Commissioned report from Norwegian Forest and Landscape Institute

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EMISSIONS AND REMOVALS OF GREENHOUSE GASES ASSOCIATED BY LULUCF IN NORWAY

Documentation of the 2006 submission to UNFCCC

Gro Hylen (ed.)

skog+ landskap
NORWEGIAN FOREST AND LANDSCAPE INSTITUTE

08/2006

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PREFACE

This report was commissioned by the Norwegian Pollution Control Authority and the Ministry of Agriculture and Food to provide documentation of the methods used for, and results from, calculation of emissions and removals of greenhouse gases associated with land use, land use change and forestry (LULUCF) activities as reported in 2006 by Norway in the National Inventory Report to the United Nations Framework Convention on Climate Change.

This report is a shortened, revised and updated version of “Emissions and removals of greenhouse gases from land, use, land use change and forestry in Norway”, NIJOS Report 11/2005.

The steering committee has consisted of Audun Rosland (The Norwegian Pollution Control Authority) and Arne Ivar Slettnes (The Ministry of Agriculture and Food).

Statistics Norway has had an overall responsibility for consistency checks of the data for the emission and removals of greenhouse gases associated with LULUCF activities in relation to the other greenhouse gas inventories for Norway.

Gro Hylen, Norwegian Forest and Landscape Institute (Skog og landskap) coordinated the revisions and edited the report.

The following persons made valuable contributions to the revision:

- Terje Gobakken Norwegian Forest and Landscape Institute (Skog og landskap) ,
- Ketil Flugsrud, Statistics Norway,
- Kristin Rypdal, Center for International Climate and Environmental Research (CICERO),
- Hans H. Kolhus, Norwegian Pollution Control Authority.

ABSTRACT

The 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 estimates for Norway for the period from 1990 to 2004 in accordance with the good practice guidance. 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 2004, the net sequestration of CO_2 from this sector has been estimated at 26 million tonnes, which correspond to about 48% of the total anthropogenic greenhouse gas emissions in Norway. The net sequestration increased by approximately 81 per cent from 1990 to 2004.

Nøkkelord:	Arealbruk, arealinngrep, klimagasser, avskoging, skogreising, biomasse karbon, CO_2
Key word:	Land use, land-use change, greenhouse gases, deforestation, afforestation, biomass, carbon, CO_2
Related publications:	NIJOS Rapport 11/2005 CICERO Policy Note 2006:01 Skog og Landskap Commissioned report 01/06 Skog og Landskap Commissioned report 02/06

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1 Summary

1.1 Emissions and removals

The average annual net sequestration from the LULUCF sector was about 14 890 Gg CO_2 for the period 1990-1998, and about 25 120 Gg per year from 1999 to 2004. More precisely, in 2004 the net sequestration was calculated at 26 308 Gg CO_2, which would offset 48 per cent of the total greenhouse gas emissions in Norway that year. The sequestration increased by approximately 81 per cent from 1990 to 2004, while the increase from 2003 to 2004 was 1.2 per cent. In 2004 the land-use category forest land remaining forest land was the single contributor to the total amount of sequestration with 28 529 Gg CO_2. All other land-use categories showed net emissions, which totalled 2 221 Gg CO_2. Of these, the most important category was grassland remaining grassland (farmed organic soils used for grass production) with total emissions of 1 870 Gg CO_2, while land converted to settlements (deforestation) was the second most important emissions category with 174 Gg CO_2.

Forest land covers around one fourth of the mainland area of Norway and is the most important land use category considered managed (see Table 5.1 Land-use classification in 1990, 1996 and 2002, representing respectively the 6th, 7th and the 8th NFI). The carbon sequestration in living biomass was estimated at 6 550 Gg C in 2004 (24 016 Gg CO_2*). This estimate is determined with a relatively high accuracy due to the high accuracy of the stock data from the National Forest Inventory and reasonably accurate conversion factors. The sequestration in forest soils was found to be 15 per cent of the sequestration in living biomass, 999 Gg carbon in 2004. The carbon stock change in dead organic matter represents 3.5 per cent of the change in living biomass; 232 Gg carbon was sequestered in 2004. The annual carbon stock has increased for living biomass since 1997, but is quite stable for soils over the period of time. The increase in living biomass can be explained by an active forest management policy, but also to some extent by natural factors. There is an annual variation for dead organic matter which is to a large extent influenced of the annual variation in forest harvest (*
Figure 1.1).

Farmed organic soils (mostly for grass production) contribute with CO_2 emissions of 1 870 Gg CO_2. The uncertainties are, however, large (more than a factor of 2). 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 mandatory spring-till) has contributed to a small sequestration.

Figure 1.1 below shows the calculated carbon stock changes in forest land from 1990 to 2004. The calculations of carbon stock change in living biomass are based on figures from the NFI which is performed for 5-year cycles. In order to smooth out the curve reported in National Inventory Report 2005 (Anon, 2005) we have from 1996 and forward used 5 years moving average in the present report. The reported value for 1990 is based on the inventory value conducted in 1986 until 1993. The values for the period 1991-1995 have been interpolated from values for the year 1990 and 1996, as annual data are not available between 1990 and 1996. Therefore, the carbon stock change in living biomass is assumed constant. The use of moving average for smoothing the time-series data results in the relatively large changes of CO_2-equivalents from 1997 and onwards. Forest harvest influences the carbon stock of living biomass (Figure 1.2). The increase in biomass is the result of an active forest management policy the last 50 years. The annual harvests are much lower than the annual increment, thus causing an accumulation of wood and other tree components biomass. Differences found between earlier submitted data are also due to development of calculation methods and updating of calculation parameters and activity data.

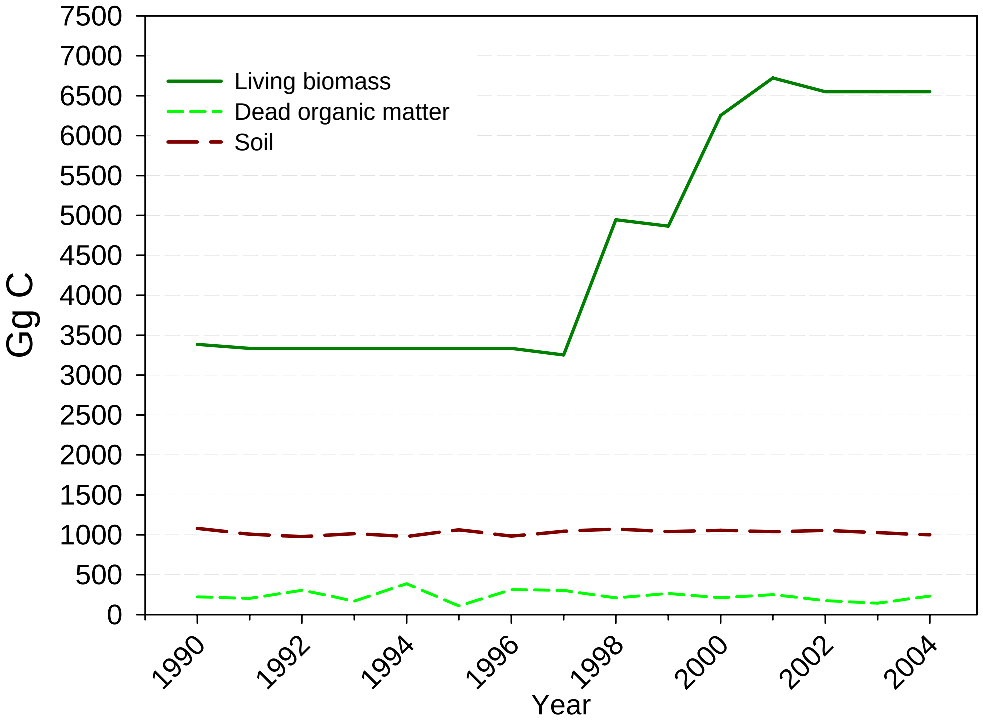


Figure 1.1. Annual carbon stock changes (Gg C) in forest living biomass, dead wood and soil organic carbon. 1990-2004.

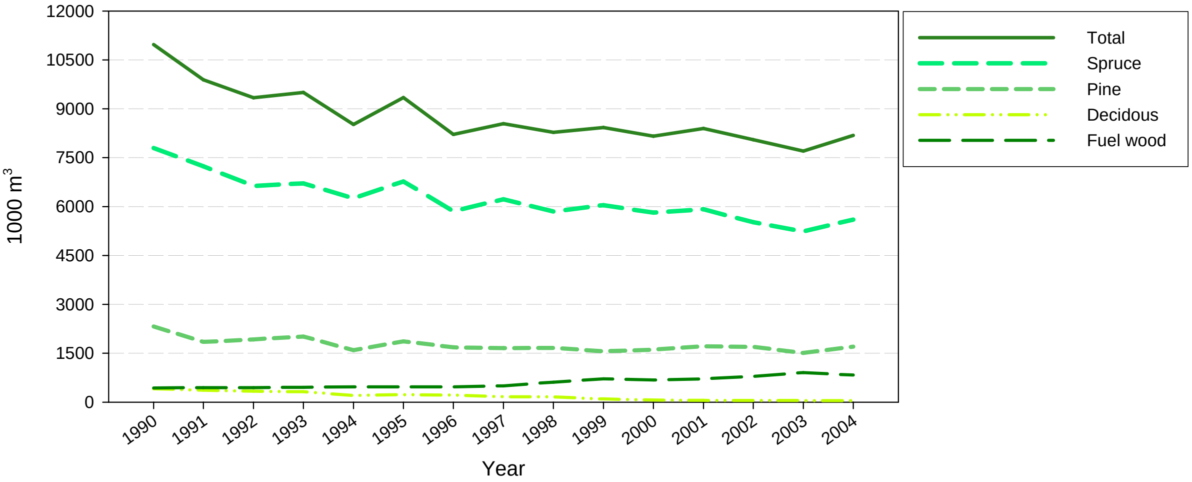
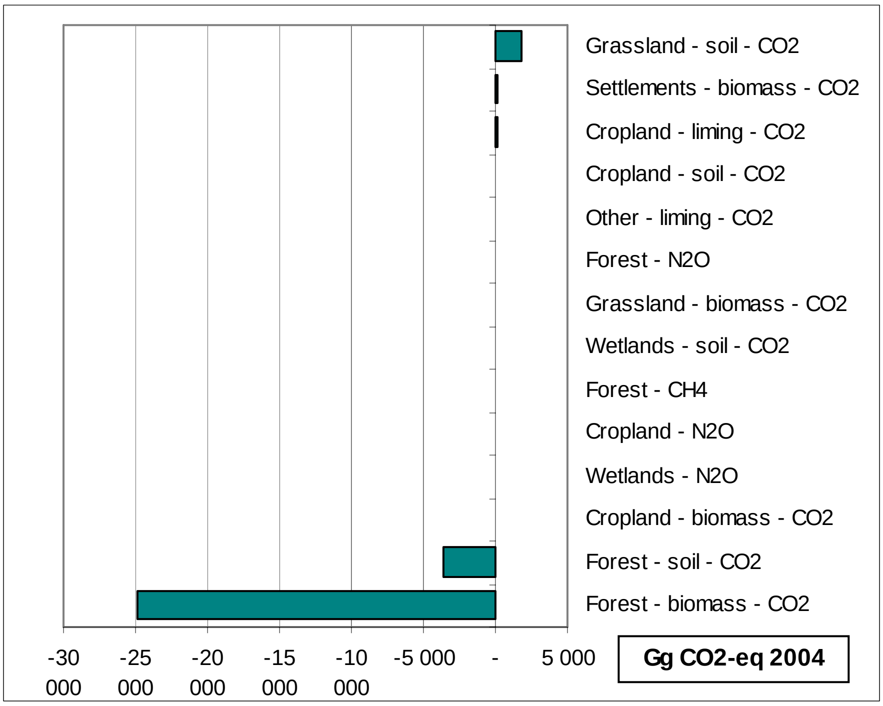


Figure 1.2. Forest harvest 1990-2004 (Statistics Norway, Forestry Statistics)

In Figure 1.3 below emissions and removals from the different LULUCF categories are compared.

a) Full scale



b) Detailed scale

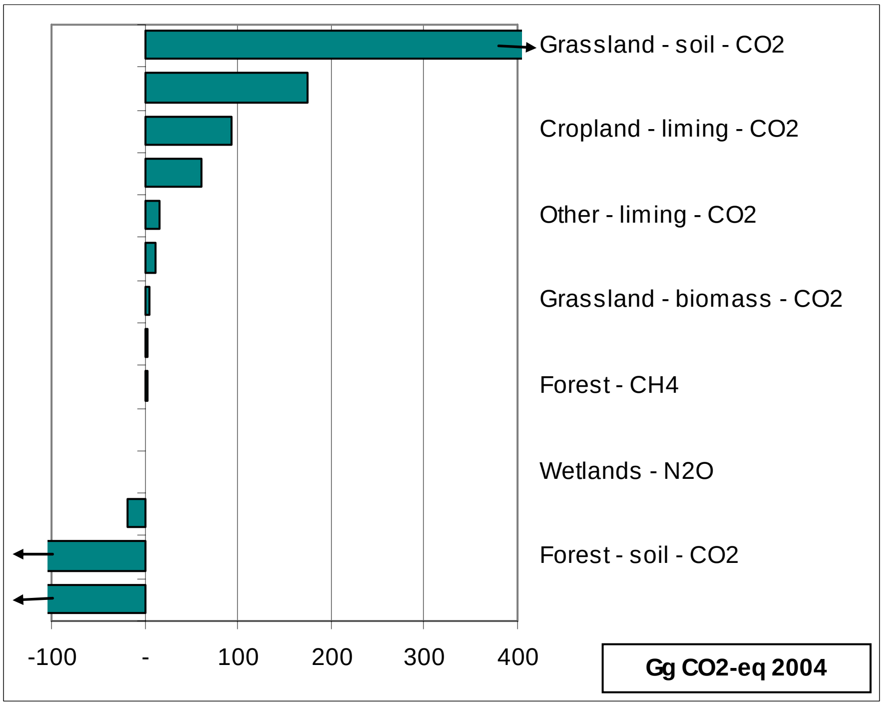


Figure 1.3 Emissions and removals in the LULUCF sector in 2004. Gg CO2-equivalents

The changes in land-use from 1990 to 2004 are quite small; the forest area is increasing and the agricultural area is decreasing. Grassland and settlement areas have increased, while the deforested areas for settlements have been quite stable between 1990 and 2004. The changes in areas distributed on the six IPCC categories from 1990 to 2004 are illustrated in Figure 1.4

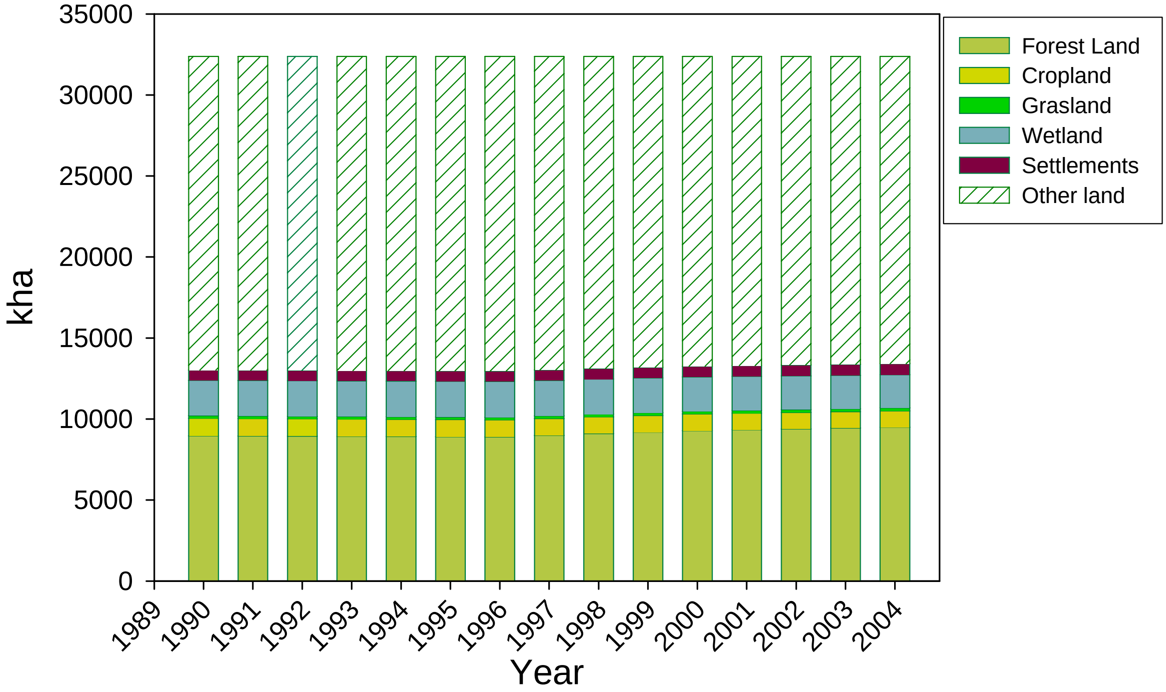


Figure 1.4 Area distribution on the IPCC land-use, land-use change and forestry categories 1990-2004 (k ha)

Table 1.1 shows the changes in carbon stocks for all categories within the LULUCF sector as defined by the IPCC (2004).

1.2 Key categories

A Tier 2 key category analysis has been performed including non-LULUCF sources and the estimates for LULUCF provided in this report. The LULUCF key categories identified using Tier 2 of IPCC (2004) include the following:

- Forest land remaining forest land, living biomass (5A1);
- Forest land remaining forest land, dead organic matter (5A1);
- Forest land remaining forest land, soil (other[1]) (5A1);
- Forest land remaining forest land, soil (drained organic soils) (5A1);
- Cropland remaining cropland, soil, (histosols) (5B1);
- Grassland remaining grassland, soil (histosols) (5C1);
- Forest converted to settlements, living biomass (5E2)

Further details are included in chapter 4.

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[1] “Other” refers to all areas except Finnmark country and drained areas

Table 1.1. CO2 emissions and removals from Land-Use, Land-Use Change and Forestry. Gg C. (IE – included elsewhere, NA – not applicable, NE – not estimated, NO – not occurring.The use of multiple codes in one category referens to different codes used in the subcategorien.)

	1990	1995	1998	1999	2000	2001	2002	2003	2004
Forest remaining forest	4 686.6	4 501.6	6 224.3	6 167.8	7 515.8	8 009.1	7 777.8	7 716.2	7 780.6
- Living biomass	3 385.4	3 333.4	4 946.8	4 866.1	6 253.0	6 722.7	6 549.9	6 549.9	6 549.9
- Dead organic matter	221.8	106.4	207.9	264.8	208.5	249.1	175.2	142.5	232.0
- Soils	1 079.4	1 061.8	1 069.6	1 036.9	1 054.2	1 037.4	1 052.7	1 023.8	998.7
Land converted to forest	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cropland remaining cropland	-51.4	-31.7	-28.0	-26.4	-10.2	-7.5	-18.9	-15.5	-11.7
- Living biomass	6.8	6.3	6.0	5.9	5.7	5.5	5.4	5.0	5.0
- Dead organic matter	NA.NE	NA.NE	NA.NE	NA.NE	NA.NE	NA.NE	NA.NE	NA.NE	NA.NE
- Soils	-58.2	-38.0	-33.9	-32.2	-15.9	-13.0	-24.4	-20.5	-16.6
Land converted to cropland	-20.0	-3.6	-32.5	NA	NO	NO	NO	NO	NO
- Living biomass	-20.0	-3.6	-32.5	NA	NO	NO	NO	NO	NO
- Dead organic matter	NO	NO	NO	NO	NO	NO	NO	NO	NO
- Soils	NO	NO	NO	NO	NO	NO	NO	NO	NO
Grassland remaining grassland	-510.0	-510.0	-510.0	-510.0	-510.0	-510.0	-510.0	-510.0	-510.0
- Living biomass	NO	NO	NO	NO	NO	NO	NO	NO	NO
- Dead organic matter	NO	NO	NO	NO	NO	NO	NO	NO	NO
- Soils	-510.0	-510.0	-510.0	-510.0	-510.0	-510.0	-510.0	-510.0	-510.0
Land converted to grassland	NO	-3.7	-0	-3.7	-4.6	-6.8	-1.1	-13.1	-1.7
- Living biomass	NO	-3.7	NO	-3.7	-4.6	-6.8	-1.1	-13.1	-1.7
- Dead organic matter	NA	NA	NA	NA	NA	NA	NA	NA	NA
- Soils	NA	NA	NA	NA	NA	NA	NA	NA	NA
Wetlands remaing wetland	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9
- Living biomass	NA.NO	NA.NO	NA.NO	NA.NO	NA.NO	NA.NO	NA.NO	NA.NO	NA.NO
- Dead organic matter	NA.NO	NA.NO	NA.NO	NA.NO	NA.NO	NA.NO	NA.NO	NA.NO	NA.NO
- 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	-60.3	-125.4	-98.5	-177.5	-60.4	-47.6	-47.6	-47.6	-47.6
- Living biomass	-60.3	-125.4	-98.5	-177.5	-60.4	-47.6	-47.6	-47.6	-47.6
- 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

2 Introduction

The IPCC report “Good Practice Guidance for Estimating and Reporting of Emissions and Removals of greenhouse gases associated with Land use, Land-use Change and Forestry”(LULUCF) activities was finalised in 2004 (IPCC, 2004). 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 reporting gives a complete coverage of emissions and removals from LULUCF on managed land (the UNFCCC inventory).

In 2005 a project team provided documentation of the implementation of the IPCC “Good Practice Guidance for Estimating and Reporting of Emissions and Removals of greenhouse gases associated with Land use, Land-use Change and Forestry” (LULUCF) activities for Norway (Rypdal et al., 2005). For carbon stock changes and each category of emissions and removals of CO_2 and other greenhouse gases the methodological choice, underlying assumptions, availability of data and recommendations for use of data were discussed. The report provided estimates of emissions and removals of greenhouse gases from LULUCF as reported in the National Inventory Report 2005 to UNFCCC (Anon, 2005).

The present report is based on the report “Emissions and removels of greenhouse gases from land, use, land use change and forestry in Norway” (Rypdal et al., 2005), hereafter referred to as NIJOS 2005. The NIJOS 2005 report included a chapter entitled “Recommendation for future reporting framework” and a chapter that discussed how data collected for reporting under UNFCCC could be used for Kyoto Protocol reporting. These chapters are excluded from the present report since those themes are covered in four separate reports; “National Greenhouse gas inventory system in Norway” (Anon, 2006c). “Framework for reporting under Article 3.3 and 3.4 of the Kyoto protocol” (Anon, 2006b), “Estimates of emissions and removals resulting from activities under Article 3.3 and 3.4 of the Kyoto Protocol” (Anon, 2006a) and “Electing Cropland Management as an Article 3.4 Activity under the Kyoto Protocol. Considerations for Norway” (Rypdal et al, 2006).

The aim of the present report is to provide documentation of the methods used and results from calculation of emissions and removals of greenhouse gases associated with LULUCF activities as reported in the National Inventory report 2006 to UNFCCC (Anon, 2006d)

Compared to the methods described in NIJOS 2005, the method used to calculate total biomass of forest trees has been revised and calculation parameters and activity data have been updated. Therefore the whole time-series for Land use class Forest Land have been recalculated. The impact of this change in formulas is an increase in biomass throughout the period and hence an increase in sequestration of carbon.

3 Definitions of land-use classes

Six broad categories of land are described in IPCC (2004), 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[2]. These are areas included in the agriculture statistics.

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 are defines as wetlands. 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.

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

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 IPCC (2004) “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 categories

To assess which sources are key categories in the Norwegian greenhouse gas inventory for the LULUCF sector a Tier 2 analysis has been performed. Key categories are identified as the categories that add up to 90 per cent of total uncertainty contribution in level and/or trend. This definition of a key category is according to IPCC (2004). The Tier 2 methodologies used are outlined in Annex 1 for National Inventory Report 2006 to UNFCCC (Anon, 2006d), as well as methodology and results from the simpler tier 1. Tier 1 is based only on 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).

Table 4.1 shows the results of the Tier 2 key category analysis performed as described in IPCC (2004). Uncertainties were not determined by a rigid analysis. There are some differences between the results of the two tiers. Tier 1 level analysis does not identify forest drained organic soil, cropland histosols and forest converted for settlements. The reason is that these categories have large uncertainties. For the trend analysis there are small differences between the two tiers with respect to the LULUCF categories identified, and the trend analysis does not identify any additional LULUCF categories to those identified in the level analysis. In both analyses, forest remaining forest (all three pools) are among the top key categories.

Table 4.1 Summary of identified LULUCF key categories Tier 2.

IPCC Category		**Gas**	**Level assessment**		**Trend assessment**	**Method (Tier)**
			1990	2004	1990-2004	2004
5A1	Forest land remaining forest land, living biomass, other	CO_2	11.53	19.27	32.48	Tier 3
5C1	Grassland remaining grassland, soils, histosols	CO_2	13.51	11.66	6.26	Tier 2
5A1	Forest land remaining forest land, soils	CO_2	6.34	5.09	1.81	Tier 3
5A1	Forest land remaining forest land, dead biomass, other	CO_2	2.52	2.28	1.46	Tier 3
5A1	Forest land remaining forest land, soils, drained organic soils	CO_2	2.38	2.17	1.44	Tier 1
5B1	Cropland remaining cropland, histosols, soils	CO_2	1.50	1.30	0.70	Tier 2
5E2	Forest converted to Settlements, Living biomass	CO_2	0.68	0.47	0.05	Tier 3

5 Inventories and statistics used for LULUCF

5.1 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. The Norwegian Forest and Landscape Institute is responsible for the NFI. Inventory work was started in 1919 with regular inventory cycles. The last inventory cycle took place from 2000 to 2004. 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 covered the most important forest districts, while inventories in western and northern Norway were carried out less frequently and sometimes incompletely. During the three most recent periods (since 1986), all counties except Finnmark were surveyed.

The sampling design is based on a systematic grid of sample plots with 3 x 3 km spacing. Permanent fixed area sample plots were introduced for the 1986-1993 inventory cycle. The plots were 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 re-measuring 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 re-measurement is carried out in such a way that 20 per cent 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.

Totally, approximately 16 500 permanent sample plots have been established below the coniferous forest limit. On average, the sampled area comprises about 3×10^{-5} of the surveyed area. 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. The number of trees and annual increment are also calculated.

Up to now there have been 8 different inventory cycles. In this report figures from the inventories carried out from 1986 to 1993 (the 6th NFI), 1994 to 1999 (the 7th NFI) and 2000 to 2004 (the 8th NFI) are used. The years 1990, 1996 and 2002 are used as reference years for the 6th, 7th and 8th NFI, respectively.

The 6th 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 7th NFI design was changed in such a way that a fraction of the field plots is measured in the entire country, except for Finnmark County and areas above the coniferous forest limit, in each year. This makes it possible to calculate single year estimates. The calculations of change in annual area estimates are based on figures form the National Forest Inventory (NFI), which is performed for 5-year cycles. From 1996 and forward we used 5 years moving average. The reported value for 1990 is based on the inventory value conducted in 1986 until 1993. The values for the period 1991-1995 have been interpolated from values for the year 1990 and 1996.

The total land area of Norway has been divided into the six land use classes: forest land, cropland, grassland, wetlands, settlements, and other land. The classifications are shown in Table 5.1. The figures are based on data from NFI and Statistics Norway which provided the figures for the total land area for Norway. Areas above the coniferous forest limit and Finnmark County and here classified as “Other land”. The category “Other land” ensures that the total land area identified equals the total area of the country.

A key finding from these data is that change in land-use from 1990 to 2002 is quite small; the forest area is increasing and the agriculture area decreasing. Grassland and settlement areas have also increased.

Table 5.1 Land-use classification in 1990, 1996 and 2002, representing respectively the 6th, 7th and the 8th NFI

Classes	**Land-use in 1990** *The 6th NFI*		**Land-use in 1996** *The 7th NFI*		**Land-use in 2002** *The 8th NFI*	
	Area (ha)	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Forest	8 969 611	27.7	8 896 579	27.5	9 394 137	29.0
Cropland	1 080 122	3.3	1 054 879	3.3	1 017 367	3.2
Grassland	155 882	0.5	155 883	0.5	174 727	0.5
Wetlands	2 186 262	6.8	2 216 918	6.8	2 084 208	6.4
Settlements	633 145	1.9	645 768	2.0	673 410	2.1
Other	19 355 178	59.8	19 410 173	59.9	19 036 351	58.8
Sum	**32 380 200**	**100.0**	**32 380 200**	**100.0**	**32 380 200**	**100.0**

The six land-use categories are consistent with the national definitions applied in 7th and 8th NFI. However, in the 6th NFI (which represents 1990) 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 assessments 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 NFI. 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 report, 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. The land use classification and the plot characteristics at the last inventory were used for these plots.

5.1.1 UNCERTAINTIES FOR NFI

About 16 500 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 plots, the formulas for simple random sampling can be used to provide approximate values for the precision of the area estimates. The report NIJOS 2005 shows that the relative errors of the uncommon categories are 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.

The uncertainties in emission and removal figures are substantially higher for all other land-use classes compared to forest. This is due to scarce of data available and all the assumptions needed to be done.

5.2 Auxiliary data

In light of the importance of the forest sector and the lack of sources of statistical information that can be used to monitor all land-use transitions on an annual basis, data from the National Forest Inventory have been used as the most important source of information to establish total area of forest, cropland, wetlands, settlements and other land and land-use transitions between these (Rypdal et al. 2005). The data from the National Forest Inventory have been complemented with other statistical data, in particular for agriculture areas. These other data are less suited to derive exact land-use transitions, but provides additional information on agriculture activities.

For the land use class Cropland statistics concerning area of perennial crops (apple, pears, plum, cherry and sweet cherry), tillage practices and area of new agriculture land, all collected by Statistics Norway, are used. In addition data of the amount of lime applied at agricultural land and lakes collected annually by the Directorate for Nature Management are used to calculate emissions of CO_2. For estimating emissions of non-CO_2 gases, national statistics of forest area where fertilizer has been applied and statistics of drainage for forest collected by Statistics Norway and data on area burned in forest fires collected by the Directorate for Civil Protection and Emergency are used. The area data for farmed organic soils (histosols) and the amount of peat extracted (used for calculation under land use class Wetland) are based on research projects at Bioforsk (Rypdal et al. 2005).

6 Estimating emissions and removals of CO_2 from LULUCF

6.1 Forest land 5.A

6.1.1 FOREST LAND REMAINING FOREST LAND – 5A1 (KEY CATEGORY)

Forest is the most important land-use category with respect to biomass sequestration in Norway. This category is found to be key category with respect to sequestration in living biomass, dead biomass, soils and drained organic soils from a Tier 2-analysis where the uncertainty in level and trend was assessed. The details of the biomass calculations are described in this section, but the same data will also be used to estimate losses of carbon when forest is converted to other land-use or removals when the forest area is increasing.

6.1.2 METHODOLOGICAL ISSUES

Change in carbon stock in living biomass
The method implemented corresponds to Tier 3 of IPCC (2004); a combination of national forest inventory data and models to estimate changes in biomass. Tier 1 has been used to estimate emissions and removals in the forest of Finnmark.

The total biomass of forest trees was estimated using a set of equations developed in Sweden (Marklund, 1988, Petersson and Ståhl, 2006) for single tree biomass of Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*) and birch (*Betula pubecens*). These equations provide biomass estimates 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 the calculation, tree and stand attributes from the permanent NFI sample plots located throughout Norway were 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 1.1 per cent of the stem volume, with a dry weight of 0.520 Mg m^{-3} (Lethonen et al., 2004).

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 at breast-height 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 than 1.3 m were excluded from the calculations because their biomass is negligible.

The calculated of carbon stock changes in forest land from 1990 to 2004 are shown in Figure 1.1 and explained in section 1.1.

In the centralized review of Norway's National Inventory Report in 2005, the Expert Review Team (ERT) suggested to separate emissions from removals (increases and decreases in stocks) in CRF table 5.A. Norway explained that the increase in net emissions is a result of a continued increase in standing volume and gross increment, while the amount of CO_2 emissions due to harvesting and natural losses has been quite stable. It should be emphasized that the net emissions are calculated directly as the difference between total stock data for different periods. Although data on increase and decrease might illuminate the situation, they would not improve the quality of the net emission data. After considering the options and consequences, Norway has therefore come to the conclusion that it will not provide separate estimates of emissions and removals (increases and decreases in carbon stocks) in CRF table 5A.

Change in carbon stock in dead organic matter and in soil

Change in carbon stock in dead organic matter due to litter from standing biomass, un-recovered fellings (trees that were felled but not removed from the forest), harvested residues and natural mortality, stumps and roots from harvested trees have been calculated. A detailed description of these calculations is given in de Wit et al. (2006). The volume and increment estimates are for NFI and removals as forest harvest are from Statistics Norway.

The dynamic soil model YASSO as described in detailed by de Wit et al. (2006), are used to calculated changes in carbon stock in soil. This model describes accumulation of soil organic matter and dead wood in upland forest soils and is designed to process data derived from forest inventories (Liski et al., 2005). The model requests estimates of litter production (natural mortality and harvest residues) and annual mean temperature. Calculations of change in carbon stock (pools of biomass, dead organic matter) are done according to a Tier 3 method.

6.1.3 RECALCULATIONS

The whole time-series have been recalculated due to changes of calculation methods, and updating of calculation parameters and activity data.

The sequestration in forest land remaining forest land was 28 529 Gg CO_2 in 2004, which would offset about 52 per cent of the total greenhouse gas emissions in Norway that year. Sequestration from this category represents the total sequestration from the LULUCF sector, since all the other categories provide net emissions. Emissions of CH_4 and N_2O from the category are negligible compared to the CO_2 sequestration; 0.11 Gg and 0.04 Gg, respectively (corresponding to about 2 Gg and 12 Gg of CO_2-equivalents)[3]. Further details about emissions of non-CO_2 gasses are included in chapter 7.

From 1990 to 2004 the sequestration of CO_2 increased by 66 per cent. The increase from 2003 to 2004 was 0.8 per cent.

6.1.4 LAND CONVERTED TO FOREST LAND– 5A2

The possible conversion under this category are the following: cropland converted to forest land, grassland converted to forest land, wetlands converted to forest lands, settlements converted to forest lands and other land converted to forest land.

6.1.4.1 Methodological issues

The emissions and removals from different "land categories to forest land" have been reported/calculated as described in Section 6.1.1 "Forest land remaining forest land". It takes time before an area change has any influence on estimates of carbon stock changes in Norway under the existing climatic conditions. IPCC (2004) suggests considering land-use transitions

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[3] It appears that these numbers may be off by a factor of ten (too large). This will be followed through and necessary changes will be made in the next country report.

over a period of 20 years. However, in the present calculations the transition area stays only one year in the transition class before it is transferred to the new appropriate class.

Change in carbon stock in living biomass
When trees at land converted to forest land have reached a height of 1.3 m they are included in the estimate of living biomass.

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”.

Change in carbon stocks in soils
The methodologies used correspond to IPCC (2004) Tier 1 where emissions and removals are estimates considering the carbon stock before and after conversion and the duration of the transition. However, national data are used to the extent available, see more detailed descriptions below.

6.1.4.2 Conversions

Cropland converted to forest land
The conversions between these categories are negligible. This conversion rarely goes directly most often it goes via “other land”. The conversion is expected to lead to uptake of carbon, because there has been a likely carbon loss on agriculture land due to management and because forest will accumulate carbon. Studies provided by Bioforsk on soil organic matter 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 soil is used for agriculture. We propose to not estimate any instant change in soil organic carbon, but to account for the C uptake by using the C accumulation data provided for forest soils.

Grassland converted to forest land
No conversion from grassland to forest is detected in the data. 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. In this situation the carbon in soil is expected to increase. However, it is not possible to conclude that the soil organic carbon 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 (IPCC, 2004), we propose to apply the same factors for soil accumulation as for forest remaining forest and assume no direct change in soil organic matter due to the conversion.

Wetlands converted to forest land
There has been recorded a conversion from wetlands to forest land as well as from wetlands to forest land. Some of these differences can be explained by difficulties in classifying areas with tree cover on wetlands. However, there may also be some actual changes from wetlands to forest land. The limit for classifying as mire is < 10 per cent 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. 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. In line with IPCC (2004) we propose using the emission factors as for drained organic soils (0.16 Mg C/ha/year) also in the year of conversion. Forestry in Norway has dramatically decreased its drainage of wetlands areas for tree planting over the last decades (Statistics Norway, 1998). The area drained in 1990 was 3.5 kha and only 0.04 kha in 2000.

Settlements converted to forest land
Conversions from settlements to forest 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).

Other land converted to forest land
There has been a conversion from other land to forest land (7th and 8th NFI). These conversions are most likely in areas close to the coniferous forest limit. Changes from other land to forest land my sometimes be real and may be partly human induced (changes in grazing). Some changes can also be due to a warmer climate (Hofgaard, 1997a, b). This conversion will be on vegetated "other land" (section 6.7.2.1). When this land is converted to forest, it is proposed to apply the carbon accumulation rates defined for forest remaining forest, assuming no change in soil organic carbon at the year of transition.

6.1.4.3 Recalculations

The whole time-series have been recalculated due to changes in of calculation methods and updating of calculation parameters and activity data.

Only area estimates are given in the CRF reporter in relation to the different land category conversions.

6.2 Cropland 5B

6.2.1 CROPLAND REMAINING CROPLAND – 5B1 (KEY CATEGORY)

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 (IPCC, 2004). The soil carbon is, however, also affected by management practices (for example ploughing and fertilization) (Singh and Lal, 2005). In addition, Norwegian soils are limed to stabilize the pH. Liming contributes to improving the biomass production and the potential for carbon sequestration.

6.2.1.1 Methodological issues

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. The method implemented corresponds to Tier 1 of IPCC (2004).

Changes in living biomass have only been considered for perennial woody crops. 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 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. 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).

Changes in biomass in existing areas of fruit trees:
The IPCC default value for biomass accumulation rate is 2.1 Mg C/ha/year (IPCC, 2004). 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 to other land categories:
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 it has 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 6.1. CO2 emissions due to reductions in fruit trees for agriculture production

	Area (ha)	**Annual uptake** (Mg)	**Annual C-loss** (Mg)	**CO_2 emissions** (Gg)
1989	3 267			
1990	3 220	6761.4	2998.8	11.0
1991	3 172	6661.4	2998.8	11.0
1992	3 124	6561.5	2998.8	11.0
1993	3 077	6461.5	2998.8	11.0
1994	3 029	6361.5	2998.8	11.0
1995	2 982	6261.6	2998.8	11.0
1996	2 934	6161.6	2998.8	11.0
1997	2 886	6061.7	2998.8	11.0
1998	2 839	5961.7	2998.8	11.0
1999	2 791	5861.7	2998.8	11.0
2000	2 718	5708.4	4599.0	16.9
2001	2 611	5483.3	6753.6	24.8
2002	2 593	5445.5	1134.0	4.2
2003	2 385	5009.3	13085.1	48.0.
2004	2 359	4952.9	1694.7	6.2

*Data for 1990 -1998 have been interpolated

Change in carbon stock in dead organic matter
This pool is considered insignificant (both the pool and changes in it) and no estimates are provided.

Change in carbon stocks in soils
A country specific methodology has been employed for these calculations, based on Tier 2. The soil organic carbon (SOC) has been estimated by Bioforsk. Data (in Mg SOC/ha) shows a large geographical variation, being highest in the south-western/western regions. SOC is also sampled by Skog og landskap. Data on SOC from Bioforsk and Skog og Landskap are shown in Table 6.4 and Table 6.5. The Skog og landskap data and their uncertainties are explained in Rypdal et al. (2005).

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 (2005) have considered the effect of ploughing 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.

The measurements of carbon in soils by Bioforsk and Skog og landskap 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; 2005). 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. On the whole, soil erosion leads to C emissions. In Norway, soil erosion is mainly a problem in south-eastern regions of the country. Based on assumptions on ploughing practices and erosion rates from these, Singh and Lal (2001) have estimated a net erosion rate of 2.2 Mg/ha/years under autumn ploughing. The rate in other areas is 0.44 Mg/ha/years.

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 per cent.
- 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 per cent has been used in the calculations.

(all these assumptions were taken from Singh and Lal (2001))

Finally, it is assumed that 20 per cent 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 per cent C, and enhance SOC and sequester carbon if returned to soil. There is, however, no statistics to monitor changes in crop residue management. 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. 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.

It is rather common to rotate crops in Norway. 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. 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. It is expected that when cover crops are used in combination with reduced till, the effect on reductions on carbon losses will be enhanced. This effect, however, also includes the effect of reduced tillage.

Nitrogen fertilization rates in Norway have not changed substantially over the last 20 years. The N-input in agriculture area was 0.11 Mg/ha in 1990, decreasing to 0.10 in 2002 (Bye et al. 2002). This reduction is around 10 per cent over a period of 12 years. However, according to data reviewed by Singh and Lal (2005) 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. 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.

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) (Bye et al., 2005), Figure 6.1. The fraction of area under autumn tillage was 82 per cent in 1989/2000, which was reduced to 43 per cent in 2001/2002 (based on annual surveys).

Moving to autumn ploughing 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 Bye et al. 2005. The classes here are autumn till, shallow till, spring till (only) and no till. We have classified spring ploughing only as “minimum till”. Erosion emissions will only be 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 basic erosion factor for agriculture land under traditional till (autumn ploughing) 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 per cent) * 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.

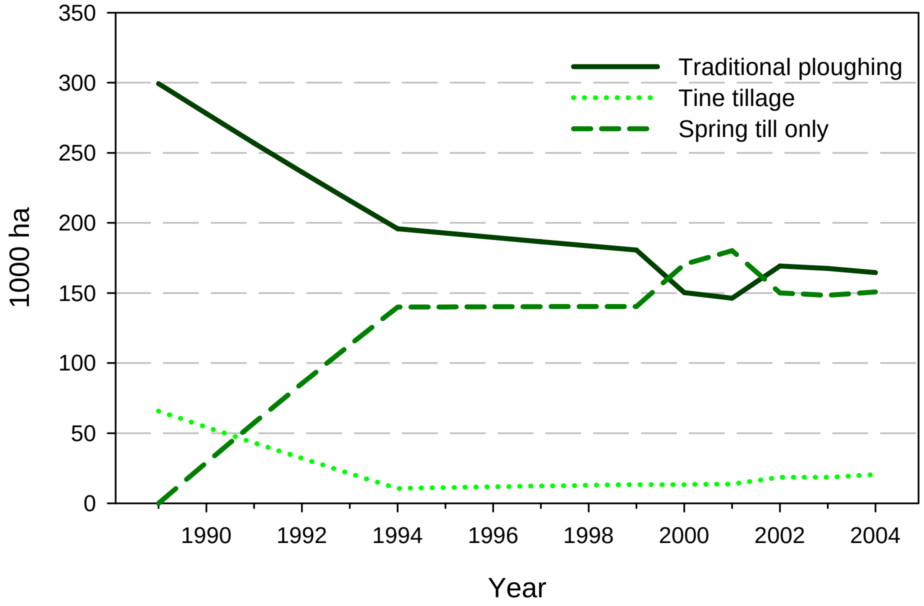

Figure 6.1. Tillage practices 1990-2004 (Statistics Norway)

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 ploughing. In fact, a small amount is also used for grass production (may subtract “surface cultivated” area, around 5 per cent). 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 soil organic carbon should be assumed. The results are shown in Table 6.2

*Table 6.2. Erosion emissions due to ploughing and uptake due to reduced ploughing in Norway**

	25 year old agriculture area (ha)	**Erosion emissions (Gg)**	**Area under tine, no till or minimum till, subtracted 1979 tine area and part of the new agriculture area (ha)**	**Carbon uptake (Gg)**
1990	151637	1.50	0	0
1991	145794	1.36	8410	4.2
1992	139696	1.21	19766	9.9
1993	133219	1.08	31553	15.8
1994	128741	0.96	42924	21.5
1995	124262	0.85	39168	19.6
1996	118839	0.81	41505	20.8
1997	113099	0.77	44012	22.0
1998	106471	0.72	46947	23.5
1999	99122	0.66	50252	25.1
2000	92132	0.61	82754	41.4
2001	85429	0.48	88316	44.2
2002	78143	0.42	65484	32.7
2003	78143	0.43	73197	36.6
2004	70208	0.40	80900	40.4

*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.

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 15 118 ha. However, because the area of potatoes has been decreasing in the nineties, we assume that all area of vegetable and potatoes has 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 per cent) * 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 4 166 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 wetlands to cropland is at present less common than previously. According to IPCC (2004) the accumulated area of organic soils should be multiplied with an emission factor. The default value for cold temperate region is 1.0 Mg C/ha/year. Bioforsk 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 per cent organic matter)	42 000 ha
Peat soils (>40 per cent 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 Bioforsk (Arne Gronlund, pers. Comm.) the soil database indicates the following distribution between crop types:

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

As soils samples are likely to be underrepresented on grass compared to cereals and more intensive productions, about 90 per cent of the farmed organic soils are used for grass. In this project we propose to assume that 10 per cent 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.

6.2.1.2 Liming of agricultural soils – 5G

Due mostly to low buffer capacity of soils, Norwegian soils may be limed using limestone (calcium carbonate - $CaCO_3$). This results in process emissions of CO_2, which traditionally have 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 tonne CO_2 per tonne calcium carbonate applied (Jerre, 1990). This emission factor is based on the stoichiometry of the lime applied and is consistent with IPCC (2004). The total emissions from this source amounted to 93 ktonnes CO_2 in 2004, which represent 0.2 per cent of Norway total GHG emissions. Thus this is regarded as a non-key category in the Norwegian greenhouse gas inventory. National total emissions have been reported yearly from 1990 and onwards, and are contained under the category “Other” in the CRF-tables.

6.2.1.3 Liming of lakes – 5G

For several years many lakes in the southern parts of Norway have been limed to reduce the damages from acidification. The total emissions from this source amounted to 16 ktonnes CO_2 in 2004, which represent 0.03 per cent of Norway total GHG emissions. The amount of calcium carbonate used for liming of lakes was collected from Directorate for Nature Management. The emission factor used is 0.44 tonne CO_2 per tonne calcium carbonate applied (Jerre et al., 1990). The emissions are reported under “Other” in the CRF-tables.

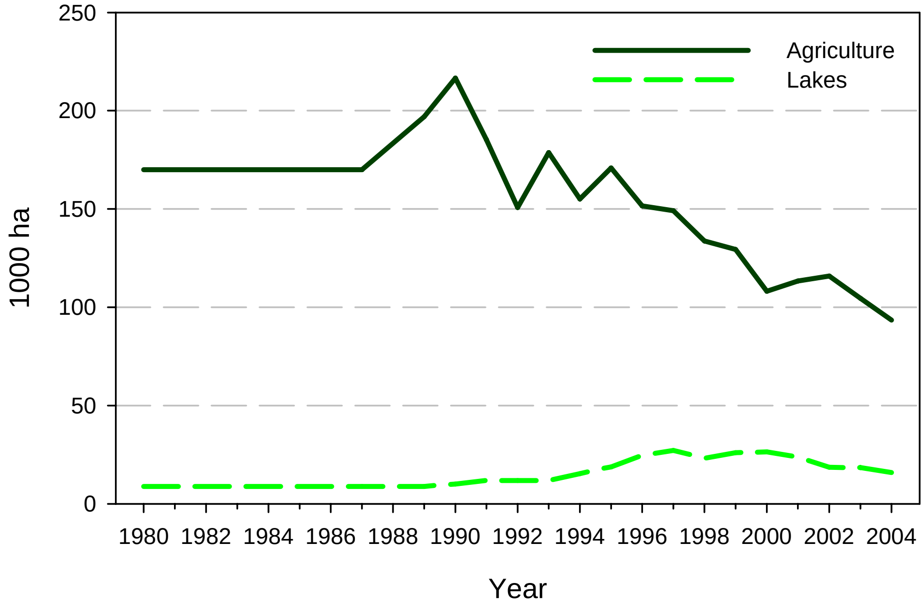

Figure 6.2. Liming of agriculture soils and lakes. 1989-2004.

Table 6.3. Amount of lime applied to agriculture area and lakes, and corresponding CO2 emissions. 1990-2004

Agriculture	**1990**	**1995**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Amount of lime applied (Mg)	492 407	388 365	294 150	245 884	257 696	263 499	23 7631	212 546
CO_2 emissions (Gg)	217	171	129	108	113	116	105	94
Lakes	**1990**	**1995**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Amount of lime applied (Mg)	23 000	42 738	59 193	60 076	54 118	42 089	41 833	36 003
CO_2 emissions (Gg)	10	19	26	26	24	19	18	16

The ERT noted that Norway uses the same emission factor as that applied to cropland, as all lime is assumed to emit CO_2. The ERT recommended that Norway provides additional information in the NIR to support the use of the agriculture emission factor for the application of lime to water. Norway does not see why lime in water should emit less CO_2 than lime in soil (based on stoichiometric considerations). These annual emissions are furthermore very minor justifying a Tier 1 approach. Until more information is available, Norway will wait to pursue this matter.

6.2.1.4 Recalculations

The whole time-series have been recalculated due to changes in of calculation methods and updating of calculation parameters and activity data.

The emissions from cropland remaining cropland were 43 Gg CO_2 in 2004, which is a reduction of 25 per cent from 2003. However, from 1990 to 2004 the emissions of CO_2 decreased by 77 per cent. The emissions from this category in 2004 represented about 2 per cent of the total emissions from the LULUCF sector.

6.2.2 LAND CONVERTED TO CROPLAND – 5B2

Administrative data show that since 1990, the annual conversion to agriculture land has been reduced from about 2 000 ha to 1 200 ha annually (Statistics Norway). Most of the area is used for grass production, but part of the area (about 10 per cent) 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 wetlands.

6.2.2.1 Methodological issues

Land conversion to cropland from forest, grassland or wetlands usually results in a net loss carbon from biomass and soils to the atmosphere (IPCC, 2004).

Change in carbon stock in living biomass

With regard to changes in carbon stocks in living biomass, we have only calculated losses for forest land converted to cropland. We assumed that all living biomass were lost the year of conversion.

Change in carbon stock in dead organic matter

When forest land is converted to cropland we assume all dead organic matter will be cleared.

Change in carbon stocks in soils

According to IPCC (2004) soil organic carbon 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 the equilibrium depend on soil, climate and management conditions. However, because Norwegian data indicate no major difference in soil organic carbon 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).

Norwegian Forest and Landscape Institute 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 at 14.1 kg C/m^2 by Bioforsk. 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.

Bioforsk has collected data on organic matter content of 3 920 farms in Norway.

Table 6.4. Organic matter and C in farm soil. Weight % (source: Bioforsk)

% grass area	Number of farms	Soil OM (%)	Organic C (%)
0	2 009	4.2	2.3
0-80	1 442	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 per cent). 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.

6.2.2.2 Conversions

Forest land converted to cropland

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 occurs via other land or grassland.

Grassland converted to cropland

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 wetlands is converted to agricultural land. Losses are accounted for according to the changes in management (see agriculture remaining agriculture).

Wetland converted to cropland
Conversions between these categories are negligible. The conversion of peatland (wetlands) to agriculture land was addressed above, under cropland remaining cropland. The emissions are not immediate, but occur over time.

Other land converted to cropland
Conversions between these categories are negligible.

6.2.2.3 Recalculations

The whole time-series have been recalculated due to changes in of calculation methods and updating of calculation parameters and activity data.

No emissions were reported for 2004. Emissions are reported every year from 1990 until 1995 and in 1998. After that NFI has not recorded that forest area has been converted to cropland.

6.3 Grassland 5C

According to the area definitions, grassland also includes pasture. Grasslands are used for harvest and pasture. Parts of the pasture land are 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).

6.3.1 GRASSLAND REMAINING GRASSLAND – 5C1 (KEY CATEGORY)

As for agriculture, we consider changes in aboveground biomass and soil carbon. As described earlier, the statistics of Skog og Landskap 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.

This category is identified as key category with respect to changes in carbon stocks in soils because of uncertainty in level. Changes in management have, however, influenced the vegetation on pastures. Gradually, some of this area will fall under the forest definition.

6.3.1.1 Methodological issues

Change in carbon stock in living biomass
As for agriculture, we consider changes in aboveground biomass. Changes in management have, however, influenced the vegetation on pastures.

Change in carbon stock in dead organic matter
We assume no change in dead organic matter for this category because the mass of aboveground biomass is small and is in a steady state in accordance with Tier 1 in IPCC (2004).

Change in carbon stocks in soils
As for agriculture, we consider changes in carbon stocks in soil. 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 have used 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 years, 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 per cent of organic soil 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 Bioforsk at 2 cm/year[4] which is equivalent to 20 Mg C/ha.[5] Some of this reduction is due to compaction and can be attributed to a sink in the height of the soil layer[6]. 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 1 000 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).

Of the total area of 85 000 ha, 90 per cent were assumed used for grass. Of these 76 500 ha, we assume one third is highly organic, the rest is mixed. 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). Further details are given in Table 6.5.

Table 6.5. Farmed organic soils by region (ha).

	20-40 % Organic Matter	**> 40 % Organig Matter**
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
Share of farmed organic soils	66 %	33 %

Given the importance of this estimate compared to other sources and the large difference from the IPCC default value, it is recommended to further improve the emission factor (measurements, modelling and literature). Other Nordic countries have similar agriculture practices. Sweden uses emission factors ranging from 1.6-7.9 Mg C/ha/year (largest for row crops). 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 peat lands) (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 compared to the existing (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).

6.3.1.2 Recalculations

The whole time-series have been recalculated due to changes in of calculation methods and updating of calculation parameters and activity data.

The emissions from grassland remaining grassland in 2004 were estimated at 1 870 Gg of CO_2, which represents 3.5 of the total emissions of greenhouse gases in Norway and 89 per cent of

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

[5] Assuming a soil density of 0.2 kg/l, and 50 per cent C.

[6] Assuming a soil density of 0.2 kg/l, and 50 per cent C.

the total emissions from the LULUCF sector. Emissions of CH_4 and N_2O from the category are negligible. The emissions are considered constant from 1990 to 2004 since there have not been any major changes in management of grasslands in Norway during this period.

6.3.2 LAND CONVERTED TO GRASSLAND – 5C2

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

6.3.2.1 Methodological issues

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

In the case of conversion of forest to grassland, losses in living biomass will be accounted for according to the methodology of estimation described in section 6.1.1. Forest land remaining forest. For other land-use change we assume no net change in carbon of living biomass. This is justified because the IPCC (2004) defaults for aboveground biomass are quite similar for grassland and cropland. (5 Mg carbon/ha for cropland, 8.5 Mg dry matter/ha for grassland (boreal zone) equal to 4.2 given a carbon content of 0.5).

Change in carbon stock in dead organic matter
We assume that all dead organic matter will be cleared when land is converted to grassland.

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

6.3.2.2 Conversions

Conversion of forest land to grassland
We assume that transition from forest land to grassland is rather unlikely, but assume no change in soil organic carbon if recorded.

In the 6th NFI grassland was not a valid option; therefore all plots classified as grassland in the 7th NFI 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 NFI. 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 NFI; 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 clearing for grazing is not current practice. We assume these areas were grassland also in previous years.

Conversion of cropland to grassland
We propose to assume that there is no change in soil organic carbon when cropland is transferred to grassland, because the changes are small and exact data are lacking. Assuming that the grassland is nominally managed and the same level of fertilization, also the IPCC (2004) default method indicates no change.
When cropland is converted to grassland the soil organic matter may change due to changes in management, for example ploughing and N-fertilization. The result is expected to be a net

uptake. According to Statistics Norway the managed grassland area has increased in the nineties. Bioforsk confirms that farms with animals (and grass production) have a slightly higher soil organic carbon than those without (Rypdal et al., 2005). There are no data for grassland outside home fields, but they likely have a lower soil organic carbon.

IPCC default Tier 1 method accounts for differences in soil organic carbon 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 (2004) default method indicates no change.

Some conversion from cropland to grassland has been detected. The lack of transformations between the 6th and 7th NFI are an artefact because grassland was not recorded separately in the 6th NFI 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 NFI. A considerable amount of conversion from cropland to grassland has been detected between the 7th and 8th NFI. 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 NFI. Because this change does not affect the estimates of emissions and removals substantially, we propose using the data as they are reported in the calculations.

Conversion of wetland to grassland

There has been some conversion between wetlands and grassland. Parts of this can be due to new areas used for grazing, but parts may be reclassifications. The changes are, however, small. See discussion on drained organic soils under grassland remaining grassland.

Conversion of other land to grassland

We assume no emissions or removals due to changes in soil carbon when other land-use is converted to grassland.

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

6.3.2.3 Recalculations

The whole time-series have been recalculated due to changes in of calculation methods and updating of calculation parameters and activity data.

Emissions from this category were estimated at 6.2 Gg of CO_2 in 2004, corresponding to 0.3 per cent of the total emissions from the sector that year. In 1990 and 1998 there were no emissions from this category, and the emissions in 2004 decreased by a factor of 7.7 compared to the emissions in 2003.

6.4 Wetlands 5D

All areas regularly covered or saturated by water for at least some time of the year are defined as wetlands. 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.
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). Forestry in Norway has dramatically decreased its drainage of wetlands areas for tree planting over the last decades (Statistics Norway, 2006). The area drained in 1990 was 3.5 kha and only 0.04 kha in 2000.

6.4.1 WETLANDS REMAINING WETLANDS - 5D1

6.4.1.1 Methodological issues

Reservoirs

At present there exists no readily available water or land use change statistics related to dams or reservoirs. Wetlands remaining wetlands is only covered in appendix 3a.3 in the Good Practice Guidance (IPCC, 2004). 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 Bioforsk, peat extraction in Norway is between 220 000 and 300 000 m^3/year (we assume no change in extraction). The extraction is around 5-10 cm/year. This corresponds to $13m^2/m^3$. 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. Although some of the extraction areas may belong to the temperate zone, we propose using the default emission factor for nutrient poor bogs in the boreal zone. The IPCC emission factor is 0.2 Mg C ha^{-1} yr^{-1}.

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/m^2/year). During extraction emissions will be around 10 Mg/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 3.4 Gg CO_2, (using IPCC default data, 1.83 Gg CO_2.)

Wooded mire

Wooded mire according to Norway's national definition will be classified as forest, 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 "wetlands". 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 on agriculture, see Table 6.3. The corresponding emissions are about 25 Gg CO_2 annually.

Other wetlands

Other wetlands are considered unmanaged, and no emissions and removals are estimated (in line with IPCC (2004)).

6.4.1.2 Recalculations

The emissions from wetlands remaining wetlands were re-estimated to 3.4 Gg CO_2 in each year over the period 1990-2004.

6.5 Land converted to wetlands - 5D2

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

Forest land converted to wetlands:
There has been recorded a conversion from forest land to wetlands. Recorded conversions to wetland are considered as artefacts and are not used in the calculations.

Cropland converted to wetlands
The conversions between these categories are negligible. These changes are small today and would not be possible to identify through the NFI.

Grassland converted to wetlands
No conversion has been recorded.

Other land converted to wetlands
There has been an apparent conversion from other land to wetlands. This conversion is hard to explain and is probably caused by differences in judgment of classification during field work. However, these apparent conversions do not have any major consequences for the calculations of emissions and removals and we assume that other land is not vegetated in this situation. We assume no loss or uptake of carbon.

6.6 Settlements 5E

6.6.1 SETTLEMENTS REMAINING SETTLEMENTS – 5E1

Reporting of emissions and removals from this category is not mandatory. There are, furthermore, no data available in Norway to estimate the tree biomass. Changes in carbon stocks for settlements remaining settlements have consequently not been estimated.

6.6.2 LAND CONVERTED TO SETTLEMENTS – 5E2 (KEY CATEGORY)

This land-use category is considered key category because of the contribution to the total emissions from the LULUCF sector (Tier 2). 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).

There has been a rather large conversion from forest land to settlements between the forest inventories. These changes are likely real and are interpreted in this project as deforestation.

Change in carbon stock in living biomass
We suggest that for forest land converted to settlements, only 75 per cent of the average biomass of forest is considered to be lost. The remaining 25 per cent refers to trees that are left standing in the built-up area. This figure is based on expert judgment.

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.

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

Forest land converted to settlements:
Forest 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 1 yr. We propose assuming that settlements have the same soil organic carbon as grassland, and use the same methodology as for cropland remaining cropland in section 6.2.1 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 this version of the inventory no change has been assumed.

Cropland converted to 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. We have assumed no change in soil organic carbon.

Grassland converted to 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. We have assumed no change in soil organic carbon.

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

If wetlands are 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/year.

Other land converted to settlements:
There has been some conversion from other land to settlements. This can be explained for example by road constructions. We assume that in these situations the other land is vegetated. We have assumed no change in soil organic carbon.

6.6.2.1 Recalculations

The whole time-series have been recalculated due to changes in of calculation methods and updating of calculation parameters and activity data.

The emission from this category was estimated at 174 Gg CO_2 in 2004. There are annual variations of emissions from this category. The highest emission was recorded in 1999 with 651 Gg CO_2, while the lowest value, 174 Gg CO_2 was found in the period from 2001 to 2004.

6.7 Other lands 5F

6.7.1 OTHER LAND REMAINING OTHER LAND – 5F1

6.7.1.1 Methodological issues

Change in carbon stock in living biomass
We assumed no change in carbon stock in living biomass. This is in accordance with IPCC (2004) because this land is by default considered unmanaged. For Norway this assumption may

underestimate carbon uptake because vegetation is increasing in many areas due to reduced animal grazing. A reference study based on Tier 1 method is described in Rypdal et al., (2005).

Change in carbon stock in dead organic matter
We assumed no change in carbon stock dead organic matter.

Change in carbon stocks in soils
We assumed no change in carbon stock in soils.

6.7.1.2 Recalculations

No emission/removals recorded

6.7.2 LAND CONVERTED TO OTHER LAND – 5F2

In the case of conversion from forest, 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.

6.7.2.1 Methodological issues

Change in carbon stock in living biomass
There will be a loss of biomass which may be calculated if the conversion is from forest or if there is some tree cover on the land which has been assessed by the NFI. If not, the biomass must be set at 0.

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 no data exists and as discussed before, soil organic carbon for grassland and forest in Norway is quite similar. "Other wooded land" will often be in marginal areas where the soil organic carbon is lower than in agriculture land. However, the same will be true for forest or grassland in these areas.

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

Cropland converted to other land:
The conversions between these categories are negligible.

Grassland converted to other land:
No conversion is detected.

Wetland converted to other land:
No conversion is detected.

6.7.2.2 Recalculations

No emission/ removals recorded.

6.8 Other 5G

Emissions of CO_2 from liming of agricultural soils and lakes are included in this category. The descriptions of the methodologies are contained in Section 6.2.1.2 (under Cropland).

7 Emissions of non-CO_2 gases

Changes in forest and other land use change will influence emissions of other greenhouse gases than CO_2. Emissions of methane (CH_4) are caused by fires. Changes in land-use may change 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 non-CO_2 gases are small (non-key) 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 in the Appendices of IPCC (2004) 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. For the non-CO_2 GHG reservoirs can be a source in Norway, but the corresponding emissions have not been estimated.

7.1.1 FORESTS

N_2O is produced in soils as a by-product 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.

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

Where

$F_{\text{Statistics Norway}}$ = the amount of synthetic fertilizer applied to forest soil adjusted for volatilization as NH_3 and NO_x. Gg N.

F_{ON} = the 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.

There are national statistics on the area with fertilizer applied. This area is very small, only 7 km^2 in 2004 and 26 km^2 in 1990 (Statistics Norway, Forestry Statistics). The statistics do 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 1995-2004. 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 according to IPCC 2004). The amount of fertilizer applied is given as total weight. The nitrogen content is depending on the type used. According to Statistics Norway, 95 per cent NPK-fertilizer is used on wetlands. 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 per cent of applied N. There are no national data to improve this. 1 per cent of the N-applied is volatized as NH_3 (the ammonia model of Statistics Norway).

Table 7.1. Estimated emissions 1990-2004 from fertilization of forest

	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
2003	3	71		74		1.5
2004	1	71		72		1.4
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

The resulting emissions are about 2-4 Mg N_2O per year, which is very small compared to the emissions from agriculture. The emission factor is highly uncertain. According to IPCC (2004), the range in emission factor can be from 0.25 per cent to 6 per cent. The amounts of fertilizer applied to forest have been subtracted from the input to the calculation of emissions from agriculture, because that figure is based on the total fertilizer sale.

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 (IPCC, 2004). However, data are unavailable to estimate this effect (IPCC, 2004) and there are no national data to estimate this. 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 IPCC (2004). 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, the corresponding emission factor is 0.1 kg N_2O-N/ha/year (0.6 for nutrient rich). The range of 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.

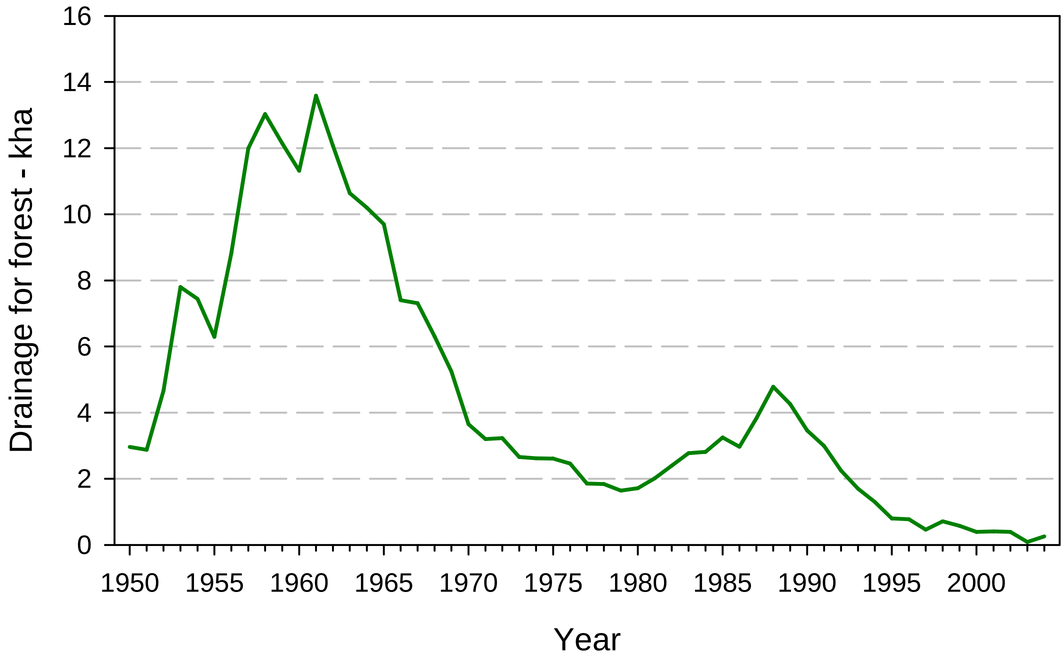

Figure 7.1. Drainage for forest. 1950-2004 (Source: Statistics Norway)

Draining back to 1950 has been taken into account (Figure 7.1). 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.

Table 7.2. Area drained and N2O emissions from drainage of forest soil. 1990-2004.

Year	Area drained (accumulated 1000 ha)	Emissions (Gg)
1990	231.8	0.04
1991	234.8	0.04
1992	237.1	0.04
1993	238.8	0.04
1994	240.0	0.04
1995	240.8	0.04
1996	241.6	0.04
1997	242.1	0.04
1998	242.8	0.04
1999	243.4	0.04
2000	243.8	0.04
2001	244.2	0.04
2002	244.6	0.04
2003	244.7	0.04
2004	244.9	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)[7]. According to IPCC (2004) 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 1993-2004. 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. Because the number of fires was higher in 1990-1992 than later, it is possible that the estimate for the base year is too high.

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 per cent, half of the biomass burned will end up as CO_2. There are no 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 per cent of this (this is consistent with IPCC (2004)). 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 7 500 kg humus per ha, we assume that 10 per cent 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 7.3. Forest fires in Norway 1990-2004

Activity data	Number of fires	Unproductive forest (ha)	Productive forest (ha)	Total area burnt (ha)
1990	578	679.6*	256.4*	935.9*
1991	972	1 142.8*	431.2*	1 574.0*
1992	892	1 048.8*	395.7*	1 444.4*
1993	253	135.5	88.3	223.8*
1994	471	123.6	108.1	231.7
1995	181	77.6	35.5	113.1
1996	246	169.7	343.8	513.5
1997	533	605.8	260.6	866.4
1998	99	164.7	110.3	275
1999	148	734.0	12.7	86.1
2000	99	142.6	29.3	171.9
2001	117	84.3	5.2	89.5
2002	213	124.7	95.8	220.5
2003	198	905.6	36.8	942.4
2004	119	84.6	32.3	116.9

(Source: Directorate for Civil Protection and Emergency Planning)

* Area estimated by Rypdal et al. (2005).

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[7] 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 7.4. CO_2 emissions from forest fires, 1990-2004. Gg

Activity data	Living biomass	Dead wood CO_2 Gg	Humus CO_2 Gg	Total CO_2 Gg
1990	17.2	0.9	1.3	19.3
1991	28.9	1.4	2.2	32.5
1992	26.5	1.3	2.0	29.8
1993	4.1	0.2	0.3	4.6
1994	4.2	0.2	0.3	4.7
1995	2.1	1.0	0.2	2.3
1996	9.4	0.5	0.7	10.6
1997	15.9	0.8	1.2	17.9
1998	5.0	0.3	0.4	5.7
1999	1.6	0.1	0.1	1.8
2000	3.2	0.2	0.2	3.6
2001	1.6	0.1	0.1	1.8
2002	4.0	0.2	0.3	4.5
2003	17.3	0.9	1.3	19.5
2004	2.1	0.1	0.2	2.4

There are no national data on emission factors for non-CO_2 gases from forest fires. Estimates of non-CO_2 gases are therefore based on C released as described in IPCC (2004). The following equations are used:

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
NOx 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.

Table 7.5. Estimates of CH_4 and N_2O emissions from forest fire. 1990-2004. Gg

	CH_4 Gg	N_2O Gg
1990	0.084	0.00058
1991	0.142	0.00097
1992	0.130	0.00089
1993	0.020	0.00014
1994	0.021	0.00014
1995	0.010	0.00007
1996	0.046	0.00031
1997	0.078	0.00054
1998	0.025	0.00017
1999	0.008	0.00005
2000	0.015	0.00016
2001	0.008	0.00006
2002	0.020	0.00014
2003	0.085	0.00058
2004	0.011	0.00007

Conversion to forest land from cropland, grassland and settlements does, according to IPCC (2004), not alter the emissions of non-CO_2 greenhouse gases. Exceptions are in cases of fertilization and drainage as addressed above.

7.1.2 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 20 years * N released by mineralization * Emission factor

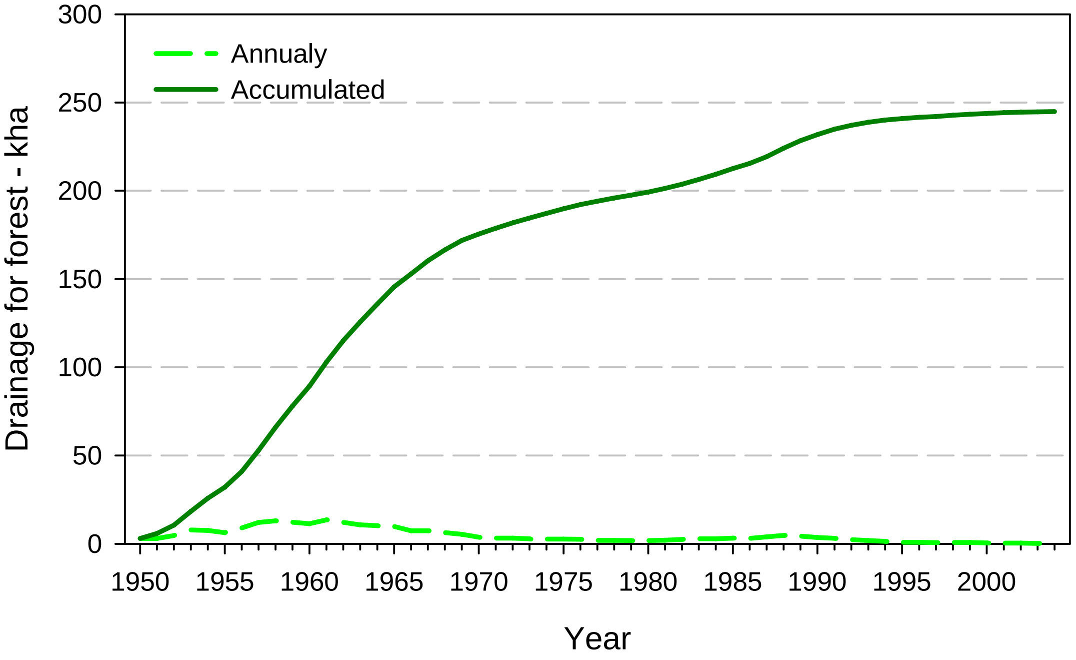

Figure 7.2. New agriculture area (ha). Annual values and accumulated. Source: Statistics Norway.

Data on the area converted last 20 year is available from Statistics Norway for 1970-1992 and for 1994-1998. Data are not available for later years. This area, however, also includes organic soils. The two data sets 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.

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 Bioforsk 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 6.2.1). The default emission factor from IPCC (2004) is 1.25 per cent.

Table 7.6. Area converted to cropland and related N_2O emissions. 1990-2004. Gg

	Area converted last 25 years	Emissions C Gg	Emissions N_2O Gg
1990	151 637	1.56	0.002
1991	145 794	1.50	0.002
1992	139 696	1.36	0.002
1993	133 220	1.21	0.002
1994	128 741	1.08	0.001
1995	124 262	0.96	0.001
1996	118 839	0.85	0.001
1997	113 099	0.81	0.001
1998	106 471	0.77	0.001
1999	99 122	0.72	0.001
2000	92 132	0.66	0.001
2001	85 429	0.61	0.001
2002	78 143	0.48	0.001
2003	70 208	0.42	0.001
2004	63 931	0.43	0.001

7.1.3 GRASSLAND

Emissions from fertilization and drainage of wetlands 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.

7.1.4 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 next year, 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 g/m^2. 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 5.1. That gives us an 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 IPCC (2004) this reduction is not accounted for in the calculations.

8 Uncertainties

The NIJOS 2005 study identified several large uncertainties in the estimates. The uncertainties are particularly large for emissions of non-CO_2 gases and CO_2 from soil (except forest soil). For these categories of emissions and removals also often the activity data are uncertain. Changes in soil organic carbon are difficult to monitor due to up scaling problems, lack of time-series and lack of management data. Nevertheless, we are able to conclude that emissions of non-CO_2 gases are small. 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 until recently has not been included in the National Forest Inventory. These changes are expected to be 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 study. Data are, however, quite certain for stock changes in forest remaining forest which constitute the largest removal of the inventory.

An updated uncertainty analysis of the Norwegian GHG emission inventory is given in Annex II of the National Inventory report 2006 (Anon, 2006d). Due to the unavailability of LULUCF data at the time of the analysis, emission data for 2003 was used. The uncertainty estimates for many LULUCF categories are not of the same quality as the rest of the inventory. More information about the uncertainty estimates for LULUCF is given in report NIJOS 2005 (Rypdal et al., 2005). By including the LULUCF sector the results from the analysis show a total uncertainty of 14 per cent of the mean both in 1990 and in 2004, against 7 per cent without LULUCF. The doubling of uncertainty is caused mainly by forest biomass and grassland histosoils.

The largest uncertainties are related to N_2O from fertilizer use and land disturbances, where the uncertainty will be larger than 100 per cent. 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 per cent. Also CO_2 from agriculture soils are quite uncertain, by more than 100per cent. CO_2 from liming is in the other hand well determined as the application is monitored and the emission factor is based on stoichiometry.

9 Source-specific QA/QC and verification

The Norwegian Forest and Landscape Institute undertakes a control assessment each year to check data quality and ensure consistent methodology in the survey. Statistics Norway examines the various statistical data for consistency over time and between various parts of the inventory. Due to time constraints, we have not provided further information on the QA/QC procedures for the LULUCF sector at this moment. However, Norway will provide more information on the specific QA/QC procedures in the National System report for the Initial Report.

The Norwegian Forest and Landscape Institute will be in charge of archiving all data from the calculations of emissions and removals from LULUCF. Statistics Norway will be in charge of ensuring consistency between LULUCF and non-LULUCF categories and make sure there is no double-counting of emissions or removals between these.

10 Recalculations

The whole time-series have been recalculated due to revision of the method used to calculate total biomass of forest trees. The methods used are described in section 7.4.1.1. New equations for below-ground biomass for *Picea abies, Pinus sylvestris, and Betual* spp. were implemented in the calculation procedure (Peterson and Ståhl, 2006). The impact of this change in formulas is an increase in biomass throughout the period. The method used to recalculate changes of carbon stock in living biomass is revised. We are now using annual data from 1996 to 2004. The uses of moving average for smoothing the time-series results in the relative large changes of CO_2-equivalents from 1997 and onwards compared to the previous submission (see Table 10.1).

Table 10.1. Recalculations in 2006 submission compared to the 2005 submission. Gg CO_2-equivalents (total estimate from the LULUCF sector)

Year	Current submission	Prevoius submission	% change
1990	-14 601	-13 427	8.7%
1991	-14 058	-13 266	6.0%
1992	-14 341	-13 551	5.8%
1993	-13 946	-13 338	4.6%
1994	-14 623	-13 918	5.1%
1995	-13 840	-13 393	3.3%
1996	-14 282	-13 814	3.4%
1997	-14 362	-21 230	-32.3%
1998	-20 209	-20 923	-3.4%
1999	-19 825	-20 922	-5.2%
2000	-25 274	-20 816	21.4%
2001	-27 129	-20 834	30.2%
2002	-26 263	-20 901	25.7%
2003	-26 017	-20 941	24.2%

11 Planned improvements

To confirm the extent of the area of forest and other wooded land at higher altitudes, NFI started in 2005 to establish a limited number of NFI plots above the coniferous forest limit. A complete forest inventory is conducted on these plots. It is not yet decided whether a complete 3x3 grid of plots will be installed in the future, or if the sampling intensity will remain at a lower level in this region.

In Finnmark County, the NFI have started to conduct a full forest inventory on plots in the 3x3 km grid in coniferous forest. Another method and design are under consideration for forest land and other wooded land mainly stocked with birch.

The NFI plans to use national aerial photographs to supplement the field survey. In 2006 a program were established for repeated aerial photo acquisitions of all regions in Norway. The photographs of scale 1:35,000 will cover the entire Norway. The plan is to repeat the photo acquisition every 5 years in the regions where most economic activities take place (agricultural regions, urban areas, other lowland regions) and probably 10 years in other regions (mountain regions).

Current aerial photographs are made available through a web-based service (www.norgeibilder.no). The service can be linked to applications where any selected location can be viewed online. We plan to use these aerial photos to supplement the NFI by update and check land cover statistics and land cover change statistics by assessing plots from the 3 × 3 km grid.

A joint research and development project between NFI and The University of Life Sciences aims at developing reliable inventory methods targeted for use in areas with limited information. Airborne LiDARs (**Li**ght **D**etection **A**nd **R**anging) is a promising remote sensing method for estimation of volume, biomass and carbon, because LiDAR is able to capture the entire 3-dimensional structure of tree canopies. The aim is to develop LIDAR to an operational large scale biomass estimation method.

12 Literature

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