[2]	116[1]	1 228
Organic	1 399[2]	107[1]	198

[1]Strand and de Wit (in prep), pers. comm. De Wit. See Table above. For soil depth down to 30 cm (from top of mineral soil for mineral soil types; from top of soil for organic soil types)
[2] Based on contribution of organic soil types and mineral soil types in NIJOS forest soil database, i.e. 12% and 88% respectively. Assuming that this division is representative for forest in Norway

Methodology to estimate emissions and removals in forest land remaining forest land soils
Soil C stocks in forest are the result of soil forming processes like geology, climate, vegetation, topography and disturbances. The soil C stocks are not necessarily in a constant state with regard to these factors. Most likely, the C stocks are at present affected by changes in the vegetation, such as the ongoing accumulation of biomass in Norwegian forest, by forest management, and possibly by climate change. So, also for forest land remaining forest land the soil may act as a source or a sink for atmospheric carbon.

De Wit et al. (submitted) calculated a mean annual sink value of *0.10 Mg C* ha^{-1} $year^{-1}$ for mineral soils in productive forest in southeast Norway from 1971-2000. This calculation was based on forest inventory data from 1971-2000, which were converted to biomass using biomass expansion factors (Lehtonen et al., 2004) from which annual litter production was calculated using biomass turnover rates. Additionally, litter production from harvest residues and natural losses from 1960 was calculated. Litter production pr ha increased during the period of 1971-2000, and this is the main driving force behind the accumulation of carbon in the soil. The rate is likely less in *non-productive forest* because there is negligible or no harvest. De Wit et al. (submitted) estimated the contribution of harvest-related litter to total litter production in productive forest in southeast Norway to 28-34%. If it is assumed that no harvesting is done in non-productive forest, one might expect maximum 34% lower litter production than in productive forest, given that litter from standing biomass does not change.

Litter from standing biomass is related to biomass, and it is reasonable to assume that biomass in non-productive forests is lower than in productive forest. As a rough estimate, one might assume that litter production in non-productive forest is 50% of the litter production in productive forest. Additionally, if it is assumed that the soil sink is linearly related to litter production, it follows that soil C accumulation in non-productive forest is about 50% of soil C accumulation in productive forest. Thus, a mean annual sink value for non-productive forest is 50 % of the estimated annual sink value of 0.10 Mg C/ha/year for productive forest: 0.05 Mg C/ha/year. The ratio of productive to non-productive forest was 3.0 in 1990 and 3.2 in 2000, and this gives a weighted average for mineral soil of 0.09 Mg C/ha/year. Productive and non-productive forest are not totally corresponding to "forest" according to FAO/ECE, but we can assume that all productive forest and a substantial part of non-productive forest can be assigned to "forest".

Accumulation of C in organic soils is most likely dominated by litter contribution from other vegetation than trees, for example mosses. Consequently, we can assume that there is not net loss or uptake of carbon from this type of soil under forest land remaining forest land. The YASSO model does, however, not distinguish between mineral and organic soil. The accumulation will change during the development phases of a forest stand. After final harvest or thinnings where a high proportion of the trees is removed, carbon removals may be considerably reduced or turned into a net emission.

The accumulation in soil is about 1/10 of the accumulation in living biomass, and has been increasing since 1990 following the increase in living biomass.

Table 7.9 Carbon pools in different components as applied for estimating accumulation of carbon in forest soils.

	Natural mortality		Harvest		Litter from living forest		Sum		Net carbon stock change in dead organic matter	Net carbon stock change in soils
Year	Biomass C (Gg)	Soil C (Gg)	Biomass C (Gg)	Soil C (Gg)	Biomass C (Gg)	Soil C (Gg)	Biomass C (Gg)	Soil C (Gg)	C (Gg)	C (Gg)
1990	8602	1504	12672	1877	37679	9720	58952	13100	753	541
1991	8676	1539	12741	1965	38233	10142	59650	13645	698	546
1992	8760	1573	12807	2055	38837	10566	60403	14194	754	549
1993	8852	1608	12739	2145	39496	10993	61087	14747	684	552
1994	8953	1643	12768	2236	40191	11424	61911	15304	824	557
1995	9065	1679	12599	2326	40928	11860	62592	15865	680	561
1996	9194	1714	12483	2416	41701	12300	63378	16430	786	565
1997	9315	1749	12425	2505	42406	12745	64146	16999	768	569
1998	9428	1785	12331	2592	43057	13196	64817	17572	671	574
1999	9533	1822	12281	2677	43666	13652	65480	18150	663	578
2000	9629	1858	12207	2761	44255	14114	66092	18733	612	582
2001	9718	1895	12142	2843	44849	14579	66709	19317	617	585
2002	9799	1932	12086	2924	45445	15050	67330	19906	621	589
2003	9873	1970	12039	3003	46057	15525	67969	20498	639	592

Drained organic soils used for forest will lead to a substantial loss of C, and abandoning this measure will after some time lead to a slow accumulation of soil C. Due to the general increase in forest we assume no such abandonment. There is no national data on the CO_2 loss from drainage. The loss is expected to be less than for agriculture soils drained because of the contribution from forest waste. The IPCC default factor for drained organic soils in managed forest is (boreal) is 0.16 Mg C/ha/year. This factor will be used due to lack of national data.

According to Table 8.2, the area of drained organic soils (total accumulated) was 243.8 kha in 2000. The estimated emissions are about 40 Gg C annually (or 0.1 Tg CO_2).

7.1.2 Land converted to forest land

Change in carbon stock in living biomass

Under the climate conditions in Norway it takes time before a land-use change has any influence on estimates of carbon stock changes. GPG2004 suggests considering land-use transitions over a period of 20 years. After 20 years the forest will be considered as forest land remaining forest land. In this project we have classified areas by field work in 1990 (1986-1993), 1996 (1994-1998) and 2001 (1999-2003). Linear interpolation is used between these years. Field measurements before 1986 were not based on permanent field plots and cannot be used for reporting of land conversions. Later, when the permanent field plots have been followed up over a longer time period, the concept may be adjusted.

When a stand of trees in measurable size has been established, the estimate of living biomass will be based on these measurements. If the area in question previously was assigned to "other wooded land", the change in living biomass could be calculated from the growing stock before and after the conversion.

Change in carbon stock in dead organic matter

Change in carbon stock in dead organic matter due to harvest residues and stumps and roots from harvested trees and natural mortality have been calculated. An average value for forest will automatically be assigned to the area when converted into forest land.

Change in carbon stocks in soils

The methodologies used correspond to IPCC Tier 1 (GPG2004) where emissions and removals are estimated considering the carbon stock before and after conversion and the duration of the transition. However, national data are used to the extent available.

From croplands
This conversion of cropland to forest land rarely goes directly (according to the LU matrix), most often it goes via "other land". The conversion is expected to lead to sequestration of carbon, because there has likely been a carbon loss on agriculture land due to management and because forest will accumulate carbon. The data provided by Jordforsk on SOC (see Section 7.2.1) does not give any smaller values than cropland for a given soil type (the value also includes pasture and meadows). This may be due to uncertainties in the data, but it can also be explained by the fact that C losses are low in Norway due to a cold climate and because the most carbon rich soils are used for agriculture. We propose to not estimate any instant change in SOC, but to account for the C uptake by using the C accumulation data provided for forest soils (see Section 7.1.1).

From grassland
Grassland may be converted to forest. In this situation the carbon in soil is expected to increase. However, according to the data in Table 7.9 and 7.12 it is not possible to conclude that the SOC in forest soil on average is higher than in grassland soils. The reason for this may be the low rate of loss from grassland soils due to a cold climate. As the accumulation of carbon in forest soil is well documented (GPG2004), we propose to apply the same factors for soil accumulation as for forest land remaining forest land and assume no direct change in SOC due to the conversion.

From wetlands
Forestry in Norway has been dramatically decreasing its practice of drainage of wetland areas for tree planting over the last decades (Statistics Norway 1998), see Figure 8.1. This is due to economic

conditions and the increased focus on preserving mires. The number of ditches maintained – cleaned out or added to- have halved since 1989 (Statistics Norway 1998). Bruun and Frank (1994) concluded for Norwegian conditions that drainage of mires can be an effective method of binding carbon in trees for a specified timespan, if certain conditions are met. These conditions include fertilising to establish a productive forest. If the forest owner does not follow up the drainage and planting of a bog, a poor stand of trees is the result and drainage will result in a net loss of CO_2 (De Wit and Kvindesland, 1999).

Conversion of wetlands to forest is expected to lead to a considerable loss of soil C at a relatively high rate, due to sudden aeration of the soils and a quick increase in decomposition rates. Initial rates of peat oxidation may range from below 1 to over 3 Mg C/ha/yr according to a British study (Cannell et al., 1993). Laine and Minkkinen (1996) found that undrained mire accumulated on average 0.3 Mg/ha/yr more C than drained mire, and that there still was a large difference 30 years after drainage. In line with GPG2004 we propose using the same emission factors as for drained organic soils also in the year of conversion (see forest land remaining forest land) (0.16 Mg C/ha/year). The area drained was 3.5 kha in 1990, which decreased to 0.4 kha in 2000 (Statistics Norway).

From settlements
Conversions from settlements to forest land are unlikely or small. For simplicity it assumed that there is no change in carbon stock in soils (this is rationalised because any such conversion is expected to be in an area which is already dominated by forest, for example abandoned small farms).

From other land
This conversion will be on vegetated "other land" (see Section 7.6). When this land is converted to forest land, it is proposed to apply the carbon accumulation rates defined for forest land remaining forest land, assuming no change in SOC at the year of transition.

7.2 Cropland

7.2.1 Cropland remaining cropland

Cropland is defined in Section 3.1.2. Contrary to forest, most of the area for agriculture in Norway is used for annual crops which imply that the carbon is not stored over a very long time in aboveground biomass. An exception is horticulture. Carbon stocks in soils can be significant (GPG2004). Land conversion to cropland from forest, grassland or wetland usually results in a net loss carbon from biomass and soils to the atmosphere (GPG2004). The soil carbon is, however, also affected by management practices (for example plowing and fertilization) (Singh and Lal 2004). In addition, Norwegian soils are limed to stabilize the pH. Liming contributes to improving the biomass production and the potential for carbon removals.

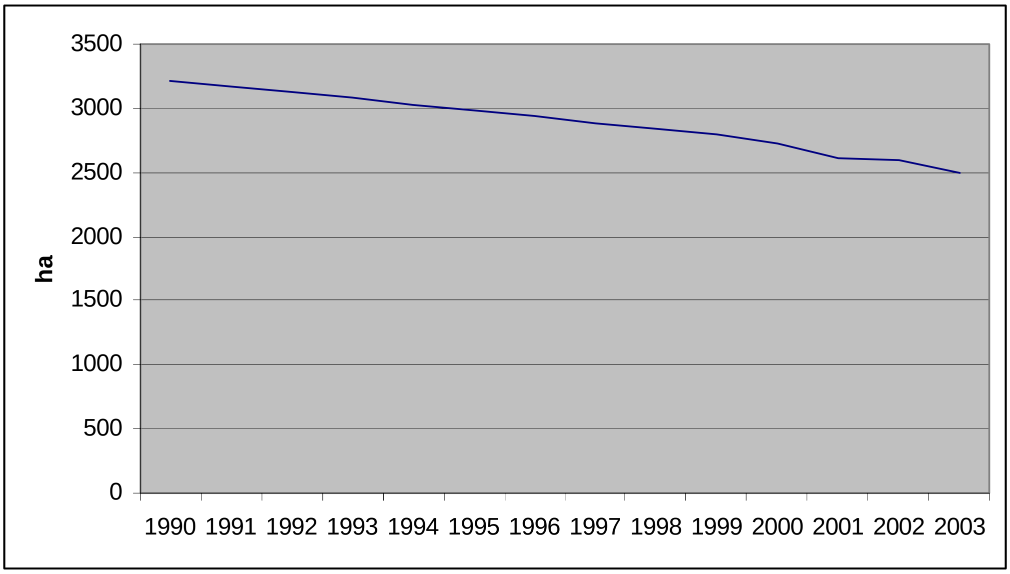
Change in carbon stock in living biomass

The annual changes in carbon stocks of cropland remaining cropland can be estimated as the sum of changes in living biomass and soil. GPG2004 has proposed three tiers for living biomass and soils, respectively. Tier 1 is based on simple equations and default emission factors, Tier 2 allows for use of national specific emission factors and Tier 3 is based on disaggregated data and/or modeling. Changes in living biomass have only been considered for perennial crops in line with GPG2004. For annual crops, the increase of biomass in crops will equal loss from harvest and mortality the same year, and there is no net accumulation or loss.

Perennial crops
Changes of carbon stocks in living biomass are only estimated for perennial woody crops. Perennial crops are used in horticulture. Statistics Norway collects data on the area of fruit trees (apple, pears, plum, cherry and sweet cherry). The area has been decreasing since 1990 (Figure 7.2). There are no

national data on their volume and carbon content. IPCC (2004) suggest default parameters for aboveground biomass carbon stock at harvest, biomass accumulation rate and biomass loss for temperate regions (it does not distinguish between vegetation types).

Figure 7.2 Area of fruit trees for production. 1979-2003. (Statistics Norway, unpublished). Data for some intermediate years are based on interpolation).



Changes in biomass in existing areas:

The IPCC default value for biomass accumulation rate (GPG2004) is 2.1 Mg C/ha/year. This gives an annual uptake corresponding to only 19 Gg CO_2 per year. The average age at harvest is somewhat lover than the IPCC default assumption (20-25 years). The average height is around 2 m and one tree occupies about 10 m^2 according to the Norwegian University of Life Sciences. The "harvest" can then be estimated at around 6.3 Gg C/ha. Because the existing areas are at balance, we propose to assume that there is no net uptake or loss from these areas.

Conversion from perennial crops:
Because the area of fruit trees has decreased, there will be a net loss of CO_2 to the atmosphere which will be reported under the respective land conversions. There is no statistics indicating directly to what type of land the horticulture areas have been converted. It is likely that on the west coast the conversion is to grassland, in the eastern parts of the country the conversion may also be for grain production. In accordance with IPCC Tier 1 we assume that all carbon is lost at the year of harvest of the tree. The IPCC default value for carbon stock at harvest (temperate region) is 63 Mg C/ha. The resulting emissions are very small.

Table 7.10 CO_2 emissions due to reductions in fruit trees for agriculture production

	Area (ha)[a]	Annual C-loss (Mg)	CO_2 emissions (Gg)
1989	3 267		
1990	3 220	2998.8	11.0
1991	3 172	2998.8	11.0
1992	3 124	2998.8	11.0
1993	3 077	2998.8	11.0
1994	3 029	2998.8	11.0
1995	2 982	2998.8	11.0
1996	2 934	2998.8	11.0
1997	2 886	2998.8	11.0
1998	2 839	2998.8	11.0
1999	2 791	2998.8	11.0
2000	2 718	4599.0	11.0
2001	2 611	6753.6	11.0
2002	2 593	1134.0	11.0
2003[b]	2 503	5676.3	11.0

[a] Data for 1990 -1998 have been interpolated
[b] Preliminary figures

Change in carbon stock in dead organic matter

This pool is considered insignificant (both the pool and changes in it) and estimates have not been made.

Change in carbon stocks in soils

The soil organic carbon (SOC) has been estimated by the Centre for Soil and Environmental Research (Jordforsk). Data (in Mg SOC/ha) shows a large geographical variation, being highest in the south-western/western regions. SOC is also sampled by NIJOS. Data on SOC from Jordforsk and NIJOS are shown in Tables 7.11 and 7.12. The NIJOS data and their uncertainties are explained in Annex 4.

The data needs to be adjusted for sand and gravel (around 10 %). This gives an average SOC in mineral soils (the dominant soil type) of 135 Mg/ha. The reference value for spodic soils of GPG2004 is 117 Mg C/ha, the value for leptosols is 68 Mg C/ha (high activity clay soils). Consequently, the value from Jordforsk is higher. Comparing these two independent sources of information from Jordforsk and NIJOS for top soils (upper 23 cm layer), they are remarkably consistent. The main uncertainties are related to the stone and gravel content of sandy soils, the thickness of organic layer soils, which is assumed to be 25 cm in mixed mineral-organic soils and 50 cm in organic soils. The carbon content of organic matter in organic soils is assumed to be 0.537, the same as for mineral soils. The soil sample depth in mineral soils is assumed to be representative for the top soil (23 cm). The carbon content may be overestimated if the sample depth in old grassland is less than 23 cm, and the organic matter is highest in the upper part of the top soil (e.g. 0-10 cm).

Table 7.11 Reference values for carbon in soil. Data from Jordforsk (based on Grønlund and Njøs 2002). C concentration=0.53

	Area, 1000 ha	Mg per ha			Total stocks Tg
		Topsoil[a]	Subsoil	Sum	
Sum all soils	1046	105	36	141	147
Sum mineral soils	975	86	39	135	122
Sand[b]	617	97	40	137	84
Silt	72	69	46	115	8
Clay	286	66	35	101	29
Mixed mineral-organic soil	55	287	0	287	16
Organic soil	16	607	0	607	10

[a] 0-23 cm in mineral soils, 0-25 cm in organic soils
[b] Sandy soils are assumed to content 10 volume percent gravel and stones.

Table 7.12 Soil C in plow layer in cultivated soils in Norway. Data from NIJOS. Depth is 23 cm; C content of organic matter is assumed to be 53.7%. Content of gravel and stones assumed to be 10%.

County	Area (ha)	Mg C/ha	Stocks Tg C
Østfold	74 172	69.1	5.1
Vestfold	60 358	82.7	5.0
Akershus	86 600	75.9[a]	6.6
Rest of Norway	824 870	82.7[b]	68.3
Total Norway	1 046 000	81.3	84.9

[a] Average C density of Østfold and Vestfold
[b] C density of Vestfold

The IPCC default method takes into account a reference SOC and changes in management practices (tillage and input). IPCC (2004) has proposed default factors for correcting changes caused by management practices and input of organic matter over a 20 year period. Singh and Lal (2004) have considered the effect of plowing and other management on SOC content in soils. They conclude that the sequestration rate due to reduced tillage or increased N-application is higher in Norway compared to other countries, possibly due to lower temperatures and consequently lower rates of decomposition.

We propose here to use a method corresponding to IPCC Tier 2 (GPG 2004) taking into account how management practices affect the SOC, but using national data. The measurements of carbon in soils by Jordforsk and NIJOS are average data per soil types which cannot be directly linked to management practices and agriculture type.

Carbon in Norwegian cropland soils has been studied by Singh and Lal (2001;2004). Singh and Lal (2001) have estimated C loss by *accelerated erosion* of agriculture and pasture land. Erosion leads to less productivity and consequently less biomass returned to soil, and it removes C from the site to somewhere else. In Norway, soil erosion is mainly a problem in southeastern regions of the country. Based on assumptions on plowing practices and erosion rates from these, Singh and Lal (2001) have estimated a net erosion rate of 2.2 Mg/ha/years under autumn plowing. The rate in other areas is 0.44 Mg/ha/years. Singh and Lal (2001) assumed 70 % autumn plowing and 30 % spring stubble, arriving at an average of 1.67 Mg/ha/year for 1999. The grass and pasture erosion rate is 67 kg/ha year.

In line with Singh and Lal (2001) the following equation has been used to estimate the erosion:

*SOC loss = Area * soil loss * sediment delivery ratio * SOC * Enrichment ratio*

- Sediment delivery ratio is assumed to be 10 %.
- Enrichment ratio is assumed to be 1.35

- The mean carbon content of soils varies between regions, 27.3-58.7 g/kg, a value of 40 % has been used in the calculations.
(all these assumptions were taken from Singh and Lal (2001))

Finally, it is assumed that 20 % of the C transported by erosion is released to the atmosphere.

We then consider other factors that may contribute to acceleration or retardation in erosion:

Singh and Lal (2001) lists:

- Tillage methods
- Residue management
- Fertilizer and organic manure
- Crop rotations
- Cover crops
- Grassroads and other types of physical erosion control

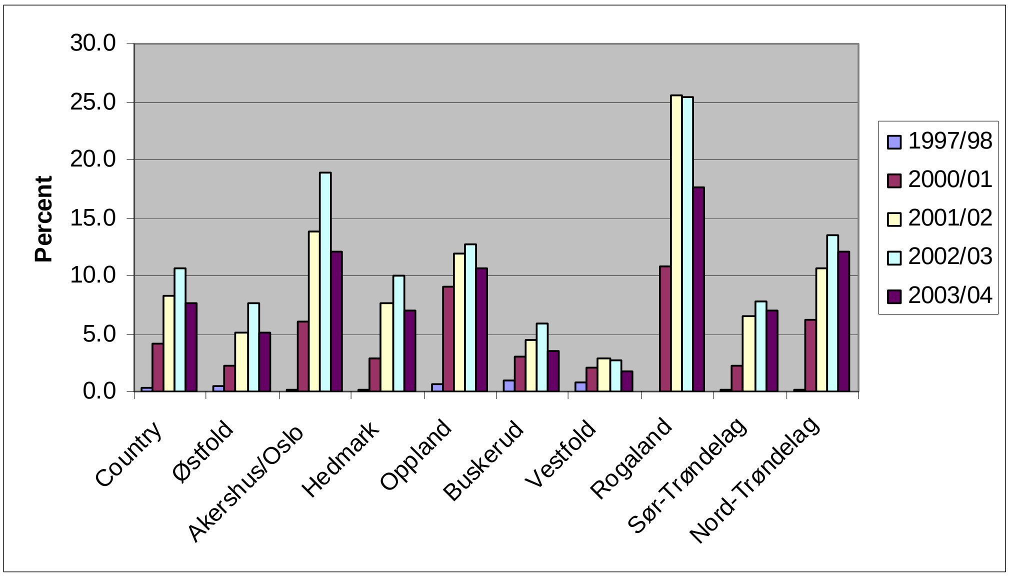
They have concluded that the largest potential for carbon sequestration lies in erosion control.

Crop residues contain about 40 % C and enhance SOC and sequester carbon if returned to soil. There is, however, no statistics to monitor changes in crop residue management. Singh and Lal (2001) have estimated the potential top at 1.74 Tg SOC/year (based on a SOC sequestration factor of around 100 Mg/ha/year). The level of this practice is not known. On-site burning of agriculture residues is regulated in some areas, there has been more focus on air quality problems, and the practice has decreased. Today around 5-10 % is annually being burned (expert estimate). However, some straw is collected and used for animal fodder. On areas without animal production it is more common to leave the residues. Around 5-10 % can be assumed used for fodder today. Because there are less combined farms and due to the regulation of onsite burning, it is likely that that more residues are left now than previously and around 80-85 % is left today. Due to lack of data we nevertheless propose to assume that there has not been any change in management and we do not estimate any carbon sequestration. Any changes would nevertheless be small – in the order of 10 Gg C per year.

In Norway it is rather common to rotate crops. There is, however, no statistics that can be used to conclude about the level of rotation practice and changes in this practice over time. However, due to the tendency of more specialized farming (previously a combination of grain and animal/grass production was normal) it is likely that crop rotation has been reduced. Due to lack of data we do not estimate any carbon sequestration due to crop rotation. In the calculations below we have ignored the effect of crop rotation when calculating carbon losses, assuming that losses only occur on new agriculture land. This assumption is meant to compensate for not accounting for sequestration due to crop rotation.

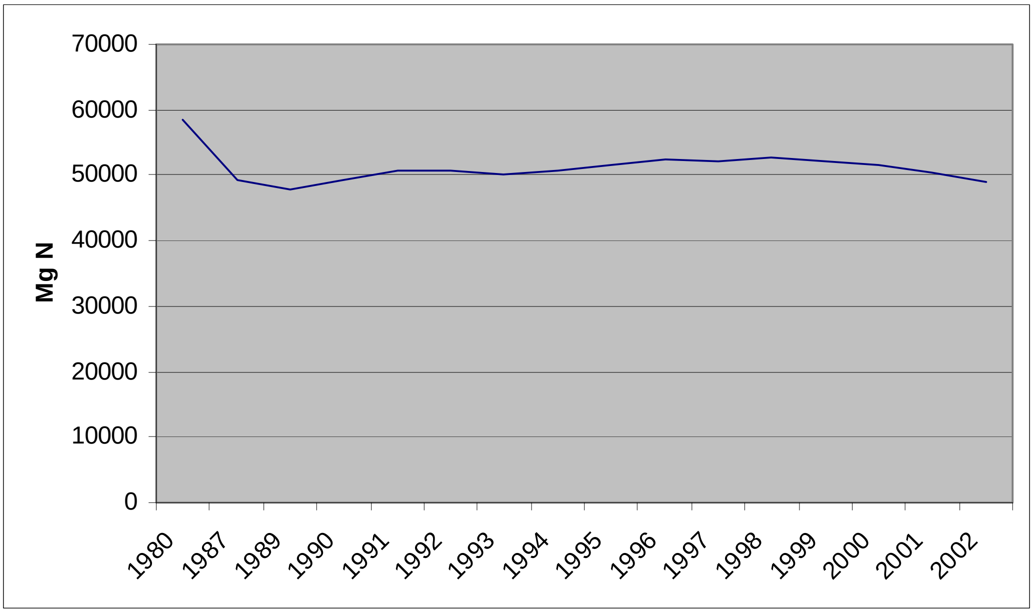
Farmers can claim economic support for using cover crops to reduce erosion. All farmers can get support, but the compensation is largest in the most vulnerable areas. The area of cover crops is shown in Figure 7.3. It can be assumed that the level was negligible in 1990. Due to support to farmers the average area with cover crops has been as high as between 5 and 10 % during the last years. It is expected that when cover crops is used in combination with reduced till, the effect on reductions on carbon losses will be enhanced. Singh (pers. comm.) has estimated a 70 % reduction in emissions using cover crops. This effect, however, also includes the effect of reduced tillage.

Figure 7.3 Area of cover crops per county in % of area of grains and oil seeds



Nitrogen fertilization rates in Norway have not changed substantially over the last 20 years. The N-input in agriculture was 0.11 Mg/ha in 1990, decreasing to 0.10 in 2002 ("Resultatkontroll i jordbruk, Annual report from Statistics Norway"). This reduction is around 10 % over a period of 12 years. However, according to data reviewed by Singh and Lal (2004) this decrease is not sufficient to assume that a major C loss has taken place (the dependency of N-content on C sequestration does not appear to be linear). Adding N as manure has a larger impact on SOC than N added as commercial fertilizers. According to Figure 7.4, however, there are no major changes in the N-application since 1990. We consequently propose ignoring the effect of changes in N-input since 1990 on the SOC and on emissions/removals. This assumption, however, needs to be reconsidered for future reporting years as a small decreasing trend is observed.

Figure 7.4 N in manure applied. Calculations by Statistics Norway



Tillage practices have been changing over the last 10 years aiming at reducing N-leakages and runoff. Farmers are informed and rewarded for reducing the tillage rates in vulnerable areas (in particular autumn tillage) (Statistics Norway, “Resultatkontroll i jordbruk”), Figure 7.5. The fraction of area under autumn tillage was 82 % in 1989/2000, which was reduced to 43 % in 2001/2002 (based on annual surveys). Singh and Lal (2001 and 2004) cite data on the effect of *reduced plowing* on SOC. By changing from traditional plowing to minimum till, there is a SOC gain (20 cm depth) of *33.8 Mg/ha* over 13 years (this value is based on limited data from a single site and it is higher than values reported from other sites in Norway or other countries). Singh (pers. comm.) has recommended rather using a factor of 500 kg C/ha/year by moving to minimum tillage.

Moving to autumn plow to tining has a very similar effect to minimum till. We assume that changes in tillage practices only have affected grain and oil crops (no change for potatoes and vegetables for example). Annual changes in management are taken from Statistics Norway (Resultatkontroll i jordbruk). The classes here are autumn till, shallow till, spring till (only) and no till. We have classified spring plowing only as “minimum till”. Erosion emissions will only be significant on new (< 25 years) agriculture land, however, the effect of sequestration due to reduced tillage will be on all land where changed tillage is practiced, but the effect of this conversion will be negligible after around 25 years. The GPG2004 suggests a time-period of 20 years, but national agriculture experts consider a 25 years horizon as more appropriate for Norway.

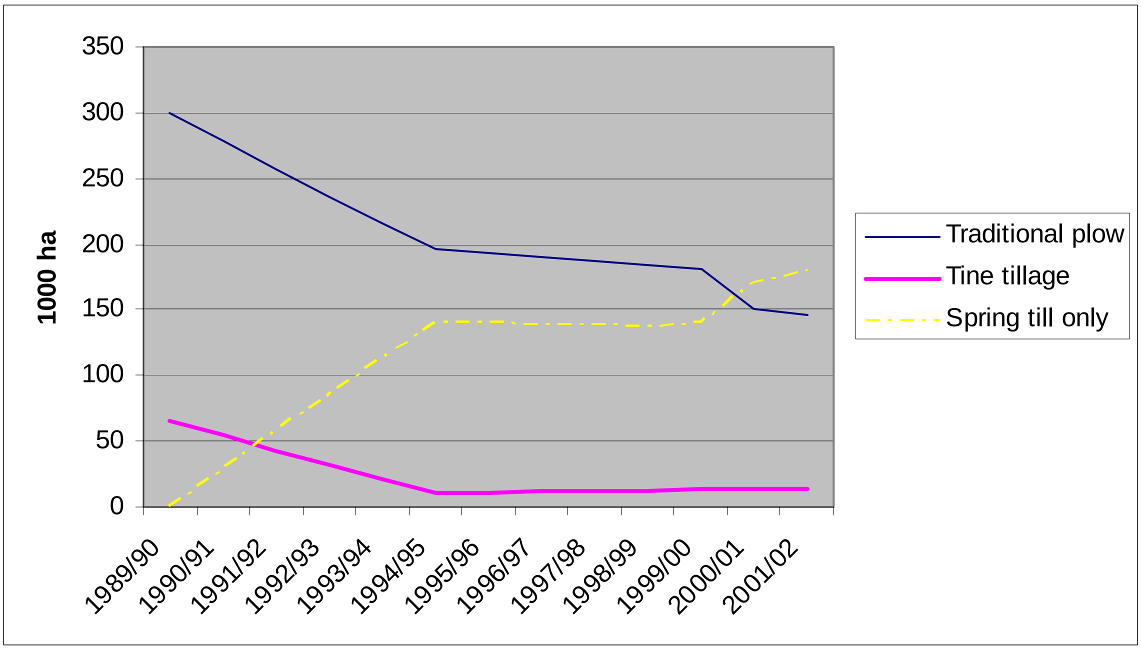
The basic erosion factor for agriculture land under traditional till (autumn plowing) is 2.2 Mg/ha/year (Singh and Lal, 2001).

This gives the following calculation:

Erosion rate (2.2 Mg/ha/year) * C content (40 g/kg) * Delivery ratio (10 %) * Enrichment ratio (1.35) = C loss by erosion (*12 kg C/ha/year*).

This figure may be distributed by county based on region specific carbon content in soil (Table 12 of Singh and Lal (2001)). We propose to use this factor only for newly cultivated agriculture areas over the last 25 years, because after that period the erosion loss will be negligible. As mentioned before, emissions and removals due to crop rotation has been ignored due to lack of data.

Figure 7.5 Tillage practices 1990-2002 (Statistics Norway)



To estimate the erosion emissions we use the statistics of new agriculture land from Statistics Norway. We assume all of this land is used for grain production (grain area has been rather stable, while other crop production has been reduced). We have assumed that half of the new land is under autumn plow. In fact, a small amount is also used for grass production (may subtract "overflatedyrka" area, around 5 %). To estimate the uptake due to reduced tillage we consider all area under no till, reduced till or tine. Because tine was common previously and the difference between tine and minimum till is small, we subtract the 1979 tine area. After 25 years no more gain in SOC should be assumed. The results are shown in table 7.13. The effect of cover crops have not been included in the table to avoid double counting as this measure is combined will changes in tillage practices.

Table 7.13 Erosion emissions due to plowing and C removal due to reduced plowing in Norway

	25 year old agriculture area (ha)	Erosion emissions (Gg)	Area under traditional till, tine, no till or minimum till, subtracted 1979 tine area (ha)	Carbon removal (Gg)
1990	151637	3.8	24700	12.3
1991	145794	3.6	34791	17.4
1992	139696	3.5	51729	25.9
1993	133219	3.3	68364	34.2
1994	128741	3.2	84693	42.3
1995	124262	3.1	84756	42.4
1996	118839	3.0	84793	42.4
1997	113099	2.8	84806	42.4
1998	106471	2.7	84795	42.4
1999	99122	2.5	88102	44.1
2000	92132	2.3	117983	59.0
2001	85429	2.1	140331	70.2
2002	78143	2.0	140331[a]	70.2

[a] Preliminary figures

For vegetables and potatoes we can assume the same erosion rate as traditional till (12 kg/ha/year). The reason is that when harvested roots are taken from the soil, a subsequent carbon loss will occur.

The area of vegetables is around 15118 ha. However, because the area of potatoes has been decreasing in the nineties, we assume that all areas used for vegetable and potatoes have been agriculture area for more than 25 years, and we assume no erosion loss of carbon.

For grassland Singh and Lal (2001) propose a basic erosion rate of 0.067 Mg/ha/year. Again this also applies to areas which are less than 25 years old.

This gives the following calculation:

Erosion rate (0.067 Mg/ha/year) * C content (40 g/kg) * Delivery ratio (10 %) * Enrichment ratio (1.35) = C loss by erosion (*0.36 kg/ha/year*). This figure may be distributed by county based on region specific carbon content in soil (Table 12 of Singh and Lal (2001)).

New area for pastures and meadows are according to Statistics Norway at present around 4166 ha annually. Assuming the same rate the last 25 years (was in fact higher previously) we get annual emissions that are very small (less than a Gg C). Some if this area may also be drained organic soils (see below).

There is also a CO_2 loss due to cropland on *organic soils* (histosols). Conversion of wetland to cropland is at present less common than previously. According to GPG2004, the accumulated area of organic soils should be multiplied with an emission factor. The IPCC default value for cold temperate region is 1.0 Mg C/ha/year. Jordforsk (the Norwegian Centre for Soil and Environmental Research) has calculated the area of farmed organic soil based on the frequency of organic soil among 500 000 soil samples.

Mixed organic-mineral soils (20-40% organic matter)	42 000 ha
Peat soils (>40 % organic matter)	21 000 ha
Sum organic soils	63 000 ha

However, they expect organic soils to be underrepresented in their sampling. The real area of farmed organic soils is therefore assessed to be between 70 000 and 100 000 ha. We have assumed 85 000 ha in the calculations. This number is smaller than previous estimates reported by Norway for estimating N_2O emissions. It is based on measurements of organic matter in soil and contrary to the previous estimate it takes into account that the C in soil is gradually decreased and after some decades the soil is no longer classified as organic. According to Jordforsk (Arne Gronlund, pers. comm.) the soil database indicates the following distribution between crop types:

Grass: 86 %
Cereals: 9 %
Other crops (potatoes, vegetables, green fodder): 5 %

As soils samples are likely to be underrepresented on grass compared to cereals and more intensive productions, about 90 % of the farmed organic soils are used for grass. In this project we propose to assume that 10 % of the organic soil area is used for agriculture, the rest for grassland. For a discussion of emission factors, see “grassland remaining grassland”.

This gives an annual estimate of 208 Gg CO_2 from agriculture farmed organic soils.

Liming

Due to mostly low buffer capacity of soils, Norwegian soils may be limed. These emissions have previously been included in the agriculture emission estimates. The estimate is based on the lime consumption as reported by "The Norwegian Agricultural Inspection Service" (for lakes "Directorate for Nature Management"). The emission factor is 0.44 Mg CO_2 per Mg calcium carbonate applied. This emission factor is based on the stoichiometry of the lime applied and is consistent with IPCC (2004).

Figure 7.6 Liming of agriculture soils and lakes. 1989-2002. Gg CO_2.

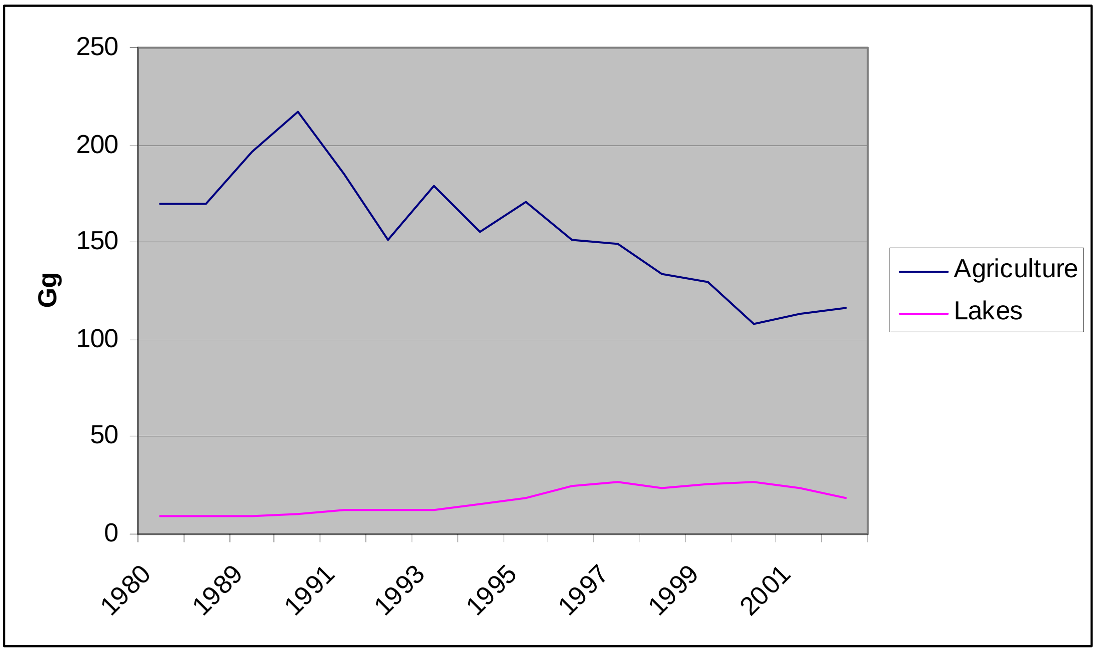


Table 7.14 Liming of agriculture area and corresponding CO_2 emissions. 1990-2002

Agriculture	1990	1995	1998	1999	2000	2001	2002
Amount of lime applied (Mg)	492407	388365	304041	294150	245884	257696	263499
CO_2 emissions (Gg)	217	171	134	129	108	113	116

Lakes	1990	1995	1998	1999	2000	2001	2002
Amount of lime applied (Mg)	23000	42738	52802	59193	60076	54118	42089
CO_2 emissions (Gg)	10	19	23	26	26	24	19

7.2.2 Land converted to cropland

Change in carbon stock in living biomass

Losses are only calculated for conversion from forest. It is assumed that all living biomass is lost the year of conversion. The biomass loss was calculated using average data for forest in Norway.

Change in carbon stock in dead organic matter

We assume that if land is converted to cropland all dead organic matter will be cleared. This has been taken into account when applying the calculation model.

Change in carbon stocks in soils

From forest land
According to GPG2004 SOC in cultivated soils is generally less than in forest and other land use, so a conversion results in a net carbon loss (emissions). After some decades there will be equilibrium. The time and level of equilibrium depend on soil, climate and management conditions. However, because Norwegian data indicates no major difference in SOC between forest and agriculture we assume no loss other than the losses which are depending on the management of the agriculture land after conversion (grassland, grain (tillage) or other use of the land).

NIJOS has estimated the mean carbon content in productive forest to 11.6 kg C/m^2. The corresponding mean value for all cultivated mineral soils (both grass and cropland) has been calculated to be 14.1 kg C/m^2 by Jordforsk. The results indicate no difference in carbon content between forest and cultivated soils. The average value for agriculture land may, however, mask some differences between grassland and cropland.

Jordforsk has collected data on organic matter content of 3920 farms in Norway (Table 7.15).

Table 7.15 Organic matter and C in farm soil. Weight % (source: Jordforsk)

% grass area	Number of farms	Soil OM (%)	Organic C (%)
0	2009	4.2	2.3
0-80	1442	5.0	2.7
80-100	469	5.4	2.9

These data shows that the carbon content in general is lower in cropland compared to grassland (26 %). These differences are consistent with the proposed differences in erosion factors between cropland and meadows/pastures. The statistics do not allow for a more detailed analysis of differences and effect of crop rotations.

From all other land use
Administrative data shows that since 1990, the annual conversion to agriculture land has been reduced from about 2000 ha to 1200 ha annually (Statistics Norway). Most of the area is used for grass production, but part of the area (about 10 %) is annually used for cropland in crop rotation systems. The original land-use is not known, but it can be forest and to a limited extent wetland.

Conversion from grassland to cropland is not recorded. However, it is expected that the conversion rather is *from* cropland to grassland, due to the abandonment of farms and because the areas of meadows and pastures have been increasing during the nineties at the cost of grain and potatoes.

Because the basic agriculture erosion factor (before accounting for management) is based on the one for grassland, we assume no immediate loss when land other than wetland is converted to agriculture land. Losses are accounted for according to the changes in management (see agriculture remaining agriculture).

The conversion of peatland (wetland) to agriculture land was addressed above, under cropland remaining cropland. The emissions are not immediate, but occur over time.

7.3 Grassland

According to the area definitions, grassland also includes pasture. Grasslands are used for harvest and pasture. Part of the pasture land is in the mountains. Pasture practices have been changing over the last decades, gradually leading to altered vegetation (including expansion of forests and other wooded land). As for agriculture, we consider changes in aboveground biomass and soil carbon. As described earlier, the statistics of NIJOS only cover grassland and pastures which are not part of the home fields (not for harvest), while the agriculture statistics cover only pasture and meadow close to the farm.

7.3.1 Grassland remaining grassland

We assume no change in living biomass or dead organic matter for this category because the mass of aboveground biomass is small and is in a steady state (in accordance with IPCC (2004) Tier 1). Changes in management have, however, influenced the vegetation on pastures. Gradually, some of this area will fall under the forest definition.

Change in carbon stocks in soils

Large amounts of carbon are stored in roots and soils. There have not been any major changes in management of grasslands (apart from pasture) in Norway. Consequently, that would justify ignoring carbon losses or uptake from mineral soils on existing grassland area. For grassland which is harvested (meadow) we propose using the erosion factor of Singh and Lal (2001) of 0.78 kg C\ha\year. This factor should, however, only be applied to grassland which is younger than 20-25years, see discussion under cropland remaining cropland.

There will be a loss of carbon from grasslands on *organic soils*. As discussed for cropland, it is assumed that 90 % of organic soil drained and used for agriculture production is used for grass production (organic soils are not suited for example for producing grain). The IPCC default emission factor is 0.25 Mg C/ha/year for cold temperate regions. However, according to Norwegian measurements emission can be larger because the age of the organic soils is lower than in Southern Europe. The average subsidence has been estimated by Jordforsk at 2 cm/year[7] which is equivalent to 20 Mg C/ha.[8] Some of this reduction is due to compaction and can be attributed to a sink in the height of the soil layer[9]. The soil loss also includes leaching of organic components in the drainage water. Based on measurements the emission losses of CO_2 from farmed organic soils in Sweden and Finland have been reported to be between 200 and 1000 g CO_2-C/m^2/year (Final report from the EU Project Greenhouse Gas Emissions for Farmed Organic Soils (GEFOS)). This corresponds to 2-10 Mg/ha/year. The assumptions on C-losses are also justified because a change in C/N ratio over time is observed. We propose using a loss factor of 10 Mg C/ha/year for high organic matter soil. For mixed organic soils the factor will be lower, we propose using 5 Mg C/ha/year (expert judgement).

[7] Meadow. The decrease in layer is larger on field grassland. However, organic soils are rarely used for the purpose.

[8] Assuming a soil density of 0.2 kg/l, and 50 % C.

[9] Assuming a soil density of 0.2 kg/l, and 50 % C.

Of the total area of 85 000 ha, 90 % were assumed used for grass. Of these 76 500 ha, we assume one third is highly organic, the rest is mixed. Further details are given in Table 7.16. This gives an annual emission rate of 510 Gg C/year or 1.9 Tg CO_2. Using the IPCC emission factor, we obtain an emission estimate of 21 Gg C/year (78 Gg CO_2).

Table 7.16 Farmed organic soils by region. ha

	20-40 % OM	More than 40 % OM
Eastern counties	7 066	3 508
South counties	2 955	1 240
West counties	19 194	7 834
Mid counties (Trøndelag)	4 934	3 513
Northern Norway	7 752	4 956
Sum	41 902	21 051
Fraction	66 %	33 %

Given the importance of this estimate compared to other sources (is identified as a key category) and the large difference from the IPCC default value, it is recommended to further improve the emission factor (measurements, modeling, literature). Other Nordic countries have similar agriculture practices. Sweden use emission factors ranging from 1.6-7.9 Mg C/ha/year (largest for row crops) (Mattias Lundblad, Naturvårdsverket, pers. comm.). Finland has concluded on a range of emission factors for organic soils of 0-4 Mg C/ha/year (2-4 Mg C/ha/year for peatlands) (Riitta Pipatti Statistics Finland, pers. comm.). Finland has initiated a comprehensive research project on emissions from peatlands in Finland. Results are expected by the end of 2005. We will propose to reconsider the Norwegian emission factors in light of the results of the Finnish study.

Furthermore, the area is kept constant in the calculations. This is justified because new cultivation of organic soils is limited at present (existing areas is about 80 000 ha, new agriculture area is 1000 ha annually, but not all of this is organic soils). However, over time organic soils will be converted to mineral. Little is known about abandoned organic soils with respect to CO_2 uptake (and emissions of non CO_2 GHG). Because the drained soil is considered marginal it will be abandoned before other soil types. This uptake has been ignored in the calculations due to lack of activity data, but may potentially be important and should be considered in the future.

Grassland is not limed (any possible liming is reported under agriculture).

7.3.2 Land converted to grassland

According to IPCC (2004) the implications of converting other land to grassland is uncertain. In the case of conversion of forest land to grassland, losses in living biomass will be accounted for according to the methodology of estimation described under forest land. For other land-use change we assume no net change in carbon of living biomass. This is justified because the IPCC default factors for aboveground biomass are quite similar for grassland and cropland. (5 Mg C/ha for cropland, 8.5 Mg dry matter/ha for grassland (boreal zone) equal to 4.2 Mg C/ha given a carbon content of 0.5).

Change in carbon stock in living biomass

Losses in biomass are only calculated for conversion from forest land. It is assumed that all living biomass is lost the year of conversion. The calculations are explained under “land converted to cropland”.

Change in carbon stock in dead organic matter

We assume that if land is converted to grassland, all dead organic matter will be cleared.

Change in carbon stocks in soils

The SOC in grassland discussed under agriculture is probably more representative for grassland and meadows close to the farm. The SOC in grazing land and unmanaged grassland is not known. However, much of the grassland will be in mountain areas where the SOC can be low.

From forest land
In line with the discussion of the area data we assume that transition from forest land to grassland is rather unlikely but assume no change in SOC if recorded. Losses in living biomass would be calculated using the same assumptions as for cropland.

From cropland
When cropland is converted to grassland the SOC may change due to changes in management, for example plowing and N-fertilization. The result is expected to be a net removal. According to Statistics Norway the managed grassland area have increased in the nineties. Data from Jordforsk confirms that farms with animals (and grass production) have a slightly higher SOC than those without (Table 7.16). There are no data for grassland outside home fields, but they likely have a lower SOC. We propose to assume that there is no change in SOC when cropland is transferred to grassland, because the changes are small and exact data are lacking.

IPCC default Tier 1 method accounts for differences in SOC in the land-use conversion according to changes in management. Assuming that the grassland is nominally managed and the same level of fertilization, also the IPCC default method indicates no change.

From wetland
See discussion on drained organic soils under grassland remaining grassland.

From all other land use
When other land use is converted to grassland we assume no emissions or removals due to changes in soil carbon.

7.4 Wetlands

Most of the wetlands in Norway are unmanaged mires, bogs and fens, as well as lakes and rivers. Managed wetlands include peat extraction and reservoirs (dams).

7.4.1 Wetland remaining wetland

Reservoirs

At present there exists no readily available water or land-use change statistics related to dams or reservoirs. Wetland remaining wetland is only covered in appendix 3a.3 in the Good Practice Guidance (GPG2004). That means that reporting is not mandatory. Consequently, changes in carbon stocks in unmanaged wetlands and reservoirs have not been considered in this report. Reservoirs should be considered in the future due to the many hydroelectric power stations in Norway.

Peat extraction

Changes in carbon stocks for peat extraction are estimated with a tier 1 method based on Swedish emission factors. According to Jordforsk, peat extraction in Norway is between 220,000 and 300,000 m^3/year (we assume no change in extraction the last years). The extraction is around 5-10 cm/year. This corresponds to 13 m^2/m^3. The total area harvested is consequently around 338 ha.

The IPCC default method considers only change in soil carbon during peat extraction. Changes in biomass and changes in soil carbon due to other processes associated with extraction (drainage, stockpiling, etc) are assumed to be zero at tier 1. Extraction is assumed to enhance oxidation, leading to a continuing decrease in soil carbon. The IPCC emission factor for nutrient poor bogs in the boreal zone is 0.2 Mg C/(ha · yr).

We propose using emission factors for Sweden (Uppenberg et al. (2001)). Prior to drainage and extraction the peatland acts as a small carbon sink (62-96 g CO_2/m^2/year). During extraction emissions will be around 10 Mg CO_2/ha/year (2.7 Mg C/ha/year), somewhat lower after drainage and before extraction. Because the age of the harvested area is not known, we apply the same emission factor for every year.

This gives an annual estimate of 0.9 Gg C or 3.4 Gg CO_2.

Wooded mire

Wooded mire according to Norway's national definition will be classified as forest land, if the requirements of the international forest definition are met. The rest of wooded mire would be considered "other wooded land", and could form a subgroup under "wetland". The living biomass would, however, be negligible compared to forest, and the usefulness of forming such a category would be questionable.

Liming

Lakes are limed in Norway to stabilize the pH. The methodology is explained in the section of agriculture, see Table 7.14. The corresponding emissions are about 25 Gg CO_2 annually.

Other wetland

Other wetland is considered unmanaged, and no emissions and removals are in line with GPG2004 estimated.

7.4.2 Land converted to wetland

No data are available on land converted to managed wetland. In practice, this is only relevant for reservoirs. Land taken into use for peat extraction would normally be unmanaged wetland

As discussed in Section 6.2.1 recorded conversions to wetland are considered as artifacts in the NFI and are not used in the calculations. To the extent the transitions are real, it is assumed that changes in SOC are small because the native vegetation is assumed close to wetlands.

Furthermore, conversion of forest land to wetlands is expected to be a slow process, because this involves regrowth of ditches and a steady increase in water level. Additionally, a conversion to the land-use category ‘wetlands’ requires a reduction in tree cover, otherwise the land would still be considered forest. Clearly, drained forest must have been abandoned for some time in order to return to the land- use category of wetlands.

From other land use
Because we assume the features of these areas will approach those of wetlands or because some of the reported changes are considered reclassification, we assume no loss or uptake of carbon.

7.5 Settlements

7.5.1 Settlements remaining settlements

Reporting of emissions and removals from this category is not mandatory. There are, furthermore, no data available to estimate the tree biomass. Changes in carbon stocks for settlements remaining settlements have consequently not been estimated. Two main trends in biomass in settlements can be outlined: 1) Growth in tree biomass on lands converted to settlements (after the initial clearing) probably extends well beyond the 20 year limit. 2) Trees are removed within settlements for new buildings, roads, etc. The balance between the two trends is not easily determined, but significant carbon sequestration in settlements is not expected.

7.5.2 Lands converted to settlements

Change in carbon stock in living biomass

IPCC (2004) suggests a method in which only forest biomass is considered. Thus, it is assumed that there are no carbon stock changes when land classes other than forest are converted to settlements. IPCC further suggests as a tier 1 method that all biomass is lost in the year of conversion. In principle there will also be losses when other wooded land is converted to settlements, but these have not been estimated due to lack of data. However, settlements on other wooded land can be expected to be on a small scale (for example mountain cabins and associated infrastructure).

We suggest that for forest land converted to settlements, only 75% of the biomass is considered to be lost. The remaining 25% refers to trees that are left standing in the built-up area. This figure is based on expert judgement.

The total biomass on forest land converted to settlements is calculated from the National Forest Inventory. Thus, the estimate takes into account the variation in forest types, and there is no need for general emission factors. The average biomass loss for forest converted in 1996-2001 was 25 Mg C/ha.

Change in carbon stock in dead organic matter

We assume that all dead organic matter is cleared in this conversion.

Change in carbon stocks in soils

From forest land
Forest land may be converted to settlements. It is reasonable to assume that soils will be disturbed in order to make the surface suitable for building purposes, for instance by levelling the surface and by removing the top soil. As most C is in the top soil, it seems reasonable to assume that most soil C will be lost in a short time. If there is any default value for soils under settlements, it can be assumed that the default forest soil value decreases to the default settlement value in one year. We propose assuming that settlements have the same SOC as grassland, and use the same methodology as for Section 7.2.1 and the erosion factor for grassland by Singh and Lal (2001). We assume that the losses occur over 25 years, so the 25 years accumulated value should be used. In the first version of the inventory no change has been assumed.

From wetland
If wetland is converted to settlements it will likely be settlements which are “wetland like” or involve drainage. We propose applying the same factor for carbon loss as for forest, 0.16 Mg C/ha/year. This factor is applied over 25 years (in practice losses may occur over a longer period). This gives an annual loss of about 18 Gg C/year. In the first version of the inventory no change has been assumed.

From all other land
For all other land we assume no change in soil organic carbon.

7.6 Other land

7.6.1 Other land remaining other land

We assume no change in carbon stock in living biomass or soil in other land remaining other land. This is to some extent in accordance with GPG2004 because this land is normally considered unmanaged. However, for Norway this assumption may underestimate carbon removal, because vegetation is increasing in many areas due to reduced grazing.

For reference we have estimated the biomass in other wooded land based on a IPCC Tier 1 method, using expert judgement. Biomass on other wooded land is calculated by means of biomass expansion factors (Table 7.17). The biomass has been considered unchanged from 1990 to 2003 due to lack of data on annual increment and harvest. As an estimate of the growing stock we have used the average value from a limited number of sample plots assessed on a similar land cover type.

Table 7.17 Total biomass on other wooded land of coniferous and deciduous trees calculated by means of biomass expansion factors.

	Total biomass (Gg)	Biomass (Mg/ha)
Conferous	15599.2	5.61
Deciduous	6158.9	2.22
Total	21758.1	7.83
Area (kha)	2779	

7.6.2 Land converted to other land

Change in carbon stock in living biomass

In the case of conversion from forest land, there will be a loss in biomass. In case the “other land” belongs to a category with some tree cover and has been assessed by the National Forest Inventory, the biomass can be estimated by repeated measurements. For the first inventory it has been assumed no change in biomass.

Change in carbon stock in dead organic matter

The same assumption as for living biomass would also be valid for dead organic matter.

Change in carbon stocks in soils

We assume no change in soil carbon when land is converted to other land. This is because there are no data, and as discussed before, SOC for grassland and forest in Norway are quite similar. “Other wooded land” will often be in marginal areas where the SOC is lower than in agriculture land. However, the same will be true for forest or grassland in these areas.

8 Emissions of non-CO_2 gases

Changes in forest land and other land use will influence emissions of other greenhouse gases than CO_2. Emissions of methane (CH_4) are caused by fires. Changes in land use may influence also natural emissions, but according to the IPCC methodology these changes are not included in the accounting framework. Emissions of nitrous oxide (N_2O) are in addition to fires caused by soil organic matter mineralization, nitrogen input and cultivation of organic soils. Indirect emissions are not considered in this sector, but under agriculture. According to IPCC (2004) liming of forest and forest management may change N_2O emissions, but the effect is uncertain. Norwegian forest is, however, not subject to liming.

The emissions of the non-CO_2 gases are small (non-key categories) and default parameters and methods have been applied in most circumstances. Norwegian experts and to some extent Swedish have been contacted in search for improved information.

Emissions and removals described in the Appendices of GPG2004 have only partly been included. Methodologies have been presented in the IPCC appendices for further methodology development and the corresponding emissions can be reported if national information is available. Reservoirs can be a source of non-CO_2 GHG emissions in Norway, but the corresponding emissions have not been estimated here due to lack of information.

8.1 Forest

N_2O is produced in soils as a byproduct of nitrification and denitrification. Emissions increase due to input of N through fertilization and drainage of wet forest soil (IPCC 2004). Forest management may also alter the natural methane sink in undisturbed forest soils (IPCC 2004), but data does currently not allow a quantification of this effect. According to IPCC (2004) fertilizer input is particularly important for this process, but fertilization of forest is of little importance in Norway.

N_2O from fertilization

Because national emission factors for fertilization of forest soil are unavailable the estimate is based on Tier 1 and default emission factors.

$N_2O\text{-direct}_{fertilizer} = (F_{SN} + F_{ON}) * EF_1 * 44/28$

Where

F_{SN} = the amount of synthetic fertilizer applied to forest soil adjusted for volatilization as NH_3 and NO_x. Gg N.

F_{ON} = he amount of organic fertilizer applied to forest soil adjusted for volatilization as NH_3 and NO_x. Gg N.

EF_1 = Emission factor for emissions from N input, kg N_2O-N/kg N input.

National statistics cover the forest area with fertilizer applied. This area is very small, only 15 km^2 in 2002 and 26 km^2 in 1990 (Statistics Norway, Forestry Statistics). The statistics does not specify whether this is synthetic or organic fertilizer. Furthermore, it does not say anything about the amount applied. Statistics Norway has supplied unpublished data on application on synthetic fertilizer for the period 1995-2002. The average ratio between the amount applied and the area fertilized was used to estimate the amount applied for 1990-1994. It is assumed that organic fertilizer is not applied to forest in Norway. To the extent that it is applied, the associated emissions will be reported under agriculture (this assumption is in accordance with GPG2004).

The amount of fertilizer applied is given as total weight. The nitrogen content is depending on the type used. According to Statistics Norway, 95 % NPK-fertilizer is used on wetland. On dry land about half is NPK and the rest N-fertilizer. The N-content of these were taken from YARA (www.hydroagri.com).

The default emission factor is 1.25 % of applied N. There are no national data to improve this factor. 1 % of the N-applied is volatilized as NH_3 (the ammonia model of Statistics Norway). The emission factor is highly uncertain. According to IPCC (2004), the range in emission factor can be from 0.25 % to 6%.

The resulting emissions are about 3-4 Mg N_2O per year, which is very small compared to the emissions from agriculture.

The amount of fertilizer applied to forest should be subtracted from the input to the calculation of emissions from agriculture, because that figure is based on the total fertilizer sale.

Table 8.1 Estimated emissions from fertilization of forest. 1990-2002

	Estimate of input of N, Mg		Estimate of net amount of N applied, Mg	Estimated emissions. Mg N_2O
	Wetland	Dry land		
1990	51	177	225	4.4
1991	77	271	344	6.8
1992	119	210	326	6.4
1993	77	150	225	4.4
1994	77	140	216	4.2
1995	90	138	226	4.4
1996	45	179	222	4.4
1997	21	200	219	4.3
1998	31	216	244	4.8
1999	44	183	225	4.4
2000	23	124	145	2.8
2001	20	100	119	2.3
2002	8	155	162	3.2

Assumptions						
Nitrogen content	15%	22.5 %	Nitrogen volatilization	1 %	Emission factor	1.25 %

Source: Fertilizer consumption Statistics Norway, N-volatilization Statistics Norway, N-content YARA and emission factors IPCC

N_2O from drainage of forest soil

Drainage of organic soils generates emissions of N_2O in addition to CO_2. Drainage will also reduce methane emissions and even generate a sink (GPG2004). However, data are unavailable to estimate this effect (GPG2004) and there are no national data. Given that the area drained in Norway currently is low, no estimate is given for methane. This methodology is given in an appendix in IPCC (2004) (for further methodology development).

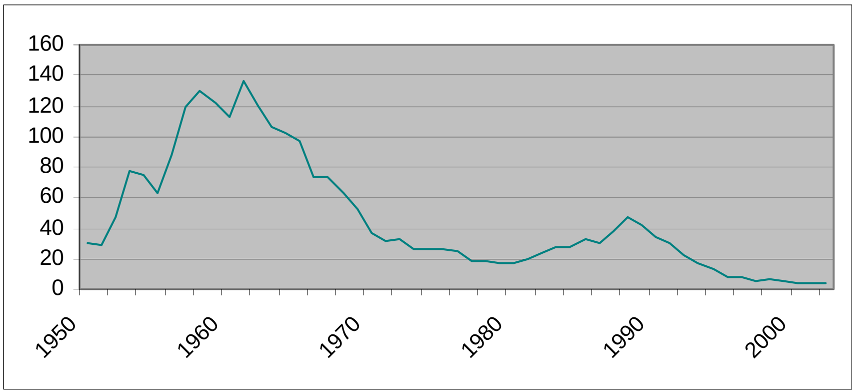
Because no national data are available, the estimation methodology for N_2O is based on GPG2004. It is assumed that all drainage is related to organic soils.

N_2O emissions = Area of drained forest soil * Emission factor

The emission factor is taken from IPCC (2004). It is assumed that all soil is nutrient poor and the corresponding emission factor is 0.1 kg N_2O-N/ha/year (0.6 for nutrient rich). The range of the emission factor is from 0.02 to 0.3 which is an indication of the large uncertainty of the estimate.

The activity data is the area of drained forest soil. Draining back to 1950 has been taken into account (Figure 8.1). The graph shows that the area drained annually has been much reduced. 250 000 ha have been drained accumulated. It is assumed that there is no rewetting of drained forest soils.

Figure 8.1 Drainage of forest. 1950-2002. 100 ha



Source: Statistics Norway

Table 8.2 Area drained and N_2O emissions from drainage of forest soil. 1990-2002.

	1990	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Area drained (accumulated 1000 ha)	231.8	238.7	240.0	240.8	241.6	242.1	242.8	243.4	243.8	244.2	244.6
Emissions (Gg)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

N_2O and CH_4 from forest fires

No prescribed burning of forest takes place in Norway and all forest fires are due to accidents in dry periods (wildfires)[10]. According to GPG2004 the emissions of CO_2 from fires should be estimated, because the regrowth and subsequent sequestration are taken into account when it takes place. However, both the loss and uptake of CO_2 will be covered by the growing stock change based CO_2 calculations. The estimate provided here is for comparison only and to be able to estimate other pollutants, and will not be used in the CO_2 calculations.

Data on area burned in forest fires are available from the Directorate for Civil Protection and Emergency Planning for 1993-2003. For 1990-1992 only data on the number of fires were available and these data were used to estimate the area burned based on the ratio for subsequent years. This method may be very inaccurate because the size of fires is very variable. The number of fires was higher in 1990-1992 than later and it has assumed that the area burned was proportionally higher.

[10] There may be some trials of burning as part of forest management, but this is only performed in small scale and is ignored here.

Table 8.3 Forest fires in Norway 1990-2002 (Source: Directorate for Civil Protection and Emergency Planning)

Activity data	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Number of fires	578	972	892	253	471	181	246	533	99	148	99	117	213
Unproductive forest (ha)	-	-	-	1355	1236	776	1697	6058	1647	734	1426		1247
Productive forest (ha)	2564*	4312*	3957*	883	1081	355	3438	2606	1103	127	293	52	958

* Estimated from the number of fires

In accordance with the principles of this report emissions in all forest is reported. The area burned varies considerably from year to year due to natural factors (for example variations in precipitation). Assuming that the carbon content of biomass is 50 %, half of the biomass burned will end up as CO_2.

There are not any exact data on the amount of biomass burned per area. Normally, only the needles/leaves, parts of the humus and smaller branches are burned. We have assumed that there are 20 m^3 biomass per ha and that the mass of trees burned constitute 25 % of this (this is consistent with GPG2004). It is also likely that there is about 1 m^3 dead-wood per ha that will be affected by the fire due to its dryness. It is difficult to assess how much of the humus is burned, and this is much dependent on forest type. There is about 7500 kg humus per ha, we assume that 10 % of this is burned. This factor is, however, very dependent on the vegetation type. Most of the forest fires in Norway take place in pine forest with a very shallow humus layer.

Table 8.4 CO_2 emissions from forest fires. Gg CO_2

	1990	1991	1993	1994	1995	1997	1998	1999	2000	2001	2002	2003
Living biomass	17	29	4	4	2	16	5	2	3	0	4	14
Dead wood	0.9	1.4	0.2	0.2	0.1	0.8	0.3	0.1	0.2	0.0	0.2	0.7
Humus	1.3	2.2	0.3	0.3	0.2	1.2	0.4	0.1	0.2	0.0	0.3	1.0
Total	19.3	32.5	4.6	4.8	2.3	17.9	5.7	1.8	3.5	0.1	4.5	15.5

There are no national data on emission factors for non-CO_2 gases from forest fires. The guidance of IPCC (2004) is either to estimate emissions of non-CO_2 gases based on the C released (method 1) or to use emission factors on the amount burned (method 2).

Method 1

CH_4 emissions = C * Emission ratio * 16/12

CO emissions = C * Emission ratio * 28/12

N_2O emissions = C * N/C ratio * Emission ratio * 44/28

NO_x emissions = C * N/C ratio * Emission ratio * 46/14

Where C is the carbon released.

IPCC (2004) suggests a default N/C ratio of 0.01. The methane emission ratio is 0.012 and for nitrous oxide 0.007.

Method 2

This method is using emission factors per kilo mass burned. The proposed emission factor is 7.1/9 g/kg for CH_4 (the average is applied here) and 0.11 g/kg for N_2O. N_2O emission factors have been derived from method 1 data.

The emissions are small – in the size of less than 0.1 Gg CH_4 and 0.001 Gg N_2O. The ranges of the data given indicate that the uncertainty in emission ratios is about 25 % for methane and 30 % in nitrous oxide, but in addition comes the uncertainty of the C released. For N_2O the results differ between the two methods (appears to be due to some inconsistency in GPG2004). We suggest using the emissions estimated using method 1 for CH_4 and N_2O.

Table 8.5 Estimates of CH_4 and N_2O emissions from forest fire. 1990-2003. Gg

	1990	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003[a]
CH_4 (method 1)	0.084	0.020	0.010	0.046	0.078	0.025	0.008	0.015	0.000	0.022	0.068
CH_4 (method 2)	0.084	0.020	0.010	0.046	0.078	0.025	0.008	0.015	0.000	0.022	0.068
N_2O (method 1)	0.0006	0.0001	0.0001	0.0003	0.0005	0.0002	0.00005	0.00011	0.00000	0.0001	0.0005
N_2O (method 2)	0.001	0.0003	0.0001	0.0006	0.0011	0.0003	0.0001	0.0002	0.0000	0.0003	0.0009

[a] Preliminary figures

Conversion to forest land from cropland, grassland and settlements does, according to GPG2004, not alter the emissions of non-CO_2 greenhouse gases. Exceptions are in cases of fertilization and drainage as addressed above.

8.2 Cropland

Emissions from on-site and off-site burning of agricultural waste are reported under the agriculture sector and are not addressed here. Emissions from application of fertilizer and cultivation of organic soils are also reported under the agriculture sector.

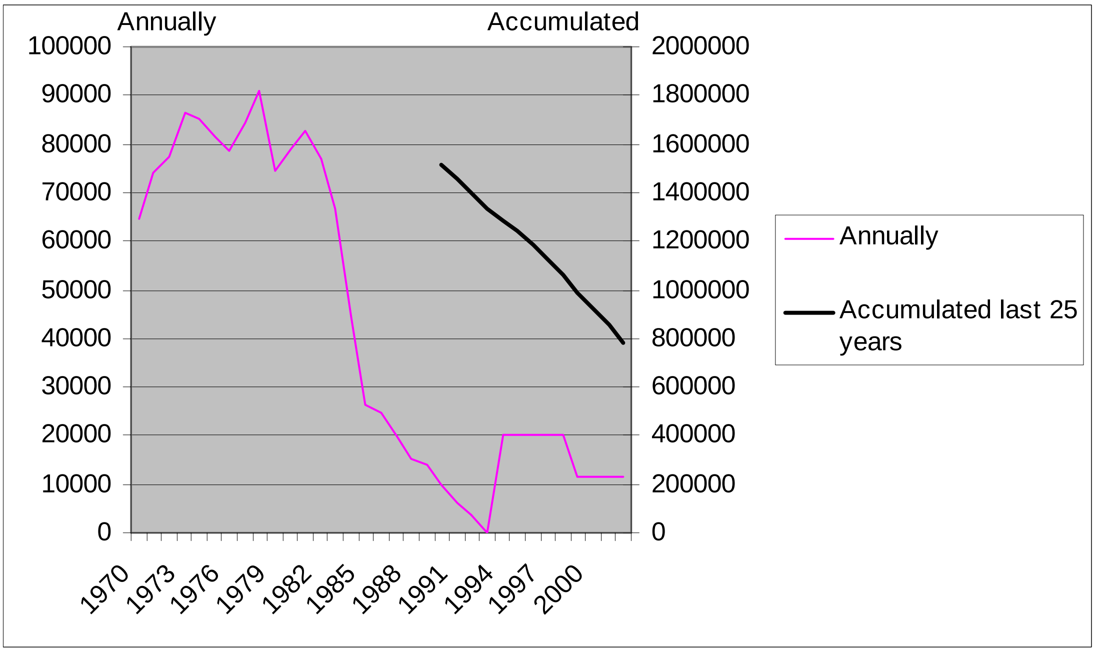
Conversion of forest, grassland and other land to cropland is expected to increase N_2O emissions. This is due to a mineralization of soil organic matter.

IPCC (2004) has proposed the following methodology:

N_2O-N = Area converted last 25 years * N released by mineralization * Emission factor

Data on the area converted last 25 year is available from Statistics Norway for 1970-1992 and for 1994-1998, see Figure 7.2. Data are not available for later years. This area, however, also includes organic soils. Data for the two periods are inconsistent because the 1970-1992 data set is also covering area with government support for drainage, while the 1994-1998 data covers the total area.

Figure 8.2 New agriculture area (ha). Annual values and accumulated. Source: Statistics Norway.



The N released by mineralization is estimated from the C released in mineral soils during conversion to cropland divided by the C:N ratio of soil organic matter (default is 15). According to Jordforsk the average C:N ratio in Norway is 13.4. The C-loss was based on the erosion loss estimated under "cropland remaining cropland" (section 7.2.1). The default emission factor from GPG2004 is 1.25 %. The estimated annual emissions of CO_2 are in the order of 2-4 Gg C and the N_2O emissions in the order of 1/1000 of a Gg.

8.3 Grassland

Emissions from fertilization and drainage of wetland are considered under agriculture. The effect of emissions from mineralization is very uncertain and is not accounted for. Fires in grasslands are ignored, the frequency of such fires is low in Norway. Fertilization of grassland may also alter the methane sink, but there are currently no data available to account for this.

8.4 Wetlands

Norway has many reservoirs due to hydroelectric power production. Flooding may generate emissions of CH_4 and N_2O. An emission methodology is given in an Appendix of IPCC (2004) for further methodology development. There is an ongoing national project (SINTEF and STATKRAFT) to estimate emissions from reservoirs. There will, however, not be any results from this project during the near future, and more measurements are needed to increase the representativity.

N_2O emissions from organic soils managed for peat extraction can be estimated based on Uppenberg et al. (2001). Emission factors after drainage and before extraction range from 0.02-0.1 g/m^2. The first years after extraction has started (6-7 years) the range is 0.2-1 g/m^2, later on reduced to 0.01-0.05. Because the age of the land is not known we propose using a factor of 0.05 g/m^2 for all years.

The area was estimated in Section 7.4.1. This gives us an annual estimate of 0.2 Gg N_2O.

According to the same study peat extraction reduces CH_4 emissions (2-40 g/m^2 before drainage and 0.2-4 after). In line with GPG2004 this reduction is not accounted for in the calculations.

8.5 Kyoto Protocol issues

The amount of fertilizer applied to Norwegian forests is generally negligible. However, a small amount might be applied in the late phases of a stand's life. These emissions can be considered part of forest management (FM).

Drainage of forest soil also has the purpose of establishing new forest, however, the emission estimate is based on forest drained also prior to 1990. The part of the drained land that met the forest definition 31 December 1989 should be considered under FM, the rest afforestation. Because current drainage is low, most emissions will be reported under FM (if elected). Spatial data are not available.

Forest fire should, according to IPCC (2004), only be considered *deforestation* if the cover loss is permanent. In Norway it is expected that areas subject to forest fires will be reforested, so emissions should be considered under FM (if elected). Spatial data on forest fires are not available. The forest fire are has to be confined to the FM definition applied.

N_2O from *conversion to cropland* can be deforestation if the original land use is forest. Emissions are dependent on land-use change prior to 1990 and emissions not related to deforestation can be seen as cropland management (CM) (if elected). According to IPCC (2004) emissions from forest converted to cropland and other land should be separated. Because spatial data are not available, this separation can be based on area data.

Wetland (reservoirs and peatland) is not relevant for any of the Kyoto activities.

9 Supplementary reporting for the Kyoto Protocol

It is not within the scope of this report to suggest a complete framework for reporting under the Kyoto Protocol. The goal of this section is rather to discuss how the data collected for reporting under UNFCCC can be used for Kyoto Protocol reporting in light of Chapter 4 of GPG (2004) ("Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol") which again is building on the decisions of the Marrakesh accords[11].

According to the Kyoto Protocol and the Marrakesh accords, activities are defined under Article 3.3 and 3.4.

Article 3.3: Every Party has to report on direct human induced afforestation, reforestation (AR) and/or deforestation (D) activities started after 1 January 1990.

Article 3.4: A Party may choose to account for anthropogenic greenhouse gas emissions by sources and removals by sinks resulting from any or all of the following human-induced activities, other than ARD activities: revegetation (RV), forest management (FM), cropland management (CM) and grazing land management (GM).

The Norwegian government has not yet taken any decision on what 3.4 activities to elect (if any). The discussion in this report is from the point of view of data requirements and sources and sinks to consider if any of these activities are elected.

There are specific accounting rules for the article 3.4 activities. For FM there is a country-specific cap on credits (for Norway 0.40 Mt C/year as defined in the Marrakesh accords)[12]. For the other activities the accounting is on a net-net basis (net emissions/removals in the commitment period subtracted the base year net emissions/removals times 5).

According to GPG2004 the system for UNFCCC reporting may be expanded to cover the Kyoto Protocol, or it is possible to use a system that generates information for both requirements. The project team suggests as far as possible to use the same methods and data for the Kyoto Protocol reporting as for the UNFCCC reporting. However, there will be additional considerations with respect to the demands for geographical boundaries and allocation to Kyoto activities under Article 3.3 and 3.4 and there is a need for detailed documentation of several assumptions beyond what is indicated in this report. The GPG2004 provides guidance on the documentation requirements.

Forest definition
According to the Marrakesh accords "forest" is a minimum area of land of 0.05-1.0 ha with tree crown cover of more than 10-30 % with trees with the potential to reach a minimum height of 2-5 meter in maturity. This is consistent with the forest definition applied in this project, see Section 3.1.1. This definition can and should be applied consistently for the base year and the commitment period.

In the national forest inventory, areas which are temporarily deforested due to harvest or disturbances are classified as forest. Consequently, such temporary "deforestation" will not be recorded as a land-use change. This is in line with GPG2004.

[11] The Marrakesh accords elaborate the treatment of LULUCF under the Kyoto Protocol (FCCC/CP/2001/13/Add.1, Annex to decision 11/CP.7 Definitions, modalities, rules and guidelines relating to land use, land-use change and forestry activities under the Kyoto Protocol).

[12] This is to exclude removals resulting from elevated carbon dioxide concentrations above their pre-industrial level, indirect nitrogen deposition and the dynamic effects of age structure resulting from activities and practices before the reference year.

Selection and hierarchy of 3.4 Activities

3.4 activities are defined and interpreted as the following:

"Revegetation" is a direct human-induced activity to increase carbon stocks on sites through the establishment of vegetation that covers a minimum of 0.05 ha and does not meet the definition of AR contained here.

In Norway there are areas that were former grazing land areas in mountainous/highland/coastal areas which are gradually vegetated, but because the areas are marginal, they will not meet the forest definition in the short run.

There is little data available to support an assessment of the area and changes in biomass.

"Forest management" is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological, economic and social functions of the forest in a sustainable manner.

The National Forest Inventory distinguishes between productive and unproductive forest. However, the unproductive forest falls in under the Kyoto Protocol FM definition. National parks fulfills ecological functions (including biodiversity) and unproductive forest is largely used for recreation (social function) and hunting (economical and social functions). Consequently, we propose to include all forest that does not meet the requirements to be included under Article 3.3 as FM. This will then also include cultivation of wetlands, fertilizing and fires.

Data are available to provide estimates of removals due to forest management.

"Cropland management" is the system of practices on land on which agricultural crops are grown and on land that is set aside for or temporarily not being used for crop production.

Norway has implemented several management practices that affect carbon in cropland soil and emissions of non-CO_2 GHG and there are additional options (Singh and Lal, 2001 and 2004). These include:

- Changes in tillage practice (CO_2)
- Residue management
- Soil fertility management: Application of manure and fertilizer (N_2O)
- Crop rotation: Selection and use of cover crops
- Management and restoration of eroded and degraded land (CO_2)
- Water management and (including drainage and rewetting of wetland (N_2O and CO_2)
- Liming (CO_2)
- Restoration of peatland (CO_2)

Not all of these are a part of Norwegian management practices today and/or data are not available to monitor the practices, see Section 7.2.1. To the extent that the level of these activities (or control of processes) has changed after 1990, these will give Norway credits (or debits).

If elected, data collection and methodology work would be recommended to improve the quality of the estimates, for example including implementation of modeling approaches.

"**Grazing land management**" is the system of practices on land used for livestock production aimed at manipulating the amount and type of vegetation and livestock produced.

In Norway, grazing practices have been changing, resulting in more bushes and trees of which not all may fall under the forest definition. This kind of vegetation change is overlapping with RV. Farmers get support for having animals on pasture. This does to some extent contribute to sparser vegetation.

There is little data available to support an assessment of the area and changes in biomass.

Hierarchy of activities

Sometimes sources and sinks fall within the definition of more than one 3.3 and 3.4 activity. To avoid double counting an emission/removal has to be included in only one activity. 3.3 activities always have precedence over 3.4 activities according to the Marrakesh accord. This means that if a unit of land meets the definition of ARD, it cannot be used for reporting for FM. It also implies that if an area is selected for FM and it is deforested, it should be reported as D. The Marrakesh accords do not rank the 3.4 activities. According to GPG2004, a Party should select a hierarchy of 3.4 activities that should be applied consistently if they have selected more than one.

The project team proposes that if elected, FM should have precedence over all the other activities due to the importance of forest in Norwegian vegetation, data quality and verification possibilities. Cropland Management (if elected) should have precedence over grazing land management, because the CM activities are more well-defined and easier to verify. The order of revegetation and grazing land management is a matter of choice, because they are overlapping.

1. FM
2. CM
3. RV and GM

Identification of land areas

According to GPG2004 the land areas to be included under the Kyoto Protocol can be determined using two alternative approaches. Norway does not have data available to use Reporting Method 2, because this method requires explicit and complete geographical identification of all units of land subject to Article 3.3 Activities and all lands subject to Article 3.4 activities. Reporting Method 1 allows for inclusion of units of land subject to multiple activities within the boundary. Reporting Method 1 is consistent with the land-use change matrices derived in Section 6.2.

Norway's land-use change matrix has been derived using a method close to Approach 2 as described in GPG2004. According to GPG2004 Approach 2 does not fully meet the requirements for reporting under the Kyoto Protocol in that the land-use change of a single unit of land cannot be tracked. It can be used, however, given that it is supplemented with additional spatial data. The dataset based on NIJOS data can give data on a finer resolution (see below) and land-use changes involving AR are slow under Norwegian climatic conditions due to long rotation periods. Consequently, using Approach 2 is sufficient for following the relevant land-use changes in the country from 1990 to 2012. This is further justified below.

The Marrakesh specifies that the minimum area of forest range between 0.05 and 1 ha. This also identifies the minimum area of land for detection of ARD. The National Forest Inventory (NFI) defines plots of 0.1 ha and is consequently appropriate for use for reporting under the Kyoto Protocol. The NFI also samples non-forested plots, consequently all land-use changes are in principle detected. The NFI identifies the land use on each 0.1 ha sample plot. The surveyor considers the environment of the plot to decide whether a change is permanent or not. This is the basis for determining whether there has been any land-use change. However, sometime the classification may be subjective, for example in the case of a plot with a mix of trees and houses, or agriculture area and forest or houses. These types of errors are to a large extent leveled out.

Because ARD activities are calculated for activities started after 1990, the basis for the calculations in the commitment period will be the land use/land cover in 1990. We assume that *all transformation from other land use to forest since 1990 is AR*. Due to the slow growth of Norwegian forest this means in practice that the land-use change was initiated before 1990. In practice almost all of this is afforestation, because the area will not have been forested over the last 50 years. Only in exceptional cases there may have been agriculture land that has been cleared, then abandoned and reforested (or most agriculture land than is now afforested has been agriculture land for more than 50 years).

The country needs to be stratified into land areas for which geographical boundaries will be reported. The stratification needs to balance the needs of having verifiable areas and the uncertainty induced by having a very fine geographical resolution. The National Forest Inventory is in principle available at the municipality level, but the sampling accuracy is too low for practical applications. The uncertainty is large even for county level data. Administrative data (for example on the use of fertilizer and agriculture management) are in principle available at the county level, but the uncertainties may be high.

Within this project we do not recommend any specific geographical boundaries, but we are presenting the forest inventory data for four regions, defined according to certain homogeneity and a reasonable resolution from the point of view of data quality. The use of administrative boundaries increases the verifiability. However, in principle, the boundaries do not have to follow the administrative classifications. For each country there are differences between the inland and the coast with respect to climate and management, and parts of Møre and Romsdal and the southern parts of Nordland may be considered as a part of mid Norway. Finnmark is not considered as a candidate for FM activities due to lack of monitoring data[13].

The initial proposal for geographical areas are:
- Western Norway (including Møre and Romsdal)
- Southern and eastern Norway (including Vest Agder)
- Mid- Norway (Trøndelag and southern Nordland)
- Northern Norway (Northern Nordland and Troms)
- Finnmark (for ARD)

Once a unit of land has entered Article 3.3 or 3.4 activities they need to be reported throughput the commitment period. In the case Norway selects several 3.4 activities it may (given that Approach 2 is used) be difficult to trace conversions between units of land. The data problems need to be considered if Norway makes a multiple selection.

[13] Finnmark (the far Northern county) is not included in the NFI. Changes in forest volume are not known, but it is likely that the area and volume rather is increasing than decreasing (Section 6.2.4). Omitting Finnmark from the land-use change transitions can be justified because of this trend.

Reporting under Article 3.3
For each of the geographical regions the areas to be reported under Article 3.3 can be identified. For reporting we will consider areas that were not forested in 1990. The changes need, according to the Kyoto Protocol, to be *directly human induced*. Increased forest area can be due to the effect of reduced grazing, but also to the effect of temperature. Studies indicate the grazing effect is most important in Norway

Deforestation should be directly traceable from the NFI. However, it should be explored whether the accuracy (also spatial information) could be improved using administrative data sources. Permanent deforestation in Norway is mostly for settlements and for grassland. Deforestation for settlements is to a large extent irreversible[14], while grassland conversion in principle may change. According to the Marrakesh accords deforestation between 1990 and 2008 need to be identified and changes in pools in these areas recorded during the commitment period. Carbon loss from soil is important in this respect. Loss in dead wood and litter will be of little importance, because the deforestation is for settlements and to some extent for grassland, and it can be expected that (dead) wood and litter is removed from the site. It is very unlikely that an area deforestated will become AR during the first commitment period. Due to the slow growth of forest in Norway it is also unlikely that AR forest will be harvested during the first commitment period. This would only happen in exceptional cases.

AR land can be identified using the permanent NFI plots, but the methodology will need some development.

The Marrakesh accords have identified five major pools for reporting
- Aboveground biomass
- Belowground biomass
- Dead wood
- Litter
- Soil organic carbon

The project team suggests using the same methodologies to estimate emissions and removals as proposed for the UNFCCC inventory.

Reporting under Article 3.4.
The land area subject to various 3.4 activities within each region needs to be identified.

For FM this will be all or parts of forest land remaining forest land, but is expected that many Parties will interpret these as being the same (GPG2004). The definition in the Marrakesh accords is wide "practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biodiversity), economic and social functions of the forest in a sustainable manner". From a data availability point of view it may be difficult to link specific practices to the forest inventory. However, GPG2004 also opens up for "classification of land subject to a system of forest management practices, without the requirement that a specified forest management practices has occurred on each land". This interpretation will be more straightforward to implement in Norway. Furthermore, in accordance with IPCC (2004) the broad definition of forest management may include certain cropland and grazing land. That is, however, not very relevant for Norway. The activity need to have occurred since 1990. As for 3.3 activities, this will include activities initiated before 1990 because it takes time to see the effect. Also emissions of non-CO_2 gases from forest fire and soils should be reported.
There are several forest management activities in Norway:

- Harvesting (changes in harvest level)

- Pre-commercial and commercial thinnings

- Planting
- Preparation for natural regeneration

Norway does not have any data or models that can be used for factoring out removals due to indirect human induced changes. As mentioned, a cap will be applied for crediting emissions from FM in the first commitment period due to this uncertainty.

Also for other activities that can be elected, the land subject to the elected activities needs to be identified for each year of the commitment period. Also data for 1990 are needed due to the principle of net-net accounting.

For CM this can be defined narrowly (certain well-defined practices) or broadly to be all cropland. We propose using broadly defined activities if CM is elected. Although several data in principle are available at the municipality level, monitoring costs may be high. The reporting requires pre 1990 data to establish the base year inventory for net-net accounting.

Because classification of land can change over time, each land needs to be assigned to a single activity at each point of time. In the case Norway would like to implement several 3.4 activities the data availability at the level of Approach 2 may be insufficient.

Time-series consistency
The NFI data are based on permanent plots, but information is collected on a rotational basis. The rotation period is five years and within these five years information from all plots in the country has been recorded. Normally the NFI data are presented as a five year average. *For use in the project it is recommended using a gradual average based on the sampling the current year, the two previous years and the two subsequent years*. The latest years need to be preliminary calculated using extrapolations (this is consistent with GPG2004). This will, however, cause recalculations two years after the reporting year (the NFI data are usually available March/April the year after the inventory year). Consequently, final reporting for the commitment period will not be possible until 2015, which is after the final report is expected. Most data are available for 1990, but the data from the NFI are based on a five year average.

A Party may report data for the commitment period on an annual basis or at the end. The project team would from a data quality point of view recommend Norway to select reporting at the end because of the non-annual data (implying frequent recalculations) and slow processes (individual year not representative).

10 Reporting consistent with the GPG2004

10.1 Time-series and annual data

Annual data have been calculated using linear interpolation and extrapolation from the 6th, 7th and 8th NFI data. Further work will be undertaken to develop these techniques to avoid abrupt changes due to merging of different data sets. For agricultural sources, annual activity data are usually available. Estimates for small sources where activity data are not annually available have been kept constant in the calculations. Estimates of organic soils are not annually available, but changes are expected to be small given the currently small rate of conversion to agriculture land and because the transformation *from* organic soils is slow.

10.2 Uncertainty assessments

A formal uncertainty analysis has not been performed as a part of this project. The uncertainties in Table 10.1 are based on expert judgements and GPG2004. The largest uncertainties are related to N_2O from fertilizer use and land disturbances, where the uncertainty will be larger than 100 %. Also the estimate of CO_2 from farmed organic soils is very uncertain, using the data from Sweden and Finland as an indicator the uncertainty is more than 100 %. Also CO_2 from agriculture soils are quite uncertain, by more than 100%. CO_2 from liming is, on the other hand, determined with a higher accuracy as the application is monitored and the emission factor is based on stoichiometry.

The uncertainties for the sequestration in forest living biomass is approximately 15 %. The uncertainty is around 25 % for forest soil (see Annex 4). For transformation of forest to settlements, the uncertainties in area are estimated at around 30%. The relative uncertainty related to other land-use changes is large, but the estimates are small. The uncertainties as used in the key category analysis are summarized in Table 10.1.

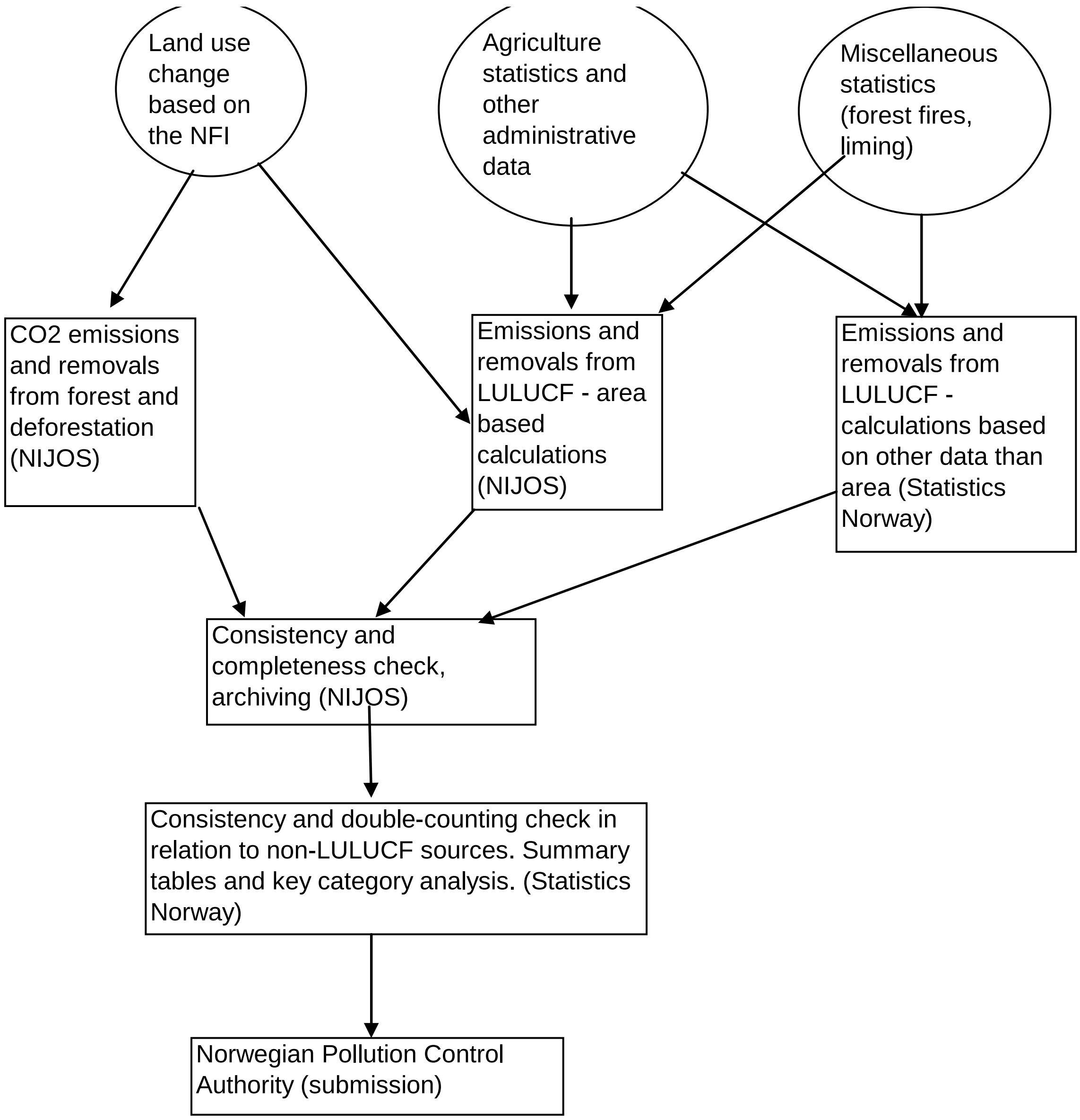
Table 10.1 Uncertainties used in the key category analysis (2 standard deviations relative to the mean)

	CO_2	CH_4	N_2O
5A Forest land remaining Forest land Living biomass	0.15	.	.
5A Forest land remaining Forest land Drained organic soils	2.30	.	.
5A Forest land remaining Forest land Dead organic matter	0.41	.	.
5A Forest land remaining Forest land Soil	0.25	.	.
5B Cropland remaining Cropland Horticulture Living biomass	0.25	.	.
5B Cropland remaining Cropland Horticulture Living biomass	0.25	.	.
5B Forest land converted to Cropland Living biomass	0.25	.	.
5B Cropland remaining Cropland Reduced tillage Soil	0.64	.	.
5B Cropland remaining Cropland Histosols Soil	1.10	.	.
5C Grassland remaining Grassland Histosols Soil	1.10	.	.
5C Cropland converted to Grassland Soil	0.64	.	.
5C Cropland converted to Grassland Horticulture	0.25	.	.
5D Wetland remaining Wetland Soil	1.10	.	.
5E Forest land converted to Settlements Living biomass	0.41	.	.
5P Forest Fertilizer	.	.	1.61
5Q Forest Drainage	.	.	2.30
5Q Wetland Drainage	.	.	2.30
5S Cropland Disturbance	.	.	2.30
5T Cropland Liming	0.10	.	.
5T G-other Liming	0.10	.	.
5U Forest Fires	.	0.56	.
5U Forest Fires	.	.	0.56

10.3 Data management and documentation

The documentation for external purposes is contained in the present document and may be used as a basis for a National Inventory Report as required by the UNFCCC. In addition, those involved in the annual data collection and reporting may need an internal document with details on what data to collect and what QA/QC to undertake. The data management and documentation will be further addressed in a separate project aiming at establishing a national system for reporting emissions and removals in accordance with the requirements of the Kyoto Protocol.

Figure 10.1 Data flow for reporting LULUCF data for Norway



11 Recommendations for future reporting framework

11.1 Responsibilities

Until now Statistics Norway has been responsible for providing estimates of CO_2 emissions and removals for reporting to the UNFCCC. Emissions of non-CO_2 gases have not been reported for the LULUCF sector. Given that the estimates of CO_2 emissions and removals for the forest sector are heavily dependent on the National Forest Inventory, the project team proposes a share of responsibilities for the future. The project team has not considered funding of these activities. Shared responsibilities are a challenge due to the need for ensuring consistency and completeness and avoid double counting. One institution, Statistics Norway or NIJOS, has to take an overall responsibility for QA/QC and archiving of data. The proposal is that NIJOS should be in charge of this responsibility. Statistics Norway will be in charge of ensuring consistency with non-LULUCF reporting.

The proposal is that the work of compiling annual data and filling in the Common Reporting Format tables is shared between NIJOS and Statistics Norway in that NIJOS is in charge of all estimates that are area based, while Statistics Norway is in charge of all estimates that are based on other activity data. In practice this means that all calculations are done by NIJOS, except CO_2 emissions from liming and N_2O from fertilizer use.

11.2 Need for enhancements of existing forest inventory systems

Reclassification from the national land-use classification categories to the six broad categories described in the GPG is quite simple. However, calibration of the field workers is important to avoid misclassification. Different surveyors may have different opinions regarding the land-use classification of a plot, thus calibration might be important. An additional solution to this problem would be that the permanent plots next time are being reviewed with regard to possible land-use changes. It will be important to know whether the different classification has been due to actual changes or only changes in how the surveyors have perceived the land-use categories. This would all be possible at relatively low cost.

In the current calculations only plots assigned to one land-use class have been used because it is difficult to handle plots including more than one land-use class in the calculations. A possible solution to this issue would be to consider only plot centers in the calculations, and disregard changes in plot divisions over time unless they imply a change for the plot center. This would probably be rather straightforward, and the reduced precision in the estimates would be minimal. Other solutions to this problem are also available, although they are more complicated and require more work in setting up consistent classification rules and the calculation system.

It is also a fact that the main focus of the NFI traditionally has been upon the forested area, and that non-forest plots not always have been re-assessed according to the same intensity as forested plots. That means, a plot initially classified as e.g. agricultural land, may not have been visited in the field during the subsequent inventories. Thus, it may sometimes happen that plots on other land-use classes than forest may have been converted into another category, without the change having been recorded in the NFI database. To improve the quality of the UNFCCC and Kyoto reporting, it would be essential to verify the classification of all sample plots in the field at regular intervals, unless the current state is obvious and not subject to changes (e.g. lakes). However, this verification is not taken into account in the current NFI budget and would need additional funding.

The whole country is not comprised by the current NFI, since the area of Finnmark County and the area above the coniferous forest limit towards the mountains were not covered. Establishing permanent sample plots above the coniferous forest limit in the mountains would be very important to obtain a reference for land-use change monitoring, but this will also be relatively expensive. As a part of another inventory system, a simple inventory trial has been carried out in Finnmark County. Is has been integrated in a system for area accounting of Norway, currently managed by Statistics Norway and Norwegian Institute of Land Inventory. Another expected result from this survey is to report the basic data for LUCAS.

The NFI has over the years applied various designs of field-based strip and plot surveys as basic sampling models, and the sampling density has been adjusted from county to county in order to provide reliable estimates at national and regional (county) levels over time. At present, the NFI is facing at least three major challenges, namely (1) to reduce costs by adopting for example remote sensing techniques (RS) to some of the tasks where RS can provide reliable and cost-efficient estimates, (2) to provide statistical estimates of the timber resources at local scales such as sub-county or municipality levels to support the local public forest administration, and (3) to provide cost-efficient and reliable estimates of biomass/carbon stocks of the forested areas to meet the UNFCCC and Kyoto protocol requirements. This includes biomass/carbon estimates of thousands of square kilometers of mountain forest above the coniferous forest line, which is currently not a part of the NFI nor any other national monitoring systems. This ecotone is of special interest in the climate change and C sequestration debate, since it is likely that a temperature induced productivity increase could more easily be detected in the mountain forest due to the steep temperature – productivity gradients. Thus, NFI is now a partner in a proposed project where the overall scientific aim is to develop and demonstrate a cost-efficient method for forest inventory that responds to all these three challenges. It is a major objective of the proposed research to develop airborne laser scanning as a strip sampling tool to inventory timber volume and biomass in large areas, and to compare the accuracy and costs of such an application with what can be obtained by a profiling system.

11.3 Development of a land-use database

A full coverage of maps or images seems unlikely in the near future. There are no exact plans for developing a complete land-use database, but the requirements are described here for possible future work. The development of a land-use database will have to rely upon a sampling design in combination with statistics. A sampling design may be said to consist of three major parts:

- Sampling grid
- Nomenclature
- Instructions for surveyors

The sampling grid needs to be systematic and random, and should preferably cover the whole country. For practical reasons this grid should be based upon a single national projection; Universal Transversal Mercator zone 33 (UTM33) with datum WGS84. This projection is used for the whole country for grid based statistics at Statistics Norway (SN), the common interchange coordinates in administrative registers as for instance the Ground property, Address and Building register (GAB) managed by the National Mapping Authority, and used in the LUCAS approach in the project run by NIJOS and SN. It seems, however, unlikely to have funding for such a shift in sampling plots. At the moment there is an EU directive that might alter this, but it is still unclear whether this directive will have implications for the data capture.

The nomenclature should be built upon a common Norwegian classification system, to cover different types of land use with special interests in Norway. This nomenclature should ideally be common for different sample based surveys, statistics and registers at such a detailed level that aggregates may be done to serve multiple purposes and interests. As Norway is a rather heterogeneous country with respect to land cover and land use, this implies a rather detailed nomenclature. The nomenclature should be based upon the building blocks in the vegetation mapping system used in the above-mentioned LUCAS project.

To ensure a common interpretation field work with regard to land cover and land-use classification should be based upon a least common multiplex of an Instruction for Surveyors. A Norwegian

Instruction for surveyors is at the moment being prepared for the above-mentioned LUCAS approach, and should form a common base for field observations.

Dependent of the data sources QA/QC might need to be adjusted for this purpose. Where possible QA/QC should build upon existing systems.

11.4 Associated costs with improvements of inventory systems and annual reporting

The project identified three areas where the current inventory system will provide incomplete data for the LULUCF reporting. One is the lack of regular re-assessment of sample plots in areas that were not initially identified as forest land. Altogether, there would be about 1,500,000 ha that would fall into such a category, corresponding to about 1,750 sample plots or 350 per year according to the normal inventory cycle. A rough estimate of the additional annual costs would be NOK 260,000.

Another important area is forest and other wooded land above the coniferous forest limit, where most of the changes in the extent of Norway's forest and other wooded land are expected to take place. NIJOS will, according to plan, start establishing a low number of plots in such mountain forest from 2005 on, but completing the 3x3 km grid is expected to take several years. Establishing permanent plots in mountain forest according to the normal grid, would have to cover about 2,000,000 ha, represented by 2,250 sample plots. Annually that would amount to 450 plots, corresponding to about NOK 1.3 million.

Finally, fully implementing the NFI in Finnmark county would require an estimated 2,000 field sample plots. Annually that would correspond to 400 plots, with the associated cost of about NOK 1,2 million. As regards Finnmark, some other solution at a lower cost may also be considered, e.g. establishing the 3x3 km grid in coniferous forest and applying a different design for forest and other wooded land mainly stocked with birch.

The methodology for annual calculations and reporting will be developed and implemented in 2005. According to plan, the filling-in of tables and reporting will then be an annual procedure. The Norwegian Institute of Land Inventory (NIJOS) and Statistics Norway (see Section 11.1) will compile the data required for the annual reporting. Unless substantial changes of the data bases and the reporting format have to be carried out, the annual workload is expected to be at the order of five working months, amounting to about NOK 650,000. This includes filling-in the CRF tables, Kyoto reporting, recalculations due to changes in data and methodologies, appropriate documentation and assistance to SFT in responding to review comments. Of this, about three working months are expected to be required for the CRF reporting and associated activities, and two working months for the Kyoto reporting. Additional resources will be needed for methodology development.

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Annex 1 Development of a land-use database

Sampling grid
Using a sampling method for reliable area statistics would benefit from a systematic and random grid for the whole country. The national monitoring programmes, 3Q and NFI, are based upon a semi-systematic and semi-random grid. Semi-systematic means that they are based upon an irregular grid, where the use of several projection zones forms an irregular grid in a transition zone. This does not have to affect the quality of the statistics, but it makes the grid less flexible in practical matters. Although there has been made an attempt to technically overcome this practical problem (Gjertsen, 2004), the prolongation of this grid is not straightforward. This may be an obstacle for others to use the same grid. Furthermore, one should expect other national or international directives on area statistics to come, and that these systems also will be based upon a sampling method and linked to a common regular grid. This will most likely build on a UTM 33 WGS84 grid for the whole country. The semi-randomness of 3Q and NFI, meaning that they are substrata of the country's land cover classes and based upon older, not updated maps, implies that both the number and geo-referencing of sampling plots should be adjusted according to new demands by the GPG. A more detailed study on this theme has been made in the report; " Tandem-GIS I - A (feasibility) study towards a common geographical base for statistics across the European Union" (Eurostat, 2002).

The sampling design should therefore preferably build upon a regular UTM33 WGS84 grid. This is in use, for instance by Nordic Forum for Geo-statistics, in reports to the municipalities on the 2001 Population and Housing Census and reports to the national Parliament (Stortingsmelding), and has been documented by Statistics Norway (Takle, 2002). This system was also used in field work by NIJOS in 2004.

Nomenclature
To develop national and reliable area statistics, area classification must be based on common nomenclature and common criteria for classification. The cross-institutional project for a national system of land cover classification (NaSAK, NIJOS, 2004/3) proposed two legends for land cover. NaSAK does, however, have some limitations (Strand, 2003/27); the operational definition of different categories or classes lacks, several criteria do in reality describe the same conditions, the classification systems lacks full coverage and are not mutually excluding, some criteria are only vaguely related to land cover, and the nomenclature is not systematic. A single classification system that satisfies all interests therefore seems difficult to make.

A nomenclature used for area statistics for reporting according to GPG should, however, be designed for multi-purpose use. This implies a give-and-take situation, where one has to find a least common multiple of interests within reasonable economic frames.

Instructions for surveyors
Related to questions of classifications are the definitions and criteria used by surveyors or interpreters. Even though the nomenclature of different sources may seem similar, the criteria used may differ, hence the results will also differ. Examples are delineations of forest, agricultural land and urban settlements, carried out by two or more of the national institutions (NIJOS, NMA and Statistics Norway).

An initiative has been taken by NIJOS and Statistics Norway to make an instruction to surveyors that should enable them to give coherent and relevant results, avoiding "holes" and overlaps in the area statistics, satisfying needs to report according to GPG, LUCAS and national area statistics.
About 1980, Statistics Norway in cooperation with The National Mapping Authority (NMA), the Norwegian Institute of Land Inventory (NIJOS), municipalities and others, prepared land statistics for the whole country based upon a sample grid interpretation of maps and aerial photos, with a variable

grid point density, from a dense grid for urban settlements (100x100 m) through less dense grids in arable land and forest land, and the lowest density point grid in mountainous areas (12x12 km). At that time, this was quite a laborious task, and has hence not been carried out in a systematic way since then. Land statistics have been prepared later on, but only sectorwise, for instance for arable land and forest land (see 3Q and NFI).

Reliable land cover/land-use change statistics for time periods as narrow as 1 year have to be based upon some kind of sampling system. Existing digital maps that cover the whole country do not reflect changes in land cover/use in such a short period. The following text will discuss principles that have to be met to make the framework for a land use/cover change statistical system. Such a framework should try to satisfy multiple purposes or interests. A framework solely made to meet the needs in the context of climate change may exclude possibilities for producing area statistics that could be used for other purposes.

The National Mapping Authority (NMA) lead a cross institutional project to make a national system for area classification (NaSAK) until 2004. The focus was here mainly at mapping and different types of map use, not at area statistics. Some ideas from this project have been used further on in this project, as the NaSAK-project identified important area classes.

To have a good framework for area statistics, one has to build upon harmonized sets of area classifications. In other words; areas has to be classified in the same manner at any geographical point or at any time. Otherwise, it will be hard to distinguish between real land cover/use changes, and changes due to different area classification criteria (data noise). Another starting point for making a framework for area statistics is the land use/cover area framework statistical system (LUCAS) developed by the European Statistical Office; Eurostat. This is a framework for area statistics with emphasis on agriculture at national and EU level, but is also designed to be a multi-purpose system. LUCAS is a fully developed system with respect to an information flow idea; from sampling design to quality controls and presentations. To satisfy especially different national and sectored interest, some modifications in the LUCAS area classification system need to be done. These modifications should further on be built upon a least common multiple of sectored interests. To make a single area statistical system that could meet all interests is regarded as, if not impossible, very difficult and costly to develop and run.

Annex 2 Agriculture statistics

Area in daa (10 ha)

		CROPLAND, IN ALL	GRAIN AND OILSEEDS	ROOTS	MEADOWS	HORTICULTURE	GRASSLAND
1969	Country	8 145 876	2 524 214	416 238	4 687 519	517 905	1 716 669
	Østfold	668 899	436 174	28 115	162 458	42 152	80 672
	Akershus	708 247	409 627	26 868	192 051	79 701	107 035
	Hedmark	879 316	455 332	53 230	328 995	41 759	105 134
	Oppland	765 239	237 753	47 824	449 736	29 926	140 569
	Buskerud	440 676	201 652	16 990	177 523	44 511	62 099
	Vestfold	401 684	264 955	27 967	65 270	43 492	36 533
	Telemark	241 947	65 640	12 033	133 414	30 860	44 156
	Aust-Agder	103 101	9 574	8 698	68 996	15 833	20 998
	Vest-Agder	151 191	7 454	8 050	122 020	13 667	44 839
	Rogaland	405 768	39 407	38 721	294 109	33 531	295 892
	Hordaland	394 486	903	11 989	341 730	39 864	141 929
	Sogn og Fjordane	369 061	1 020	13 417	333 355	21 269	115 008
	Møre og Romsdal	470 966	16 907	20 802	405 653	27 604	135 609
	Sør-Trøndelag	586 661	127 304	25 122	417 192	17 043	114 665
	Nord-Trøndelag	643 523	247 021	45 396	331 129	19 977	104 727
	Nordland	513 400	3 498	20 095	476 984	12 823	111 979
	Troms	298 524	4	10 175	285 497	2 848	48 375
	Finnmark	103 203	0	747	101 410	1 046	6 451

		CROPLAND, IN ALL	GRAIN AND OILSEEDS	ROOTS	MEADOWS	HORTICULTURE	GRASSLAND
1979	Country	8 205 506	3 252 271	243 512	4 349 357	360 366	1 329 772
	Østfold	717 572	584 543	16 029	85 256	31 744	37 000
	Akershus	750 383	591 833	12 152	113 425	32 973	49 683
	Hedmark	950 370	590 538	37 801	284 051	37 980	50 982
	Oppland	795 534	279 142	28 804	463 324	24 264	115 477
	Buskerud	458 555	272 468	9 455	142 262	34 370	41 147
	Vestfold	414 748	333 804	14 510	34 192	32 242	15 844
	Telemark	235 413	100 146	7 662	108 858	18 747	25 810
	Aust-Agder	97 093	16 096	5 562	61 981	13 454	18 395
	Vest-Agder	136 610	9 175	5 269	114 736	7 430	39 693
	Rogaland	446 078	33 248	21 381	369 920	21 529	305 818
	Hordaland	338 898	1 752	6 981	307 324	22 841	137 224
	Sogn og Fjordane	337 936	1 751	7 947	310 047	18 191	110 299
	Møre og Romsdal	458 208	12 987	10 990	417 661	16 570	107 799
	Sør-Trøndelag	586 711	135 891	12 104	427 677	11 039	93 332
	Nord-Trøndelag	720 413	285 889	30 277	382 418	21 829	70 566
	Nordland	442 002	2 855	10 861	416 931	11 355	72 063
	Troms	233 102	164	5 164	224 613	3 161	30 317
	Finnmark	85 897	0	564	84 681	652	8 327

		CROPLAND, IN ALL	GRAIN AND OILSEEDS	ROOTS	MEADOWS	HORTICULTURE	GRASSLAND
1989	Country	8 771 715	3 529 804	214 636	4 710 900	316 375	1 139 060
	Østfold	750 853	648 277	14 920	64 173	23 483	16 192
	Akershus	789 969	673 608	8 048	83 940	24 373	26 130
	Hedmark	1 021 575	614 331	48 381	319 721	39 142	45 425
	Oppland	864 112	281 783	25 518	538 324	18 487	100 651
	Buskerud	475 893	293 384	6 789	146 039	29 681	40 423
	Vestfold	428 827	330 512	18 351	33 003	46 961	9 802
	Telemark	237 903	108 668	6 122	107 811	15 302	19 572
	Aust-Agder	100 289	15 321	4 465	70 043	10 460	13 819
	Vest-Agder	151 975	9 958	2 586	132 910	6 521	34 950
	Rogaland	521 878	43 958	17 830	445 240	14 850	325 288
	Hordaland	347 778	1 267	3 140	325 661	17 710	117 190
	Sogn og Fjordane	352 026	1 211	5 157	329 059	16 599	104 802
	Møre og Romsdal	509 654	26 937	7 012	464 440	11 265	82 862
	Sør-Trøndelag	648 126	157 593	8 773	471 772	9 988	71 186
	Nord-Trøndelag	795 747	317 706	24 834	436 539	16 668	45 982
	Nordland	464 617	5 276	8 226	440 217	10 898	57 491
	Troms	222 199	16	3 884	215 113	3 186	20 193
	Finnmark	88 309	0	603	86 899	807	7 102

		CROPLAND, IN ALL	GRAIN AND OILSEEDS	ROOTS	MEADOWS	HORTICULTURE	GRASSLAND
1990	Hele landet	8 801 786	3 619 110	210 295	4 733 414	238 967	1 138 910
	Østfold	771 522	670 623	15 829	66 870	18 200	17 610
	Akershus	804 121	692 606	8 155	87 781	15 579	20 345
	Hedmark	1 048 912	634 802	50 266	334 983	28 861	41 376
	Oppland	868 956	284 825	24 134	547 084	12 913	87 702
	Buskerud	475 583	298 755	7 007	145 900	23 921	38 239
	Vestfold	441 794	337 467	19 872	37 735	46 720	7 710
	Telemark	234 099	113 057	6 047	102 179	12 816	24 181
	Aust-Agder	109 454	15 232	4 889	81 289	8 044	7 975
	Vest-Agder	152 558	8 975	2 007	136 801	4 775	36 982
	Rogaland	541 277	43 587	16 577	470 077	11 036	309 770
	Hordaland	288 321	1 075	2 097	270 828	14 321	160 265
	Sogn og Fjordane	313 804	1 223	4 220	295 601	12 760	132 657
	Møre og Romsdal	504 161	27 166	5 570	465 631	5 794	76 865
	Sør-Trøndelag	678 909	164 189	7 332	501 692	5 696	43 951
	Nord-Trøndelag	802 928	320 547	23 802	449 026	9 553	35 727
	Nordland	458 133	4 972	7 773	440 582	4 806	66 091
	Troms	220 495	12	4 333	213 693	2 457	23 228
	Finnmark	86 774	0	387	85 665	722	8 238

		CROPLAND, IN ALL	GRAIN AND OILSEEDS	ROOTS	MEADOWS	HORTICULTURE	GRASSLAND
1991	Hele landet	8 924 897	3 734 430	201 029	4 767 935	221 503	1 177 797
	Østfold	783 265	684 943	15 316	67 343	15 663	17 579
	Akershus	819 960	711 347	6 981	87 801	13 831	21 777
	Hedmark	1 065 775	655 175	48 846	333 483	28 271	41 285
	Oppland	877 107	295 382	23 193	545 927	12 605	94 650
	Buskerud	483 928	307 535	6 748	147 702	21 943	39 201
	Vestfold	451 637	356 003	19 095	38 848	37 691	7 863
	Telemark	236 475	116 155	5 723	102 391	12 206	24 246
	Aust-Agder	111 466	15 719	4 453	83 367	7 927	7 957
	Vest-Agder	154 504	9 970	1 900	137 853	4 781	38 069
	Rogaland	547 787	48 716	15 316	473 692	10 063	321 385
	Hordaland	290 008	1 017	2 012	272 878	14 101	163 712

	Sogn og Fjordane	316 969	1 467	4 034	298 993	12 475	138 179
	Møre og Romsdal	506 748	28 610	4 902	467 347	5 889	79 542
	Sør-Trøndelag	684 369	169 743	6 694	501 917	6 015	46 426
	Nord-Trøndelag	817 153	328 301	23 184	455 316	10 352	36 661
	Nordland	464 502	4 329	7 858	447 982	4 333	67 784
	Troms	224 111	0	4 369	217 174	2 568	23 413
	Finnmark	89 120	0	404	87 924	792	8 069

		CROPLAND, IN ALL	GRAIN AND OILSEEDS	ROOTS	MEADOWS	HORTICULTU RE	GRASSLAN D
1992	Hele landet	8 821 308	3 652 477	208 266	4 776 173	184 392	1 201 539
	Østfold	769 684	675 945	15 607	66 929	11 203	18 613
	Akershus	812 010	703 093	7 642	90 083	11 192	22 088
	Hedmark	1 043 365	638 826	51 110	330 987	22 442	42 053
	Oppland	878 567	293 913	24 474	551 128	9 052	97 608
	Buskerud	482 918	308 865	6 615	147 655	19 783	39 163
	Vestfold	439 551	349 647	22 108	39 885	27 911	7 874
	Telemark	231 033	114 002	5 606	100 787	10 638	23 886
	Aust-Agder	108 250	15 890	4 596	80 991	6 773	8 069
	Vest-Agder	152 327	9 050	1 974	137 447	3 856	37 995
	Rogaland	549 344	37 135	16 259	485 848	10 102	328 460
	Hordaland	287 370	746	1 904	271 476	13 244	166 049
	Sogn og Fjordane	311 897	1 275	3 480	294 885	12 257	140 038
	Møre og Romsdal	503 166	23 799	4 664	469 395	5 308	80 908
	Sør-Trøndelag	670 092	159 764	6 298	498 957	5 073	51 230
	Nord-Trøndelag	808 185	316 527	23 718	458 782	9 158	38 043
	Nordland	461 370	2 869	7 482	447 317	3 702	68 415
	Troms	224 099	0	4 349	217 703	2 047	23 186
	Finnmark	86 952	0	380	85 918	654	7 862

		CROPLAND, IN ALL	GRAIN AND OILSEEDS	ROOTS	MEADOWS	HORTICULT URE	GRASSLAN D
1993	Hele landet	8 887 535	3 613 891	197 020	4 894 942	181 682	1 233 426
	Østfold	772 550	674 333	14 643	71 942	11 632	19 256
	Akershus	817 754	704 929	7 621	93 182	12 022	22 413
	Hedmark	1 046 032	632 471	51 629	339 307	22 625	41 574
	Oppland	879 460	284 177	22 803	562 988	9 492	102 715
	Buskerud	478 807	301 409	6 602	152 190	18 606	39 599
	Vestfold	437 405	346 629	20 188	43 657	26 931	8 155
	Telemark	231 473	112 467	4 622	104 342	10 042	23 673
	Aust-Agder	108 909	14 805	3 874	83 763	6 467	8 524
	Vest-Agder	155 686	8 191	1 559	141 642	4 294	36 866
	Rogaland	558 115	32 617	13 424	502 344	9 730	338 343
	Hordaland	290 913	659	1 769	275 354	13 131	171 198
	Sogn og Fjordane	317 941	1 031	2 990	301 465	12 455	145 006
	Møre og Romsdal	510 145	21 235	4 558	479 617	4 735	82 730
	Sør-Trøndelag	674 727	158 647	5 732	505 382	4 966	53 331
	Nord-Trøndelag	820 153	317 318	22 809	471 453	8 573	39 768
	Nordland	468 005	2 594	7 315	454 550	3 546	69 507
	Troms	229 117	0	4 496	222 584	2 037	23 778
	Finnmark	89 972	0	389	89 182	401	6 989

		CROPLAND, IN ALL	GRAIN AND OILSEEDS	ROOTS	MEADOWS	HORTICULT URE	GRASSLAN D
1994	Hele landet	8 907 638	3 585 080	182 532	4 951 027	188 999	1 276 469
	Østfold	772 662	670 834	13 788	74 624	13 416	20 714
	Akershus	817 824	700 706	7 085	96 599	13 434	25 708
	Hedmark	1 051 928	632 805	49 431	348 106	21 586	43 308
	Oppland	879 128	278 653	21 681	569 034	9 760	107 486
	Buskerud	480 776	297 978	6 296	157 023	19 479	42 318
	Vestfold	434 913	340 114	18 201	44 621	31 977	8 744
	Telemark	232 642	110 535	4 229	107 656	10 222	25 063
	Aust-Agder	109 621	13 803	3 495	85 358	6 965	8 504
	Vest-Agder	157 984	7 691	1 294	144 868	4 131	39 182
	Rogaland	560 072	32 390	12 487	505 775	9 420	344 874
	Hordaland	290 224	567	1 308	275 400	12 949	173 598
	Sogn og Fjordane	317 725	1 056	2 513	302 477	11 679	147 547
	Møre og Romsdal	514 661	18 621	3 804	488 064	4 172	85 942
	Sør-Trøndelag	679 132	160 370	4 812	509 359	4 591	56 933
	Nord-Trøndelag	817 763	315 924	20 610	471 899	9 330	42 179
	Nordland	467 772	2 968	6 976	454 382	3 446	72 106
	Troms	231 773	0	4 170	225 841	1 762	23 988
	Finnmark	90 977	0	351	89 942	684	8 275
		CROPLAND, IN ALL	GRAIN AND OILSEEDS	ROOTS	MEADOWS	HORTICULT URE	GRASSLAN D
1995	Hele landet	8 955 428	3 491 926	190 371	5 068 733	204 398	1 299 717
	Østfold	772 870	663 498	14 152	80 162	15 058	20 456
	Akershus	820 781	691 177	7 137	106 449	16 018	27 293
	Hedmark	1 051 310	614 895	53 886	359 125	23 404	44 499
	Oppland	884 883	265 906	20 954	586 289	11 734	109 404
	Buskerud	481 369	291 269	6 863	163 162	20 075	43 546
	Vestfold	437 893	330 637	19 313	50 308	37 635	9 349
	Telemark	232 715	104 948	4 506	112 477	10 784	25 780
	Aust-Agder	112 213	12 807	3 539	88 558	7 309	8 847
	Vest-Agder	158 893	6 918	1 552	145 862	4 561	39 037
	Rogaland	560 769	32 503	14 093	504 071	10 102	347 435
	Hordaland	291 205	578	1 313	276 657	12 657	177 141
	Sogn og Fjordane	319 773	684	2 447	305 209	11 433	148 991
	Møre og Romsdal	514 968	15 400	3 803	492 082	3 683	86 367
	Sør-Trøndelag	685 246	153 546	5 022	521 908	4 770	59 656
	Nord-Trøndelag	821 922	302 958	20 417	489 311	9 236	45 917
	Nordland	476 558	2 208	6 898	463 646	3 806	74 145
	Troms	239 052	0	4 153	233 255	1 644	24 279
	Finnmark	91 012	0	320	90 201	491	7 577
		CROPLAND, IN ALL	GRAIN AND OILSEEDS	ROOTS	MEADOWS	HORTICULT URE	GRASSLAN D
1996	Hele landet	8 986 324	3 417 971	189 434	5 168 946	209 973	1 325 535
	Østfold	765 533	653 632	13 700	86 603	11 598	21 741
	Akershus	815 631	680 864	6 758	112 485	15 524	27 641
	Hedmark	1 049 234	605 789	56 480	369 475	17 490	45 932
	Oppland	883 181	255 691	20 730	599 441	7 319	112 920
	Buskerud	478 530	287 070	5 904	169 867	15 689	45 715
	Vestfold	430 038	324 577	19 498	56 969	28 994	9 655
	Telemark	235 424	101 893	4 292	119 354	9 885	26 598
	Aust-Agder	109 100	11 578	3 186	89 629	4 707	9 195
	Vest-Agder	159 877	7 514	1 405	148 048	2 910	39 716
	Rogaland	557 576	34 025	13 428	505 492	4 631	350 598
	Hordaland	291 071	0	1 232	277 367	12 472	177 983
	Sogn og Fjordane	317 816	0	2 252	305 740	9 824	149 402
	Møre og Romsdal	517 138	15 802	3 533	494 103	3 700	89 602
	Sør-Trøndelag	686 950	147 181	5 201	530 674	3 894	61 383

	Nord-Trøndelag	824 277	287 195	21 259	510 206	5 617	48 355
	Nordland	479 147	2 516	6 316	468 002	2 313	76 782
	Troms	240 417	0	3 855	235 430	1 132	24 343
	Finnmark	90 856	0	323	90 057	476	7 973
		CROPLAND, IN ALL	GRAIN AND OILSEEDS	ROOTS	MEADOWS	HORTICULT URE	GRASSLAN D
1997	Hele landet	9 019 746	3 396 841	186 072	5 237 426	199 407	1 363 602
	Østfold	767 592	649 610	13 561	87 527	16 894	22 396
	Akershus	815 257	676 301	7 171	114 793	16 992	28 342
	Hedmark	1 054 029	604 600	56 782	373 195	19 452	46 821
	Oppland	890 540	252 709	20 314	606 913	10 604	122 046
	Buskerud	486 076	287 593	6 133	171 870	20 480	46 753
	Vestfold	440 507	324 326	18 622	59 277	38 282	9 131
	Telemark	241 286	104 306	3 942	122 408	10 630	27 929
	Aust-Agder	111 938	12 675	3 218	88 980	7 065	9 561
	Vest-Agder	163 510	8 117	1 291	150 461	3 641	41 619
	Rogaland	568 411	31 877	12 556	513 841	10 137	353 473
	Hordaland	291 019	710	956	276 578	12 775	179 083
	Sogn og Fjordane	319 448	1 145	1 939	306 459	9 905	152 191
	Møre og Romsdal	521 586	14 376	3 361	500 180	3 669	95 601
	Sør-Trøndelag	693 127	145 221	4 871	538 146	4 889	64 482
	Nord-Trøndelag	831 960	280 810	21 293	520 713	9 144	50 806
	Nordland	487 057	2 465	6 125	475 234	3 233	80 493
	Troms	244 334	0	3 661	239 392	1 281	24 546
	Finnmark	92 072	0	277	91 459	336	8 331
		CROPLAND, IN ALL	GRAIN AND OILSEEDS	ROOTS	MEADOWS	HORTICULT URE	GRASSLAN D
1998	Hele landet	8 989 945	3 385 250	168 313	5 247 603	188 779	1 436 246
	Østfold	768 995	650 798	12 183	90 401	15 613	22 772
	Akershus	803 631	667 971	6 634	115 094	13 932	31 831
	Hedmark	1 049 002	603 670	52 710	376 261	16 361	51 036
	Oppland	888 474	251 602	18 469	607 396	11 007	139 057
	Buskerud	477 513	278 293	5 806	174 376	19 038	48 847
	Vestfold	436 660	317 912	17 001	59 705	42 042	9 592
	Telemark	240 896	102 481	3 655	123 826	10 934	29 525
	Aust-Agder	112 094	12 947	3 000	88 883	7 264	9 412
	Vest-Agder	162 339	7 905	1 230	149 947	3 257	42 467
	Rogaland	569 858	35 478	10 135	515 109	9 136	357 743
	Hordaland	290 125	676	874	276 601	11 974	184 376
	Sogn og Fjordane	321 755	1 165	1 971	309 423	9 196	159 769
	Møre og Romsdal	517 953	16 351	2 829	495 680	3 093	99 656
	Sør-Trøndelag	691 003	150 168	4 250	532 950	3 635	71 907
	Nord-Trøndelag	832 746	285 138	18 819	520 547	8 242	52 181
	Nordland	489 377	2 576	5 099	479 250	2 452	86 706
	Troms	245 204	120	3 351	240 452	1 281	26 720
	Finnmark	92 323	0	296	91 703	324	12 649
		CROPLAND, IN ALL	GRAIN AND OILSEEDS	ROOTS	MEADOWS	HORTICULTURE	GRASSLAND
1999	Country	8 868 791	3 345 034	152 399	5 182 631	188 727	1 510 688
	Østfold	749 845	636 926	10 466	87 528	14 925	21 346
	Akershus	783 167	653 171	5 822	111 660	12 514	30 766
	Hedmark	1 034 821	599 591	49 403	367 762	18 065	51 445
	Oppland	885 408	252 662	17 011	604 230	11 505	142 554
	Buskerud	471 218	270 980	4 941	175 905	19 392	50 922
	Vestfold	425 738	311 661	15 497	59 136	39 444	9 909
	Telemark	232 328	97 140	3 076	120 759	11 353	29 502
	Aust-Agder	108 810	12 586	2 420	86 629	7 175	11 288
	Vest-Agder	159 239	7 777	1 009	147 927	2 526	43 337
	Rogaland	567 830	36 261	9 393	512 197	9 979	399 819

	Hordaland	284 753	615	623	271 054	12 461	185 698
	Sogn og Fjordane	315 455	1 161	1 656	303 754	8 884	161 029
	Møre og Romsdal	512 018	16 790	2 773	488 831	3 624	103 878
	Sør-Trøndelag	687 766	152 917	4 032	527 484	3 333	76 641
	Nord-Trøndelag	831 817	292 129	16 366	513 771	9 551	53 117
	Nordland	483 654	2 667	4 690	473 709	2 588	95 704
	Troms	243 181	0	2 904	239 381	896	29 599
	Finnmark	91 538	0	306	90 914	318	14 134

		CROPLAND, IN ALL	GRAIN AND OILSEEDS	ROOTS	MEADOWS	HORTICULTURE	GRASSLAND
2000	Country	8 852 600	3 369 600	154 500	5 143 100	185 400	1 583 200
	Østfold	749 900	640 100	10 000	85 200	14 600	21 600
	Akershus	782 000	654 300	5 700	109 800	12 200	31 300
	Hedmark	1 034 200	598 600	47 900	370 300	17 400	53 900
	Oppland	888 100	250 400	17 700	608 600	11 400	153 700
	Buskerud	470 900	269 100	4 600	177 900	19 300	55 300
	Vestfold	424 900	312 800	16 400	57 800	37 900	10 400
	Telemark	233 100	97 100	3 300	121 900	10 800	32 000
	Aust-Agder	107 200	12 100	2 400	85 900	6 800	12 000
	Vest-Agder	158 100	9 000	1 000	145 500	2 600	44 800
	Rogaland	568 100	44 300	10 400	502 900	10 500	405 900
	Hordaland	283 600	500	600	270 100	12 400	192 600
	Sogn og Fjordane	313 300	1 000	1 700	301 700	8 900	166 300
	Møre og Romsdal	507 700	18 800	2 800	482 500	3 600	108 600
	Sør-Trøndelag	685 500	159 700	4 100	517 900	3 800	83 500
	Nord-Trøndelag	831 300	299 000	17 700	505 200	9 400	57 800
	Nordland	484 600	2 600	4 900	474 700	2 400	104 000
	Troms	239 100	0	2 900	235 100	1 100	33 500
	Finnmark	91 100	0	400	90 200	500	16 200

		CROPLAND, IN ALL	GRAIN AND OILSEEDS	ROOTS	MEADOWS	HORTICULTURE	GRASSLAND
2001	Country	8 724 834	3 319 430	154 915	5 072 609	177 880	1 586 748
	Østfold	740 455	631 512	8 981	85 819	14 143	20 814
	Akershus	769 385	648 058	5 945	104 856	10 526	30 293
	Hedmark	1 015 559	584 880	49 418	363 790	17 471	52 731
	Oppland	875 549	243 565	17 507	602 730	11 747	156 900
	Buskerud	463 178	261 875	4 236	177 970	19 097	55 098
	Vestfold	416 000	306 621	16 197	58 680	34 502	8 972
	Telemark	227 372	94 305	3 106	120 701	9 260	31 536
	Aust-Agder	105 494	12 974	2 155	83 902	6 463	11 227
	Vest-Agder	155 347	9 067	963	142 787	2 530	44 909
	Rogaland	563 544	43 812	11 096	498 326	10 310	407 377
	Hordaland	272 238	492	578	259 225	11 943	189 046
	Sogn og Fjordane	309 388	970	1 675	298 142	8 601	168 282
	Møre og Romsdal	501 165	19 892	2 840	474 982	3 451	107 972
	Sør-Trøndelag	677 488	159 090	4 035	511 201	3 162	85 822
	Nord-Trøndelag	829 077	300 053	17 861	500 736	10 427	58 673
	Nordland	480 370	2 264	4 968	470 760	2 378	108 063
	Troms	235 377	0	2 841	231 008	1 528	33 163
	Finnmark	87 848	0	513	86 994	341	15 870

		CROPLAND, IN ALL	GRAIN AND OILSEEDS	ROOTS	MEADOWS	HORTICULTURE	GRASSLAND
2002	Country	8 706 170	3 320 075	151 178	5 065 300	169 617	1 618 681
	Østfold	741 865	634 338	8 136	85 486	13 905	21 810
	Akershus	767 462	648 737	6 017	102 006	10 702	31 019
	Hedmark	1 014 849	586 050	49 532	363 594	15 673	55 311
	Oppland	874 037	242 664	16 724	602 948	11 701	161 309
	Buskerud	462 701	260 843	3 983	179 083	18 792	58 408
	Vestfold	416 055	307 596	16 593	59 545	32 321	10 005
	Telemark	226 980	93 594	3 184	120 732	9 470	33 330
	Aust-Agder	104 518	13 127	2 334	83 079	5 978	11 641
	Vest-Agder	153 053	9 102	902	140 794	2 255	44 479
	Rogaland	576 323	43 934	10 225	511 723	10 441	422 353
	Hordaland	254 342	446	390	242 334	11 172	179 636
	Sogn og Fjordane	304 897	744	1 536	294 615	8 002	166 843
	Møre og Romsdal	499 325	19 348	2 593	474 292	3 092	109 096
	Sør-Trøndelag	676 809	159 005	3 661	511 240	2 903	91 668
	Nord-Trøndelag	827 812	297 996	17 061	502 772	9 983	59 553
	Nordland	483 884	2 185	4 524	475 088	2 087	113 839
	Troms	234 196	366	3 228	229 836	766	33 641
	Finnmark	87 062	0	555	86 133	374	14 740

Annex 3 Regional data from the National Forest Inventory

Region 1 “Østlandet + Sørlandet”

Table A.3.1. Land-use classification of 6th National Forest Inventory.

Classes	Land use 6th inventory Area (ha)	%
Cropland	562 434	5.1
Forest land	5 100 856	45.9
Grassland	20 196	0.2
Other land	4 127 909	37.2
Settlements	345 864	3.1
Wetland	943 641	8.5
Sum (6th)	11 100 900	100.0

Table A.3.2 Land-use classification of 7th National Forest Inventory.

Classes	Land use 7th inventory Area (ha)	%
Cropland	553 418	5.0
Forest land	5 081 922	45.8
Grassland	20 196	0.2
Other land	4 128 810	37.2
Settlements	364 798	3.3
Wetland	951 756	8.6
Sum 7th)	11 100 900	100.0

Table A.3.3 Land-use classification of 8th National Forest Inventory.

Classes	Land use 8th inventory Area (ha)	%
Cropland	537 188	4.8
Forest land	5 264 050	47.4
Grassland	29 213	0.3
Other land	3 991 763	36.0
Settlements	383 732	3.5
Wetland	894 953	8.1
Sum 8th)	11 100 900	100.0

Table A.3.4 Land-use transfers between 6th and 7th National forest inventory, relative values (%)

Land-use classes 6th inventory	Land-use classes 7th inventory Cropland	Forest land	Grassland	Other land	Settlements	Wetland	Sum (6th)
Cropland	99.7	0.1	0.0	0.0	1.5	0.0	5.1
Forest land	0.3	99.5	0.0	0.4	4.7	1.2	45.9
Grassland	0.0	0.0	100.0	0.0	0.0	0.0	0.2
Other land	0.0	0.3	0.0	99.6	0.0	0.2	37.2
Settlements	0.0	0.1	0.0	0.0	93.8	0.1	3.1
Wetland	0.0	0.1	0.0	0.0	0.0	98.5	8.5
Sum (7th)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table A.3.5 Land-use transfer matrix between the 7th and the 8th National forest inventory, relative values (%).

Land-use classes 7th inventory	Land- use classes 8th inventory						
	Cropland	Forest land	Grassland	Other land	Settlements	Wetland	Sum (7th)
Cropland	99.7	0.2	18.5	0.0	1.2	0.0	5.0
Forest land	0.0	95.8	6.2	0.4	4.2	0.8	45.8
Grassland	0.0	0.0	69.1	0.0	0.0	0.0	0.2
Other land	0.0	2.9	3.1	99.5	0.5	0.1	37.2
Settlements	0.2	0.0	3.1	0.0	94.1	0.0	3.3
Wetland	0.2	1.1	0.0	0.1	0.0	99.1	8.6
Sum (8th)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Region 2 “Vestlandet”

Table A.3.6 Land-use classification of 6th National Forest Inventory.

Classes	Land use 6th inventory Area (ha)	%
Cropland	237 308	4.1
Forest land	1 144 704	19.5
Grassland	109 457	1.9
Other land	3 933 049	67.1
Settlements	136 416	2.3
Wetland	297 266	5.1
Sum (6th)	5 858 200	100.0

Table A.3.7 Land-use classification of 7th National Forest Inventory.

Classes	Land use 7th inventory Area (ha)	%
Cropland	232 800	4.0
Forest land	1 101 426	18.8
Grassland	109 457	1.9
Other land	3 962 803	67.6
Settlements	139 121	2.4
Wetland	312 594	5.3
Sum (7th)	5 858 200	100.0

Table A.3.8 Land-use classification of 8th National Forest Inventory.

Classes	Land use 8th inventory Area (ha)	%
Cropland	225 587	3.9
Forest land	1 159 130	19.8
Grassland	113 064	1.9
Other land	3 915 918	66.8
Settlements	146 334	2.5
Wetland	298 168	5.1
Sum 8th)	5 858 200	100.0

Table A.3.9 Land-use transfers between 6th and 7th National forest inventory, relative values (%)

Land-use classes 6th inventory	Land-use classes 7th inventory						
	Cropland	Forest land	Grassland	Other land	Settlements	Wetland	Sum (6th)
Cropland	99.2	0.2	0.0	0.0	2.6	0.3	4.1
Forest land	0.0	99.1	0.0	1.0	3.9	2.0	19.5
Grassland	0.0	0.0	100.0	0.0	0.0	0.0	1.9
Other land	0.4	0.6	0.0	98.8	1.3	2.3	67.1
Settlements	0.0	0.2	0.0	0.1	92.2	0.6	2.3
Wetland	0.4	0.0	0.0	0.0	0.0	94.8	5.1
Sum (7th)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table A.3.10 Land-use transfer matrix between the 7th and the 8th National forest inventory, relative values (%).

Land-use classes 7th inventory	Land-use classes 8th inventory						
	Cropland	Forest land	Grassland	Other land	Settlements	Wetland	Sum (7th)
Cropland	99.6	0.2	4.8	0.0	0.0	0.3	4.0
Forest land	0.4	93.1	0.0	0.5	1.2	0.6	18.8
Grassland	0.0	0.2	94.4	0.0	0.6	0.0	1.9
Other land	0.0	5.1	0.0	99.4	4.3	1.2	67.6
Settlements	0.0	0.0	0.8	0.0	93.2	0.0	2.4
Wetland	0.0	1.5	0.0	0.1	0.6	97.9	5.3
Sum (8th)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table A.3.11 Land-use 6th NFI.

	Land use 6th inventory	
Classes	Area	%
Cropland	237 308	4.1
Forest land	1 150 113	19.6
Grassland	96 835	1.7
Other land	3 936 656	67.2
Settlements	140 022	2.4
Wetland	297 266	5.1
Sum 8th)	5 858 200	100.0

Region 3 “Trøndelag and southern part of Nordland county”

Table A.3.12. Land-use classification of 6th National Forest Inventory.

	Land use 6th inventory	
Classes	Area (ha)	%
Cropland	197 185	3.3
Forest land	1 590 287	26.5
Grassland	12 352	0.2
Other land	3 433 021	57.2
Settlements	88 089	1.5
Wetland	684 965	11.4
Sum (6th)	6 005 900	100.0

Table A.3.13 Land-use classification of 7th National Forest Inventory.

Classes	Land use 7th inventory Area (ha)	%
Cropland	187 268	3.1
Forest land	1 585 779	26.4
Grassland	12 352	0.2
Other land	3 440 234	57.3
Settlements	84 482	1.4
Wetland	695 784	11.6
Sum (7th)	6 005 900	100.0

Table A.3.14 Land-use classification of 8th National Forest Inventory.

Classes	Land use 8th inventory Area	%
Cropland	180 956	3.0
Forest land	1 716 515	28.6
Grassland	17 762	0.3
Other land	3 357 285	55.9
Settlements	83 581	1.4
Wetland	649 802	10.8
Sum 8th)	6 005 900	100.0

Table A.3.15 Land-use transfers between 6th and 7th National forest inventory, relative values (%)

Land-use classes 6th inventory	Land-use classes 7th inventory						
	Cropland	Forest land	Grassland	Other land	Settlements	Wetland	Sum (6th)
Cropland	99.0	0.3	0.0	0.0	5.3	0.1	3.3
Forest land	1.0	98.9	0.0	0.2	2.1	1.7	26.5
Grassland	0.0	0.0	100.0	0.0	0.0	0.0	0.2
Other land	0.0	0.2	0.0	99.6	0.0	0.5	57.2
Settlements	0.0	0.3	0.0	0.1	91.5	0.3	1.5
Wetland	0.0	0.2	0.0	0.1	1.1	97.4	11.4
Sum (7th)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table A.3.16 Land-use transfer matrix between the 7th and the 8th National forest inventory, relative values (%).

Land-use classes 7th inventory	Land-use classes 8th inventory						
	Cropland	Forest land	Grassland	Other land	Settlements	Wetland	Sum (7th)
Cropland	99.5	0.1	20.3	0.0	0.0	0.1	3.1
Forest land	0.5	90.4	5.1	0.6	0.0	1.8	26.4
Grassland	0.0	0.0	69.5	0.0	0.0	0.0	0.2
Other land	0.0	5.9	0.0	99.3	0.0	1.0	57.3
Settlements	0.0	0.1	0.0	0.0	100.0	0.0	1.4
Wetland	0.0	3.6	5.1	0.1	0.0	97.1	11.6
Sum (8th)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Region 4 "Nord-Norge"

Table A.3.17 Land-use classification of 6th National Forest Inventory.

Classes	Land use 6th inventory Area (ha)	%
Cropland	82 679	1.8
Forest land	998 550	21.9
Grassland	12 623	0.3
Other land	3 128 717	68.8
Settlements	58 155	1.3
Wetland	269 676	5.9
Sum (6th)	4 550 400	100.0

Table A.3.18 Land-use classification of 7th National Forest Inventory.

Classes	Land use 7th inventory Area (ha)	%
Cropland	78 171	1.7
Forest land	993 140	21.8
Grassland	12 623	0.3
Other land	3 143 143	69.1
Settlements	54 548	1.2
Wetland	268 775	5.9
Sum (7th)	4 550 400	100.0

Table A.3.19 Land-use classification of 8th National Forest Inventory.

Classes	Land use 8th inventory Area (ha)	%
Cropland	75 466	1.7
Forest land	1 076 090	23.6
Grassland	10 820	0.2
Other land	3 071 013	67.5
Settlements	52 745	1.2
Wetland	264 266	5.8
Sum 8th)	4 550 400	100.0

Table A.3.20 Land-use transfers between 6th and 7th National forest inventory, relative values (%)

Land-use classes 6th inventory	Land-use classes 7th inventory Cropland	Forest land	Grassland	Other land	Settlements	Wetland	Sum (6th)
Cropland	97.7	0.3	0.0	0.0	5.0	0.0	1.8
Forest	1.2	97.9	0.0	0.7	1.7	0.7	21.9
Grassland	0.0	0.0	100.0	0.0	0.0	0.0	0.3
Other	0.0	1.5	0.0	99.0	0.0	0.7	68.8
Settlements	1.2	0.1	0.0	0.2	91.7	0.0	1.3
Wetland	0.0	0.3	0.0	0.0	1.7	98.7	5.9
Sum (7th)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table A.3.21 Land-use transfer matrix between the 7th and the 8th National forest inventory, relative values (%).

Land-use classes 7th inventory	Land-use classes 8th inventory						
	Cropland	Forest land	Grassland	Other land	Settlements	Wetland	Sum (7th)
Cropland	98.8	0.2	8.3	0.0	1.7	0.0	1.7
Forest	0.0	90.4	8.3	0.5	0.0	1.7	21.8
Grassland	1.2	0.3	75.0	0.0	0.0	0.0	0.3
Other	0.0	8.1	0.0	99.4	3.4	0.7	69.1
Settlements	0.0	0.2	0.0	0.1	94.9	0.0	1.2
Wetland	0.0	0.8	8.3	0.0	0.0	97.6	5.9
Sum (8th)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Annex 4 SOC calculated based on data from NIJOS

Data and methods

Calculation of C stock in plow layer:

Soil C density = C content (g/g) x bulk density (g/cm^3) x soil depth (cm) x CF

Soil C stock (mill. Mg C) = area (ha) x soil C density (Mg C/ha)

CF = correction factor for stone and gravel content of the soil

Klakegg (2004) has described soil resources in counties Østfold and Vestfold, based on a systematic mapping of soils. Six classes of organic matter content were distinguished (Table A.4.1).

Table A.4.1 Klasser for innhold av organisk materiale. For calculations of soil C density, the middle of each class was taken as the typical soil C content.

Class	Content of organic matter	% organic material	C in % (for calculation)
1	Very low	<1	0.5
2	Low	1-3	3
3	Medium	3-6	4.5
4	High	6-12	9
5	Very high	12-20	16
6	Organic horizon	>20	25

Table A.4.2 Area distribution (in ha) in counties Østfold and Vestfold after organic matter content in plow layer. For description of classes, see Table A.5.1 (from Klakegg, 2004)

		Area distribution according to organic matter in plowing depth					
Fylke		Low	Medium	High	Very high	Organic horizon	Sum
7	VESTFOLD	46455	356022	18707	6884	7119	435186
1	ØSTFOLD	86596	575675	54586	14130	10720	741708

Riley (1996) described pedo-transfer functions for bulk density in different soil textures in cultivated soils southeast Norway (Table A.4.3). For calculations for Vestfold and Østfold, bulk density from clay loam was taken as cultivated soils in Vestfold and Østfold mostly stem from marine deposits with a high clay content.

Table A.4.3 Bulk density for cultivated soils (adapted from Riley, 1996, table 3.2)

Bulk density in g/cm3		
soil grouping	15 cm soil depth	
Content of OM in %	5.50 %	2.50 %
Sand	1.2	1.4
Silt	1.08	1.27
Loam	1.18	1.38
clay loam	1.22	1.41

Uncertainty in soil C estimates

The following considerations about uncertainties in estimation of soil C densities are adapted from de Wit and Kvindesland (1999) but might also apply for soil C density calculations for cultivated soils. Uncertainty in the quality and accuracy of available data and missing data affect the estimations of soil C densities. For the forest soils, C densities were calculated per horizon and summed to obtain a number for a certain soil depth. Carbon content was measured directly, and depth, stone and gravel content was given for each horizon. Bulk density was taken from a bulk density database for forest soils.

For cultivated soils, Grønlund and Njøs (2002) calculated C densities from individual soil samples taken in the plow layer. C-content was measured indirectly using loss on ignition in clayey soils and silty soils. From loss on ignition C content was calculated. For sandy soils, a different approach was used. Bulk density was calculated from a laboratory-weighed volume, and converted to field bulk density using an equation. Soil depth was not measured but assumed to be 23 cm. Stone and gravel content were not measured but assumed to be 10%. The estimate for cultivated soils from the NIJOS database was based on aggregated data for counties, and not on individual soil samples.

C densities (kg/m^2) in soil horizons were calculated using the following equation:

$$\text{C-stock} = d \times BD \times \text{C-content} \times CF_{st}$$

C-stock (kg/m^2)
d: depth of horizon (m)
BD: bulk density (kg/m^3)
C-content ($g\ g^{-1}$)
CF_{st}: correction factor for stoniness and gravel content

An account of uncertainty should be given by calculating uncertainty for every soil profile or every soil sample, and from there on calculate the overall uncertainty. However, this was not possible within the time frame of the project. Therefore, we demonstrate which factors determine uncertainty in the outcome of simplified calculations.

Standard errors (standard deviation / $n^{0.5}$) for elements in the equation above, for forest soils, are given in Table A.4.4 These errors are partly based on expert judgement and partly calculated (De Wit and Kvindesland, 1999).

The total uncertainty per soil horizon is calculated using the following equation:

$$se(\text{C-density, horizon}) = (se^2(d)+se^2(BD)+se^2(C)+se^2(CF_{st}))^{-0.5}$$

se: standard error (in %)

For the whole profile, uncertainty is calculated by taking the root of the quadratic sum of *absolute* uncertainties in each horizon of which the profile consists.

$$se(\text{C-stock, profile}) = (se(\text{C-stock, horizon 1})^2 + se(\text{C-stock, horizon 2})^2 + ..)^{0.5}$$

Table A.4.4 Standard error in C-stock estimations (%) per horizon and per profile (consisting of two horizons which contribute equally to the total C-stock). d=depth; BD = bulk density; CFst= correction factor stoniness

	se(d)	se (BD)	se (C-content)	se (CFst)	total
organic soil types					
soil horizon	5	11.5	5	10	17
soil profile (2 horizons)					25
mineral soil types					
O-horizon	5	8.2	10	10	17
mineral soil	5	4.2	5	20	22
soil profile (2 horizons)					28

From this table, we read that the standard error in the soil C density of an organic soil of two horizons is 25% and is 28% for mineral soil of two horizons, for the forest soil NIJOS database.

Uncertainties in the estimates of C densities in cultivated soils can be considered in comparison to the approach for forest soils. For cultivated soils, only the plow layer was considered. The depth of the plow layer was not measured but is assumed to be 23 cm. The standard error may be somewhat larger as for forest soils, where the thickness of the horizons was measured. Bulk density estimates in cultivated soils are derived from lab measurements and uncertainty here may be similar to that in forest soils. C content in forest soils was measured with high precision, and here data for cultivated soils had a lower precision, so that the uncertainty in the C content may be doubled to 10% for the mineral soil. Correction factors for stoniness were not given in the data for cultivated soils, contributing to the uncertainty, but in general stoniness is smaller than in forest soils, reducing the uncertainty. Thus the uncertainty estimates for stoniness in table xx may be acceptable for cultivated soils.

A calculation according to the equation above gives then an uncertainty of 25 % for C densities in cultivated soils. The uncertainty in the estimate based on the NIJOS data is larger than 25% because the data were integrated before C densities were calculated.

In conclusion, the uncertainty estimates for C densities in forest soils, based on the NIJOS database for forest soils (De Wit and Kvindesland, 1999), and for the cultivated soils, based on Jordforsk data (Grønlund and Njøs, 2002) are about 25%. The estimate based on the reports from Klakegg (2004) for cultivated soils has a larger uncertainty because it is based on aggregated data.

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Annex 5 Results of the key category analysis

Table A.5.1 Tier 1 level analysis 1990 and 2003

IPCC Source category		Gas	Source category level assessment, without uncertainty (fraction of total) 1990	2003	Cumulative total 2003
5A1	Forest land remaining Forest land, Living biomass	CO_2	**16.68 %**	**23.43 %**	23.43 %
1A	Fuel Combustion Activities (Sectoral Approach) (gas)	CO_2	**10.32 %**	**16.46 %**	39.88 %
1A3b	Road Transportation	CO_2	**11.31 %**	**11.77 %**	51.66 %
1A	Fuel Combustion Activities (Sectoral Approach) (oil)	CO_2	**9.19 %**	**8.04 %**	59.70 %
5A1	Forest land remaining Forest land, Dead organic matter	CO_2	**2.78 %**	**3.06 %**	62.75 %
1A3d	Navigation	CO_2	**3.98 %**	**2.88 %**	65.64 %
2C2	Ferroalloys Production	CO_2	**3.71 %**	**2.72 %**	68.36 %
5A1	Forest land remaining Forest land, Soil, Other	CO_2	**2.86 %**	**2.67 %**	71.03 %
6A	Solid Waste Disposal on Land	CH_4	**3.55 %**	**2.52 %**	73.54 %
2C3	Aluminium Production	CO_2	**2.06 %**	**2.32 %**	75.87 %
5C1	Grassland remaining Grassland, Histosols, Soil	CO_2	**2.69 %**	**2.30 %**	78.17 %
4D1	Agricultural soils – direct soil	N_2O	**2.57 %**	**2.13 %**	80.30 %
2B2	Nitric Acid Production	N_2O	**2.97 %**	**2.10 %**	82.40 %
1B2a	Oil (incl. oil refineries, gasoline dist	CO_2	**1.61 %**	**1.73 %**	84.13 %
1B2c	Venting and Flaring	CO_2	**2.16 %**	**1.59 %**	85.72 %
4A1	Cattle	CH_4	**1.96 %**	**1.58 %**	87.30 %
1A3a	Civil Aviation	CO_2	**0.98 %**	**1.17 %**	88.47 %
2A1	Cement Production	CO_2	**0.94 %**	**1.09 %**	89.56 %
1A3b	Road Transportation	N_2O	0.13 %	**0.88 %**	90.44 %
2C3	Aluminium Production	PFCs	**4.75 %**	**0.86 %**	91.30 %
1A3e	Other (snow scooters, boats, motorized e	CO_2	**0.78 %**	**0.79 %**	92.10 %
1A	Fuel Combustion Activities (Sectoral Approach) (coal/coke)	CO_2	**0.78 %**	**0.67 %**	92.77 %
4D3	Indirect	N_2O	**0.60 %**	**0.50 %**	93.27 %
5E1	Forest land converted to Settlements, Living biomass	CO_2	**0.51 %**	**0.42 %**	93.69 %
2C1	Iron and Steel Production	CO_2	0.29 %	**0.40 %**	94.10 %
1B2a	Oil (incl. oil refineries, gasoline dist	CH_4	0.27 %	**0.37 %**	94.47 %
4A3	Sheep	CH_4	**0.37 %**	**0.36 %**	94.83 %
1B2c	Venting and Flaring	CH_4	0.21 %	**0.34 %**	95.17 %
2B1	Ammonia Production	CO_2	**0.32 %**	0.27 %	
2C4	SF_6 Used in Aluminium and Magnesium Foundries	SF_6	**0.72 %**	0.22 %	
1A5b	Military - Mobile	CO_2	**3.09 %**	0.21 %	
2B4	Carbide Production	CO_2	**0.57 %**	0.14 %	

Table A.5.2 Tier 2 level analysis 1990 and 2003. Categories in bold are identified as key.

IPCC Source category		Gas	Source category level assessment, with uncertainty (fraction of total) 1990	2003	Cumulative total 2003
4D1	Agricultural soils – direct soil	N_2O	**32.26 %**	**29.43 %**	29.43 %
5A1	Forest land remaining Forest land, Living biomass	CO_2	**6.80 %**	**10.53 %**	39.96 %
5C1	Grassland remaining Grassland, Histosols, Soil	CO_2	**8.04 %**	**7.57 %**	47.52 %
1A3b	Road Transportation	CO_2	**6.22 %**	**7.13 %**	54.66 %
4D3	Indirect	N_2O	**7.56 %**	**6.99 %**	61.65 %
5A1	Forest land remaining Forest land, Dead organic matter	CO_2	**2.26 %**	**3.97 %**	65.62 %
1A	Fuel Combustion Activities (Sectoral Approach) (gas)	CO_2	**3.96 %**	**3.77 %**	69.40 %
4D2	Animal production	N_2O	**4.39 %**	**3.50 %**	72.90 %
1A3b	Road Transportation	N_2O	0.40 %	**2.93 %**	75.83 %
5A1	Forest land remaining Forest land, Soil, Other	CO_2	**1.94 %**	**2.00 %**	77.83 %
6A	Solid Waste Disposal on Land	CH_4	**3.48 %**	**2.72 %**	80.55 %
1B2a	Oil (incl. oil refineries, gasoline dist	CO_2	**1.47 %**	**1.75 %**	82.31 %
4A1	Cattle	CH_4	**1.43 %**	**1.27 %**	83.58 %
5A1	Forest land remaining Forest land, Soil, Drained organic soils	CO_2	**1.23 %**	**1.22 %**	84.80 %
2C3	Aluminium Production	PFCs	**5.25 %**	**1.05 %**	85.85 %
1A	Fuel Combustion Activities (Sectoral Approach) (Oil)	CO_2	**1.06 %**	**1.02 %**	86.87 %
1A3d	Navigation	CO_2	**0.79 %**	**0.96 %**	87.83 %
5B1	Cropland remaining Cropland, Histosols, Soil	CO_2	**0.89 %**	**0.85 %**	88.68 %
1A3a	Civil Aviation	CO_2	0.54 %	**0.71 %**	89.39 %
1B2c	Venting and Flaring	CH_4	0.40 %	**0.71 %**	90.09 %
2C2	Ferroalloys Production	CO_2	**0.77 %**	0.62 %	90.72 %
2C3	Aluminium Production	CO_2	**0.63 %**	0.51 %	91.23 %
1B2c	Venting and Flaring	CO_2	**32.26 %**	**29.43 %**	29.43 %
2B2	Nitric Acid Production	N_2O	**6.80 %**	**10.53 %**	39.96 %

Table 4.4 Tier 1 trend analysis 1990-2003. All categories listed are key

IPCC Source category		Gas	Source category trend assessment, with uncertainty (fraction of total) 1990-2003	Cumulative total 1990-2003
5A1	Forest land remaining Forest land, Living biomass	CO_2	**28.62 %**	**28.62 %**
1A	Fuel Combustion Activities (Sectoral Approach) (gas)	CO_2	**23.16 %**	**51.78 %**
2C3	Aluminium Production	PFCs	**7.99 %**	**59.77 %**
1A3b	Road Transportation	CO_2	**7.97 %**	**67.74 %**
2C4	SF_6 Used in Aluminium and Magnesium Foundries	SF_6	**6.16 %**	**73.90 %**
1A3d	Navigation	CO_2	**2.42 %**	**76.32 %**
1A	Fuel Combustion Activities (Sectoral Approach) (Oil)	CO_2	**2.25 %**	**78.58 %**
1A3b	Road Transportation	N_2O	**2.15 %**	**80.72 %**
2C3	Aluminium Production	CO_2	**1.95 %**	**82.68 %**
1B2a	Oil (incl. oil refineries, gasoline dist	CO_2	**1.30 %**	**83.97 %**
5A1	Forest land remaining Forest land, Soil, Other	CO_2	**1.16 %**	**85.14 %**
1A3a	Civil Aviation	CO_2	**1.12 %**	**86.26 %**
5A1	Forest land remaining Forest land, Dead organic matter	CO_2	**0.97 %**	**87.22 %**
2B1	Ammonia Production	CO_2	**0.96 %**	**88.18 %**
2A1	Cement Production	CO_2	**0.85 %**	**89.03 %**
1A5b	Military - Mobile	CO_2	**0.82 %**	**89.85 %**
2F	Consumption of Halocarbons and Sulphur Hexafluoride	HFCs	**0.76 %**	**90.61 %**
6A	Solid Waste Disposal on Land	CH_4	**0.69 %**	**91.30 %**
2B2	Nitric Acid Production	N_2O	**0.65 %**	**91.95 %**
2B4	Carbide Production	CO_2	**0.58 %**	**92.53 %**
2C2	Ferroalloys Production	CO_2	**0.54 %**	**93.08 %**
1A3e	Other (snow scooters, boats, motorized equipment)	CO_2	**0.50 %**	**93.57 %**
2C1	Iron and Steel Production	CO_2	**0.49 %**	**94.07 %**
1B2c	Venting and Flaring	CH_4	**0.49 %**	**94.55 %**
5C1	Grassland remaining Grassland, Histosols, Soil	CO_2	**0.49 %**	**95.04 %**

Table 4.5 Tier 2 trend analysis 1990-2003. All categories listed are key

IPCC Source category		Gas	Source category trend assessment, with uncertainty (fraction of total) 1990-2003	Cumulative total 1990-2003
5A1	Forest land remaining Forest land, Living biomass, net change	CO_2	**20.03 %**	**20.03 %**
2C3	Aluminium Production	PFCs	**15.12 %**	**35.15 %**
1A3b	Road Transportation	N_2O	**11.19 %**	**46.34 %**
1A	Fuel Combustion Activities (Sectoral Approach) (gas)	CO_2	**8.71 %**	**55.05 %**
1A3b	Road Transportation	CO_2	**7.54 %**	**62.59 %**
4D1	Agricultural soils – direct	N_2O	**6.32 %**	**68.91 %**
5C1	Grassland remaining Grassland, Histosols, Soil	CO_2	**2.56 %**	**71.47 %**
5A1	Forest land remaining Forest land, Dead organic matter	CO_2	**2.05 %**	**73.51 %**
1B2a	Oil (incl. oil refineries, gasoline dist	CO_2	**1.87 %**	**75.38 %**
4D3	Indirect	N_2O	**1.57 %**	**76.96 %**
1B2c	Venting and Flaring	CH_4	**1.55 %**	**78.51 %**
2F	Consumption of Halocarbons and Sulphur Hexafluoride	HFCs	**1.47 %**	**79.98 %**
2C4	SF_6 Used in Aluminium and Magnesium Foundries	SF_6	**1.44 %**	**81.42 %**
4D2	Animal production	N_2O	**1.35 %**	**82.77 %**
5A1	Forest land remaining Forest land, Soil, Other	CO_2	**1.31 %**	**84.08 %**
6A	Solid Waste Disposal on Land	CH_4	**1.27 %**	**85.36 %**
1A3d	Navigation	CO_2	**1.18 %**	**86.53 %**
1A3a	Civil Aviation	CO_2	**1.06 %**	**87.59 %**
2C3	Aluminium Production	CO_2	**0.69 %**	**88.28 %**
1B2a	Oil (incl. oil refineries, gasoline dist	CH_4	**0.68 %**	**88.97 %**
5A1	Forest land remaining Forest land, Soil, Drained organic soils	CO_2	**0.67 %**	**89.64 %**
1A	Fuel Combustion Activities (Sectoral Approach) (fuel wood)	CH_4	**0.65 %**	**90.29 %**