

Commissioned Report

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**FRAMEWORK FOR REPORTING  
UNDER ARTICLE 3.3 AND 3.4 OF  
THE KYOTO PROTOCOL**

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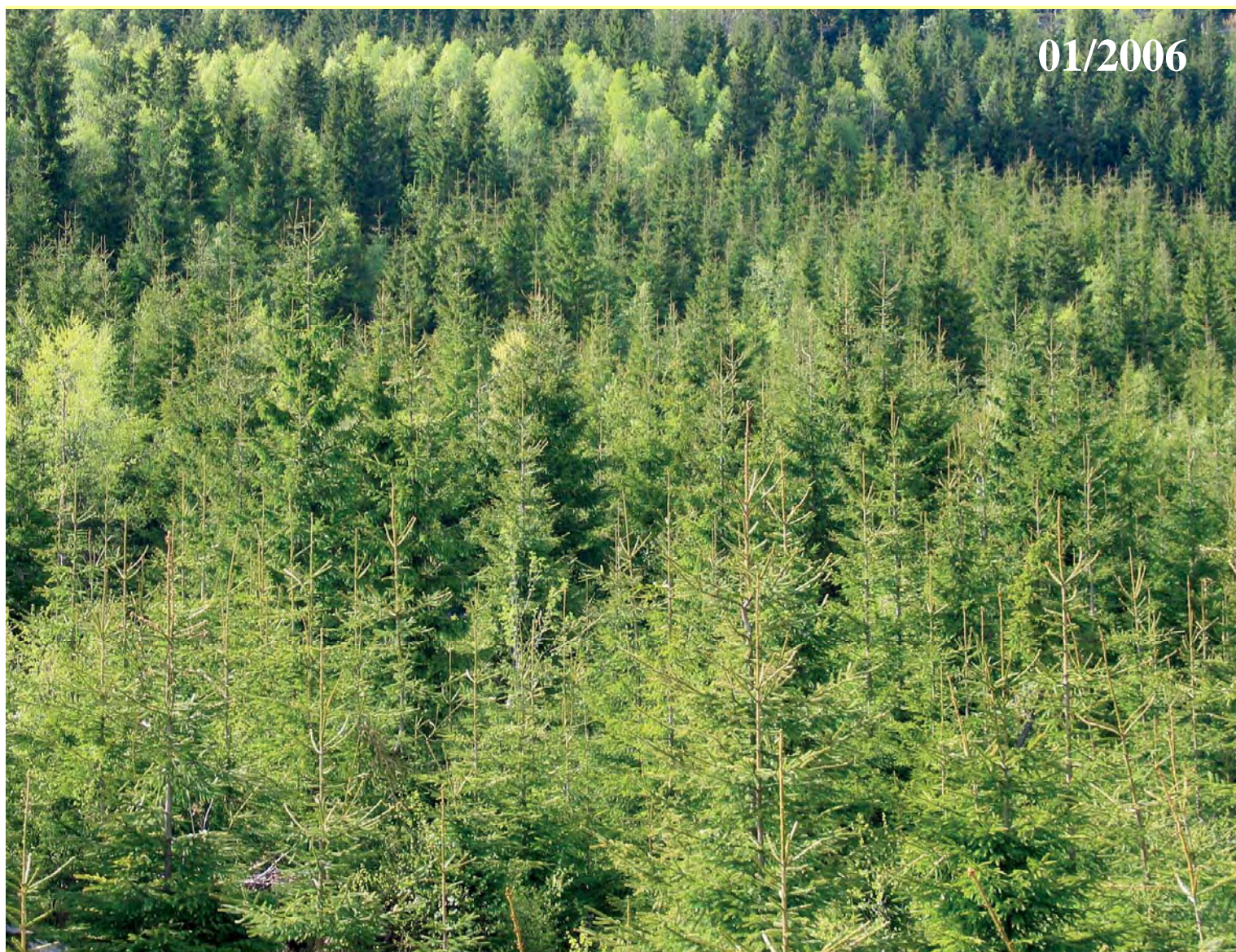


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UNDER ARTICLE 3.3 AND 3.4 OF  
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# CONTENT

- 1. Summary ..... 1**
- 2. Introduction..... 5**
- 3. Definitions ..... 6**
  - Forest..... 6
- 4. Data sources ..... 9**
  - 4.1 National forest inventory ..... 9
  - 4.2 AR18x18 Land resource accounting system..... 10
  - 4.3 Other data sources ..... 10
  - 4.4 Summary of data sources ..... 12
- 5. Methodology ..... 13**
  - 5.1 Framework for methodology ..... 13
  - 5.2 Methodology ..... 15
- 6. Implementation ..... 19**
  - 6.1. Organization..... 19
  - 6.2. Activities..... 19
- References ..... 20**

# 1. SUMMARY

This report describes a methodology for Norwegian reporting under Article 3.3 and Article 3.4 (if elected) of the Kyoto protocol.

The proposal is to report Afforestation/Reforestation (AR) and Deforestation (D) under Article 3.3 (mandatory) and Forest management (FM) under Article 3.4 (if elected). The reporting requirements can probably not be fulfilled if Norway also elects Cropland management (CM), Grazing land management (GM) or Revegetation (RV) under Article 3.4 (all electives) because the necessary data are unavailable and probably also unobtainable. The reason is that *change* in carbon pools in 1990 is needed as part of the report for these three electives. Such data, with the required quality, are not available in Norway today.

Regional stratification is recommended in order to use two different approaches in two different parts of the country (here called "Lowlands" and "Highlands"). It is not recommended to stratify the Norwegian reports because it is not realistic to provide the additional statistical support (in terms of additional sampling units) needed to break the results down to meaningful regional reporting units (eg County).

It is recommended to account for the Article 3.3 activities by the end of the period (2008-2012) and only for Norway as a whole<sup>1</sup>. The mandatory annual reporting of Article 3.3 activities can still be accomplished by using estimates based on the annual NFI results. The sum of these annual reports will, however, be different from the accounting calculated by the end of the commitment period, because the samples are different and because the annual reports will be based on incomplete data.

It is recommended to account for Article 3.4 activities (if elected) by the end of the period (2008-2012) and only for Norway as a whole. These activities can, however, be accounted annually if required<sup>2</sup>.

The National Forest Inventory (NFI) is, with minor adjustments, a reliable data source for reporting Article 3.3 activities, and FM under Article 3.4, for areas below the coniferous tree line. No similar data source exists for areas above the coniferous tree line (including large deciduous forest areas in Northern Norway). Unless these areas are excluded from the accounting system, data must either be obtained through an extension of the NFI or by including supplementary data sources. Existing systems developed for providing land cover and vegetation statistics can provide such supplementary data.

It is recommended to use the National Forest Inventory (NFI) as the main data source in the "lowlands" (more or less below the coniferous tree line) and an extended version of the Area Frame Survey of Land Resources (AR18X18) as the main data source in the "highlands" (above the coniferous tree line and in the deciduous areas of Northern Norway). The boundary between "highland" and "lowland" is arbitrary but should be well defined and documented through digitizing. We recommend that the boundary is placed approximately along the coniferous tree line in 2006. The exact location of the boundary is not important, but it must be clearly documented. It is also possible to use the NFI as the sole data source for all areas, but this choice will require a substantial extension of the survey.

It is recommended to use the following definition of *forest*, in accordance with the definition of forest used by FAO<sup>3</sup> and the requirement laid down in the Marrakesh accords:

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<sup>1</sup> The data from the National Forest Inventory (NFI) is collected over a five year period. Some of the preparations needed for accounting will only be implemented in 2007, providing results only when the plots are remeasured in 2012.

<sup>2</sup> The annual data will be incomplete and uncertain, probably resulting in a negative bias (from a national point of view) which is acceptable under the Kyoto protocol.

<sup>3</sup> Food and Agriculture Organization of the United Nations

*Land with tree crown cover of more than 10 per cent and area of more than 0.5 ha, stocked with trees that are able to reach a minimum height of 5 m at maturity in situ. Areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention or natural causes but which are expected to revert to forest is included.*

It is furthermore recommended to define all forest in Norway as *managed*.

A preparatory project is required in order to establish the 1990 land use on the sample plots. All available data sources including aerial photographs and data from past surveys, as well as expert judgments, must be used to fulfil this task.

The suggested method for reporting AR in the “lowlands” under Article 3.3 includes

1. Only plots known to be non-forest in 1990 and found to be forest in 2012 are included.
2. Each plot is assigned initial values based on the 1990 land use (Tier 2).
3. If AR has taken place between 1990 and 2007, the initial value is replaced with the Tier 3 values calculated from the observations made in 2007.
4. Final biomass is assigned using the Tier 3 values calculated from the observations made in 2012.
5. The effect of AR is calculated as the difference between the final and the initial values.
6. National statistics are calculated based on the sample plots.

The suggested method for accounting D in the “lowlands” under Article 3.3 includes

1. Only plots known to be forest in 1990 and found to be non-forest in 2012 are included.
2. Each plot is assigned initial values based on Tier 3 values calculated from the observations made in 2007.
3. Final values are assigned using Tier 2 values based on the 2012 land use (the entire change is thus assumed to have taken place by 2012).
4. The effect of D is calculated as the difference between the final and the initial values.
5. National statistics are calculated based on the sample plots.

The suggested method for accounting FM in the “lowlands” under Article 3.4 includes

1. Only plots known to be forest in 1990 and found still to be forest in the accounting year are included.
2. Each plot is assigned initial values based from the last NFI measurement. Tier 3 values can be used if the plot was missing during previous NFI..
3. Each plot is assigned final values based on Tier 3 values calculated from the observations made in the accounting year.
4. The effect of FM is calculated as the difference between the final and the initial values.
5. National statistics are calculated based on the sample plots.

The AR18X18 area frame survey of land resources will replace the NFI in the “highlands”. Here, single tree measurements will be replaced by area measurements, leading to the use of Tier 2 values. Initial measurements and classification must be carried out in situ, while the 1990 situation and changes due to AR and D will be identified using aerial photographs. Estimated changes due to FM will, if reported be model based.

It is recommended that the implementation of the accounting system should be done by the Norwegian forest and landscape institute (*Skog og landskap*).

It is recommended to implement a separate project for verification of the results, carried out by *Statistics Norway* using independent data sources.

It is recommended that relevant research institutes (among them *Skog og landskap* and *Bioforsk*) should develop the necessary values and parameters for estimation of biomass values and other relevant carbon pools and non-CO<sub>2</sub> greenhouse gas emissions from both single-tree measurements and from area estimates of relevant land use categories.

We recommend that *Skog og landskap* and *Statistics Norway* should develop a coordinated system for national accounting related to land use and land cover for use as a framework for future reports, also including CM, GM and RV. *Skog og landskap* and *Bioforsk* should develop operational methods for measuring the effects of CM, GM and RV under such a system.

**Nøkkelord:** Kyoto protokoll, Karbon, Arealbruk, Arealdekke, Overvåking

**Key word:** Kyoto protocol, Carbon, Land use, Land cover, Surveillance

CICERO Policy Note 2006:1

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**tions:** NIJOS Rapport 11/2005.

Skog og landskap Commissioned report 2/2006





## 2. INTRODUCTION

Emissions and removals from land use, land-use change and forestry (LULUCF) under the Kyoto Protocol are reported separately from the main inventory. All Parties are committed to report and will be credited/debited for “human-induced land use change and forestry activities, limited to afforestation, reforestation and deforestation 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<sup>4</sup>), 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 cap for credits. For Norway this cap is 0.4 Mt C/year (1.47 Mt CO<sub>2</sub>, equivalent to 2.7 % of present total 2004 GHG emissions in Norway). The other Article 3.4 activities are credited on a net-net<sup>5</sup> basis, meaning that annual change in emissions and removals during the commitment period are calculated and compared to the change in the base year<sup>6</sup>.

Guidance for reporting emissions and removals from 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 that 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 a LULUCF inventory for reporting to UNFCCC (NIJOS 2005) consistent with IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry. The LULUCF sector constitutes a large net sink for Norway. The national forest inventory has been the main source of data to estimate this sink. It was supplemented with administrative information, research data and default data. The report, 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 purpose of the present report is to

- clarify and/or interpret the definitions needed for reporting under Article 3.3 and 3.4
- discuss data sources available for reporting under Article 3.3 and 3.4
- recommend a framework, together with selection of options, for reporting under Article 3.3 and 3.4
- describe a realistic and operational methodology and organization for reporting under Article 3.3 and 3.4

The methods recommended here are not ideal with respect to the recommendations given in IPCC (2004). Many of the recommendations are practically unachievable because the required monitoring system must have been in place for a long period already in order to fulfil the requirements. The suggested methodology is a compromise representing a practical, workable solution that is thought to be acceptable under the Good Practice Guidance and that will allow Norway to report under Articles 3.3 and 3.4 (if elected) with an acceptable accuracy and with a reasonable use of resources.

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<sup>4</sup> FCCC/CP/2001/13/Add.1

<sup>5</sup> Net-net accounting is defined in IPCC (2004, p. G.14) as “The carbon sink or source in the reporting year minus the carbon sink or source in the base year. This is the accounting method for grazing land management, cropland management and revegetation under Article 3.4”

<sup>6</sup> IPCC (2004, p.4.67)

### 3. DEFINITIONS

This chapter provides definitions of central concepts for reporting Article 3.3 and 3.4 activities of the Kyoto protocol together with suggested interpretations of these definitions in the Norwegian context. The chapter starts with a definition of the term *forest*, followed by interpretation of the terms *afforestation*, *reforestation* and *deforestation* (already defined by the Marrakesh Accord). These definitions are directly related to Article 3.3. The chapter then addresses the key concepts of Article 3.4: *Forest management*, *Cropland management*, *Grazing land management* and *Revegetation*. Finally, the chapter addresses the question of how to define *human induced changes*. These concepts are also defined by the Marrakesh Accord, but must be given an interpretation in the Norwegian context.

#### **Forest**

*Land with tree crown cover of more than 10 per cent and area of more than 0.5 ha, stocked with trees that are able to reach a minimum height of 5 m at maturity in situ. Areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention or natural causes but which are expected to revert to forest are included.*

This definition is consistent with the definition of *forest* used by FAO<sup>7</sup> and with the Marrakesh accords. The Marrakesh accords require a minimum area of 0.5 - 1 ha, a minimum tree height at maturity of 2 – 5 m and a minimum crown closure at maturity of 10 - 30%.

#### **Afforestation and reforestation (AR)**

Under the definitions of the Marrakesh Accords, both *afforestation and reforestation* refer to direct, human-induced conversion of the land cover to forest (from another land cover). The definitions do not include replanting or regeneration following harvest or natural disturbance. Afforestation occurs on land that has not been forest for at least 50 years, while reforestation occurs on land that has been forest more recently, though not since 31.12.1989.

Detailed accounts of the land use in the period 1957 – 1990 are required in order to separate A from R. Such records are not easily available, and we thus propose to treat AR as a single topic in Norway. We can not see that this has any practical consequences.

#### **Deforestation (D)**

*Deforestation* is the direct human-induced conversion of forested land to non-forested land.

#### **Forest management (FM)**

*Forest management* is defined by the Marrakesh Accords as

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

All forest in Norway is managed. The most obvious management is through commercial forestry. Other forms of management include energy production (firewood and fuel), foraging, environmental protection and protective purposes, recreation and hunting. The intensity of the various management practices will decrease, but management will still be present, on more marginal and less productive forested land. The Marrakesh accords also consider conservation and protection as a type of management.

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<sup>7</sup> Food and Agriculture Organization of the United Nations

### **Cropland managements (CM)**

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

The areas subject to cropland management is covered by the categories *Fulldyrka jord* and *Overflate-dyrka jord* in the Norwegian classification of land resources (NIJOS 2001 pp. 17-18)

The sources under this category comprise changes in carbon storage related to

- changes in land use and agricultural practice
- drainage - or restoration - of organic soils and wetlands
- changes in biomass in fruit plantations
- application of lime to agricultural land

### **Grazing land managements (GM)**

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

The intention in the Kyoto protocol is probably to cover the management of permanent grass areas used for livestock production. This is the area defined as *Innmarksbeite* (Infield pasture) in the Norwegian classification of land resources (NIJOS 2001, p.19). In addition, considerable forest and other outfield areas are also used as pasture – often involving human intervention and manipulation of the vegetation. The workable solution if GM is elected under Article 3.4 is, however, to limit GM to the areas defined as *Innmarksbeite*. The effects of changing grazing behaviour or practices on other land will probably be covered by RV (if elected). Where changes are leading to AR or D, these effects will in any case take precedence over GM.

### **Revegetation (RV)**

*Revegetation (RV) is the direct human-induced growth of vegetation on formerly unvegetated or sparsely vegetated land, but not leading to AR.*

The area subject to possible revegetation is all categories of land not included under the definitions of Forest, Cropland and Grazing land above.

### **Human induced change**

The concepts AR, D, FM, CM, GM and RV defined above and as used under the Kyoto protocol require that changes must be human induced, not natural.

In Norway there hardly exists any extensive, continuous area that has not been exploited by man. Wood and timber as been extracted for forest industry, coal production and mining. Summer farming under a system of short-distance transhumance was prevalent for many hundred years, having a large impact, especially near the alpine tree line (Larsson 2004).

The present position of the alpine tree line results from complex inter-relationships between past and present climate regimes, natural disturbance regimes and human land use (Hofgaard 1997). Future vegetation responses to diminished grazing pressure are likely to override changes forced by changing climate. Such responses can easily be misinterpreted as being governed by climate change, rather than by changes in land use.

Bryn (in prep) carried out a study in a representative mountain area in south-eastern Norway. He concluded that more than 95% of the increase in forest areas was due to natural recovery of areas that were formerly covered with forest, previously deforested due to human activities (including grazing by

domestic animals) and later abandoned. Thus, there is a strong reason to believe that the major part of the transformation of non-forest mountain areas into forest (or other wooded land) is due to a change in land use, rather than climate change.

Since 1920 the growing stock in Norwegian forests has shown an increase of about 130%, while the annual felling has remained at a rather constant level. It has been a policy of the forest administration to increase the productivity of the forests. Especially important in this respect was the shift from dimension felling and single-tree selection into stand-based forest management. Also a higher focus on regeneration efforts, e.g. by planting and other silvicultural work, contributed to denser stands and a better utilization of the production capacity. It is therefore quite obvious that the increase in growing stock (and biomass) experienced today is a result of human intervention through forest management.

## 4. DATA SOURCES

Potential data sources for reporting under Article 3.3 and 3.4 of the Kyoto protocol include:

- The National forest inventory (NFI)
- The Land resource accounting system (AR18X18)
- The Monitoring system for cultural landscape (3Q)
- National statistics of planted forest area
- Various land resource maps
- Agricultural censuses, registers and surveys
- Registers of buildings (GAB)
- The national road data bank (NVDB)
- Analysis of satellite images

The National Forest Inventory (NFI) is the obvious choice as the main data source for reporting under Article 3.3 and 3.4 (if elected). AR18X18 should be considered as a supplementary source covering “highland” areas. Other data sources should be used whenever relevant.

### 4.1 National forest inventory

The Norwegian National Forest Inventory dates back to 1919. Permanent sample plots making estimates of area class transitions possible were introduced in 1986-1993 (reference year 1990). The system is based on eight 3×3 km grids, each covering a sector of the country (Figure 1). In each intersection of this grid, a sample plot has been installed. The size of the sample plot is 250 m<sup>2</sup> for detailed measurements (e.g. trees) and 1,000 m<sup>2</sup> for land use and stand characteristics. The National Forest Inventory will start a new cycle every five years. That means, it takes five years to re-assess all permanent sample plots. The plots visited each year do; however, represent a national random sample, thus making it possible to calculate statistics for any given year. Another option is to calculate annual statistics by using a five-year moving average.

The total number of sample plots in forest is more than 10,000. The design is random systematic, but statistics for large areas is calculated as if the design was simple random. The result is a conservative estimate of uncertainty. The standard error of total stem volume for the whole country is in the order of 1%.

The NFI is designed to give a complete national coverage (except for Finnmark) every year. However, only 20% of the plots are measured every year, and the statistical support for single year estimates is thus weaker than the five year average that includes all plots. A possible solution is to calculate yearly estimates based on the measurements obtained within ±2 years of the year in question.

The NFI is the most comprehensive existing data source for reporting under Article 3.3 and 3.4 of the Kyoto protocol, but practical solutions must be found regarding the lack of data in Finnmark County and in the mountains and sparsely forested areas. A regime of systematic re-examination of areas previously found (or thought) to be unforested must also be introduced.

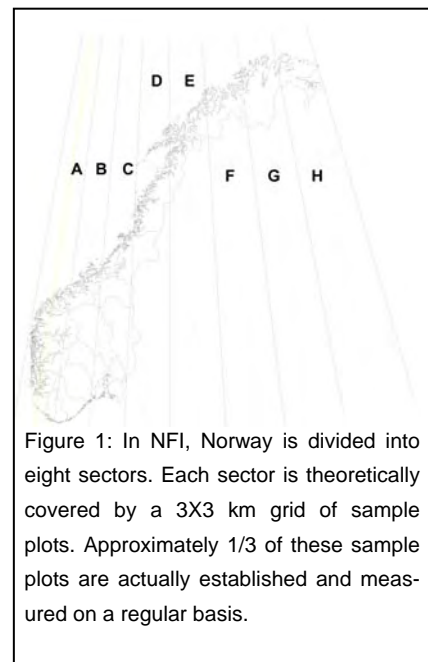


Figure 1: In NFI, Norway is divided into eight sectors. Each sector is theoretically covered by a 3X3 km grid of sample plots. Approximately 1/3 of these sample plots are actually established and measured on a regular basis.

## 4.2 AR18×18 Land resource accounting system

AR18×18 is an area frame survey that started in 2004 (Strand and Rekdal 2006). Plots (each 0,9 km<sup>2</sup>) are located on a systematic grid throughout Norway (Figure 2). The system is linked to the original version of Eurostat's LUCAS (Land use/cover area frame survey) but adjusted to fit Norwegian requirements. Each plot is surveyed in the field, producing a detailed land cover map. 209 plots (20% of the total) were surveyed by the end of 2005. Another 52 plots will be surveyed during the summer of 2006. The goal is to cover the whole country and produce a national land cover statistic. A possible repeated survey in the future will produce a change matrix leading to a national land resource accounting system. The results are unbiased for all land in Norway and can be used to track vegetation and land use/land cover changes.

In 2006, detailed soil mapping is – as a test - carried out on the agricultural land found on the AR18×18 plots in Telemark County. If this addition is implemented on a national scale, the system will also provide unbiased national soil statistic for agricultural land.

The current system does not include biomass estimation. This could be done by implementing a full NFI survey on a subset of point locations on each AR18×18 plot. A more viable alternative is to develop a simplified subset of the NFI survey to be carried out on the AR18×18 plots. An even more realistic scenario is to omit single-tree measurements and rely on area measurements alone. This solution is acceptable under the Kyoto protocol.

Funding for AR18×18 is uncertain and the program proceeds on an experimental basis. Data are obtained county by county, and there is no national coverage in a particular year. Baseline data for 1990 does not exist, but can be obtained using aerial photographs. This must be done after the initial in situ mapping of the each site, because knowledge about the current land cover is a prerequisite for photo interpretation.

## 4.3 Other data sources

A number of other data sources have been considered and for various reasons found less suitable. A brief summary follows<sup>8</sup>:

### Monitoring system for cultural landscape (3Q)

An area frame survey that started in 1998. 1484 plots (each 1 km<sup>2</sup>) are located on a systematic grid throughout the agricultural areas in Norway. The system is statistically biased for non-agricultural land, but could be used for monitoring CM and GM.

### Planted forest area

A statistical report published annually by the Norwegian Agricultural Authority (SLF). The data are only available as aggregated statistics. Locations can not be identified. The land use/cover in 1990 is unknown. The data set does not fulfil the requirement of the Marrakesh accord that areas of land must be both identifiable and also tracked in the future<sup>9</sup>.

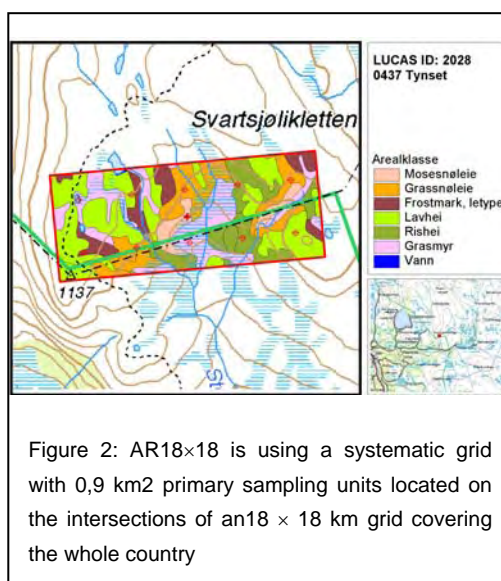


Figure 2: AR18×18 is using a systematic grid with 0,9 km<sup>2</sup> primary sampling units located on the intersections of an 18 × 18 km grid covering the whole country

<sup>8</sup> The constraints limiting the usefulness of several of the data sets and mentioned implicit here are described generically in chapter 5.1

<sup>9</sup> IPCC (2004, p.4.23)



### Land resource maps

Land resource maps in scale 1:5,000 are available for all areas below the tree line. The map is established over a period of 40 years and the date of validity of the information at a specified location is uncertain. Historical records are not kept in digital form and changes can not be traced without a major endeavour to digitize the old data – consisting of approximately 180,000 map sheets. Furthermore, due to the lack of a system for documentation of changes, the data set does not fulfil the requirement of the Marrakesh accord that areas of land must be both identifiable and also tracked in the future<sup>9</sup>.

### Agricultural censuses, registers and surveys

Indicators of land-use change can also be found in agricultural censuses, registers and surveys. Figures are, however, not necessarily consistent over time, there might be time gaps and gaps or discrepancies in nomenclature. The individual locations are not easily identified and these data will also not show the initial land use.

### GAB

GAB is a database containing (a.o) data on buildings – including the date of construction, location and size. The register can be used to estimate the amount of land covered by new buildings each year. The register does not include information about the land use prior to construction or about the land use at the site in 1990<sup>10</sup>.

### NVDB

The national road databank (NVDB) is a database containing information about all roads in Norway. Data include location, standard and for recently constructed roads also year of construction. The register can be used to estimate the amount of land covered by roads. The register does not include information about the land use prior to construction or about the land use at the site in 1990.

### Satellite images

Norwegian climate and topography limits the use of satellite images. The topography produces strong shadows on hills and in the valleys. Norway is often covered by clouds and it is difficult to obtain images during the season with high sun angle. Vegetation boundaries are not very distinct, and the forest density and tree heights will usually decrease gradually with increasing altitude. The spectral signatures of the forest and other wooded land are overlapping. Thus, estimates of land-use classes and land-use change will be very imprecise and also systematically biased towards the more common land cover class (Strand 1997).

There are several projects concerned with using satellite images to map and measure vegetation in Norway. These are AR-Skog (operated by Skog og landskap), Sat-Nat (operated by Norsk romsenter) and a new attempt by Norut-IT and DN to compile a national vegetation map based on satellite images. AR-Skog is using NFI data as input and can not replace NFI. Sat-Nat is not a national program with a systematic approach, but rather a test of various kinds of technology. The published results so far do not show convincing accuracy. The Norut-IT/DN program has a sound methodological approach but is under development and the accuracy of the results has not been tested.

A national satellite mapping program will in any case rely on systematic sampling of field data (from sources like NFI, AR18X18 and the land resource maps) for both calibration and verification and can not replace these sources. None of the existing programs have data from 1990 or an operational program for national surveys that satisfies the requirements of the Kyoto protocol.

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<sup>10</sup> It has been suggested to develop a model where the present land use in the neighborhood of a building is used to conjecture the previous land use of the building site. Such a model will have to be developed and tested before it can be used.

#### 4.4 Summary of data sources

Table 1 below is an attempt to summarize the different data sources presented above. Such a summary is necessarily a simplification and the evaluation of each source is qualitative. An in depth description and documentation of the advantages and disadvantages of each data source with respect to each of the article items has not been attempted. Such an attempt would be voluminous and probably more confusing than enlightening.

	AR		D		FM		CM	GM		RV	
	L	H	L	H	L	H		L	H	L	H
L="Lowlands" H="Highlands"											
NFI	☺	☹	☺	☹	☺	☹	-	-	-	☹	☹
AR18X18	☹	☹	☹	☹	☹	☹	☹	☹	☹	☹	☹
3Q	-	-	-	-	-	-	☹	☹	☹	-	-
Planted forest area	☹	☹	-	-	-	-	-	-	-	-	-
Land resource maps	☹	☹	☹	☹	-	-	-	-	-	-	-
Agricultural censuses	-	-	-	-	-	-	☹	☹	☹	-	-
GAB	-	-	☹	☹	-	-	-	-	-	-	-
NDVB	-	-	☹	☹	-	-	-	-	-	-	-
Satellite images:											
AR-Skog	☹	-	☹	-	☹	-	-	-	-	-	-
Sat-Nat	-	-	-	-	-	-	-	-	-	-	-
Norut/DN	☹	☹	☹	☹	☹	☹	-	-	-	☹	☹

Table1 : Suitability of various data sources (see text) for reporting the different items under Articles 3.3 and 3.4 of the Kyoto protocol:

Item:

- AR Afforestation/Reforestation
- D Deforestation
- FM Forest Management
- CM Cropland Management
- GM Grazing land Management
- RV Revegetation

Stratum

- L Lowlands
- H Highlands

Suitability

- ☺: Suitable with minor modifications
- ☹: Suitable, but with larger modifications, additions and assumptions
- ☹: Can be used, but require substantial modifications, additions and assumptions
- : Unavailable or not suitable

## 5. METHODOLOGY

This chapter discusses options and suggests methodology for reporting under Article 3.3 and Article 3.4 (if elected) of the Kyoto protocol.

### 5.1 Framework for methodology

#### Constraints

The choice of methodology for accounting is made under a number of constraints. The most important constraints are

- The method must be technically and economically feasible within the given time frame for reporting
- The areal units used must be statistically representative or constitute a complete mapping of all relevant land
- The land use of the areal units in 1990 must be known or obtainable
- It must be possible to examine the land use and measure or estimate the biomass values and other relevant carbon pools and non-CO<sub>2</sub> greenhouse gas emissions. from the areal units in 2007
- It must be possible to examine the land use and measure or estimate the biomass values and other relevant carbon pools and non-CO<sub>2</sub> greenhouse gas emissions. from the areal units in 2012

For the required annual reporting, it is also necessary to examine the land use and measure or estimate the biomass values and other relevant carbon pools and non-CO<sub>2</sub> greenhouse gas emissions from the areal units every year from 2007 up to and including 2012

Additional constraints may apply, depending on choice of reporting options.

#### Pools and tiers

The Marrakesh accords have identified five major pools for reporting:

- Aboveground biomass
- Belowground biomass
- Dead wood
- Litter
- Soil organic carbon

And three levels (tiers) of methods for estimating these pools

Tier 1: Area estimates multiplied with an international, default value. This tier can be used for any part of the report where area estimates are available.

Tier 2: Area estimates multiplied with a national, value. This tier can be used for any part of the report where area estimates are available, provided that national values can be found.

Tier 3: Any more sophisticated methods.

We recommend the use of Tier 3 methods (e.g NIJOS 2005) when possible and Tier 2 methods elsewhere (e.g. when only area measurements are available). It will be necessary to develop new Tier 2 and/or 3 methods for reports based on area estimates without single-tree measurements.

## Identification of land areas

According to IPCC (2004) Good Practice Guidance for LULUCF the land areas to be included under the Kyoto Protocol can be identified using two alternative methods.

Reporting method 1 entails delineating areas that include multiple land units subject to Article 3.3 and 3.4 activities by using legal, administrative, or ecosystem boundaries. This stratification is based on sampling techniques, administrative data, or grids on images produced by remote sensing techniques. The identified geographical boundaries must be georeferenced. The areas are remeasured in order to produce a matrix describing the amount of land changing between each pair of land types.

Reporting method 2 is based on the spatially explicit and complete geographical identification of all units of land subject to Article 3.3 activities and all land subject to article 3.4 activities.

Norway does not have existing mapping programs fulfilling the requirements of reporting method 2. The Norwegian National Forest Inventory (NFI) with planned improvements and combined with additional statistical surveys of land resources outside the forest areas will meet the requirements of reporting method 1.

We recommend the use of the NFI (see chapter 4.1 above) as the main data source for reporting AR and D under Article 3.3 and FM under Article 3.4 (if elected) in the areas covered by the NFI. The NFI is consistent with approach 2. We recommend that AR18X18 (see chapter 4.2 above) is used as a supplementary data source for areas not covered by the NFI. AR18X18 strengthened with soil sampling and detailed biomass measurements should be used as the main source for data on CM, GM and RV under Article 3.4 (if elected)<sup>11</sup>. AR18 X18 is also consistent with approach 2. Other data sources should be used when this is found to be necessary and practical.

## Stratification

A country may also be stratified into regions. The justification can be practical (using different approaches in different regions) or pedagogical (showing differences between regions). When statistical surveys (approach 2) are used, stratification of the results inevitably leads to less precise estimates. Furthermore, the administrative subdivision in Norway is under revision and the final outcome (for use in 2012) is still not known.

The annual changes reported under Article 3.3 and 3.4 in Norway are expected to be small. In order to be meaningful, the regional reports should be sufficiently precise to avoid that the small changes are hidden behind random fluctuations. This will require large and expensive samples. Regional stratification should therefore only be carried out if 1) the justification is clear; and 2) funds for sufficiently intensive monitoring are available.

In the paragraph "Identification of land areas" above, we recommend using data from two different sources: NFI in areas where this survey exists and AR18X18 in the rest of the country. This recommendation implies a "practical stratification" of the country into "Highlands" and "Lowlands" in order to use two different approaches. There is, however, no obvious reason to keep the reports from these two regions apart.

Consequently, we *do* recommend a regional stratification of the Norwegian methodology, but *not* of the Norwegian reports.

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<sup>11</sup> It is possible to use NFI for reporting AR, D and FM in the "Highlands". This will, however, require a substantial increase in the geographical coverage of the NFI field survey. The new survey plots will furthermore not have the long historical records of the existing plots and many of the advantages of using NFI will therefore be lost in these areas. It is also possible to use AR18X18 for reporting AR, D and FM in the "Lowlands", replacing the NFI. This approach will discard the use of historical records and single-tree measurements in the "Lowland" areas and is expected to give less precise results than the NFI here.

## Periodicity

Accounting under Article 3.3 and 3.4 (if elected) can be produced for each year during the reporting period (2008 – 2012), or for the period as a whole. We recommend that accounting is done for the period as a whole (and not for single years). We further recommend that accounting under Article 3.3 is carried out using data collected in two year only (2007 and 2012). Accounting of FM under Article 3.4 can be carried out annually.

## Electives

Norway is obliged to report AR and D under Article 3.3

Norway may elect to report FM, CM, GM and/or RV under Article 3.4

We recommend that Norway elects FM but not CM, GM and RV under Article 3.4. CM, GM and RV are reported on a net-net basis, implying that annual change in 1990 must be known and compared to the annual change during the reporting period. Norway does not have the necessary data and systems to report these electives and benefits are likely small in the first commitment period Skog og landskap (2006). FM is probably important in Norway. We have an operational system that allows us to report FM and this should be done in order to give as complete accounts as possible.

## 5.2 Methodology

This sub-chapter describes an accounting system based on the recommendations in chapter 5.1 above. The system covers reporting AR and D under Article 3.3 and FM under Article 3.4. Other elective activities are covered in brief.

### Preparations

The Norwegian land area should be stratified into two parts, approximately covering “lowland” areas and “highland” areas. The border should approximately follow the coniferous tree line<sup>12</sup>. It is important that the border is well defined and documented (i.e digitized). The rationale behind the choice is that the NFI already has a good coverage of areas below the coniferous tree line.

The NFI is the main data source for the “lowland” areas. This requires a preparatory database project in order to establish every NFI candidate plot in the “lowlands” (including those plots that for some reason are excluded from the NFI database) with information about the land use in 1990. It is not necessary to include information about the biomass in 1990.

The AR18X18 is the main data source for the “highland” areas. Only plots in the “highland” area should be used. A randomized subset of the plots should be selected for measurement each year. Again, the land-use in 1990 must be established for the AR18X18 plots.

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<sup>12</sup> We recommend that the boundary is placed approximately along the tree line in 2006. The exact location of the boundary is not important, but it should be clearly documented.

### **Accounting AR in Lowland areas under Article 3.3**

The method described here provides for accounting at the end of the commitment period

1. Only plots known to be non-forest in 1990 and found to be forest in 2012 are included.
2. Each plot is assigned initial values based on the 1990 land use (Tier 2).
3. If AR has taken place between 1990 and 2007, the initial value is replaced with the Tier 3 values calculated from the observations made in 2007.
4. Final biomass is assigned using the Tier 3 values calculated from the observations made in 2012.
5. The effect of AR is calculated as the difference between the final and the initial values.
6. National statistics are calculated based on the sample plots.

Annual reports of AR under Article 3.3 can be estimated from the annual NFI results (as 20% of the AR each year found over the previous five-year-period). The numbers will, however, fluctuate and the sum will most likely be somewhat different from the final account.

### **Accounting D in Lowlands under Article 3.3**

The method described here provides for accounting at the end of the commitment period

1. Only plots known to be forest in 1990 and found to be non-forest in 2012 are included.
2. Each plot is assigned initial values based on Tier 3 values calculated from the observations made in 2007.
3. Final values are assigned using Tier 2 values based on the 2012 land use (the entire change is thus assumed to have taken place by 2012).
4. The effect of D is calculated as the difference between the final and the initial values.
5. National statistics are calculated based on the sample plots.

Annual reports of D under Article 3.3 can be estimated from the annual NFI results (as 20% of the D each year found over the previous five-year-period). The numbers will, however, fluctuate and the sum will most likely be somewhat different from the final account.

### **Accounting FM in Lowlands under Article 3.4**

The method described here can be used for accounting at the end of the commitment period, as well as for annual accounting

1. Only plots known to be forest in 1990 and found still to be forest in the accounting year are included.
2. Each plot is assigned initial values based from the last NFI measurement. Tier 2 values can be used if the plot was missing during previous NFI..
3. Each plot is assigned final values based on Tier 3 values calculated from the observations made in the accounting year.
4. The effect of FM is calculated as the difference between the final and the initial values.
5. National statistics are calculated based on the sample plots.



### **Accounting AR in Highland areas under Article 3.3**

The method described here provides for accounting at the end of the commitment period

1. Only areas known to be non-forest in (or close to) 1990 and found to be forest in (or close to) 2012 are included.
2. Each area is assigned initial values based on the 1990 land use (or close to 1990) (Tier 2).
3. If AR has taken place between 1990 and 2007, the initial value is replaced with the Tier 2 values related to the observations made in (or close to) 2007.
4. Final biomass is assigned using the Tier 2 values calculated from the observations made in (or close to) 2012.
5. The effect of AR is calculated as the difference between the final and the initial values.
6. National statistics are calculated based on the annual average AR in the sample areas.

### **Accounting D in Highlands under Article 3.3**

The method described here provides for accounting at the end of the commitment period

1. Only areas known to be forest in (or close to) 1990 and found to be non-forest in (or close to) 2012 are included.
2. Each plot is assigned initial values based on Tier 2 values related to the observations made in (or close to) 2007.
3. Final values are assigned using Tier 2 values based on the 2012 land use (or close to 2012) (the entire change is thus assumed to have taken place by 2012).
4. The effect of D is calculated as the difference between the final and the initial values.
5. National statistics are calculated based on the annual average D in the sample areas.

### **Accounting FM in Highlands under Article 3.4**

The method described here provides for accounting at the end of the commitment period

1. Only areas known to be forest in (or close to) 1990 and found still to be forest in (or close to) the accounting year are included.
2. Each plot is assigned Tier 2 values for FM based on the forest type
3. National statistics are calculated based on the sample areas.

### **Accounting CM, GM and RV under Article 3.4**

It is not possible to report CM, GM and RV under Article 3.4 in Norway, as described in the regulations of the Kyoto protocol. The main reason is that the annual change in 1990, required as a base value, is unknown. The problem is aggravated by the fact that the individual land areas used in the accounting system must be identified. This requires detailed historical records or an existing monitoring system in place before 1990. We will, however, shortly describe a monitoring method that can be used in the future. The method requires that a different base year is selected, and that the monitoring system is fully implemented *before* the base year. A comprehensive discussion of CM is found in Rypdal et al. (2006).

The monitoring system can be based on any area frame survey (e.g. AR18x18 described in chapter 4 above). Both CM and GM accounting can be implemented through regular sampling and measurement of soil carbon from the agricultural and grazing land found on the survey plots. RV accounting can be implemented through detailed measurement of the vegetation on (part of) the survey plots. The effects of CM, GM and RV are all expected to develop slowly in Norway, and the monitoring frequency can be quite low.

### **Hierarchy of activities**

Accounting and reporting under Article 3.3 is mandatory

The Marrakesh accords do not rank the 3.4 activities. According to GPG2004, a Party should develop a hierarchy of 3.4 activities that should be applied consistently if they have elected more than one.

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

1. FM
2. CM
3. RV and GM

## 6. IMPLEMENTATION

### 6.1. Organization

Implementation of the methodology should be done by the Norwegian forest and landscape institute (*Skog og landskap*).

A verification of the results should be carried out by *Statistics Norway* using independent sources (e.g. GAB, NVDB and other data described in chapter 4.3 above). The verification should use all available sources in order to make crude estimates of AR, D and FM. The purpose of the verification is not to control the accounts but to examine the credibility of the results. Large discrepancies between the accounts and the verification results should lead to closer examination of the data, methods and results.

Relevant research institutes (among them *Skog og landskap* and *Bioforsk*) should must develop, document and verify the necessary Tier 2 and Tier 3 parameters. Tier 2 parameters are needed to calculate carbon pool values directly from area measurements of land cover classes. Tier 3 parameters are needed to calculate carbon pools from biomass values or other non-area measurements carried out on the sample plots.

We furthermore recommend that *Skog og landskap* and *Statistics Norway* should develop a coordinated system for national accounting related to land use and land cover for use as a framework for future reports, possibly including CM, GM and RV. We recommend that *Skog og landskap* and *Bioforsk* should develop operational methods for measuring the effects of CM, GM and RV that can be used with such a system.

### 6.2. Activities

The methodology described here will require several new activities.

- Establish and document a boundary between “Lowland” and “Highland” areas.
- Select or develop, and document, the necessary tier 3 values for estimation of carbon pools from measurements related to biomass for use where such measurements are available
- Select or develop, and document, the necessary tier 2 values for estimation of carbon pools from measurements of land cover and area for use where only these measurements are available

For use in the “lowlands”:

- The 1990 land use/land cover for around 17.500 NFI plots will have to be determined. This can to a large extent be done automatically, but will require some manual work.
- Around 900 new NFI plots in the “lowlands” will have to be checked annually. Around 400 may have to be visited in the field (the remaining can be checked on aerial photographs).

For use in the “highlands” using AR18X18:

- Approximately 150 AR plots will have to be visited and surveyed in situ annually.
- The 1990 land use/land cover for approximately 750 AR plots will have to be determined using aerial photographs from approximately 1990.
- The 2010-2012 land use/landcover for approximately 450 AR plots will have to be determined using aerial photographs from this period together with extrapolation of annual change.
- Develop tier 2 values for use with area estimates

For future monitoring of CM, GM and RV:

- Develop survey methods and tier 2 or 3 values

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