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ESTIMATES OF EMISSIONS AND REMOVALS RESULTING FROM ACTIVITIES UNDER ARTICLE 3.3 AND 3.4 OF THE KYOTO PROTOCOL

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Photo frontpage: Forest in county Buskerud, John Y. Larsson, Skog og landskap

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PREFACE

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The compilation of this report has been carried out in parallel with the development of the (proposed) methodology for accounting and reporting for Norway under Articles 3.3 and 3.4 (if elected) of the Kyoto Protocol. The proposed methodology has naturally changed somewhat since the project started. The proposed methodology also includes data and information not yet available and data quality requirements that are not yet enforced on the available data. It is thus important to be aware that the figures presented in this report are different from those that will be presented in the final reporting and accounting system and should only be interpreted as indicative of the figures that will be presented in the future.

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SUMMARY

As a party to the Kyoto Protocol, Norway will be required to report its emissions by sources and removals by sinks of CO_2 and other greenhouse gases resulting from afforestation, reforestation and deforestation (Article 3.3 of the Kyoto Protocol) for the first commitment period (2008-2012) and receive credits or debits accordingly. Norway will, in 2006, need to make a choice on election of activities under Article 3.4 – Forest Management, Cropland Management, Revegetation and Grazing Land Management. The purpose of this report is to provide estimates of the amount of emissions and removals to be expected under Article 3.3 and initial estimates of magnitudes of emissions/removals for different choices of 3.4 activities. The estimates are preliminary and uncertain

Afforestation and reforestation under Article 3.3.

Sequestration of CO_2 due to afforestation and reforestation is considered small in Norway for the period 1990 to 2012 when only trees established after 1990 are taken into account. In Norway, the rotation period is about 60-120 years and it takes about 8-20 years before a tree reaches breast height[1].

Using National Forest Inventory (NFI) data and considering all land-use change transitions, calculations of carbon sequestration due to afforestation and reforestation overestimate carbon sequestration since all trees on plots meeting the forest definition after 1990 are included in the estimate. Trees that were established before 1990 on other land use classes will also be included as carbon sequestration once the forest definition is met. Although this means that the absolute level of carbon sequestration is overestimated, the difference in carbon stocks between 2008 and 2012 should not be influenced.

Calculations based on statistics of area planted per year indicate that the annual removal of CO_2 is about 3.5 ktonnes CO_2 for the first commitment period 2008-2012. This estimate of afforestation/reforestation is evidently conservative since natural (but human induced) regeneration is not included. Only 0.2 percent of the afforestation/reforestation area since 1991 was regenerated by planting.

Afforestation/reforestation of wetland or other land will in most cases be a result of natural regeneration following altered land management practices. In this respect, it can to some extent be considered human induced, but the land use classification has previously not been monitored systematically and some plots may have jumped between land use classes. During recent years, land use transfers have been carefully checked and the land use classification should be carefully handled for the commitment period 2008-2012 for all land use classes. The estimated annual removal in the commitment period amounts to 0.8 million tonnes CO_2 if all area converted to forest is included. The annual removal amounts to 0.2 million tonnes CO_2 if only area converted from cropland, grassland and settlement is included and area converted from wetland and other land is excluded (Table 1). Theese estimates are based on NFI data which comprises all types of land below the coniferous forest limit and except Finnmark County.

Within the sample-based land inventory programme known as AR18×18, measurements have been carried out for the mountain areas of all counties in south eastern Norway and the area estimates of the different land use/cover classes will be available during the second half of 2006. If we can find acceptable parameters for converting these area estimates to biomass, then total biomass estimates can be provided. Estimation of changes in biomass will, however, require estimates of the area distribution both before and after the reporting period. This can either be solved by repetition of the AR18×18 field inventory, or by using aerial photographs. Aerial photographs will be made available

[1] Breast height is defined as 1.3 metres above the forest floor on the uphill side of the tree. Tree diameter, a parameter used in biomass functions etc., is measured at this height.

through a program for continuous and systematic orthophoto coverage that started in 2006.

Table 1. Preliminary data for CO_2 removal related to afforestation and reforestation under article 3.3 of the Kyoto protocol. 2008-2012. Million tonnes CO_2 per year.

Data from NFI	Average area 1991-2005 kha/yr	Biomass removal 2008-2012 Mt CO_2/yr	Biomass removal 2008-2012 t CO_2/ha
• All area converted to forest	50	0.804	16
• Area converted from cropland, grasland and settlement to forest	4	0.204	50

Taking into account the provisions of the Marrakesh accords, the estimate including all area converted to forest probably overestimates CO_2 sequestration. The estimate based only on land converted from cropland, grassland and settlements is conservative and gives a lower boundary for the expected potential. The results of the calculations are preliminary and uncertain. Methods need further development (cf. NIJOS 2005) and therefore new estimates may turn out to be different from those presented here (Table 1). Main uncertainties and potential error sources for afforestation and reforestation (AR) for reporting under Article 3.3 are listed in table 2 (See also Anon. 2006). In addition to these are problems in distinguishing between natural and human induced changes.

A preparatory database project is required in order to establish the 1990 land use on all the NFI sample plots in Norway. All available data sources including aerial photographs, as well as expert judgments, must be used to fulfill this task (Anon. 2006).

Table 2. Main uncertainties and potential error sources for afforestation and reforestation (AR) for reporting under Article 3.3.

Uncertainties and potential error sources	Effect	Suggestion
National Forest Inventory (NFI) plots on land types other than forest are not inventoried as carefully as forest plots.	Reporting based on NFI data underestimates AR.	Strengthening the NFI with a systematic survey of formerly non-forested plots in the lowlands will improve the reliability considerably. Further strengthening the NFI with a systematic survey above the conifer border line will improve the results, but the cost is high (cf. Anon. 2006).
Uncertain classification in previous inventories (including/excluding wetland or other land types)	The estimates of carbon stock in tables 5-6 are too high but the estimated annual removal in the commitment period should not be influenced.	Include all land use classes and thus avoid having to exclude large potential future forested areas. If land use classes are excluded now, the same land use classes must be excluded in both AR and D to avoid unbalanced results.
Lack of data about biomass on non-forested areas	Overestimation of sequestration when non-forest becomes forest	Development of models for estimating biomass in non-forested areas
Soil carbon estimation: Soil carbon is assumed unchanged for AR	Possibly leads to very small underestimation of sequestration	
Non-CO_2	Omission of non-CO_2 gases leads to an overestimate of net sequestration. However, this error is small.	

Deforestation under Article 3.3.

Emission of CO_2 due to deforestation is considered small in Norway for the period 1990 to 2012 and mainly caused by forest converted to cropland, grassland and settlement.

When we consider all possible area transitions that have been detected from forest to another land-use class, the annual emissions for the period 2008-2012 are estimated at 0.66 million tonnes CO_2, see Table 3. Changes in above- and below-ground biomass carbon stock constitute 0.20 million tonnes CO_2 of this estimate, while decomposition of carbon in litter, dead wood and soils amounts to 0.46 million tonnes CO_2. The estimates are based on interpolation of NFI data from recent years. The uncertain estimates of carbon in litter, dead wood and soils are calculated from area based average Norwegian values.

The estimates above include transitions from forest to wetland or other land. It is likely that the recorded changes from forest to wetland or other land are the result of assessment difficulties

(borderline cases) or natural changes in decreasing crown cover below the forest threshold and are therefore not human induced deforestation events. When disregarding land use changes from forest to wetland or other land the emissions are estimated to be 0.35 million tonnes CO_2 per year. This estimate may be more representative for deforestation reported under Article 3.3 of the Kyoto Protocol. The carbon changes due to deforestation are summarized in table 3.

Table 3. Preliminary data for CO_2 emissions related to deforestation under article 3.3 of the Kyoto protocol 2008-2012. Million tonnes CO_2 per year.

		Emission from deforestation			
	Area deforested 2001 kha	Living carbon Mt CO_2/yr	Dead carbon Mt CO_2/yr	Total MtCO_2/yr	Emission pr area tCO_2/ha
All area converted from forest	12	0.203	0.459	0.661	50
Forest area converted from cropland, grasland and settlement	4.5	0.175	0.176	0.351	80

Different error sources are listed in table 4 (See also Anon. 2006).

Table 4. Main uncertainties and potential error sources when reporting deforestation (D) under Article 3.3.

Uncertainties and potential error sources	Effect	Suggestion
Only NFI plots below the conifer border line in mountainous areas.	The NFI underestimates the conversion of unproductive forest to other land use (D) for reporting under Article 3.3.	Solutions are discussed in Anon. (2006).
Uncertain classification in previous inventories (including/excluding wetland or other land)		Include all land use classes and thus avoid having to exclude large potential future forested areas. If land use classes are excluded now the same land use classes must be excluded in both AR and D to avoid unbalanced results.
Soil carbon estimation: Average national values pr. ha used.	Too high estimates for less dense plots and to small estimates for fully stocked stands.	Improve soil carbon calculation by implementing plot based calculations.
Soil carbon estimation: All soil carbon is counted at time of area transfer.	If the deforestation level is stable, this will probably not have any effects.	Some kind of discounting might be used.
Non-CO_2	High uncertainties and lack of spatial data	

The preliminary estimates for Article 3.3 show that D constitutes only a small source of emissions and that AR nearly balances D when wetland and other land are disregarded. More accurate and representative data can change this picture and it is more likely that sequestration is underestimated than that deforestation is underestimated.

Forest Management under Article 3.4

For Forest Management (FM), the estimated removals are currently more than 7,780 Gg C annually (corresponding to more than 28 Mt CO_2), and the annual removals are expected to be of approximately the same size during the commitment period. This removal is 15 times the cap for crediting set in the Marrakesh Accords of 0.4 Mt (Tg) C/year. This estimate is conditional on the assumption that all land considered as “forest remaining forest” is considered as forest management. The estimate has low uncertainty, but can be considered slightly underestimated since some areas meeting the forest definition (but not included in the NFI, for example Finnmark county) are excluded from the estimates.

Other Activities under Article 3.4

This includes cropland management (CM), revegetation (RV) and Grazing Land Management (GM). GM and RV are considered overlapping and GM has not been considered separately.

Since this work has not evaluated the areas suitable for the different activities, the estimates include all potential area. It is probably realistic that only a fraction of this will be suitable for implementation of mitigation measures. The potential is furthermore given for a longer time horizon than 2012. Generally, the effect of measures until 2012 will be small since processes are slow and incentives are not in place. Therefore, overall the potential for sequestration due to 3.4 activities is considered small until 2012. The basis for reporting in accordance with the requirements is also poor (especially for the base year 1990) and electing to report CM would require improved monitoring. The same considerations apply to RV. Preliminary calculations show that the annual sequestration due to RV is small and it is hard to distinguish between natural and human induced changes. Furthermore, sufficient data are not available for accurate reporting.

1. INTRODUCTION

Under the Kyoto Protocol, all parties are committed to report their emissions by sources and removals by sinks of CO_2 and other greenhouse gases (GHG) resulting from land use, land use change and forestry (LULUCF) activities. The parties will be credited/debited for "human-induced land use change and forestry activities limited to afforestation (A), reforestation (R) and deforestation (D) since 1990" taking place in the commitment period (2008-2012). These are the so-called Article 3.3 activities and are often abbreviated AR and D. A Party may also elect other activities (Article 3.4 activities as elaborated in the Marrakesh Accords[2]), these are forest management (FM), cropland management (CM), grazing land management (GM) and revegetation (RV). Special accounting rules apply for these activities. For FM there is a predefined threshold for credits. For Norway this threshold is 0.4 Mt C/year (1.47 Mt CO_2, equivalent to 3.0 % of the total GHG emissions in Norway in 1990). The other Article 3.4 activities are credited on a net-net basis, meaning that annual average emissions and removals over the commitment period are calculated relative to the base year and credits are given for a reduction in emissions or increase in sinks relative to 1990. The activities, if elected, will similarly be debited if emissions have increased or sinks decreased.

As a Party to the Kyoto Protocol, Norway will be required to report its emissions and removals due to afforestation, reforestation and deforestation (Article 3.3 of the Kyoto protocol) for the first commitment period (2008-2012) and receive credits or debits accordingly. As part of its Initial Report, Norway must by the end of 2006 make a choice on electing of activities under Article 3.4 – Forest Management, Cropland Management, Revegetation and Grazing land management. The purpose of this report is to provide estimates of the amount of emissions and removals to be expected under Article 3.3 and to give initial estimates of magnitudes of emissions/removals for different choices of 3.4 Activities. The results of the calculations are regarded as preliminary and uncertain. The methods used need further development (cf. NIJOS 2005) and therefore later calculations may give different estimates compared to those presented here.

Guidance for reporting emissions and removals under the Article 3.3 and 3.4 activities of the Kyoto Protocol is included in the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC 2004). Chapter 4 of this report specifically addresses reporting under the Kyoto Protocol, while relevant methodology guidance is also given in Chapter 3 as recommended for UNFCCC reporting.

Norway has developed an inventory of emissions and removals from LULUCF for reporting to UNFCCC (NIJOS 2005) consistent with the IPCC Good Practice Guidance. The LULUCF sector constitutes a large net sink for Norway. The National Forest Inventory (NFI) was the main source of data to estimate this sink. It was supplemented with administrative information, research data and default values (IPCC 2004). NIJOS (2005), consistent with IPCC 2004, suggested that the Kyoto Protocol reporting as far as possible should be based on the same methods and data as the UNFCCC reporting.

The present report provides estimates of emissions and removals for the commitment period using the best available information. The methods and definitions applied are given in Anon. (2006).

[2] FCCC/CP/2001/13/Add.1

2. ARTICLE 3.3 ACTIVITIES

2.1. AFFORESTATION AND REFORESTATION

As stated in Anon. (2006) reporting of emissions and removals from activities under Article 3.3 and FM (if elected) in Norway has to rely on data from the NFI. There are no other sources of data with an appropriate coverage in space and time to substitute these data. However, use of other administrative and research data to actively verify the data from the NFI is recommended. Use of other data sources is discussed in Anon. (2006). The NFI comprises all types of land below the coniferous forest limit and except Finnmark County, but a more comprehensive description is made only for forest land. Estimates are here based on tree and stand attributes from the permanent NFI sample plots located throughout Norway. However, statistics of planted area per year available from Norwegian Agricultural Authority (SLF) are presented for verification of the calculations based on NFI data.

Calculations based on NFI sample plots provide a complete description of afforestation and reforestation since 1990. However, effects of activities before 1990 influence NFI data. For example, area transitions have been registered by the NFI after 1990 but the trees in these areas might have been established before 1990. In this case, the whole carbon stock of these trees will be counted when the areas meet the definition of forest land which is consistent with the FAO definitions. It is also difficult to extract *human-induced* land use change and forestry activities, limited to afforestation, reforestation and deforestation *since 1990* based on NFI data. Consequently land use change calculations based on NFI data will be overestimates since trees that were established before 1990 on other land use classes are included in the estimate of carbon sequestration when the forest definition is met (assuming zero biomass before the forest definition is met). The difference between the estimates for 2008 and 2012 should not be influenced even if the level of total carbon sequestration is overestimated. This interpretation of the Kyoto protocol article 3.3 requirements means that sequestration from trees established before 1990 are counted when the plot meets the forest definition after 1990. Otherwise, a careful evaluation of the NFI database is needed to sort out NFI plots with only trees established after 1990 on plots meeting the Kyoto protocol article 3.3 requirements.

A preparatory database project is required in order to establish the 1990 land use on all the NFI sample plots in Norway. All available data sources including aerial photographs, as well as expert judgments, must be used to fulfill this task (Anon. 2006).

Calculations based on statistics from SLF will not include carbon stock of trees established by natural (but still human induced) regeneration after 1990. However, with Norwegian growth conditions effects of natural regeneration after 1990 will be small when only changes in the period 2008 – 2012 are considered. Furthermore, the SLF data are not spatially explicit and these do not meet the requirements for reporting under the Kyoto Protocol.

Carbon in dead organic matter and in soil is considered unchanged when effects of afforestation and reforestation are calculated. This will result in a small under-reporting of the carbon sequestration. This assumption should be reconsidered when the reporting framework is developed for the commitment period.

2.1.1 CALCULATIONS BASED ON NFI DATA

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. The biomass of deciduous tree foliage was calculated by assuming it to be 1.1 % of the stem volume, with a dry weight of 0.520 Mg m^3 (Lethonen et al. 2004).

Tree and stand attributes from the permanent NFI sample plots, located throughout Norway (below the coniferous forest limit and except Finnmark County), were used for the calculations. Biomass estimates are based on tree and stand attributes on forest and other wooded land.

The biomass for trees with larger diameter than 10cm at breast height*(d_{bh})* was calculated by using diameter and height for the basal area mean tree. For trees with d_{bh} between 5cm and 10cm the biomass was calculated by means of biomass equations based only on diameter at breast height. The volume of coniferous and deciduous trees in young forest was calculated on the basis of observed mean height, estimated mean diameter and the number of coniferous and deciduous trees on the NFI plot. Mean diameter was calculated by using the simple equation given in section 2.1.1 (Tomter 1998, unpubl).

The calculations of annual carbon stock in living biomass are based on figures from the NFI, which is performed for 5-year cycles. For the period 1991-1995 we have used the average change in carbon stock for the period. From 1996 and onward we have used 5 years moving average in order to smooth out the estimated carbon stock. The reported value for 1990 is based on the inventory value conducted in 1986 until 1993 (Tables 5-6).

Carbon stock is calculated according to a Tier 3 method of IPCC (2004).

Two different alternatives for the calculations based on NFI data are presented:

a) All land use transfers (Table 5).

b) Only land use transfers from cropland, grassland and settlements since only these land use transfers can with high certainty be considered “human induced” (Table 6).

Afforestation/reforestation of wetland or other land will in most cases be a result of natural regeneration following altered land management practices. In this respect, it can also be considered human induced, but this has not previously been monitored systematically and it is hard to decide which changes have taken place after 1990.

Land use class for some NFI plots has changed to and from the forest class during the years. However, during recent years land use classification is more carefully handled and misclassification is thus more seldom.

The values from 2002 to 2012 are calculated as averages for the period from 1997 to 2001.

The estimates are assessed to be inaccurate for individual years. Any bias is due to the delineation of area changes included and accounting for biomass in non-forested plots. A conservative reporting (under-estimating the removal) may be recommended in case of difficulties in documenting changes and to what extent they are human induced.

Table 5. Accumulated area and carbon stock of afforested and reforested land since 1990.

Year	Forest area (kha) converted from land use class								Carbon stock (Gg C)[3]
	Cropland	Grassland	Other	Settlements	Wetland	Sum	Accumulated Forest Area	Total	
1990	2.10	0.00	3.46	1.65	1.50	8.72	0.00	8.72	158.73
1991	2.10	0.00	3.46	1.65	1.50	8.72	8.72	17.43	317.47
1992	2.10	0.00	3.46	1.65	1.50	8.72	17.43	26.15	476.20
1993	2.10	0.00	3.46	1.65	1.50	8.72	26.15	34.86	634.93
1994	2.10	0.00	3.46	1.65	1.50	8.72	34.86	43.58	793.67
1995	2.10	0.00	3.46	1.65	1.50	8.72	43.58	52.30	952.40
1996	1.80	0.00	62.21	0.90	25.25	90.16	52.30	142.46	1111.13
1997	0.90	0.00	67.62	0.90	30.66	100.08	141.56	241.64	1269.87
1998	2.71	0.90	62.21	0.00	20.74	86.56	241.64	328.19	1614.55
1999	2.71	2.71	51.39	0.90	26.15	83.85	328.19	412.04	1939.80
2000	3.61	0.90	35.16	1.80	18.03	59.51	410.24	469.75	2139.76
2001	0.90	0.00	27.05	0.00	15.33	43.28	469.75	513.03	2366.84
2002	2.16	0.90	48.69	0.72	22.18	74.66	513.03	587.68	2586.23
2003	2.16	0.90	48.69	0.72	22.18	74.66	587.68	662.34	2805.62
2004	2.16	0.90	48.69	0.72	22.18	74.66	662.34	736.99	3025.02
2005	2.16	0.90	48.69	0.72	22.18	74.66	736.99	811.65	3244.41
2006	2.16	0.90	48.69	0.72	22.18	74.66	811.65	886.30	3463.81
2007	2.16	0.90	48.69	0.72	22.18	74.66	886.30	960.96	3683.20
2008	2.16	0.90	48.69	0.72	22.18	74.66	960.96	1035.61	3902.59
2009	2.16	0.90	48.69	0.72	22.18	74.66	1035.61	1110.27	4121.99
2010	2.16	0.90	48.69	0.72	22.18	74.66	1110.27	1184.92	4341.38
2011	2.16	0.90	48.69	0.72	22.18	74.66	1184.92	1259.58	4560.78
2012	2.16	0.90	48.69	0.72	22.18	74.66	1259.58	1334.23	4780.17

[3] Accumulated forest area in e.g. 2000 is less than the Total area of afforestation and reforestation since the beginning of the commitment period because some plots have changed from forest to other land uses again.

Table 6. Accumulated area and carbon stock of afforested and reforested land since 1990 (excluding transfers from wetland and other land classes).

Year	Forest area (kha) converted from land use class						Carbon stock (Gg C)
	Cropland	Grassland	Settlements	Sum	Accumulated Forest Area	Total	
1990	2.10	0.00	1.65	3.76	0.00	3.76	42.35
1991	2.10	0.00	1.65	3.76	3.76	7.51	84.69
1992	2.10	0.00	1.65	3.76	7.51	11.27	127.04
1993	2.10	0.00	1.65	3.76	11.27	15.03	169.39
1994	2.10	0.00	1.65	3.76	15.03	18.79	211.73
1995	2.10	0.00	1.65	3.76	18.79	22.54	254.08
1996	1.80	0.00	0.90	2.71	22.54	25.25	296.42
1997	0.90	0.00	0.90	1.80	25.25	27.05	338.77
1998	2.71	0.90	0.00	3.61	27.05	30.66	377.19
1999	2.71	2.71	0.90	6.31	30.66	36.97	462.08
2000	3.61	0.90	1.80	6.31	36.97	43.28	515.16
2001	0.90	0.00	0.00	0.90	43.28	44.18	616.11
2002	2.16	0.90	0.72	3.79	44.18	47.97	671.58
2003	2.16	0.90	0.72	3.79	47.97	51.76	727.05
2004	2.16	0.90	0.72	3.79	51.76	55.55	782.51
2005	2.16	0.90	0.72	3.79	55.55	59.33	837.98
2006	2.16	0.90	0.72	3.79	59.33	63.12	893.45
2007	2.16	0.90	0.72	3.79	63.12	66.91	948.92
2008	2.16	0.90	0.72	3.79	66.91	70.70	1004.39
2009	2.16	0.90	0.72	3.79	70.70	74.48	1059.85
2010	2.16	0.90	0.72	3.79	74.48	78.27	1115.32
2011	2.16	0.90	0.72	3.79	78.27	82.06	1170.79
2012	2.16	0.90	0.72	3.79	82.06	85.85	1226.26

When all area transitions are included, the estimated annual removal in the commitment period amounts to 0.8 million tonnes CO_2. Taking into account only transitions from cropland, grassland and settlements, the estimated annual removal in the commitment period amounts to 0.2 million tonnes CO_2. The lowest estimate is conservative, while the real value that can be attributed to human induced changes falls within the interval.

2.1.1.1 Calculations based on statistics of planted area

To verify the data from the National Forest Inventory, statistics for planted area per year have been used. The data is compiled by the Norwegian Agricultural Authority (SLF). The area is in hectares and can be subdivided into different land categories.

Table 7. Planted area (ha) per year.

Year	Other open land	Agricultural land	Wetland	Open land Covered with juniper	Total
1991	502	153	389	86	1129
1992	480	681	398	91	1650
1993	435	375	262	92	1163
1994	510	290	152	57	1009
1995	457	224	125	56	863
1996	558	157	95	54	864
1997	280	148	92	52	572
1998	376	137	80	72	665
1999	449	143	69	59	719
2000	388	121	60	81	649
2001	646	99	35	81	862
2002	218	101	13	39	371
2003	109	84	6	12	210
2004	87	60	5	13	165
2005	63	42	3	2	109
Total	5555	2816	1783	847	11001

By applying the following assumptions, a rough estimate can be obtained of the standing volume and the associated biomass that would be expected in the area in the future.

Assumptions:

Site quality class: H_{40}=14 (production capacity for spruce = 5.5 m^3/ha/year)

Number of trees per hectare = 1800

Simplified equations for the relationship between diameter at breast height(d_{bh}) and tree height (h), and between stem volume (v) and dbh have been used:

$d_{bh} = 1.4h - 1.8$
$v = 0.2(1 + d_{bh}^2)$

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.

Total volume of all biomass of a tree has been estimated as 1.5 times stem volume.
Dry matter has been estimated as 0.4 tonnes/m^3 of total volume.
Carbon contents have been estimated as 0.5 of total dry matter.

Table 8. Estimated tree growth and carbon uptake in tree biomass.

Year	Height	d_{bh}	Volume/tree	Cu.m./ha	Tonnes C/ha
13	1.30	0.02	0.20008	0.36014	0.1080432
14	1.65	0.51	0.25202	0.45364	0.1360908
15	2.00	1.00	0.40000	0.72000	0.2160000
16	2.35	1.49	0.64402	1.15924	0.3477708
17	2.70	1.98	0.98408	1.77134	0.5314032
18	3.05	2.47	1.42018	2.55632	0.7668972
19	3.40	2.96	1.95232	3.51418	1.0542528
20	3.75	3.45	2.58050	4.64490	1.3934700
21	4.10	3.94	3.30472	5.94850	1.7845488
22	4.45	4.43	4.12498	7.42496	2.2274892
23	4.80	4.92	5.04128	9.07430	2.7222912

d_{bh}: diameter at breast height

Based on these assumptions the effects of afforestation and reforestation since 1990 have been calculated (Table 9). Since data for area planted in 1990 are missing, it has been assumed that they are equal to those reported in 1991.

Table 9. Accumulated carbon stock (Gg C) in trees on land that has been afforested or reforested since 1990.

Year	Other open land	Agricultural land	Wetland	Open land Covered with juniper	Total
1990	0	0	0	0	0
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	0	0	0	0	0
1994	0	0	0	0	0
1995	0	0	0	0	0
1996	0	0	0	0	0
1997	0	0	0	0	0
1998	0	0	0	0	0
1999	0	0	0	0	0
2000	0	0	0	0	0
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0.065	0.093	0.054	0.012	0.225
2005	0.159	0.174	0.111	0.032	0.476
2006	0.336	0.275	0.164	0.052	0.827
2007	0.579	0.394	0.230	0.082	1.285
2008	1.007	0.514	0.303	0.123	1.947
2009	1.302	0.670	0.400	0.178	2.550
2010	1.825	0.862	0.511	0.279	3.477
2011	2.626	1.117	0.634	0.383	4.760
2012	3.490	1.385	0.766	0.565	6.206

This corresponds to an average annual removal in the commitment period of 3.5 ktonnes CO_2. Compared with the estimates based on National Forest Inventory data, the calculations based on planting statistics suggest that most of the regeneration and carbon removal is based on natural regeneration, although a large part of this can be considered human induced as it is related to changes in land and agricultural management.

2.2. DEFORESTATION

Calculation of deforestation is based on NFI data. The calculation of living biomass is described in chapter 2.1.1.

The carbon stock in dead organic matter due to litter from standing biomass, unrecovered 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 for the whole country. Average national values pr. ha have then been assigned to the deforested NFI plots as approximate values. In addition to NFI data, harvest statistics compiled by Statistics Norway (SSB) have been used as input to the calculation of the amount of dead organic carbon and soil carbon subroutine.

The dynamic soil model YASSO, as described in detail by de Wit et al. (2006), was used to calculate 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 requires estimates of litter production and simple climate data. The model has two litter compartments that relate to physical fractions of litter and five soil components that differentiate microbial decomposition and humidification processes. The litter and soil compartments can be viewed as “dead wood” and “soil organic matter”. With the current parameters (Liski et al., 2005) the model gives an estimate of the soil organic matter down to the depth of 1 m in mineral soil.

Forest harvest influences the amount of harvest waste and therefore also the estimate of “dead organic matter”. Calculations of carbon stock are done according to a Tier 3 method.

Two different alternatives for the calculations based on NFI data are presented:

A. All land use transfers
    - Deforested area (Table 10).
    - Carbon stock in living above and below-ground biomass at the time of deforestation (Table 12).
    - Carbon stock in litter, dead wood and soils at the time of deforestation, calculated from average values for forested areas (Table 14).
    - The total effect of deforestation i.e. the sum of carbon stock in living above and below-ground biomass and the carbon stock in litter, dead wood and soils at the time of deforestation (Table 16).
B. Only land use transfers from cropland, grassland and settlements since only these land use transfers were considered “human induced”.
    - Deforested area (Table 11).
    - Carbon stock in living above and below-ground biomass at the time of deforestation (Table 13).
    - Carbon stock in litter, dead wood and soils at the time of deforestation, calculated from average values for forested areas (Table 15).
    - The total effect of deforestation i.e. the sum of carbon stock in living above and below-ground biomass and the carbon stock in litter, dead wood and soils at the time of deforestation (Table 17).

It is likely that changes from forest to wetland or other land come about as a result of assessment difficulties (borderline cases) or natural changes decreasing the crown cover below the forest threshold and not human induced deforestation events. Therefore the latter estimate may be more appropriate for reporting under Article 3.3 of the Kyoto Protocol.

The estimate of land use transfers should be improved from 2005 since the reason for the land use transfers is also registered for the NFI plots.

Table 10. Annual area of deforestation since 1990.

Year	Deforestation area, new land use class					
	Area (k ha)					
	Cropland	Grassland	Other	Settlements	Wetland	Sum
1990	0.60	0.00	12.47	4.21	4.96	22.24
1991	0.60	0.00	12.47	4.21	4.96	22.24
1992	0.60	0.00	12.47	4.21	4.96	22.24
1993	0.60	0.00	12.47	4.21	4.96	22.24
1994	0.60	0.00	12.47	4.21	4.96	22.24
1995	0.60	0.00	12.47	4.21	4.96	22.24
1996	0.00	0.00	9.02	3.61	4.51	17.13
1997	0.00	0.90	10.82	1.80	4.51	18.03
1998	0.90	0.00	10.82	3.61	2.71	18.03
1999	0.00	0.00	5.41	2.71	2.71	10.82
2000	0.00	1.80	5.41	5.41	4.51	17.13
2001	0.00	0.90	3.61	3.61	3.61	11.72
2002	0.00	0.90	3.61	3.61	3.61	11.72
2003	0.00	0.90	3.61	3.61	3.61	11.72
2004	0.00	0.90	3.61	3.61	3.61	11.72
2005	0.00	0.90	3.61	3.61	3.61	11.72
2006	0.00	0.90	3.61	3.61	3.61	11.72
2007	0.00	0.90	3.61	3.61	3.61	11.72
2008	0.00	0.90	3.61	3.61	3.61	11.72
2009	0.00	0.90	3.61	3.61	3.61	11.72
2010	0.00	0.90	3.61	3.61	3.61	11.72
2011	0.00	0.90	3.61	3.61	3.61	11.72
2012	0.00	0.90	3.61	3.61	3.61	11.72

Table 11. Annual area of deforestation since 1990 (Only cropland, grassland and settlements).

Year	Deforestation area (k ha), new land use class			
	Cropland	Grassland	Settlements	Sum
1990	0.60	0.00	4.21	4.81
1991	0.60	0.00	4.21	4.81
1992	0.60	0.00	4.21	4.81
1993	0.60	0.00	4.21	4.81
1994	0.60	0.00	4.21	4.81
1995	0.60	0.00	4.21	4.81
1996	0.00	0.00	3.61	3.61
1997	0.00	0.90	1.80	2.71
1998	0.90	0.00	3.61	4.51
1999	0.00	0.00	2.71	2.71
2000	0.00	1.80	5.41	7.21
2001	0.00	0.90	3.61	4.51
2002	0.00	0.90	3.61	4.51
2003	0.00	0.90	3.61	4.51
2004	0.00	0.90	3.61	4.51
2005	0.00	0.90	3.61	4.51
2006	0.00	0.90	3.61	4.51
2007	0.00	0.90	3.61	4.51
2008	0.00	0.90	3.61	4.51
2009	0.00	0.90	3.61	4.51
2010	0.00	0.90	3.61	4.51
2011	0.00	0.90	3.61	4.51
2012	0.00	0.90	3.61	4.51

Table 12. Carbon stock in living above and below-ground biomass at the time of deforestation.

Year	Deforestation, new land use class					Sum
	Carbon stock (Gg C)					
	Cropland	Grassland	Other	Settlements	Wetland	
1990	-6.52	0.00	-38.69	-60.31	-4.64	-110.16
1991	-6.52	0.00	-38.69	-60.31	-4.64	-110.16
1992	-6.52	0.00	-38.69	-60.31	-4.64	-110.16
1993	-6.52	0.00	-38.69	-60.31	-4.64	-110.16
1994	-6.52	0.00	-38.69	-60.31	-4.64	-110.16
1995	-6.52	0.00	-38.69	-60.31	-4.64	-110.16
1996	0.00	0.00	-22.95	-138.39	-6.82	-168.16
1997	0.00	0.00	-20.02	-88.69	-9.42	-118.13
1998	-32.04	0.00	-49.40	-98.50	-1.17	-181.10
1999	0.00	0.00	-3.57	-177.46	-3.80	-184.83
2000	0.00	-6.21	-4.75	-60.38	-14.43	-85.77
2001	0.00	0.00	-4.22	-47.56	-3.60	-55.38
2002	0.00	0.00	-4.22	-47.56	-3.60	-55.38
2003	0.00	0.00	-4.22	-47.56	-3.60	-55.38
2004	0.00	0.00	-4.22	-47.56	-3.60	-55.38
2005	0.00	0.00	-4.22	-47.56	-3.60	-55.38
2006	0.00	0.00	-4.22	-47.56	-3.60	-55.38
2007	0.00	0.00	-4.22	-47.56	-3.60	-55.38
2008	0.00	0.00	-4.22	-47.56	-3.60	-55.38
2009	0.00	0.00	-4.22	-47.56	-3.60	-55.38
2010	0.00	0.00	-4.22	-47.56	-3.60	-55.38
2011	0.00	0.00	-4.22	-47.56	-3.60	-55.38
2012	0.00	0.00	-4.22	-47.56	-3.60	-55.38

Table 13. Carbon stock in living above and below-ground biomass at the time of deforestation (Only conversions to cropland, grassland and settlements).

Year	Deforestation, new land use class			
	Carbon stock (Gg C)			
	Cropland	Grassland	Settlements	Sum
1990	-6.52	0.00	-60.31	-66.83
1991	-6.52	0.00	-60.31	-66.83
1992	-6.52	0.00	-60.31	-66.83
1993	-6.52	0.00	-60.31	-66.83
1994	-6.52	0.00	-60.31	-66.83
1995	-6.52	0.00	-60.31	-66.83
1996	0.00	0.00	-138.39	-138.39
1997	0.00	0.00	-88.69	-88.69
1998	-32.04	0.00	-98.50	-130.54
1999	0.00	0.00	-177.46	-177.46
2000	0.00	-6.21	-60.38	-66.59
2001	0.00	0.00	-47.56	-47.56
2002	0.00	0.00	-47.56	-47.56
2003	0.00	0.00	-47.56	-47.56
2004	0.00	0.00	-47.56	-47.56
2005	0.00	0.00	-47.56	-47.56
2006	0.00	0.00	-47.56	-47.56
2007	0.00	0.00	-47.56	-47.56
2008	0.00	0.00	-47.56	-47.56
2009	0.00	0.00	-47.56	-47.56
2010	0.00	0.00	-47.56	-47.56
2011	0.00	0.00	-47.56	-47.56
2012	0.00	0.00	-47.56	-47.56

Table 14. Carbon stock in litter, dead wood and soils at the time of deforestation, calculated from average values for forested areas.

	Deforestation				
	Area	Net carbon stock (Gg C)			
Year	(kha)	Litter	Dead wood	Soils	Sum
1990	22.24	-17.09	-46.91	-129.34	-193.34
1991	22.24	-17.35	-47.28	-132.26	-196.89
1992	22.24	-17.73	-47.79	-135.09	-200.61
1993	22.24	-18.03	-48.03	-138.02	-204.09
1994	22.24	-18.50	-48.66	-140.87	-208.04
1995	22.24	-18.73	-48.81	-143.94	-211.48
1996	17.13	-14.78	-37.94	-113.08	-165.81
1997	18.03	-15.63	-39.90	-119.99	-175.52
1998	18.03	-15.61	-39.65	-120.76	-176.02
1999	10.82	-9.41	-23.75	-73.07	-106.23
2000	17.13	-14.91	-37.43	-116.54	-168.87
2001	11.72	-10.28	-25.63	-80.64	-116.54
2002	11.72	-10.33	-25.60	-81.59	-117.52
2003	11.72	-10.38	-25.53	-82.49	-118.39
2004	11.72	-10.47	-25.53	-83.35	-119.35
2005	11.72	-10.53	-25.53	-84.23	-120.29
2006	11.72	-10.60	-25.52	-85.11	-121.24
2007	11.72	-10.67	-25.51	-85.99	-122.17
2008	11.72	-10.74	-25.50	-86.87	-123.11
2009	11.72	-10.80	-25.49	-87.74	-124.03
2010	11.72	-10.87	-25.48	-88.61	-124.95
2011	11.72	-10.93	-25.46	-89.47	-125.87
2012	11.72	-10.99	-25.44	-90.33	-126.77

Table 15. Carbon stock in litter, dead wood and soils at the time of deforestation, calculated from average values for forested areas (Only conversions to cropland, grassland and settlements).

	Deforestation				
	Area	Net carbon stock (Gg C)			
Year	(kha)	Litter	Dead wood	Soils	Sum
1990	4.81	-3.70	-10.14	-27.97	-41.81
1991	4.81	-3.75	-10.22	-28.60	-42.57
1992	4.81	-3.83	-10.33	-29.21	-43.38
1993	4.81	-3.90	-10.39	-29.85	-44.13
1994	4.81	-4.00	-10.52	-30.46	-44.98
1995	4.81	-4.05	-10.55	-31.12	-45.73
1996	3.61	-3.11	-7.99	-23.81	-34.91
1997	2.71	-2.35	-5.98	-18.00	-26.33
1998	4.51	-3.90	-9.91	-30.20	-44.01
1999	2.71	-2.35	-5.94	-18.27	-26.56
2000	7.21	-6.28	-15.76	-49.07	-71.10
2001	4.51	-3.95	-9.86	-31.02	-44.83
2002	4.51	-3.97	-9.85	-31.39	-45.21
2003	4.51	-3.99	-9.82	-31.73	-45.55
2004	4.51	-4.03	-9.82	-32.06	-45.91
2005	4.51	-4.05	-9.82	-32.40	-46.28
2006	4.51	-4.08	-9.82	-32.74	-46.64
2007	4.51	-4.10	-9.81	-33.08	-47.00
2008	4.51	-4.13	-9.81	-33.42	-47.36
2009	4.51	-4.15	-9.81	-33.75	-47.71
2010	4.51	-4.18	-9.80	-34.09	-48.07
2011	4.51	-4.21	-9.79	-34.42	-48.42
2012	4.51	-4.23	-9.79	-34.75	-48.77

Table 16. Total effect of deforestation i.e. the sum of carbon stock in living above and below-ground biomass and the carbon stock in litter, dead wood and soils at the time of deforestation

Year	Carbon stock (Gg C)		
	Living	Litter, dead wood and soils	Sum
1990	-110.16	-193.34	-303.50
1991	-110.16	-196.89	-307.05
1992	-110.16	-200.61	-310.76
1993	-110.16	-204.09	-314.24
1994	-110.16	-208.04	-318.19
1995	-110.16	-211.48	-321.63
1996	-168.16	-165.81	-333.96
1997	-118.13	-175.52	-293.65
1998	-181.10	-176.02	-357.13
1999	-184.83	-106.23	-291.06
2000	-85.77	-168.87	-254.65
2001	-55.38	-116.54	-171.92
2002	-55.38	-117.52	-172.90
2003	-55.38	-118.39	-173.78
2004	-55.38	-119.35	-174.73
2005	-55.38	-120.29	-175.67
2006	-55.38	-121.24	-176.62
2007	-55.38	-122.17	-177.56
2008	-55.38	-123.11	-178.49
2009	-55.38	-124.03	-179.41
2010	-55.38	-124.95	-180.34
2011	-55.38	-125.87	-181.25
2012	-55.38	-126.77	-182.15

These estimates of carbon stock give an average annual emission of 0.66 million tonnes CO_2 for the commitment period.

Table 17. Total effect of deforestation i.e. the sum of carbon stock in living above and below-ground biomass and the carbon stock in litter, dead wood and soils at the time of deforestation (Only conversions to cropland, grassland and settlements).

Year	Carbon stock (Gg C)		
	Living	**Litter, dead wood and soils**	**Sum**
1990	-66.83	-41.81	-108.64
1991	-66.83	-42.57	-109.40
1992	-66.83	-43.38	-110.21
1993	-66.83	-44.13	-110.96
1994	-66.83	-44.98	-111.81
1995	-66.83	-45.73	-112.56
1996	-138.39	-34.91	-173.30
1997	-88.69	-26.33	-115.02
1998	-130.54	-44.01	-174.56
1999	-177.46	-26.56	-204.02
2000	-66.59	-71.10	-137.69
2001	-47.56	-44.83	-92.40
2002	-47.56	-45.21	-92.77
2003	-47.56	-45.55	-93.11
2004	-47.56	-45.91	-93.48
2005	-47.56	-46.28	-93.84
2006	-47.56	-46.64	-94.20
2007	-47.56	-47.00	-94.56
2008	-47.56	-47.36	-94.92
2009	-47.56	-47.71	-95.28
2010	-47.56	-48.07	-95.63
2011	-47.56	-48.42	-95.98
2012	-47.56	-48.77	-96.33

These estimates give an average annual emission of 0.35 million tonnes CO_2 for the commitment period.

3. ARTICLE 3.4 ACTIVITIES

3.1. FOREST MANAGEMENT

The results from the LULUCF reporting for land use class “Forest” are summarized below. The results given in figures 1 and 2 cover the area of land use class “Forest remaining forest”. The calculations are carried out for the entire country except for Finnmark county and areas with drained organic soil. Table 18 shows the net carbon (Gg CO_2) accumulation in forest land remaining forest land. The assumption here is that all area classified as “forest remaining forest” in the UNFCCC reporting is included in FM if elected. There is some double counting since some sources and sinks are included in the reporting of 3.4 Activities. The 3.4 activities should therefore be slightly reduced for some activities already counted as 3.3 activities. However, the forest management cap for Norway is only 400 Gg C/year or 1467 Gg CO_2/year and further calculations should not be necessary to illustrate the potential of FM.

The level of carbon sequestration is influenced by changes in forest management. Reduced harvest is an important factor. Other forest management activities include:

- Pre-commercial and commercial thinning
- Planting
- Preparation for natural regeneration

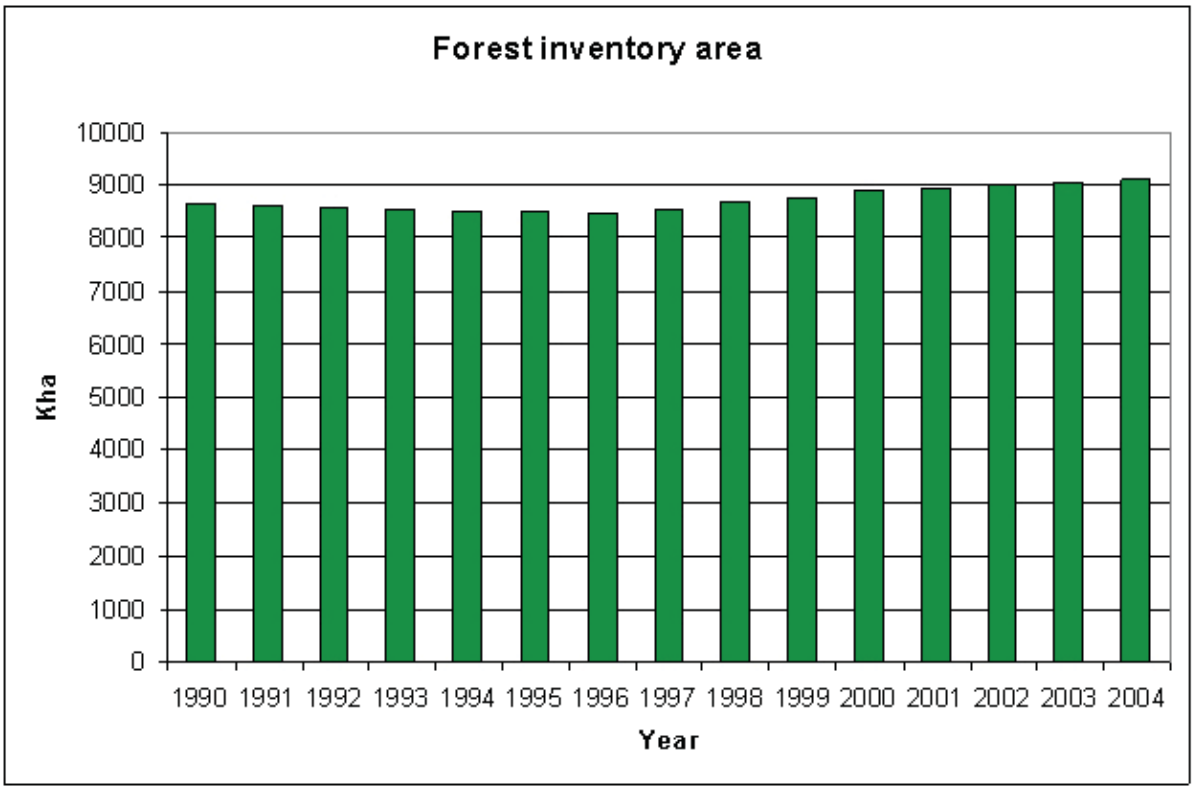

Fig. 1. Forest management area (k ha) excluding Finnmark county and drained organic soils.

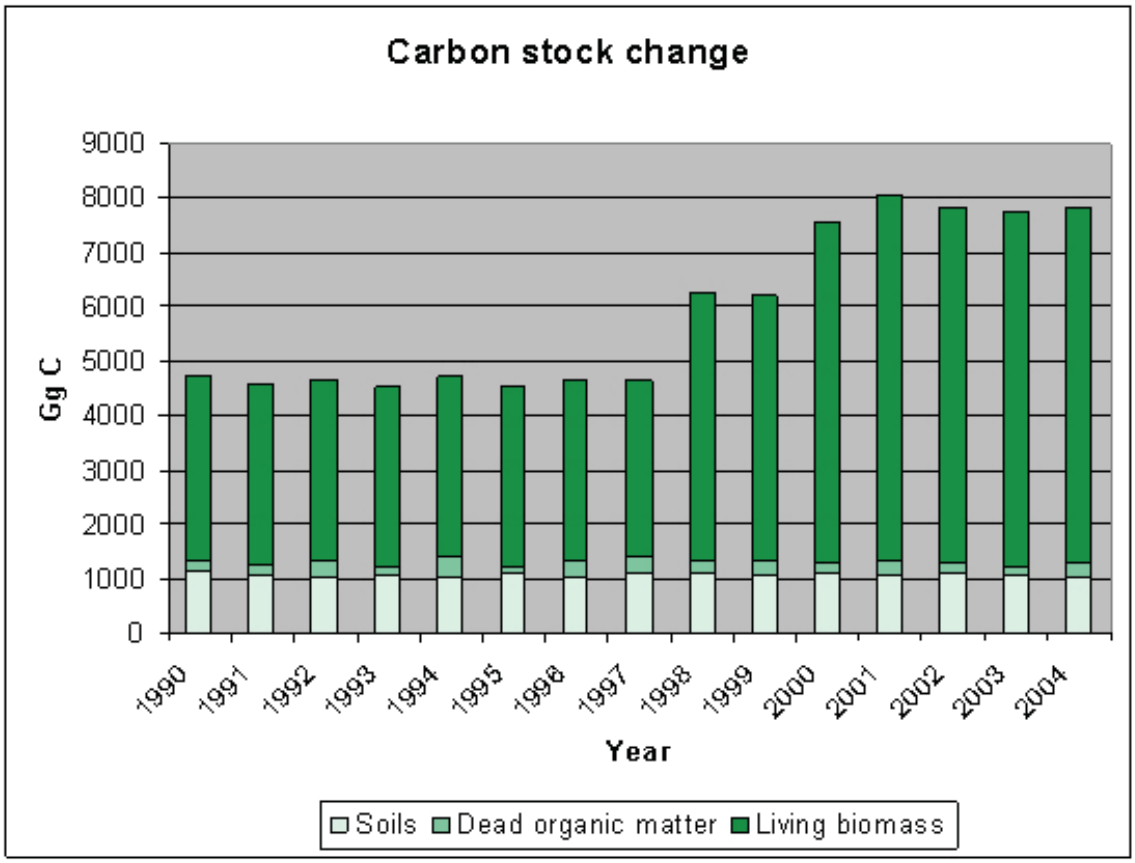

Fig. 2. Carbon stock change (Gg C) in living biomass, dead organic matter and in soils (Finnmark county and drained organic soils excluded).

Table 18. Net carbon (Gg CO_2) accumulation in forest land remaining forest land.

Year	Gg CO_2
1990	-17184
1991	-16646
1992	-16910
1993	-16557
1994	-17228
1995	-16506
1996	-16964
1997	-16859
1998	-22822
1999	-22615
2000	-27558
2001	-29367
2002	-28519
2003	-28293
2004	-28529

3.2. OTHER ARTICLE 3.4 ACTIVITIES

The options for electing 3.4 Activities were discussed in Rypdal et al. (2006). Grazing land management was not considered separately as an option as it overlaps with Forest Management, Cropland Management and Revegetation.

Rypdal et al (2006) did not consider the area suitable for 3.4 activities. The calculations here are based on total available area, although implementation of mitigation measures may only be feasible on a fraction of that area. These numbers also give the potential for a longer time horizon than 2012. Generally the effect of measures until 2012 will be small since processes are slow and incentives are not in place.

CROPLAND MANAGEMENT
Targeting peat-land:

Change in crop to grass: Maximum 300 ktonnes CO_2 eq./year (assuming all area converted)
Restoration: Maximum 85-1020 ktonnes CO_2 eq./year (assuming all area restored).
Forest planting: Maximum 600 ktonnes CO_2 annually (assuming all area planted with trees)

These measures can be combined, but not on the same area.

Erosion control: 367 ktonnes CO_2/year (assuming no autumn till, not taking into account any increases in N_2O emissions)

Reduced application of lime: Maximum 200 ktonnes CO_2/year (assuming no liming in the commitment period, current level of liming emits 100 Gg CO_2, level was 200 Gg in 1990)

Land cover change cropland to grassland: Not estimated

Estimates have not been made for the option “horticulture and energy crops”. 20 000 ha of energy crops would as an example amount to an annual sequestration of 220 ktonnes CO_2.

REVEGETATION
For the reporting to TBFRA 2000 (UN-ECE/FAO 2000), an expert estimate was created supported by various data sources. The reporting period was 1987-1996, and the annual changes were reported as follows:

Natural conversion of non-forest land to forest: 20,000 ha
Natural conversion of other wooded land to forest: 11,000 ha
Natural conversion of non-forest land to other wooded land: 26,000 ha

It must be emphasized that these figures are highly uncertain and have not been verified. Still, they may be useful for giving a rough indication of the order of magnitude of the areas with a natural conversion from one category into another. As the development of the stands growing on these areas is a gradual process, it is expected that the tree cover often will be just below the threshold value prior to the conversion, and just above the threshold value immediately after conversion. Even if some of the individual trees may already have reached a rather advanced level of development when entering the "forest" category, the 10% crown cover limit indicates a very low level of stocking. The maximum number of years for a stand to be growing within the first commitment period will be 22 years. At least when the trees are young, the annual increment of biomass growing on these areas will be rather negligible. Actual figures must be taken from NFI data, although the NFI is not yet fully capable of reporting changes in land-use categories near the alpine tree-line. An estimate of the growing stock on sample plots that recently have entered the "forest" category is about 8.5 m^3/ha. Based on NFI data from the sub-alpine zone, one could estimate roughly 20 m^3/ha at the age of 20-30 years and 30 m^3/ha at the age of 40-50 years. That would correspond to about 2.55, 6.0 and 9.0 Mg C per hectare, respectively, or an annual uptake of carbon of about 0.15 Mg C/ha/year. Combined with 31 000 ha converted to forest this would be about 20 Gg CO_2/year. If this can be considered under article 3.3

(meeting the forest definition) the accumulated area since 1990 and changes in the commitment period would be considered. The development of these stands will differ quite a lot from the corresponding data for a planted stand. A reason for this may be that there is often already some tree cover (standards) when an area enters the "forest" category from "other wooded land" or "non-forest", but at the same time the young trees will grow rather slowly over the coming years.

The potential for revegetation would be even smaller than the annual figure for conversion to forest. It is not possible to develop a time series for revegetation as necessary for election of a 3.4 activity requiring data for 1990 in addition to the commitment period. From the data above it appears likely that the area of revegetation has increased since 1990. Assuming it was 0 in 1990 (just to get a point of reference) it would be 520 000 ha in 2010 (clearly not all of this will strictly speaking be other wooded land as some of this can have the potential to meet the forest definition). Assuming an uptake of 0.05 Mg C/ha/year this would amount to 26 Gg C/year (or 100 Gg CO_2). Clearly electing RV would require better monitoring than present and the election would need to take into account that data are not available for 1990 by making conservative assumptions.

If the above estimates are correct, nearly 700,000 ha will have been converted into forest and almost 600,000 ha into other wooded land over a period of 22 years, corresponding to about 7% of the total forest area and an even higher proportion of other wooded land. However, the net change of area categories will be different, in that there may be areas with active planting of non-forest land and also transition from forest into non-forest.

4. EMISSIONS OF NON-CO_2 GASES

Estimates of non-CO_2 gases from forest (CH_4 and N_2O) were included in NIJOS (2005) using emission factors and relevant activity data. The sources identified were forest fertilization, drainage of wetland for forest, land use conversions to cropland and wildfires.

Table 19. Emissions of non-CO_2 GHg from forest (Gg)

Source	CH_4	N_2O	CO_2 eq.	Kyoto activity
Drainage of forest soils	-	0.038	11.9	FM (AR)
Fertilization	-	0.0014	0.44	FM (AR)
Forest fires[1]	0.8	0.006	18.7	FM (AR)

[1] Emissions vary from year to year depending on climate and other factors. The values shown are the maximum reported since 1990.

These emissions are small and can be treated as non-key sources (using lower tier estimation methods). As long as these emissions are non-key, development of higher tier estimation methods can be given a lower priority. Forest fires can be the largest source in some years, while drainage of forest soils is the largest source in other years.

At present these emissions are not distributed between AR, D and FM. The activity data to estimate these emissions are not spatially defined. Therefore we have used expert knowledge to distribute them between activities. Due to the low level of emissions, this approximation does not cause any major error.

Fertilization of forest: Such fertilization is limited and mainly takes place in the late phase of a stand's life. Therefore we consider these emissions as part of Forest Management.

Drainage of forest soils: Such drainage is for establishing new forest, however the emission estimate includes forest drained also prior to 1990. The part of the drained land that met the forest definition 31 December 1989 should be considered under FM (if elected), the rest under afforestation. Because current drainage activities are low, the larger part of emissions will be considered as FM.

Forest fires: These should only be considered deforestation if the loss of forest cover is permanent. In Norway, areas subject to forest fires are expected to be reforested so these emissions should be included in Forest Management (if elected). Spatial data on forest fires are not available.

N_2O emissions from conversion to cropland can be considered as deforestation if the original land use is forest. At present these emissions (from all original land use) are of the same size as forest fertilization. The land-use change matrix can be used to make this separation.

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