Updates of the Dutch National System for greenhouse gas reporting of the LULUCF sector

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Updates of the Dutch National System for greenhouse gas reporting of the LULUCF sector

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Alterra, Wageningen, 2006

ABSTRACT

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This report contains the updates and improvements that have been made in the Dutch National System for Greenhouse gas Reporting of the LULUCF (Land Use, Land Use Change and Forests) sector. These updates are incorporated in the submission of 2006.

Keywords: national system greenhouse gases, LULUCF, Netherlands

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Preface

This report contains the updates and improvements that have been made in the Dutch National System for Greenhouse gas Reporting of the LULUCF sector. These updates are incorporated in the submission of 2006. We thank the Steering Committee in the form of WEB LULUCF, especially Bas Clabbers, Harry Vreuls, and Gert-Jan van den Born.

Summary

This report contains the updates and improvements that have been made in the Dutch National System for Greenhouse gas Reporting of the LULUCF sector. These updates are incorporated in the submission of 2006.

Updates concern validation of the land use changes, an uncertainty and sensitivity analysis of the forest biomass changes, and improvements for the soil carbon estimate. Furthermore the outcome of the external review is reported here.

1 Introduction

For greenhouse gas reporting of the Land Use, Land Use Change and Forests (LULUCF) sector, the Netherlands has developed a National System since 2003. This system has been deployed for the National Inventory Reports (NIR's) since 2005, covering the period since 2003. This system has also been used for a full recalculation of the period 1990 – 2003.
This system has been documented in several publications. See e.g. Nabuurs et al. (2003, 2005) and De Groot et al (2005), Kuikman et al. (2003).

Several updates and improvements have been done in the course of 2005. These comprise:

- a sensitivity and uncertainty analysis of the biomass component of forest remaining forest;
- a validation in the field of the land use changes as derived from the topographical map comparison
- an improvement of the soil carbon stock assessment by working with more strata.

This report describes the methodologies and results, and presents the changed data for the NIR.

2 Validation of the land use changes and updates of the Kyoto estimates

In the National System as set up for the Dutch LULUCF greenhouse gas reporting, a considerable deforestation area was found. This originated from a digital overlay of the topographical maps of 1990 and 2000. The land use change matrix made from this overlay, gave gross values for deforestation of 2500 ha/y (forest according to definition) and 800 ha/y (trees outside forest). For afforestation it yielded respectively 3100 ha/y and 800 ha/y (see also Nabuurs et al. 2005).

These values seemed high, as other types of previous information indicated deforestation areas in the range of 500 ha/y (pers. comm. Van Tol) and afforestations registered by Groenfonds of around 1000 ha in 5 years (Groenfonds data, see Annex D). This, together with the fact that a very fine pattern of single grid cell deforestation seemed to occur (Fig 2.1), led to the necessity of a field validation.

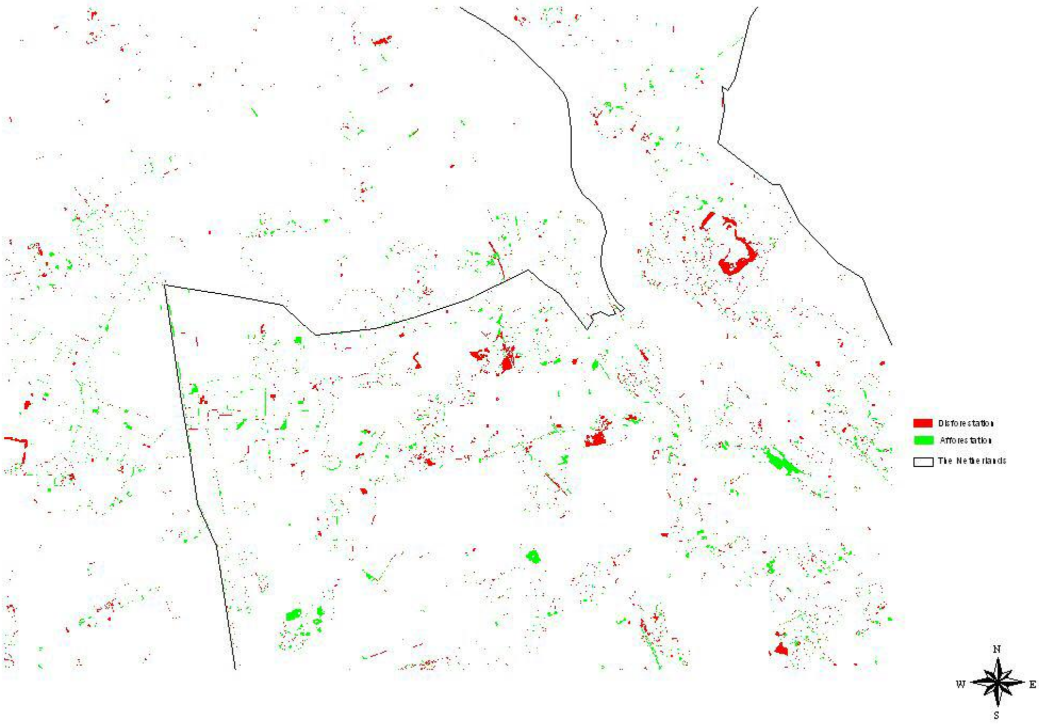

Figure 2.1. Pattern of afforestation (green) and deforestation (red) in one case area (the figure spans some 50x50 km).

Two areas for field validation were selected as regional cases, both measuring some 10x10 km. Each of the red or green pixels was visited. From the situation in the field it was decided whether a land use change had actually occurred, or whether a land use change did not seem plausible over the past 15 years (2005 – 1990). Data were processed. Each single occurrence of deforestation/afforestation was weighted equally. From these two regional cases an average correctness level was quantified. Data of the field validation are stored in the project folder 'national greenhouse gas system nr 230986' at Alterra, Wageningen.

Table 2.1. Afforestation and deforestation areas as assessed from the map overlay and after the field validation.

	Gross afforestation (ha)	Gross deforestation (ha)
Forest according to definition	3100	2500
Trees outside forest	800	800
Correctness (%)	64	44
Forest according to definition (after validation)	1984	1100
Trees outside forest (after validation)	512	352
Total	2496	1452

Correctness percentages between the cases varied only slightly (between 41 and 47%). Correctness for either forest according to definition and trees outside the forest were also very comparable.

What constitutes the errors:

- we have assumed that the topographical maps as such represent the truth.
- when applying re-gridding these polygon based maps, small errors may occur. Knol et al. 2004 carried out a validation of several hundreds of points between the gridded map and polygon map. A correctness percentage of 95-97% was found.
- when comparing two maps for land use changes, these mistakes can be multiplied, thus if a 5% mistake is assumed, a 25% error in the land use changes would be minimal.
- in addition, some methodological differences are carried through in the topographical maps between 1990 and 2000, e.g. yards and farmyards are delineated clearly and coloured differently from the neighbouring land use in the 2000 map. This was not the case in the 1990 map. This gives additional errors. This error is not quantified here.
- the basis for the 1990 gridded map was a 1:25,000 map, the basis for the 2000 gridded map was the 1:10,000 map. In principle these are derived from the same drawings, however small deviations map be caused by this difference in origin.

Validation against other independent data sources (e.g. RS derived land use maps for the Netherlands) was not carried out.

Table 2.2 gives the impact that these corrections have on the reporting quantities.

Table 2.2. Emissions and sinks of CO2 as reported earlier for A & D in the NIR over 1990 (UNFCCC), and as reported in the Kyoto CRF of January 2006 over the year 1990. Convention as in the final CRF summary, i.e. negative is sink.

	Sink from afforestation in 1990 (Gg CO2/y)	Source from deforestation in 1990 (Gg CO2/y)
Before validation (both forest according to definition and trees outside forest) (Nabuurs et al 2005)	-21	865
After validation (both forest according to definition and trees outside forest) (UNFCCC)	-10.6	286
After validation and only forest according to definition (Kyoto)	-8.4	216

3 Uncertainty analysis of forest biomass

3.1. Introduction

Several cross cutting issues need to be considered when preparing national greenhouse gas inventories (IPCC 2003, p 5.7)
These are 1. uncertainty assessment, 2. sampling, 3. key category analysis, 4. QA/QC, 5. time series consistency, and 6. verification.

Here we deal with item 1. Item 2 is mainly dealt with in the forest inventory itself, 3 was dealt with in the Kuikman et al. (2003) report, 4. QA is dealt with at Alterra internally, QC: a review of the forest part of the national system has been set out in Dec 2005 to Joanneum Research, Graz, Austria (see chapter 5: the review was received after compilation of the results presented in this report and comments will be taken into account for future updates), 5 is dealt with in the modelling approach used for the forest part of the national system, and 6: was reported in Nabuurs et al. (2005, p 43).
For item 1 both a sensitivity assessment as well as an uncertainty assessment were carried out. Both were carried out with realistic parameter uncertainties for the current situation in the Netherlands. The sensitivity analysis is thus focused to give insight in the effects of the uncertainty cq. errors in single parameters cq. measured or recorded variables on the current carbon budget assessment for "forests remaining forest", while the uncertainty analysis is designed to obtain a reasonable estimate of the total uncertainty in the Dutch carbon budget for "forests remaining forest".

3.2. Defining the uncertainties

The assessment of carbon in "forests remaining forest" is based on measured plot data collected from all over the Netherlands. These are translated to biomass and carbon data using species specific and general parameters. Thus input parameters exist at three different levels: plot level data, with as many input values as there are plots, species level data for all 14 distinguished species(-groups), and general parameters or national data, for which only one value is required per assessment year. For each parameter/variable a distribution was assigned and a unity of the variability was given (Saucier et al. 2000). This was either expressed as an absolute standard deviation of a Gaussian distribution (e.g. age or height in the plot data), or relative as a coefficient of variation (most other variables) (table 1).

For two parameters, i.e. mortality and volume at which to start harvesting, the Gaussian distribution was adapted. For mortality the high uncertainty resulted in negative, and thus biologically impossible, values, which were rejected. For volume at which to start harvesting some of the highest values resulted in no plots being selected for harvesting after several years in the 1990-1999 assessment of the HOSP data. Those runs were rejected as well.

Not all uncertainty can be expressed as the variance of a single parameter. The choice of the equations relating biomass to structural plot variables was motivated in a previous report (Nabuurs et al., 2005), and to assess the effect of choosing a certain equation, we randomly picked any from all suitable equations available for each species, using a uniform distribution on all possibilities (appendix A). However, not many of the species groups had many possibilities for biomass equations, especially not for below-ground biomass. As there was only one possibility per species group for the equations relating volume to tree height and diameter, a distribution was assumed for the volume coefficients to assess sensitivity. However, it should be kept in mind that the coefficients of these volume equations were estimated all simultaneously and independently varying the coefficients is likely to result in an overestimation of the real variability.

Some of the assumptions the assessment was based on could not be translated into varying parameter values or equations. These are left out of the current uncertainty analysis.

Table 3.1 : Uncertainty estimates used for the sensitivity and uncertainty analysis of the Dutch carbon budget in forest not influenced by land use change (negative values are excluded as these are biologically impossible)*

Variable	Distribution	Uncertainty	Expressed as	Draws per run
Recorded plot data				
Age	Gaussian	2 years	Standard deviation	Nr of plots
Dominant height	Gaussian	0.4 m	Standard deviation	Nr of plots
Diameter of middle tree	Gaussian	3 %	Coeff. of variation	Nr of plots
Growing stock	Gaussian	4 %	Coeff. of variation	Nr of plots
Net annual increment	Gaussian	10 %	Coeff. of variation	Nr of plots
Nr of live trees	Gaussian	3 %	Coeff. of variation	Nr of plots
Volume dead trees - standing	Gaussian	5 %	Coeff. of variation	Nr of plots
Volume dead trees - lying	Gaussian	10 %	Coeff. of variation	Nr of plots
Recorded national data				
Total harvested volume	Gaussian	15 %	Coeff. of variation	One per year
Total forest surface	Gaussian	2 %	Coeff. of variation	One
Species specific parameters				
Dead wood density	Gaussian	15 %	Coeff. of variation	Nr of species
Longevity dead wood – standing	Gaussian	30 %	Coeff. of variation	Nr of species
Longevity dead wood - lying	Gaussian	30 %	Coeff. of variation	Nr of species
Volume expansion equations – coefficients	Gaussian	10 %	Coeff. of variation	Nr of species
Biomass expansion equations – equation choice	Uniform	-	Random equation choice from species biomass equations	Nr of species
Optab values	Gaussian	10 %	Coeff. of variation	Nr of species
General parameters				
Wood carbon content	Gaussian	5 %	Coeff. of variation	One
Natural mortality rate	Adapted Gaussian*	80 %	Coeff. of variation	One
Start age for harvesting	Gaussian	20 %	Coeff. of variation	One
Start volume for harvesting	Triangular	30 %	Coeff. of variation	One

3.3. Sensitivity analysis

For the sensitivity analysis the assessment was run 500 times for each parameter/variable to derive the carbon budget at national scale for forests remaining forest for:

- carbon uptake in growing trees
- carbon uptake in and release from dead woody material
- carbon released through harvesting
- net effect of the three above mentioned output variables is the final net carbon budget

Table 3.2: Results of sensitivity analysis of the carbon budget of forests not influenced by land use change: variation in net carbon uptake induced by estimated variation in input parameters (standard deviation in tons CO_2 year^{-1} at national scale) (-: parameter not relevant / not used in calculation)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Coefficients of volume equation	660699	694060	721359	730933	727391	719084	708605	681006	698564	698789	847224
Total volume harvested (NL)	256543	240410	234376	212265	219879	215983	229131	258679	235265	249297	331853
Natural mortality	187279	187613	188029	188641	189264	189769	190159	190478	190371	190441	225912
Choice of biomass equation	165799	177497	184223	187034	186423	183470	176195	171671	171795	183366	210715
Wood carbon content	178303	180942	187929	188265	184088	179931	177261	161708	167530	164444	179263
Total forested surface											75694
Start volume for harvesting	4025	6038	8084	12071	14725	15184	12918	10880	8953	6877	54848
Optab values	29281	30856	32079	33028	33524	34246	34413	34781	35019	34866	31591
Longevity dead wood - lying											29692
Start age for harvesting	2532	2621	3267	5427	3608	9340	4086	8001	4948	3761	27836
Net annual increment	12688	12633	12667	12919	13681	13242	12517	13373	12718	12656	18518
Plot age	4151	4333	4508	4412	4480	4366	4627	4200	4335	4729	16796
Growing Stock	6224	6757	6731	6388	6466	6193	5559	6223	6166	5074	13594
Longevity dead wood - standing	3205	3957	4892	5748	6561	7333	8068	8766	9430	10060	8694
Dominant height	5345	4192	3252	2837	2605	2369	2847	2506	2750	3473	5091
Representative Area (plot)	1257	1232	1159	1110	1152	1280	1854	1881	1546	1610	
Dead wood density	718	704	689	675	662	648	635	622	610	598	3012
Nr of live trees	520	509	414	419	345	324	387	400	278	339	1297
Diameter of middle tree	524	585	550	482	456	360	500	822	365	274	364
Volume dead trees – lying											251
Volume dead trees – standing	39	38	38	37	36	35	35	34	33	32	65

The 500 runs with random draws lead to 500 outcomes for each parameter/variable. The normality of the resulting distributions of output variables was tested with the Shapiro-Wilks test of normality (appendix B) using SPSS version 10. Despite the significant deviation from normality for some parameters, the results were expressed as the standard deviation of the calculated distribution of output parameters (table 3.2).

In general, two types of variability have a substantial effect on the outcomes of the assessment: (coefficients of) equations that relate structural characteristics to volume or biomass and parameters that are drawn only once for the whole assessment. Overall, the largest variability (about 0.7 million tons CO_2 year^{-1} at national scale) is caused by a random variation of the coefficients that relate wood volume to structural wood characteristics (height, diameter) from Jansen et al. 1996. The variation introduced through these is an overestimate, as the different coefficients were drawn independently from each other, there is very little information on a realistic distribution and the relations are highly non-linear. Therefore the estimation of the total uncertainty was calculated both with and without taking into account the variation in coefficients of equations that relate wood volume to structural wood characteristics (see below). The random selection of existing allometric relations between biomass and structural characteristics resulted in a more realistic standard deviation of about 0.2 million tons CO_2 year^{-1} at national scale.

Parameters that are drawn only once for the whole uncertainty assessment by nature have a systematic effect on the outcome, in contrast to e.g. parameters that are drawn independently for each plot or even each species. Their eventual effect depends to a large extent on the mathematical sensitivity of the calculations. Most variability (more than 0.1 million tons CO_2 year^{-1} at national scale) is caused by the total volume that is harvested and by natural mortality, as more harvest is directly translated into more carbon loss, and more natural mortality is directly translated in a higher carbon uptake (as mortality is considered inclusive in net annual increment on plot level). Of similar importance is carbon content of wood biomass, as it is linearly translates biomass changes to carbon changes.

Though drawn only once, there is very little sensitivity to the parameters that are linked to the distribution of the harvested wood over the different plots, i.e. age and volume from which harvesting starts. The distribution of the total harvested volume over the plots causes only a marginal variation in total carbon harvested (data not shown), and thus on the total carbon budget.

On the other hand, species specific parameters converting (dead) volume into biomass or variation in the recorded or measured plot data has little to no effect on the final outcome. The plot data have a low to very low estimate of recording error, and as more than 1000 values are drawn per run (one for each plot), there is very little chance for any overall systematic effect to occur. A similar effect can be found for the species specific parameters, though to a lesser extent. There are less draws and some species occur more frequently and thus have a stronger effect more on the final result than others. Also, all species specific parameters that are not linked to allometric equations (and thus coefficients) are related to emission of carbon from dead wood only, which is a slightly less important component of the total flux (e.g. Figure 3.1).

3.4. Effect of forward calculating several years

For the year 2000, the carbon budget was calculated based on measurements in MFV plots. For 1990, the carbon budget was calculated based on measurements in Hosp plots. A very simple model was then developed to close this gap of ten years using a forward calculation based on the 1990 data and the assumption that net annual increment would not change over the years (Nabuurs et al., 2005). Thus were calculated the values for 1991-1999. However, it was also possible to extend the forward calculation of the Hosp-plots from 1990 to 1999 for one more year, and thus to compare the 2000 carbon budget for forest remaining forest based on Hosp and on MFV data for the same year. It is clear from figure 3.1 that the overall uncertainty is larger than the differences between the two different ways of calculation. Differences between the two types of base data are also based on small differences in method of calculation resulting from small differences in type of data available and assumptions needed to develop the forward calculation. These are most pronounced in the calculation of live tree biomass and the calculation of wood harvested, though in opposite directions, resulting in very little difference for the overall carbon budget (Figure 3.1).

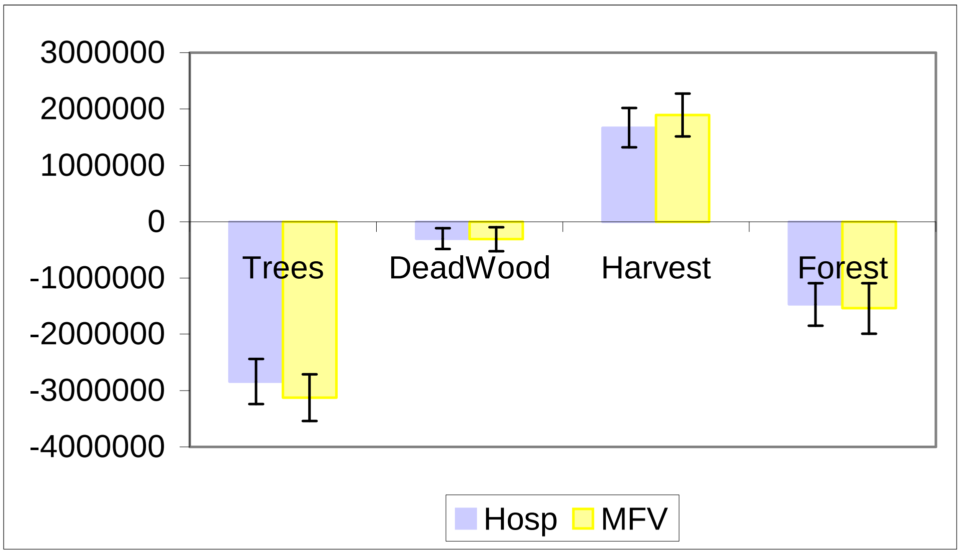

Figure 3.1: Comparison of net CO_2 budget (tons year^{-1}) for 2000 for forests remaining forests based on MFV data and based on Hosp data. Error bars are standard deviations based on uncertainty analysis with coefficients of equations relating volume to structural tree characteristics fixed to the original value.

3.5. Uncertainty analysis

For the uncertainty analysis the assessment was run 500 times with random draws of all parameters and variables simultaneously. This was done an additional time with the coefficients of the equations relating volume to structural characteristics fixed, as it is unclear to what extent the variability created by these is an artefact (see discussion above).

The derived output variables at national scale for forests remaining forest are:

- carbon uptake in growing trees

- carbon uptake in and release from dead woody material

- carbon released through harvesting

- net effect of the three above mentioned output variables is the final net carbon budget

Each of the series of 500 runs lead to 500 outcomes, with the resulting distributions of output variables strongly deviating from normality (e.g. figure 3.2a for MFV data in 2000, Shapiro-Wilk test for normality of distribution p=0.000) if the coefficients of the equations relating volume to structural tree characteristics are drawn randomly. However, if the coefficients for volume equations are not varied, the distribution of the resulting net outcome is not significantly different from a normal distribution (figure 3.2b for MFV data in 2000).

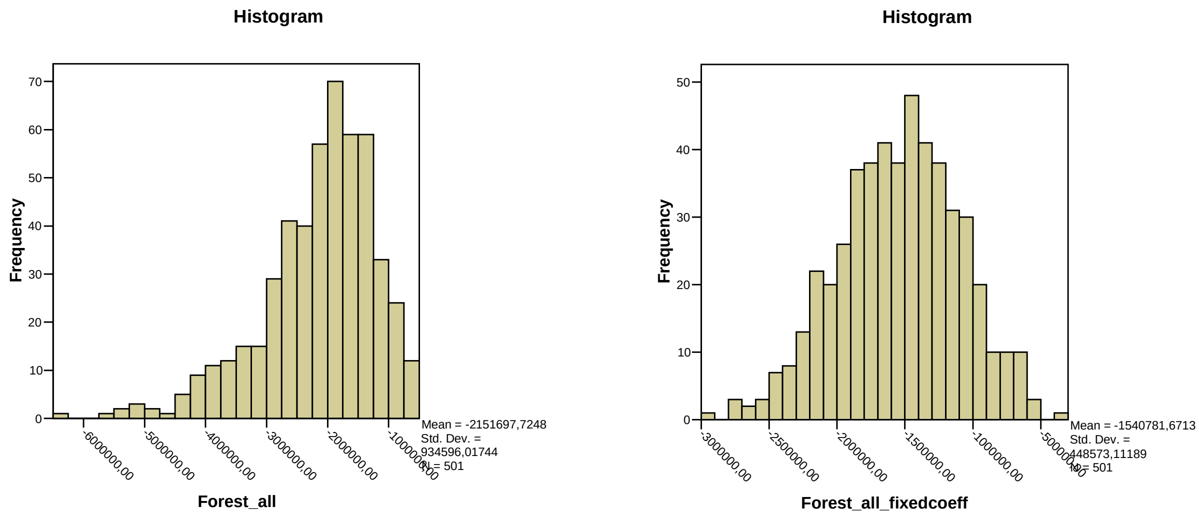

Figure 3.2: Distribution of net CO_2 budget (tons year^{-1}) for forests remaining forests based on MFV data for 2000 with all parameters and variables varying simultaneously with volume equation coefficients varying (a) or fixed (b). See sensitivity analysis for reasoning on including random drawing of equation coefficients

There is a high uncertainty in the estimate of the carbon budget, for 2000 this ranges from an uptake of 0.5 to 3 million tons CO_2 $year^{-1}$ when the effect of varying coefficients for volume equations is not taken into account, and even 6 million tons CO_2 $year^{-1}$ (with a long tail of low frequency towards a high carbon uptake) if also the coefficients of the equations relating volume to structural characteristics are varied (but see comments above). However, despite the high uncertainty, the resulting outcome always indicates a net uptake of carbon for forest remaining forest.

For distributions that do not conform to normality, and especially in case of an asymmetrical distribution as found in figure 3.2a, mean and standard deviation are not the appropriate measures to describe the results. Therefore, in figure 3.3 the median (i.e. the value where 50% of all outcomes is lower and 50% is higher) and 5 and 95 percentiles (i.e. the value where 5% of all outcomes is lower and 95% is higher, respectively where 95% of all outcomes is lower and 5% is higher) of the resulting distributions are shown for all years. For the uncertainty estimated with the coefficients for volume equations fixed, the resulting outcomes are normally distributed and figure 3.4 shows the mean and standard deviations of the different components of the carbon budget for forest remaining forest at national scale.

The uncertainty with the coefficients of the equations relating volume to structural characteristics fixed is much lower than if they are varied. Though this result is in accordance with the sensitivity analysis, it should be kept in mind also that different measures are used for uncertainty in both cases. Still, even with the coefficients of the equations relating volume to structural characteristics fixed the uncertainty is large in almost all components of the carbon budget. There is, however, no additive effect of the uncertainties in the different components, i.e. the uncertainty of the net budget is of about the same size as or even slightly smaller than the most uncertain component, which is carbon uptake in live trees. This uncertainty is much larger than any variability between years, though this latter is underestimated for 1990-1999 as all years except 2000 are based on the same monitoring data.

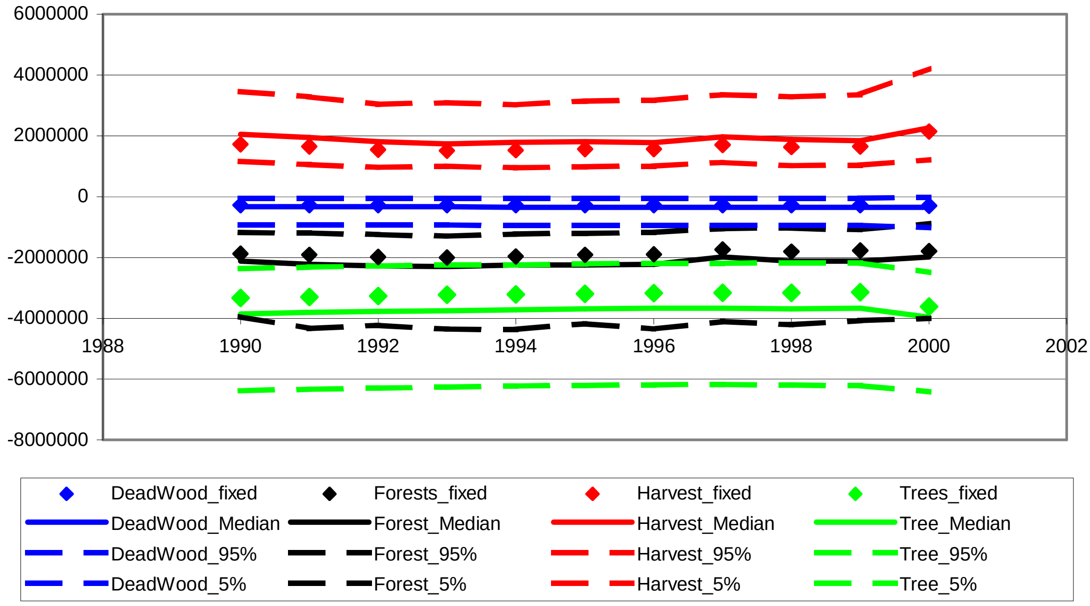

Figure 3.3: Distribution of CO_2 budget (tons year^{-1}) and components for forests remaining forests based on MFV (2000) and HOSP (1990-1999) data with all parameters and variables varying simultaneously.

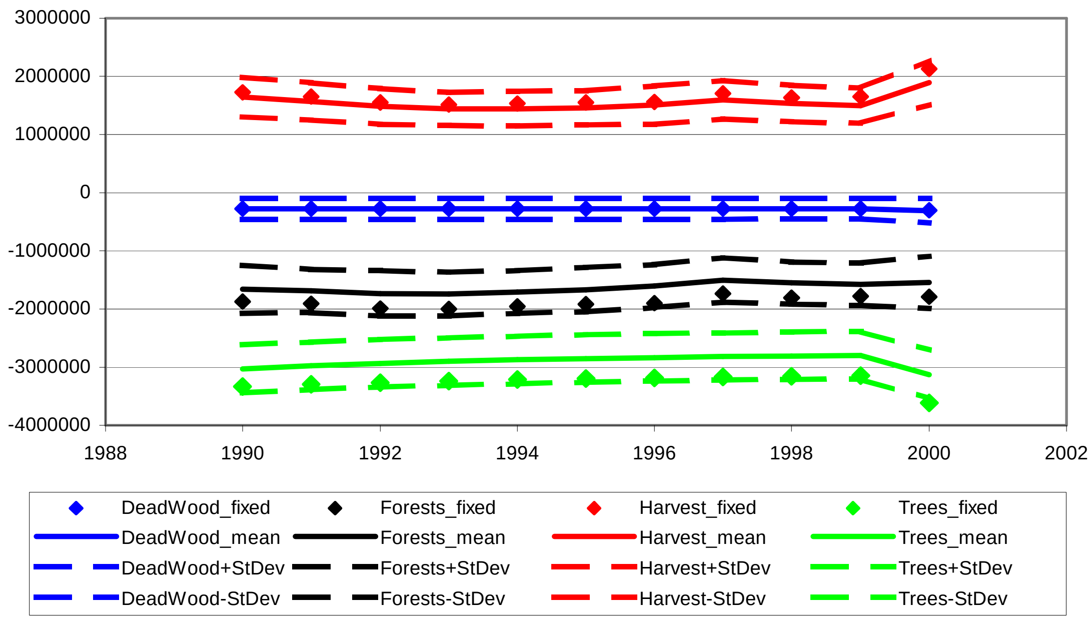

Figure 3.4: Distribution of CO_2 budget (tons year^{-1}) and components for forests remaining forests based on MFV (2000) and HOSP (1990-1999) data with all parameters and variables varying simultaneously except coefficients of equations relating volume to structural characteristics.

3.6. Improving the reliability of the carbon budget of forests remaining forest

Three recommendations for reducing total uncertainty can be made. First of all, the (coefficients of the) equations used have a strong effect on the total outcome. Currently, for the equations relating wood volume to structural characteristics the uncertainty in these coefficients is not well known, and a standardized distribution was assumed. For allometric biomass equations, the uncertainty was incorporated by random drawing from the different (realistic) possibilities, and though still important, this gave a much lower share in the total uncertainty. A better estimate of the (distribution of) the uncertainties involved with the coefficients of different equations and how to incorporate them should give a more realistic and less skewed estimate of the total uncertainty. Then a better evaluation could be made to what extent it would be worth to invest time and money for a more precise determination of these equations for the different Dutch situations.

The second and third recommendations are both related to parameters that are currently drawn only once for each run: total harvested volume, total forested surface, natural mortality and wood carbon content. As these parameters have a strong effect on the final outcome, these seem the highest priority for a more precise determination. For some, like total forested surface and total harvested volume, this is possible. To do this is the second recommendation. However, for e.g. wood carbon content, an enormous amount of measurements already exist and the incorporated uncertainty reflects natural variability rather than lack of data. Though the amount of measured data for natural mortality is substantially lower, it is expected that also in this case natural variability will predominate the estimate of the total uncertainty of only one value is determined for all Dutch forests. One way of reducing uncertainty in such a case is to estimate the parameters at a lower level, e.g. species specific wood carbon content and natural mortality possibly even at plot level, as part of the monitoring, and this is the third recommendation. The effect of this on total uncertainty is twofold. First of all, it is expected that natural variability will be less within a species or for specific circumstances than on a national level. Secondly, on a purely mathematical level, the method of calculation is much less sensitive for parameters that have multiple draws per run than those that are drawn only once, as the chance of all draws leading to an extremely high or low outcome is strongly reduced. Thus, even if the natural variability does not allow a lower uncertainty of the parameters considered, just by multiple drawing from the same distribution the result will be a lower overall uncertainty.

4. Improvements to the methodology to estimate soil carbon stocks in the Netherlands

4.1. Introduction

De Groot et al. (2005) presented a national system with a methodology to estimate soil carbon stocks. This methodology and estimates are the basis for reporting on carbon stocks and change of carbon stock related to land use and changes in land use in the Netherlands to the UNFCCC. For a summary of this methodology we refer to the Annex C. The methodology has been improved in 2005 with respect to the following three points:

1. The carbon stocks have been estimated more accurately by calculating average carbon stocks for each soil stratum separately, resulting in 70 classes (methodology NIR2004), instead of applying only 8 classes of carbon stock, as was prescribed in methodology NIR2003;
2. The estimated carbon stocks have been corrected for some wet organic soils (Water Table Class II[1]);
3. The depth for which carbon stocks are estimated for organic soils have been extended to 120 centimetres below the ground surface.

In the following section the effects of the three improvements will be discussed in detail.

4.2. Effects of using the improved methodology

4.2.1 Effects of estimates based on soil strata (Improvement 1)

Distinction can be made between effects related to soil and effects related to land use.

Soil

For the part of the Netherlands in which the National Sample from Soil Map Units took place 70 soil strata were distinguished for which average carbon stocks were calculated from soil data. This resulted in an estimated carbon stock which is 0.8 % larger than the preliminary estimate based on averages for 8 classes of carbon stock according to De Groot et al. (2005). As a consequence, 3411 Gg should be added to the preliminary estimate of the soil carbon stock for a total area of 4.1 millions of hectares, which was reported in March 2005. It should be mentioned that in an earlier stage an increase by 5 % was reported to WEBsinks. However, this estimate was based on an area in which 70,000 hectares were mistakenly included.

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[1] The Soil Map of the Netherlands, 1:50,000, discriminates between seven classes of annual water table fluctuation, varying from shallow (I) to deep (VII). Water table class II represents relatively wet situations, with annual fluctuations with water table depths between 0 and 40 cm in the wet season and depths between 50 and 80 cm in the dry season.

Land use
For several combinations of soil type and land use categories in the Netherlands information on the carbon stock is lacking. Therefore, in 2004 values were estimated for these areas by averaging the values of areas within the same land use category, but with varying soil types.

In March 2005 new estimates were made by calculating weighted averages of 8 classes of carbon stock, using the areas as weights. In the improved procedure which was applied most recently, a weighted average was calculated for each of 70 soil strata of the Netherlands Soil Sampling Programme (NSSP) separately. The areas of each combination of land use in the years 1990 and 2000 were used as weights.

4.2.2 The carbon stock of some wet organic soils in Water Table Class II (Improvement 2)

In a preliminary stage an area of 25,000 hectares of organic soils in Water Table Class II was mistakenly assigned to another Water Table Class. Recalculation resulted in an increase of the carbon stock for the area of Water Table Class II with 32,000 kilogram carbon per hectare, which equals 800 Gg C.

4.2.3 Effects of improvements 1 and 2 at the estimations in NIR2004

Improvements 1 and 2 have a restricted net effect only: the estimated carbon stock for 1990 which is calculated in October 2005 decreases with 912 Gg as compared to the stock which was estimated in March 2005.

The calculations can be summarized as follows:

Carbon stock 1990 (estimated March 2005):	336,450 Gg C
Improvement 1, contribution of soil only:	+ 3,411 Gg C
Improvement 1, contribution of averaging:	- 5,123 Gg C
Improvement 2:	+ 800 Gg C

Carbon stock 1990 (estimated October 2005):	335,538 Gg C

4.2.4 Estimated carbon stocks for organic soils up to 120 cm below the ground surface (Improvement 3)

Kuikman et al. (2003) estimate a carbon stock for all soils up to a depth of 30 centimetres below the ground surface. In the current, improved, procedure the carbon stock is estimated for all soils up to a depth of 120 centimetres below the ground surface, as far as data are available. Since the sample depth of the NSSP is restricted to the Mean Lowest Watertable, data up to a depth of 120 centimetres below the ground surface were not available for relatively wet soils. Therefore, for these soils the data of the deepest horizon were extrapolated to a depth of 120 centimetres below the ground surface.

The estimated emissions of CO_2 and N_2O in organic agricultural soils by Kuikman et al. (2005) are based on an area of 223,000 ha. This area is an improved estimate based on research on decreased areas of organic soils. Note that the area of organic soils decreased drastically: the soil map of the Netherlands, scale 1:50,000, represents

422,455 hectares of organic soils. Figure 4.1 gives the relative areas of the major soil types of this soil map. The total area for which carbon stocks are estimated on the basis of the Dutch soil map, scale 1:50,000, equals 2,980,622 hectares. Table 1 lists the carbon stocks of organic soils in The Netherlands up to 30 centimetres and 120 centimetres depth.

Table 4.1 Carbon stocks of organic soils in The Netherlands, up to 30 cm and 120 centimetres depth

Depth considered in estimation	Carbon stock (Tg C)	Percentage of all soils
0-120 cm	218	27
0-30 cm	66	22.9
difference	152	4.1

Figure 4.2 shows how the total carbon stock up to 30 cm below the ground surface is distributed over the main soil types in The Netherlands. The carbon stock has been estimated on the basis of the soil map of The Netherlands, scale 1:50,000. The total carbon stock amounts 289 Tg C.

Figure 4.3 shows the distribution of the total carbon stock up to 120 cm below the ground surface over the main soil types. The total carbon stock amounts 610 Tg C.

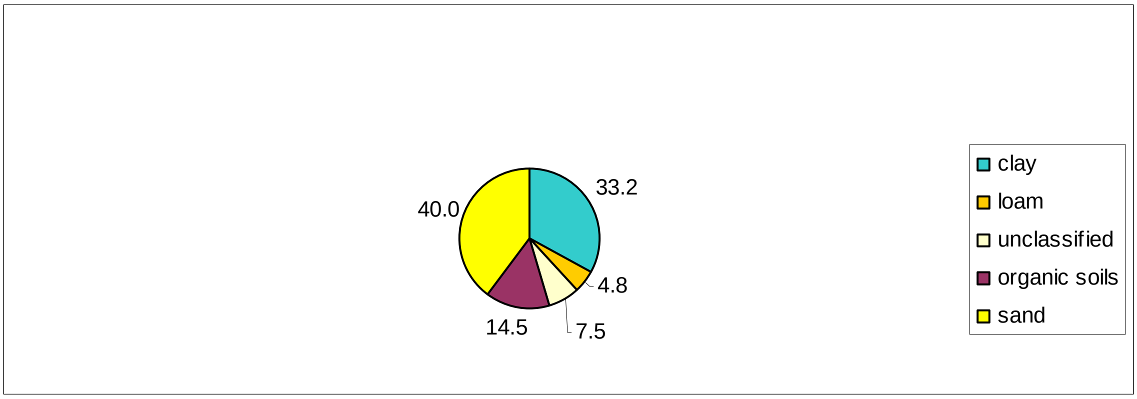


Figure 4.1Relative areas of the mean soil types in The Netherlands, based on the Soil Map of the Netherlands, 1:50,000

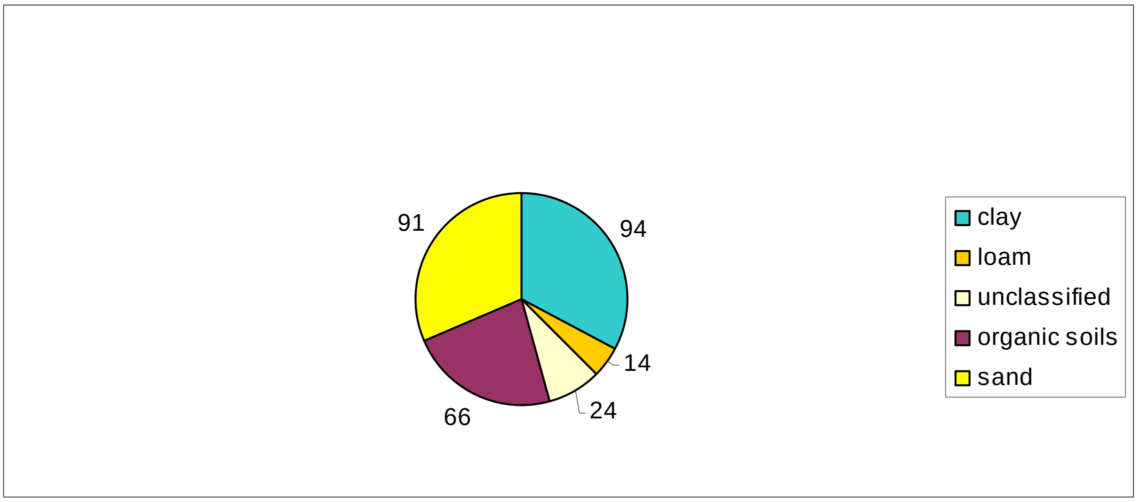


Figure 4.2 Distribution of the carbon stock up to 30 cm below the ground surface over the main soil types in the Netherlands (Tg C)

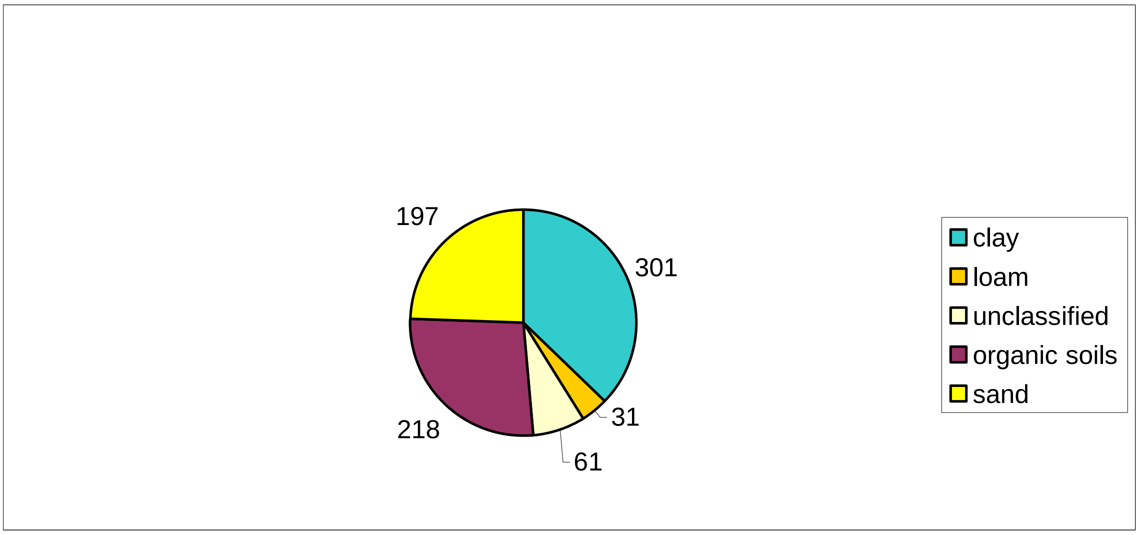


Figure 4.3 Distribution of the carbon stock up to 120 cm below the ground surface over the main soil types in the Netherlands (Tg C)

4.2.5 Summary of effects

Table 2 lists the effects of the improvements to estimated net CO_2-emissions. NIR2005 reflects the estimates before improvements were incorporated, NIR2006 reflects the estimates after improvements to the methodology were made.

Table 4.2 Sectoral report for land use, land-use change and forestry of Net CO_2 emissions or removals in 1990. NIR2005: report before improvements were applied. NIR2006: report after improvements were applied. NE: not estimated. NA: not applicable

Land-Use Category	Net CO_2 emissions/removals in 1990[(1), (2)]	
	NIR2005	NIR2006
Total Land-Use Categories	2711.17	2570.92
A. Forest Land	-2594.57	-2512.77
1. Forest Land remaining Forest Land	-2505.43	-2505.43
2. Land converted to Forest Land	-89.14	-7.33
B. Cropland	-35.20	-35.57
1. Cropland remaining Cropland	0.00	NE
2. Land converted to Cropland	-35.20	-35.57
C. Grassland	4782.18	4370.67
1. Grassland remaining Grassland	4246.00	4246.00
2. Land converted to Grassland	536.18	124.67
D. Wetlands[(3)]	0.00	NE
1. Wetlands remaining Wetlands	0.00	NE
2. Land converted to Wetlands	0.00	NE
E. Settlements[(3)]	-151.43	-151.54
1. Settlements remaining Settlements	0.00	NE
2. Land converted to Settlements	-151.43	-151.54
F. Other Land[(4)]	710.20	716.98
1. Other Land remaining Other Land		
2. Land converted to Other Land	710,20	716,98
G. Other[(5)]	0,00	183,15
Harvested Wood Products[(6)]	NE	NE
		183,15
Information items[(7)]		
Forest Land converted to Other Land-Use Categories	236,10	-124,67
Grassland converted to Other Land-Use Categories	NA	NA

(1) According to the Revised 1996 IPCC Guidelines, for the purposes of reporting, the signs for removals are always negative (-) and for emissions positive (+). Net changes in carbon stocks are converted to CO_2 by multiplying C by 44/12 and by changing the sign for net CO_2 removals to be negative (-) and for net CO_2 emissions to be positive (+).

(2) CO_2 emissions from liming and biomass burning are included in this column.
(3) Parties do not have to prepare estimates for categories contained in appendices 3a.2, 3a.3 and 3a.4 of the IPCC good practice guidance for LULUCF, although they may do so if they wish and report in this row. In NIR2005 categories not estimated were set at zero, however the implicit assumption of equilibrium was later considered not acceptable and those categories are now indicated NE.
(4) Parties do not have to prepare estimates for this category contained in Chapter 3.7.1 of the IPCC good practice guidance for LULUCF, although they may do so if they wish and report in this row. This land-use category is to allow the total of identified land area to match the national area.
(5) May include other non-specified sources and sinks.
(6) Parties do not have to prepare estimates for this category contained in appendix 3a.1 of the IPCC good practice guidance for LULUCF, although they may do so if they wish and report in this row.
(7) These items are listed for information only and will not be added to the totals, because they are already included in subcategories 5.A.2 to 5.F.2.

5. External review results by: Wojtek Galinski

Graz, January 2006

Introduction and aim

One of the consequences for any country of being a Party to the United Nations Framework Convention on Climate Change (UNFCCC) is the obligation to design and operationalise a national system for preparation of the national GHG inventory on annual basis. One of the elements of such a system is GHG inventory system for the Land Use, Land-Use Change and Forestry sector. Following its obligations, the Netherlands prepared such a system and described it a paper prepared by G.J. Nabuurs, J. van den Wyngaert, W.D. Daamen, A.T.F. Helmink, W de Groot, W.C. Knol, H. Kramer and P Kuikman titled: National System of Greenhouse Gas Reporting for Forest and Nature Areas under UNFCCC in The Netherlands. Aim of this paper is to offer remarks, reflections and suggestions (if any) on further development of the Dutch system

The paper

The reviewed paper describes Dutch national system of greenhouse gas reporting for forest and nature areas under UNFCCC. It consists of eight main chapters:

1 Introduction
2 Approach used for the national System for forest and nature areas
3 Methods and data for area determination
4 Methods and data for forest biomass and dead wood stock changes
5 Methods and data for soil carbon stock changes
6 Results for the forest sector carbon balance 1990 - 2002
7 Discussion and Conclusions
8 References

and four Appendixes:

1. Equations used to derive total tree biomass
2. Validation of the land use map through field visited forest inventory plots
3. The Dutch NIR 2005 over 1990
4. Forest definition as applied by the Netherlands

Remarks and reflections

Chapter 1: Introduction

No remarks. The author agrees with views and ideas presented in this chapter

Chapter 2: Approach used for the national System for forest and nature areas

According to the GPG LULUCF, the Key Category Analysis in LULUCF may be based on sinks and sources separately (if data exists, see p. 5.31). Hence, the statement that the Dutch LULUCF sink comprises ca. 0.8% of the total national emissions does not necessary exclude that the gross emissions and removals in the LULUCF sector are not candidates to a key category. It may happen that a small difference is based on large numbers. An additional analysis is suggested to solve the problem whether LULUCF sector belongs to key categories or not.

The practice of revision of NIRs prepared by the Annex I countries promotes reporting on the highest possible level limited only by existence of data and national scientific knowledge. In the case of the Netherlands both suggest a necessity of reporting on level higher than the Tier 1. For the sake of completeness the GHG inventory for LULUCF should cover all categories. Some of them may be reported under higher tiers while those with little data should be reported under Tier 1. Reporting on all categories enables comparison of advancement of data collection and scientific efforts. This may be used for better funding the GHG inventory process.

The review of data available to the Dutch National System for GHG reporting shows that there are plenty of sources of data and the available data virtually covers all five carbon pools. Hence, there is no justification for excluding some categories or carbon pools from GHG inventory preparation.

Chapter 3: Methods and data for area determination

Figure 3.1 indicates apparent problems with unique definition of forest in the past, which are more and more solved because the estimates for the year 2000 are very similar. It is not entirely clear from the paper, what definitions of forest were applied by the different studies mentioned in the Figure 3.1. I would be interesting to get insight into the definitional issues of forest by different data sources an years (even the same data sources show changes in forest area which are inexplicable by the ARD rates).

Problem of optimal greed for reporting on forest area

In my opinion, solution to the problem of optimal greed for reporting on forest area should include consideration on distribution of areas of individual forest area change events and distribution of areas of individual forest complexes. A study over limited land area may yield information on individual forest area changes (areas of individual ARD events) and areas of individual forest complexes. This information may be transformed into probability density functions and then a size of grid may be calculated. The size should allow for estimation of forest area or forest area change with known (assumed) error. GPG LULUCF attributes significant changes in the carbon pools to changes in forest area hence, the applied grid should allow for determination of estimates of changes in forest area with a known (assumed) error. The size of the grid will also depend of area threshold in the definition of forest however, the dynamic approach applied by GPG LULUCF points rather to change in area and in the second instance to forest area. For example, it is possible to prepare the GHG inventory as required by Art. 3.3 of the KP without mentioning the total area of forest.

Topographical maps may serve as a good source of data for land use type estimation however, the maps themselves are already a product of generalization of the original background data hence they may contain a mapping error. It would be interesting to assess this error and use it error calculus in the NIR. Digitalization, classification and aggregation will introduce their own method related errors. The errors may be used to determine the minimal area of land use change event, which may be estimated with the known significance level.

Chapter 4: Methods and data for forest biomass and dead wood stock changes

Consideration of existence or absence of clearcuts in The Netherlands may be limited to the statement that "the clearcuts are hardly carried any more in The Netherlands". The argument on methodological difficulties of forward calculations may draw the reviewer attention to possible importance of clear cuts if they are able to introduce "highly uncertain forest development" factor to the calculations.

Conversion from volumetric dimensions to the whole tree biomass data
There is no need to search for a single analytical formula relating DBH, or DBH and height with tree biomass. You may use more computer intensive method, e.g. beta spline or you may create your own subroutine based on the measured data collected by Van Hess. The subroutine may smooth and interpolate his data locally (here locally is understood in mathematical way) based on numerical values of derivatives of various level. The local smoothing is important because when you apply any analytical formula you add error hidden in predefined shape of this formula. Simple formulae are not "elastic" while complicated have to many parameters to control. Often these parameters have no physical meaning so the complicated formula is not different from local smoothing with one exception the local smoothing is easier. Local smoothing will enable you to produce biomass relationships based on species and height and/or diameter or both. Your relationships will be able to match your NFI data. If I understand it well, Van Hees database contains really country specific data.

You may use Van Hees file for aboveground biomass and default or COST E21 shoot root ratio (or any other estimate relating the aboveground biomass with the belowground one).

Applying Van Hees data and any method of smoothing them, you will be able to calculate error in biomass estimates resulting from application of this data set.

In my opinion locally validated data (based on smoothing method as discussed above) or local equations (but preference is given to numerical local smoothing – here local is understood in mathematical way) should have preference over any non-local products.

Calculation method

In the relations of Jansen, the parameter S should be validated against the field data. In general, I would rather prefer to estimate S based on field data from old stands.

If I understand well, you have introduced the Jansen's approach to obtain missing data diameter or height if one of them and volume are known. You do it because you want to apply equations from the COST E21 data base. I think that this procedure adds error to the estimations (i – error hidden in Jansen's approach; ii – error hidden in the biomass equations). It might be better to apply the local smoothing method.

Assumption that litter is in a steady state in forest remaining forest is OK however, the litter decomposition creates flux for forest converted to other land uses. For the sake of completeness, it may be advisable to use Tier 1 method to estimate this flux (assuming that all litter decomposes in one year). The same tier approach might be applicable to land converted to forest (assumption on period needed for forest litter to reach the steady state is required here).

Assumptions on thinning are acceptable if the forest under question plays more protection than productive function, which is probably the case in The Netherlands.

The assumption that "The net C flux to dead wood is the remainder of the input of dead wood due to mortality minus the decay of dead wood" means that there is no harvesting or collecting of dead wood. The build up of dead wood pool in the forest is not dependent on attention paid by forestry to the dead wood but on the dead wood management. If it may be assumed that the pool was never managed then the assumption of steady state (on a country level) might be applicable, unless, long term intensity of natural disasters changes.

The MFV data on the dead wood volume may be used to calculate the equilibrium flux to the dead wood however, a decay model has to be assumed. The equilibrium flux (mortality rate) may be compared to field data obtained from a limited number of sample plots. If the actual mortality rate is higher than the equilibrium mortality rate then the build up of the dead wood pool may occur.

On the other hand, if you want to include the dead wood in your calculations, you should also include the inherited dead wood and CO_2 emission caused by it. The period over which the dead wood should be inherited should follow the local decay curves (i.e. the period allowing for decomposition of 95% of the biomass). In my personal opinion, the dead wood pool is not important in the long term perspective however, it may change the emission pattern in a short perspective especially, if some disturbances occur. If forest ecosystems are in a steady state then the dead wood pool does not influence the emission pattern and it may be easy assumed that all annually created dead wood releases all its carbon in the year of the inventory.

I can't fully agree with the sentence: "Leaves and roots were not taken into account for the built up of dead wood, as it was assumed that these rather small litter fractions decomposed within one year". First, leaves do not take part in building the dead wood pool. Second, for the sake of symmetry, if you take into account allocation of carbon to roots (when calculating removals) you should take into account roots when estimating GHG emission from dead wood pool. If it is not done so, then an artificial sink in never decaying dead roots may be created. Third, only a part of dead wood is included under litter hence, there might be some problems with definitional issues for the five carbon pools. It is not entirely clear to me, what is the way of calculating emission from roots. Is it so, that only above ground wood is included in creation of the dead wood and carbon from the belowground dead biomass is fully released in the inventory year. There is no equation presented in the report to clarify the issue.

F_{carbon} - carbon content of dry mass (kg C kg-1 DW), and,
WD_{Dead} - density of dead wood
can not be regarded as constants during the decay process, hence some factors accounting for the advancement of the decay process should be added. On the other hand, if they have to be constant then they should be averages over time during the decay process. The report should elaborate more on estimation of these parameters.

Equation on p. 26 approximates the decay curve with a straight line. Was it checked if it introduced any significant error to time dependence of the decay process? The procedure for estimation of $TBP_{S\ and\ L}$ should be included.

"The IPCC (2003) gives a default period of 20 years for the soil to reach an equilibrium again with the litter input". The report is not clear if this assumption was accepted or not.

"For afforestations it is assumed that half of the carbon uptake factor applies as was found on average for the existing forest". It is not clear how long the newly afforested land is reported under land converted to forest. It is almost certain that this assumption overestimates carbon uptake during the first years after planting. This may result in inconsistency of time series. My suggestion would be to assume a period after which the plantation reaches the carbon uptake of the mature forest and accept linear changes in carbon uptake during this period. This procedure allows for better consistency of time series as it avoids jumps of carbon uptake after planting and when the carbon uptake factor reaches its full value.

The whole paragraph is not entirely clear:
"For soil carbon stock changes after land use change it is assumed that the average carbon stock in the soil under the new and old land use are the same (De Groot et al. 2003).The soils database was not geographically explicit enough to accurately derive the soil carbon stock at the specific site where the land use change took place. Furthermore, accurate information on soil C changes after land use change was lacking for the Netherlands. Therefore it was simply assumed that the soil C stock stays the same. For the total area of a land use type as a whole however, the total stock under this land use can change in time, because of area changes."

The lack of national data on soil carbon stock changes after land use change may imply use of the IPCC default data. The NIR should elaborate why defaults are not used as they are supposed to be used in such conditions.

The assumption: "the average carbon stock in the soil under the new and old land use are the same" breaks the IPCC rule that land use changes are followed by carbon fluxes. Any change in activity should be accompanied with carbon flux unless I am totally wrong.

I do not understand the sentence: "For the total area of a land use type as a whole however, the total stock under this land use can change in time, because of area changes". The change in area will not cause any change in carbon stock if the average carbon stock in the soil under the new and old land use are the same. I understand that the average carbon stock in the soil is expressed on a per hectare basis.

If I am wrong, it means that the whole paragraph should be rewritten as it allows misinterpretation.

I have no more remarks on chapter 4.

Chapter 5: Methods and data for soil carbon stock changes

The assumption that "the soil C does not reach a new equilibrium in relation to the new land use" does not follow the IPCC approach. This statement requires further clarification.

Chapter 6: Results for the forest sector carbon balance 1990 – 2002

The statement: "The strongest sink amounted to -3.7 tonne C y-1, and the strongest source amounted to 7.1 tonne C y-1" requires further clarification with respect to units. Most frequently the unit tC/y/ha is applied hence, a reason why it is not used should be given or benefits from using tC/y as a unit should be more explicit.

The statement: "The results for 'forest remaining forest' show a very stable sink in the Dutch forest" should be discussed with regard to influence of assumptions and method applied when compared to the Dutch forest management to show that the lack of variability in results is not an artifact of the approach.

In the Table 6.1, it is difficult to recognize which numbers are given in unit ha and which in unit ha/10 years.

In a case of the statement: "the estimate for the stock assessment of trees outside the forest might be different from the previous NIR reports, as the area estimate differs now (22 kha now versus 10 kha)", it should be explained what are the reasons for 120% change in area estimate (change of definition, change of method, etc.).

More details on the approach used in estimation of carbon uptake for trees outside forest should be given.

Chapter 7: Discussion and Conclusions

Land use changes may partly relay on differences in background definitions used by different institutions offering the land use maps. If it is possible the unique classification of the original data might be very useful because error related to use of different classifications may be reduced. The obtained absolute changes in areas of land subjected to different land uses should be associated with error estimates. The calculus of error should be mainly aimed at influence of differences in definitions and in approaches used for expansion of point data to areal data, on the error of land use change estimates.

General remarks

- The report could compare what is covered by it with the formal requirements following the GPG LULUCF. This could be done using a table (transition matrix) showing the reported removals and emissions and those required by GPG LULUCF. This form of presentation could let assess the degree of advancement in GHG reporting under the UNFCCC.
- All obtained results could be presented using the CRF tables (in Appendix).
- In Europe, usually deforestation follows harvest. If so, there is a possible danger that the biomass removed from the deforested area may be reported twice: as harvest and as deforestation. Safeguards should be applied to avoid such a situation.
- According the IPCC definition afforestation is not an abandonment of the managed land but part of forest land management. Land which was used for non forest purposes, begins to be used for forest purposes. The land was not abandoned but planted or naturally regenerated in result of decision of an owner. Abandonment occurs when the current land use is ceased and no other management is introduced. The piece of land is left to its own fate without any kind human intervention.
- It was not clear from the report whether the area of afforestation is not reported twice: under 5A and 5C. Usually data on forest area include the area of afforestation.

Literature

Bartelink, H.H. 1997. Allometric relationship for biomass and leaf area of beech (*Fagus sylvatica* L). Annals of Forest Science 54: 39-50.

Bartelink, H.H. 1996. Allometric relationships on biomass and needle area of Douglas-fir. Forest Ecology and Management 86: 193-203.

Brække, F.H. 1986. Distribution and Yield of Biomass from Young *Pinus sylvestris* and *Picea abies* Stands on Drained and Fertilized Peatland. Scandinavian Journal of Forest Research 1: 49-66.

Briggs, E.F. and T. Cunia. 1982. Effect of cluster sampling in biomass tables construction: linear regression models. Canadian Journal of Forest Research 12(2): 255-263.

Chroust, L. and J. Tesarova. 1985. Quantification of above-ground components of 20 years old Norway spruce (Picea abies (L.) Karsten). Communicationes Instituti Forestalis Cechosloveniae 14: 111-126.

Drexhage, M., M. Chauvière, F. Colin and C.N.N. Nielsen. 1999. Development of structural root architecture and allometry of *Quercus petraea*. Canadian Journal of Forest Research 29: 600-608.

Drexhage, M. and F. Gruber. 1999. Above- and below- stump relationships for Picea abies: estimating root system biomass from Breast height diameters. Scandinavian Journal of Forest Research 14: 328–333.

Duvigneaud, P. and P. Kestemont. 1977. La hetraie ardennaise a Festuca Altissima a mirwart biomasse et productivite primaire. In: P. Duvigneaud and P. Kestemont (eds.) Productivite biologique en Belgique. Editions Duculot, Paris-Gembloux: 107-154.

Fiedler, F. 1986. Die Dendromasse eines hiebsreifen Fichtenbestandes. Beiträge für die Forstwirtschaft 20(4): 171-180.

Le Goff, N. and J.M. Ottorini. 2001. Root biomass and biomass increment in a beech (Fagus sylvatica L.) stands in North-East France. Annals of Forest Science 58: 1-13

De Groot, W.J.M., R. Visschers, E. Kiestra, P.J. Kuikman and G.J. Nabuurs, 2005. National system to report to the UNFCCC on carbon stock and change of carbon stock related to land use and changes in land use in the Netherlands (in Dutch). Wageningen, Alterra-rapport 1035-3.

Hamburg, S.P., D.M. Zamolodchikov, G.N. Korovin, V.V. Nefedjev, A.I. Utkin, J.I. Gulbe, T.A. Gulbe. 1997. Estimating the carbon content of Russian forests: a comparison of phytomass/volume and allometric projections. Mitigation and adaptation strategies for Global Change 2: 247-265.

Hazell, P. 1999 Conservation and Yield aspects of old European aspen Populus tremula in Swedish forestry. PhD Thesis Silvestria 102

van Hees, A.F.M. 2001. Biomass development in unmanaged forests (in Dutch). Nederlands Bosbouwtijdschrift 73 (5): 2-5.

Hochbichler, E. 2002. Vorläufige Ergebnisse von Biomasseninventuren in Buchen- und Mittelwaldbeständen. In: Dietrich, H.P., S. Raspe and T. Preushsler (eds). Inventur von Biomasse- und Nährstoffvorräten in Waldbeständen. Forstliche Forschungsberichte, Heft 186, LWF, München, Germany: 37 - 46

IPCC 2003. LUCF Sector Good Practice Guidance. Penman et al. (Eds.), IPCC Good practice Guidance for Land Use, Land Use Change and Forestry. IPCC NGGIP Programme. Published by IGES for IPCC. Japan.

Jansen, J.J., J. Sevenster and P.J.Faber. 1996. Opbrengsttabellen voor belangrijke boomsoorten in Nederland. IBN rapport 221. Hinkeloord report number 17. Wageningen, The Netherlands.

Johansson, T. 1999a. Biomass production of Norway spruce (Picea abies (L,) Karst,) growing on abandoned farmland. Silva Fennica 33 (4): 261-280.

Johansson, T. 1999b. Biomass equations for determining functions of pendula and pubescent birches growing on abandoned farmland and some practical implications. Biomass and Bioenergy 16: 223-238.

Johansson, T. 1999c. Biomass equations for determining fractions of European aspen growing on abandoned farmland and some practical implications. Biomass and Bioenergy 17: 471-480.

Johansson, T. 2000. Biomass equations for determining functions of common and grey alder growing on abandoned farmland and some practical implications. Biomass and Bioenergy 18: 147-159.

Johansson, T. 2002. Dry matter amounts and increment in 21-to 91-year-old common alder and grey alder some practical implications. Canadian Journal of Forest Research 29: 1679-1690.

Knol, W., H. Kramer and H. Gijsbertse. 2004. Historisch grondgebruik in Nederland: een landelijk reconstructie van het grondgebruik rond 1900. Alterra rapport 573. Alterra Wageningen. 89 p.

Kuikman, P.J., W.J.M. de Groot, R.F.A. Hendriks, J. Verhagen and F. de Vries, 2003. Stocks of C in soils and emissions of CO_2 from agricultural soils in the Netherlands. Alterra-report 561. Alterra Wageningen.

Kuikman, P.J., J.J.H. van den Akker and F. de Vries, 2005. Emission of N_2O and CO_2 from organic agricultural soils. Alterra-report 1035.2. Alterra Wageningen.

Lee, D.H. 1998. Architektur des Wurzelsystems von Fichten (Picea abies [L.] Karst.) auf unterschiedlich versauerten Standorten, Göttingen, Forschungszentrum Waldökosysteme der Universität Göttingen. Reihe A, Bd, 153: 1-142.

Nabuurs, G.J., W. Daamen, G.M. Dirkse, J. Paasman, P.J. Kuikman, J. Verhagen. 2003. Present readiness of and white spots in the Dutch National System for greenhouse gas reporting of the Land Use, Land-Use Change and Forestry sector (LULUCF) Alterra-report 774. Alterra Wageningen.

Makela, A. and P. Vanninen. 1998. Impacts of size and competition on tree form and distribution of aboveground biomass in Scots pine. Canadian Journal of Forest Research 28(2): 216-227.

Mälkönen, E. 1977. Annual primary production and nutrient cycle in a birch stand, Metsäntutkimuslaitoksen tiedonantoja 91: 1-35.

Møller, I.S. 2000. Calculation of biomass and nutrient removal for different harvesting intensities. New Zealand Journal of Forestry Science 30(1/2): 29-45.

Nabuurs, G.J., I.J. van den Wyngaert, W.D. Daamen, A.T.F. Helmink, W. de Groot, W.C. Knol, H. Kramer, P. Kuikman. 2005. National system of greenhouse gas reporting for forest and nature areas under UNFCCC in the Netherlands. Alterra report 1035-I. Alterra, Wageningen. 57 p.

Nihlgard, B. 1972. Plant biomass, primary production and distribution of chemical elements in a beech and a planted spruce forest in South Sweden. Oikos 23: 69-81.

Oleksyn, J., P.B. Reich, W. Chalupka and M.G. Tjoelker. 1999. Differential above- and below-ground biomass accumulation of European Pinus sylvestris populations in a 12-year-old provenance experiment. Scandinavian Journal of Forest Research 14 (1): 7-17

Poeppel, B. 1989. Untersuchungen der Dendromasse in mittelalten Fichtenbeständen. Forsteinrichtung und Forstliche Ertragskunde. Dresden. Technische Universität Dresden: 66

Pretzsch, H. 2000. Die Regeln von Reineke, Yoda und das Gesetz der räumlichen Allometrie. Allgemeine Forst- und Jagd-Zeitung, 171(11): 205-210.

Santa Regina, I., T. Tarazona. 2001. Organic matter and nitrogen dynamics in a mature forest of common beech in the Sierra de la Demanda, Spain. Annals of Forest Science 58: 301-314.

Saucier, R. 2000. Computer Generation of Statistical Distributions. Army Research Laboratory.

Wirth, C., J. Schumacher and E.D. Schulze. 2004. Generic biomass functions for Norway spruce in Central Europe—a meta-analysis approach toward prediction and uncertainty estimation. Tree Physiology 24: 121–139.

Xiao, C.W., J.C. Yuste, I.A. Janssens, P. Roskams, L. Nachtergale, A. Carrara, B.Y. Sanchez, R. Ceulemans 2003. Above-and belowground biomass and net primary production in a 73-year-old Scots pine forest. Tree Physiology 23(8): 505-516

Annex A List of all equations used for calculation of above- and below ground biomass.

The following tables include all equations used for calculation of above- resp. below- ground biomass. For list of equations chosen for standard runs and motivation see Nabuurs et al., 2005.

Table 1: Equations for belowground biomass Abbreviations: AB: Aboveground Biomass; D : Diamater at breast height; H: Height; RT: Root Biomass.

Species (group)	Format of equation	Units of Biomass	Units of D	Units of H	coeff_a	coeff_b	coeff_c	coeff_d	coeff_e	Reference
Acer spp										
Betula pubescens	AB = a*D^b	kg	mm	m	0,00029	2,50038	n/a	n/a	n/a	Johansson, 1999b
Alnus spp										
Alnus glutinosa	AB = a*D^b	kg	mm	m	0,00079	2,28546	n/a	n/a	n/a	Johansson, 2000
Alnus glutinosa	AB = a*D^b	kg	mm	m	0,00309	2,022126	n/a	n/a	n/a	Johansson, 2002
Alnus incana	AB = a*D^b	kg	mm	m	0,0003	2,42847	n/a	n/a	n/a	Johansson, 2000
Alnus incana	AB = a*D^b	kg	mm	m	0,000499	2,337592	n/a	n/a	n/a	Johansson, 2002
Betula spp										
Betula pendula	AB = a*D^b	kg	mm	m	0,00087	2,28639	n/a	n/a	n/a	Johansson, 1999b
Betula pubescens	AB = a*D^b	kg	mm	m	0,00029	2,50038	n/a	n/a	n/a	Johansson, 1999b
Betula spp.	AB = a*(D^2*H)^b	kg	cm	m	0,5443	0,6527	n/a	n/a	n/a	Hamburg et al., 1997
Betula spp.	AB = a*D^b*H^c	kg	cm	m	0,0054	1,0221	2,3905	n/a	n/a	Hamburg et al., 1997
Broadleaved other										
Quercus spec, (robur or petraea)	LN(AB) = a+b*LN(D)	kg	cm	m	-0,883	2,14	n/a	n/a	n/a	Hochbichler, 2002
Coniferous other										
Picea abies	AB = a*(D^2*H)^b	kg	cm	m	0,0533	0,8955	n/a	n/a	n/a	Hamburg et al., 1997
Fagus sylvatica										
Fagus sylvatica	AB = a*D^b	Kg	cm	n/a	0,1315	2,4321	n/a	n/a	n/a	Santa Regina & Tarazona, 2001
Fagus sylvatica	AB = a*D^b*H^c	kg	cm	m	0,0306	2,347	0,59	n/a	n/a	Bartelink, 1997
Fagus sylvatica	AB = a*D^b	kg	cm	n/a	0,0798	2,601	n/a	n/a	n/a	Bartelink, 1997
Fagus sylvatica	AB = a*D^b	kg	cm	n/a	0,70961	2,0666	n/a	n/a	n/a	Duvigneaud & Kestemont, 1977

Fagus sylvatica	AB = a*D^b	kg	cm	n/a	0,1143	2,503	n/a	n/a	n/a	Pretzsch, 2000
Fagus sylvatica	AB = a+b*LN(D)+c*LN(H)	kg	cm	m	-2,872	2,095	0,678	n/a	n/a	Hochbichler, 2002
Fagus sylvatica	AB = a+ b * LOG10(D^2*H)	kg	cm	m	-1,7194	1,0414	n/a	n/a	n/a	Nihlgard, 1972
Fagus sylvatica	AB = a*D^b	kg	cm	n/a	0,1143	2,503	n/a	n/a	n/a	Pretzsch, 2000
Fagus sylvatica	AB = a+b*LN(D)+c*LN(H)	kg	cm	m	-2,872	2,095	0,678	n/a	n/a	Hochbichler, 2002
Quercus spec, (robur or petraea)	LN(AB) = a+b*LN(D)	kg	cm	m	-0,883	2,14	n/a	n/a	n/a	Hochbichler, 2002
Larix spp										
Picea abies	AB = a*(D^2*H)^b	kg	cm	m	0,0533	0,8955	n/a	n/a	n/a	Hamburg et al., 1997
Picea spp										
Picea abies	AB = a+b*D+c*D^2	kg	cm	n/a	19,018	-4,806	0,565	n/a	n/a	Briggs & Cunia, 1982
Picea abies	AB = a+b*D^2+c*(D^2*H)	kg	cm	m	0,257	0,187	0,01	n/a	n/a	Briggs & Cunia, 1982
Picea abies	AB = a*(1-exp(-b*D))^c	Kg	mm	m	21988,76	0,0006	2,44	n/a	n/a	Johansson, 1999a
Picea abies	AB = a+b*D+c*D^2	kg	cm	n/a	-43,13	2,25	0,452	n/a	n/a	Fiedler, 1986
Picea abies	AB = a+b*D+c*D^2	kg	cm	n/a	-60,557	5,46558	0,27567	n/a	n/a	Poeppel, 1989
Picea abies	AB = a+b*D+c*D^2	kg	cm	n/a	-142,609	13,63896	0,12593	n/a	n/a	Poeppel, 1989
Picea abies	AB = a*D^2*H	kg	cm	m	0,02155	n/a	n/a	n/a	n/a	Møller, 2000
Picea abies	AB = a*D^2*H	kg	cm	m	0,01815	n/a	n/a	n/a	n/a	Møller, 2000
Picea abies	AB = a*(D+1)^(b+c*log(D))*H^d	kg	cm	m	0,4274	0,8674	1,0099	-0,2028	n/a	Chroust & Tesarova, 1985
Picea abies	AB = a+b*D+c*D^2	kg	cm	n/a	-43,13	2,25	0,452	n/a	n/a	Fiedler, 1986
Picea abies	AB = a*D^2+b*(D-c)	gr	cm	n/a	200,3691	99,3609	25	n/a	n/a	Brække, 1986
Picea abies	AB = a*D^2	gr	cm	n/a	200,3691	n/a	n/a	n/a	n/a	Brække, 1986
Picea abies	AB = a*H^b	kg	cm	m	0,3173	1,7011	n/a	n/a	n/a	Hamburg et al., 1997
Picea abies	AB = a*(D^2*H)^b	kg	cm	m	0,0533	0,8955	n/a	n/a	n/a	Hamburg et al., 1997
Picea abies	AB = a*D^b*H^c	kg	cm	m	0,0842	1,9443	0,5941	n/a	n/a	Hamburg et al., 1997
Pinus other										
Pinus sylvestris	AB = a*(D^2*H)^b	kg	cm	m	0,0217	0,9817	n/a	n/a	n/a	Hamburg et al., 1997
Pinus sylvestris										
Pinus sylvestris	AB = a+b*D+c*D^2	kg	cm	n/a	7,041	-1,279	0,201	n/a	n/a	Briggs & Cunia, 1982
Pinus sylvestris	AB = a*(D+1)^(b+c*log(D))*H^d	kg	cm	m	0,0146	2,3868	-0,0618	0,8581	n/a	Chroust & Tesarova, 1985
Pinus sylvestris	AB = a*D^2+b*(D-c)	gr	cm	n/a	209,699	48,8075	49	n/a	n/a	Brække, 1986

Pinus sylvestris	AB = a*D^2	gr	cm	n/a	209,699	n/a	n/a	n/a	n/a	Brække, 1986
Pinus sylvestris	AB = a*D^2+b*(D-c)	gr	cm	n/a	200,8719	124,6808	49	n/a	n/a	Brække, 1986
Pinus sylvestris	AB = a*D^2	gr	cm	n/a	200,8719	n/a	n/a	n/a	n/a	Brække, 1986
Pinus sylvestris	AB = a*D^b	kg	cm		0,037602	2,6931	n/a	n/a	n/a	Makela & Vanninen, 1998
Pinus sylvestris	AB = a*D^b	kg	cm		0,099839	2,2608	n/a	n/a	n/a	Makela & Vanninen, 1998
Pinus sylvestris	AB = a*D^b	kg	cm		0,124059	1,994	n/a	n/a	n/a	Oleksyn et al., 1999
Pinus sylvestris	AB = a*H^b	kg	cm	m	0,2169	1,4172	n/a	n/a	n/a	Hamburg et al., 1997
Pinus sylvestris	AB = a*(D^2*H)^b	kg	cm	m	0,041	0,9076	n/a	n/a	n/a	Hamburg et al., 1997
Pinus sylvestris	AB = a*D^b*H^c	kg	cm	m	0,0374	1,7459	1,0096	n/a	n/a	Hamburg et al., 1997
Pinus sylvestris	AB = a*(D^2*H)^b	kg	cm	m	0,0217	0,9817	n/a	n/a	n/a	Hamburg et al., 1997
Pinus sylvestris	AB = a*D^b*H^c	kg	cm	m	0,0191	1,9249	1,0613	n/a	n/a	Hamburg et al., 1997
Populus spp										
Populus tremula	AB = a*D^b	kg	mm	m	0,000146	2,603533	n/a	n/a	n/a	Johansson, 1999c
Populus tremula	AB = a*(D^2*H)^b	kg	cm	m	0,0208	0,9856	n/a	n/a	n/a	Hamburg et al., 1997
Populus tremula	AB = a*D^b*H^c	kg	cm	m	0,0102	1,845	1,3386	n/a	n/a	Hamburg et al., 1997
Populus tremula	AB = a*D^b	kg	cm	m	0,087161	2,43	n/a	n/a	n/a	Hazell, 1999
Pseudotsuga menziesii										
Pseudotsuga menziesii	AB = a*D^b	Kg	cm	n/a	0,197899	2,41	n/a	n/a	n/a	Bartelink,1996
Pseudotsuga menziesii	AB = a*D^b	kg	cm	m	0,111	2,397	n/a	n/a	n/a	van Hees, 2001
Quercus spp										
Quercus spec, (robur or petraea)	LN(AB) = a+b*LN(D)	kg	cm	m	-0,883	2,14	n/a	n/a	n/a	Hochbichler, 2002

Table 2: Equations for belowground biomass Abbreviations: AB: Aboveground Biomass; D : Diamater at breast height; H: Height; RT: Root Biomass.

Species (group)	Format of equation	Units of Biomass	Units of_D	Units of H	coeff_a	coeff_b	coeff_c	coeff_d	coeff_e	Reference
Acer spp										
Betula spp.	RT = a*D^b*H^c	kg	cm	m	0,0607	2,6748	-0,561	n/a	n/a	Hamburg et al., 1997
Alnus spp										
Betula spp.	RT = a*D^b*H^c	kg	cm	m	0,0607	2,6748	-0,561	n/a	n/a	Hamburg et al., 1997
Betula spp										
Betula pendula	RT = a+b*LOG(D^2*H)	kg	cm	m	-3,887	1,3668	n/a	n/a	n/a	Mälkönen, 1977
Betula pubescens	RT = a+b*LOG(D^2*H)	kg	cm	m	-3,887	1,3668	n/a	n/a	n/a	Mälkönen, 1977
Betula spp.	RT = a*H^b	kg	cm	m	0,0356	1,4149	n/a	n/a	n/a	Hamburg et al., 1997
Betula spp.	RT = a*(D^2*H)^b	kg	cm	m	0,0387	0,7281	n/a	n/a	n/a	Hamburg et al., 1997
Betula spp.	RT = a*D^b*H^c	kg	cm	m	0,0607	2,6748	-0,561	n/a	n/a	Hamburg et al., 1997
Broadleaved other										
Quercus petraea	RT = a+b*D^2	kg	cm		-1,551	0,099	n/a	n/a	n/a	Drexhage et al., 1999
Coniferous other										
Picea abies	RT = a*(D^2*H)^b	kg	cm	m	0,0239	0,8408	n/a	n/a	n/a	Hamburg et al., 1997
Fagus sylvatica										
Fagus sylvatica	RC = a+b*LN(D)	kg	cm	n/a	-4,1302	2,6099	n/a	n/a	n/a	Le Goff & Ottorini, 2001
Fagus sylvatica	RT = a+b*LN(D)	kg	cm	n/a	-3,8219	2,5382	n/a	n/a	n/a	Le Goff & Ottorini, 2001
Fraxinus excelsior										
Quercus petraea	RT = a+b*D^2	kg	cm		-1,551	0,099	n/a	n/a	n/a	Drexhage et al., 1999
Larix spp										
Picea abies	RT = a*(D^2*H)^b	kg	cm	m	0,0239	0,8408	n/a	n/a	n/a	Hamburg et al., 1997
Picea spp										
Picea abies	RT = a*D^b	kg	cm	n/a	0,02	2,36	n/a	n/a	n/a	Drexhage & Gruber, 1999
Picea abies	RT = a+b*D	kg	cm	n/a	-33,225	2,3915	n/a	n/a	n/a	Lee, 1998
Picea abies	RC = a*D^b	kg	cm	n/a	0,33989	1,4728	n/a	n/a	n/a	Xiao et al.
Picea abies	(RC+RS) = a*D^b	kg	cm	m	0,02	2,36	n/a	n/a	n/a	Drexhage & Gruber, 1999
Picea abies	RT = a*D^b	kg	cm	n/a	0,02	2,36	n/a	n/a	n/a	Drexhage & Gruber, 1999
Picea abies	RT = a*D^b	kg	cm	n/a	0,004613	2,92111	n/a	n/a	n/a	Wirth et al., 2004

Picea abies	LN(RT) = a+b*LN(D)+c*LN(H)	kg	cm	n/a	-5,98132	2,32428	0,834968	n/a	n/a	Wirth et al., 2004
Picea abies	RT = a*(D^2*H)^b	kg	cm	m	0,0239	0,8408	n/a	n/a	n/a	Hamburg et al., 1997
Picea abies	RT = a*D^b*H^c	kg	cm	m	0,0386	2,5377	-0,1832	n/a	n/a	Hamburg et al., 1997
Pinus other										
Pinus sylvestris	RT = a*(D^2*H)^b	kg	cm	m	0,0144	0,8569	n/a	n/a	n/a	Hamburg et al., 1997
Pinus sylvestris										
Pinus sylvestris	RT = a+b*LOG(D)	kg	cm	n/a	-1,967	2,458	n/a	n/a	n/a	Mälkönen, 1977
Pinus sylvestris	RT = a*D^b	kg	cm		0,016924	2,252	n/a	n/a	n/a	Oleksyn et al., 1999
Pinus sylvestris	RT = a*(D^2*H)^b	kg	cm	m	0,0144	0,8569	n/a	n/a	n/a	Hamburg et al., 1997
Pinus sylvestris	RT = a*D^b*H^c	kg	cm	m	0,006	1,4615	1,439	n/a	n/a	Hamburg et al., 1997
Populus spp										
Populus tremula	RT = a*(D^2*H)^b	kg	cm	m	0,0145	0,8749	n/a	n/a	n/a	Hamburg et al., 1997
Populus tremula	RT = a*D^b*H^c	kg	cm	m	0,0307	2,4427	-0,0708	n/a	n/a	Hamburg et al., 1997
Pseudotsuga menziesii										
Picea abies	RT = a*(D^2*H)^b	kg	cm	m	0,0239	0,8408	n/a	n/a	n/a	Hamburg et al., 1997
Quercus spp										
Quercus petraea	RT = a+b*D^2	kg	cm		-1,551	0,099	n/a	n/a	n/a	Drexhage et al., 1999

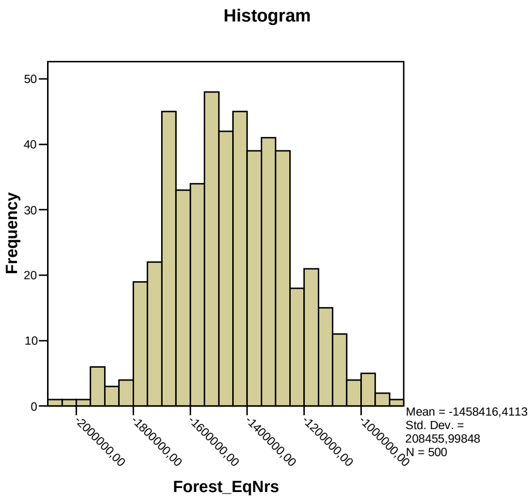
Annex B. Normality tests and histograms of results of sensitivity analysis

Table 1: Results of Shapiro-Wilk test of normality of the distribution, skewness as a measure of asymmetry of the distribution (negative values indicate tailing towards lower, more negative, values, positive values indicate tailing to higher values) and kurtosis as a measure of "peakedness" (higher values indicate more peaked, negative values indicate less peaked/more flat than normal distribution) of the distribution compared to a normal distribution. Outcomes significantly differing from normality are printed in bold

	Shapiro-Wilk test of normality (p-value)	Skewness	Kurtosis
Choice of biomass equation	0,392	0,069	-0,274
Wood carbon content	0,260	0,103	0,104
Start age for harvesting	**0,000**	**-1,818**	**3,455**
Start volume for harvesting	**0,000**	**-0,774**	**-0,442**
Natural mortality	**0,000**	**-0,508**	**-0,121**
Total forested surface	**0,011**	**0,304**	**0,310**
Total volume harvested (NL)	**0,017**	**-0,211**	**-0,131**
Diameter of middle tree	**0,000**	**-6,239**	**37,073**
Growing Stock	0,309	0,030	0,261
Dominant height	0,639	-0,051	0,474
Net annual increment	0,074	0,189	-0,200
Plot age	0,582	0,046	0,177
Nr of live trees	**0,016**	**0,163**	**0,271**
Volume dead trees - lying	**0,004**	**-0,245**	**-0,336**
Dead wood density	0,138	0,200	0,375
Longevity dead wood - lying	**0,000**	**16,315**	**318,127**
Longevity dead wood - standing	**0,000**	**14,447**	**269,778**
Coefficients of volume equation	**0,000**	**-1,285**	**4,306**
Volume dead trees - standing	0,264	-0,076	-0,304
Optab values	**0,002**	**0,330**	**0,211**

Figure 1: Histograms of the results of sensitivity analysis (net carbon budget at national scale for forest remaining forest). The frequency distributions illustrate the type of variation that is introduced in the results by varying the respective variable. In most cases variation followed the Gauusian distribution (for exceptions and parameters of distributions see table 3.1) See following table for explanation of abbreviations.

Abbreviation	Variable	Abbreviation	Variable
	Recorded plot data		**General parameters**
Forest_PD_RegYear	Age / Regeneration year	Forest_GP_CarbCon	Wood carbon content
Forest_PD_Height	Dominant height	Forest_GP_Mort	Natural mortality rate
Forest_PD_Diam	Diameter of middle tree	Forest_GP_HstAge	Start age for harvesting
Forest_PD_Growing Stock	Growing stock	Forest_GP_HstVol	Start volume for harvesting
Forest_PD_NAI	Net annual increment		**Species parameters**
Forest_PD_TreeNR	Nr of live trees	Forest_SD_DWDens	Dead wood density
Forest_PD_VolDst	Volume dead trees - standing	Forest_SD_LongSD	Longevity dead wood – standing
Forest_PD_VolDly	Volume dead trees - lying	Forest_SD_LongLD	Longevity dead wood - lying
	Recorded national data	Forest_VolCoeff	Volume expansion equations – coefficients
Forest_GP_VolNL	Total harvested volume	Forest_EqNrs	Biomass expansion equations – equation choice
Forest_GP_TotSurf	Total forest surface	Forest_Optab	Optab values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Frequency
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40
30
20
10
0
-2000000,00
-1800000,00
-1600000,00
-1400000,00
-1200000,00
-1000000,00
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Std. Dev. =
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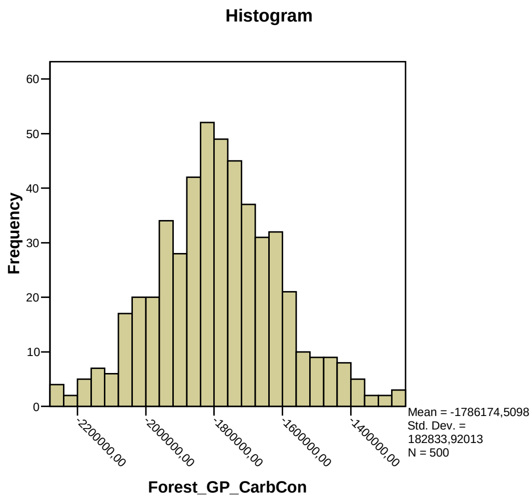
N = 500
Forest_EqNrs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Frequency
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50
40
30
20
10
0
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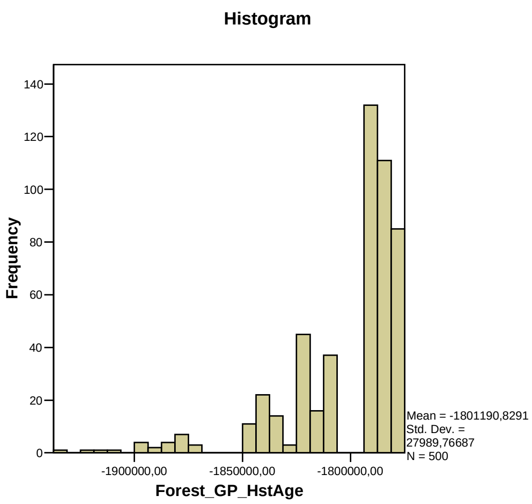
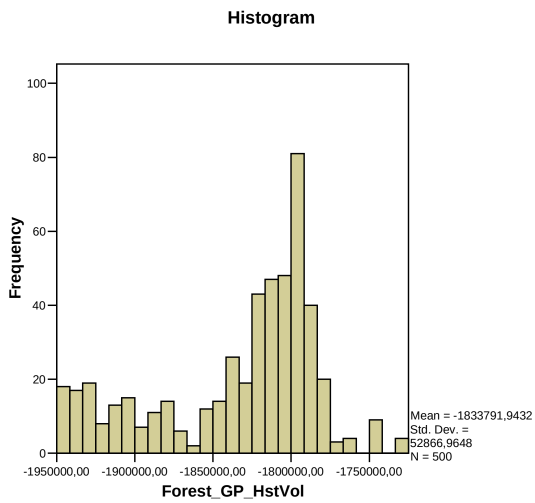
-2000000,00
-1800000,00
-1600000,00
-1400000,00
Mean = -1786174,5098
Std. Dev. =
182833,92013
N = 500
Forest_GP_CarbCon


Histogram
Frequency
140
120
100
80
60
40
20
0
-1900000,00
-1850000,00
-1800000,00
Mean = -1801190,8291
Std. Dev. =
27989,76687
N = 500
Forest_GP_HstAge


Histogram
Frequency
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80
60
40
20
0
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-1900000,00
-1850000,00
-1800000,00
-1750000,00
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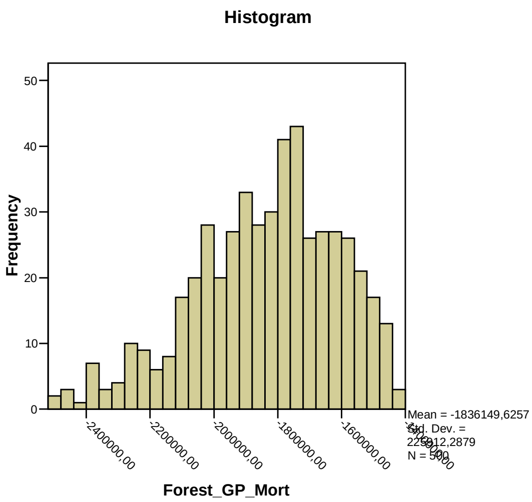
N = 500
Forest_GP_HstVol


Histogram
Frequency
50
40
30
20
10
0
-2400000,00
-2200000,00
-2000000,00
-1800000,00
-1600000,00
Mean = -1836149,6257
Std. Dev. =
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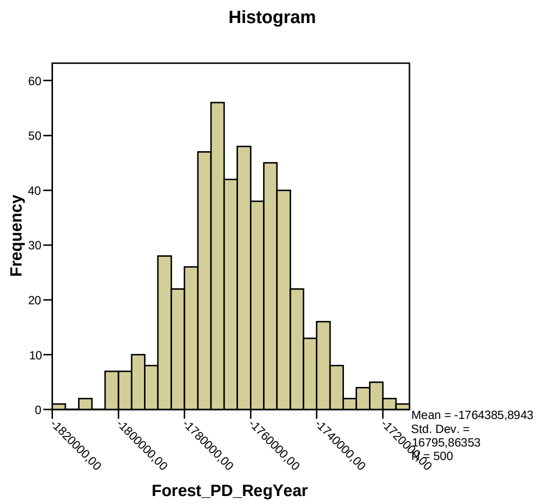
N = 500
Forest_GP_Mort


Histogram
Frequency
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50
40
30
20
10
0
-1820000,00
-1800000,00
-1780000,00
-1760000,00
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-1720000,00
Mean = -1764385,8943
Std. Dev. =
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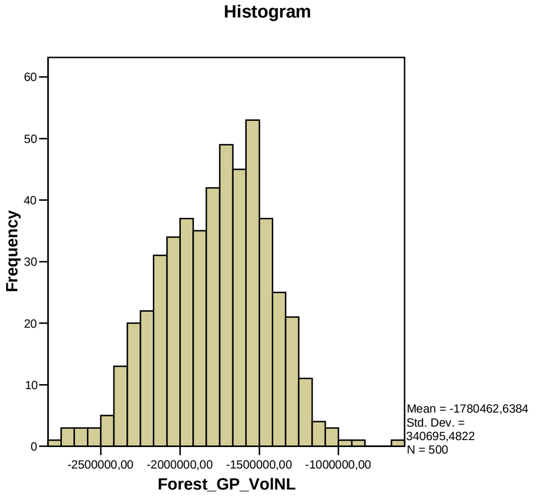
N = 500
Forest_PD_RegYear


Histogram
Frequency
Forest_GP_VolNL
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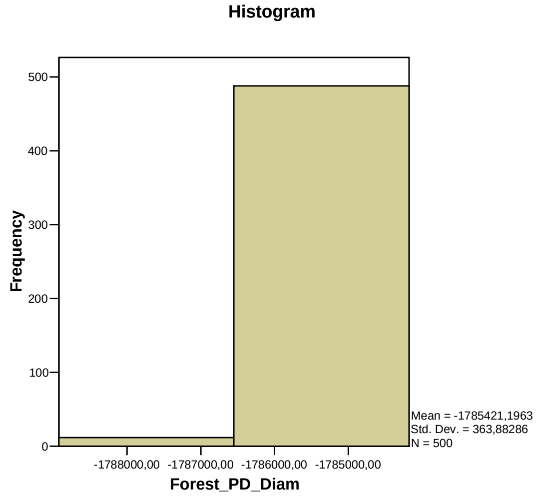
340695,4822
N = 500


Histogram
Frequency
Forest_PD_Diam
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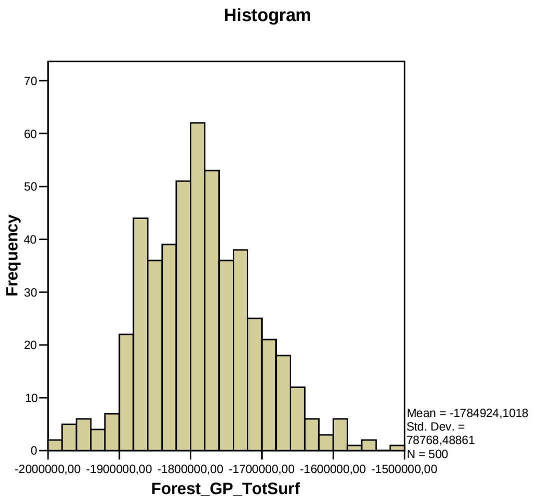
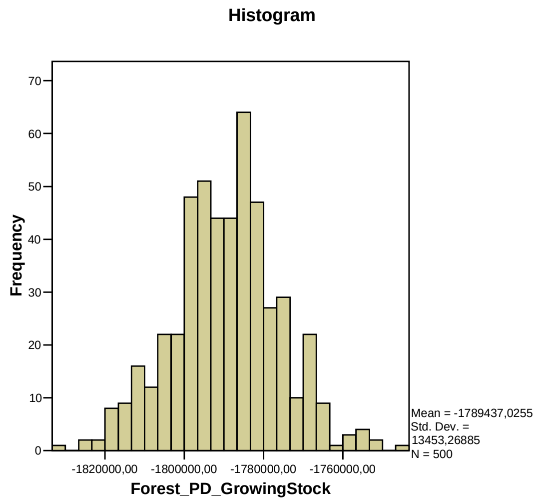
Std. Dev. = 363,88286
N = 500


Histogram
Frequency
Forest_GP_TotSurf
Mean = -1784924,1018
Std. Dev. =
78768,48861
N = 500


Histogram
Frequency
Forest_PD_GrowingStock
Mean = -1789437,0255
Std. Dev. =
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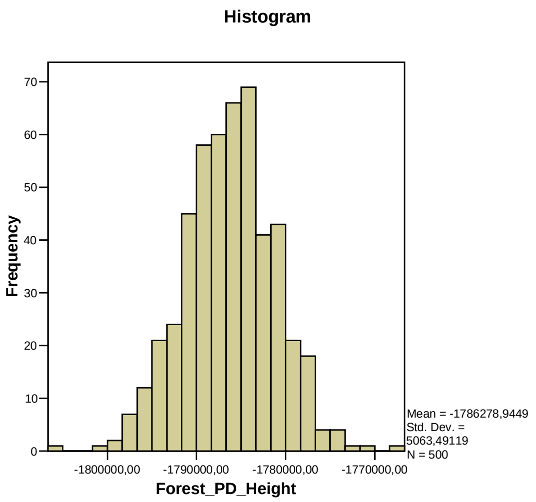
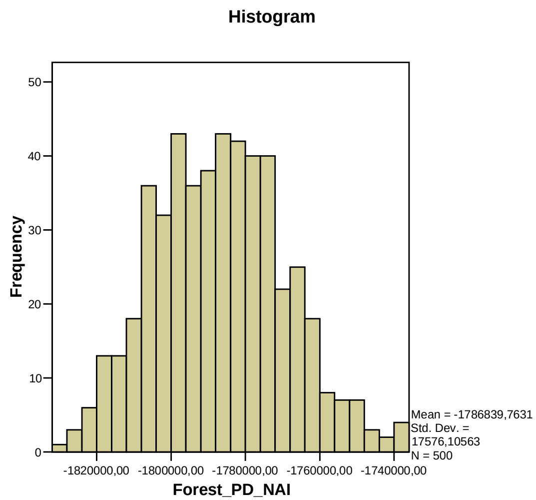
N = 500


Histogram
Frequency
Forest_PD_Height
Mean = -1786278,9449
Std. Dev. =
5063,49119
N = 500


Histogram
Frequency
Forest_PD_NAI
Mean = -1786839,7631
Std. Dev. =
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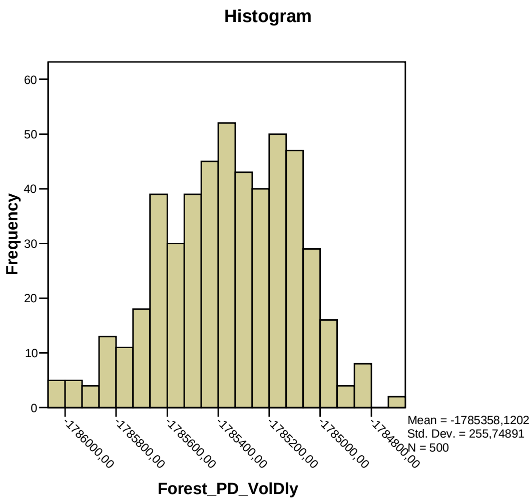
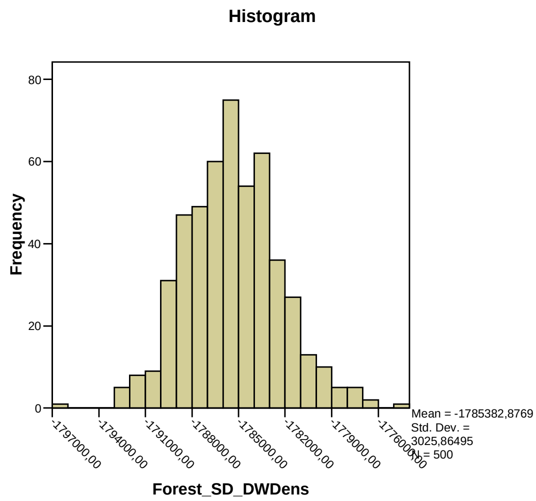
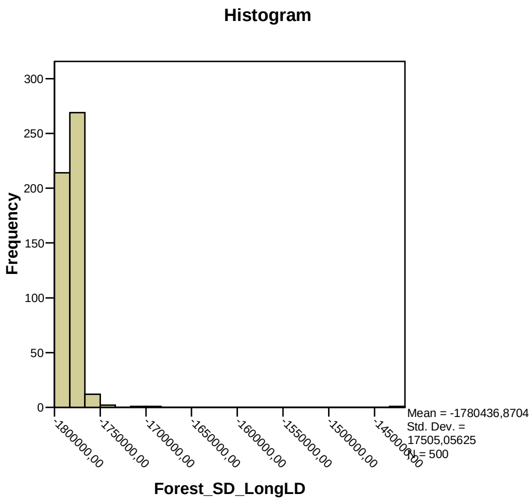
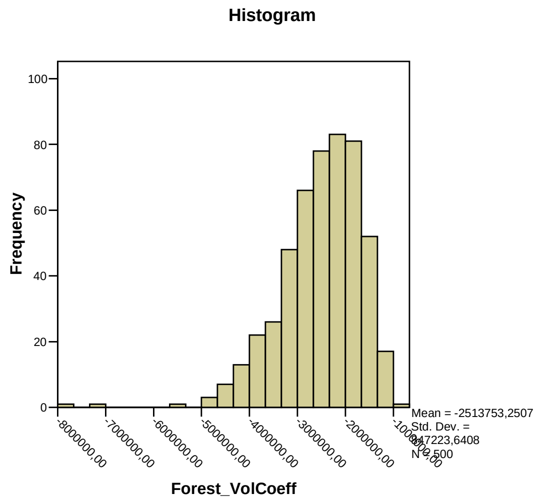
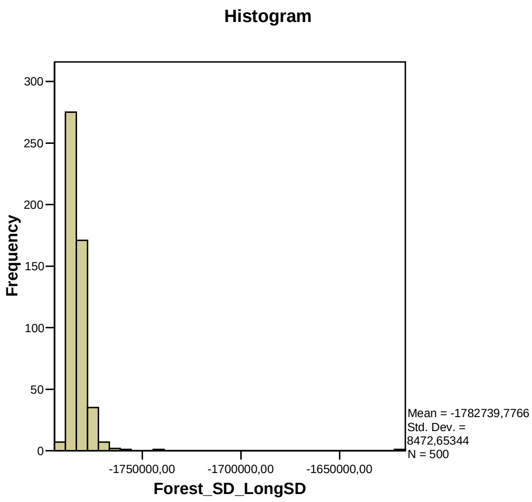
N = 500

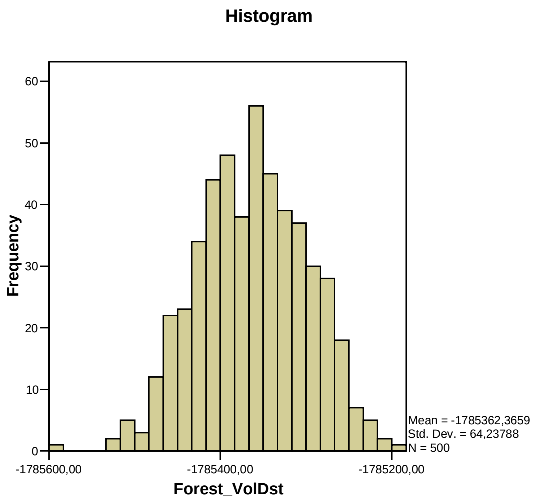

Histogram
Frequency
Forest_PD_VolDly
Mean = -1785358,1202
Std. Dev. = 255,74891
N = 500

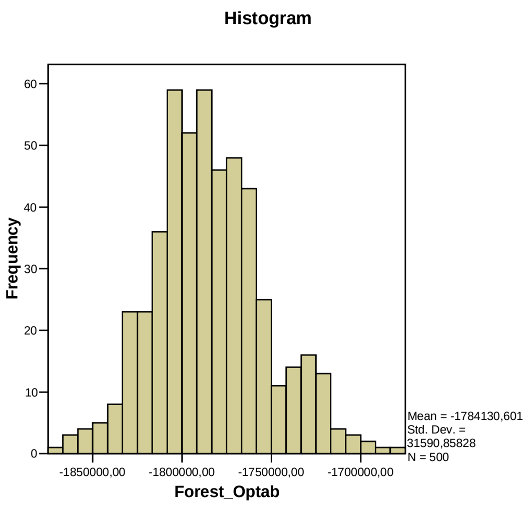

Histogram
Frequency
Forest_SD_DWDens
Mean = -1785382,8769
Std. Dev. =
3025,86495
N = 500

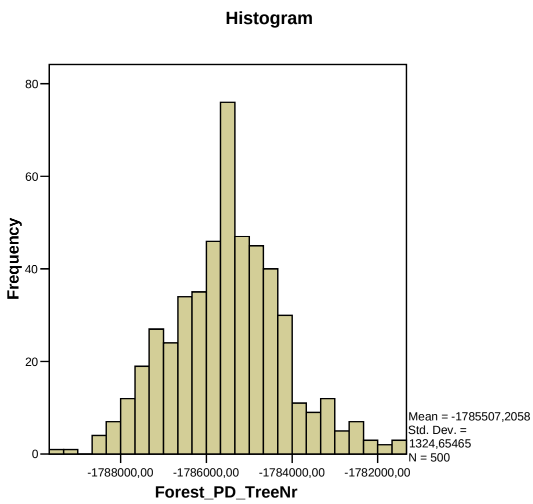

Histogram
Frequency
Forest_SD_LongLD
Mean = -1780436,8704
Std. Dev. =
17505,05625
N = 500


Histogram
Frequency
Forest_VolCoeff
Mean = -2513753,2507
Std. Dev. =
847223,6408
N = 500


Histogram
Frequency
Mean = -1782739,7766
Std. Dev. =
8472,65344
N = 500
Forest_SD_LongSD


Histogram
Frequency
Mean = -1785362,3659
Std. Dev. = 64,23788
N = 500
Forest_VolDst


Histogram
Frequency
Mean = -1784130,601
Std. Dev. =
31590,85828
N = 500
Forest_Optab


Histogram
Frequency
Mean = -1785507,2058
Std. Dev. =
1324,65465
N = 500
Forest_PD_TreeNr

Annex C: summary of De Groot et al., 2005 concerning soil C

The Netherlands participate in the United Nations Framework Convention on Climate Change and the Kyoto protocol and as such are obliged to report annually to the international community on stocks of carbon in soil and the impact of land use and land use changes. The Netherlands has not reported these carbon stocks until 2004. To facilitate reporting it is necessary to design and operationalise a national system for the reporting under the category Land Use, Land Use Change and Forestry. This report presents the design and selection of such a national system for soil carbon and land use. With this national system, we have calculated the carbon stocks for the required land use categories in the period 1990 to 2003. Similarly, a national system has been designed for forests and for emissions from cultivated organic soils (Nabuurs et al., 2005).

In this report we present and discuss:

- requirements on the determination of the carbon stock that must be met under the UNFCCC;
- alternatives and options to determine carbon stocks and changes of such carbon stocks on the basis of the current knowledge and availability of databases and GIS;
- a step-by-step scheme of the determination of carbon stocks in the Netherlands according to directives of the IPCC;
- calculated carbon stocks on the basis of the default IPCC method according to Tier 1;
- calculated carbon stocks and changes between 1990 and 2003 on the basis of a country specific methodology according to Tier 2 with the National Soil Sampling Programme/soil map of the Netherlands 1:50,000 and land use on the basis of detailed topographic maps (historical land use of the Netherlands; HGN);
- selection of the basis for a national system and protocol for the determination of carbon stocks in Dutch soils;
- suggestions and recommendations concerning the measurements on carbon stocks in the near future and related to verification and monitoring of carbon stocks and changes in carbon stocks.

Land use

The UNFCCC requires that estimates for soil carbon stocks discriminate between at least six categories of land use and are explicit for 1990 and the following years. These are: forest, grassland, cropland, wetland, settlements and other land. Several options for estimating areas for specific land use have been considered. Statistics could provide the total area for agriculture (grassland and cropland) and forest. Such statistics would not be covering the total land area in the Netherlands. A wall – to – wall approach is the assessment of land use with satellite images. This technology is developing fast and used for respectively LGN – 1, 2, 3,4 and 5 in the time period of 1985 till recent. As technology is developing the precision and accuracy increases over time. Another methodology is using the HGN (historical land use) which is based on the topographical survey and maps. This methodology is well established and the changes in its methodology are minor.

The use of a LGN-3-file produced a strong over-estimate of the area grass compared to the area grass that was determined by CBS for 1990 (1998). The HGN has the advantage that it is possible to update the land use very frequently (2 – 4 years) and the quality of the data will remain constant over time. Also the classification in land use categories corresponds to the IPCC division. We have thus selected the latter methodology as it will produce land use maps more and more frequently and will continue to use a well established methodology which provides wall – to – wall data of constant quality and likely include ground verification and will easily follow the IPCC classification of land use.

Soil type and carbon stock
Carbon stocks can be determined with several methodologies as well. UNFCCC requires that carbon stocks are reported for land use categories for the top 30 cm. The traditional method and first option is to use the soils map and soil carbon data for different soil types. The carbon stock in soil is mainly determined by climate, soil type, groundwater class and the land use. Changes in the carbon stock are determined by land use and changes in land use and by interventions in the soil and groundwater management such as for example peat cultivation and drainage. As a consequence the traditional soil map may not represent the Dutch soils well enough anymore since frequent interventions have taken place locally. Many soils have been subject to intensive drainage during 1950 – 1990. After 1990 drainage intensity and practices have not changed much anymore compared with the period 1950-1990. Many soil improvement projects have been undertaken. Last but not least many organic soils have been intensively managed to such an extent that the loss of C has been severe and these soils are no longer classified as organic soils.

Another option in the Netherlands is to use the results of the recent National Soil Sampling Programme (NSSP). The NSSP was carried out to quantify the Soil Map of the Netherlands scale 1:50,000 with statistical features. The NSSP resulted in a representative dataset, providing map units with statistically determined values. Organic matter content has been determined for all sample elements. The sample locations are geographically fixed and by means of the soil map the measurements are extrapolated to the areas which they represent. The best way to calculate the carbon stock of the Netherlands in 1990 is by utilising the NSSP dataset.

The following conclusions can be drawn from the results in the NSSP:

- The C stock between grass and cropland in the Netherlands is not different for any groundwater level class with the exception of groundwater class VI. The groundwater class has a much larger impact on the carbon stock than land use;
- All groundwater classes have a significantly different carbon stock except groundwater classes IV and V, ánd IV and VI;
- Measuring of organic matter content is more reliable than estimating; the standard error increases at lab analysis with the organic matter content to a maximum of 3.6%; determining bulk density with pedo-transfer functions is for peat soils rather uncertain and the carbon content of organic matter varies although 50% is a reasonable estimate.

The soil map is to a limited extent a reproduction of the differences in carbon stock in the Netherlands.
At the set-up of the NSSP not only differences in organic matter content has been taken into account. The stratification (division of the Dutch soil units in homogeneous groups) as a means of translation to a land covering picture of the carbon stock can be improved. For example in the North of the Netherlands as a result of climate differences soils are richer to carbon. The soil map of the Netherlands scale 1:50,000 appears also out-of-date especially in areas where peaty material occurred. In those areas, the soil map will have to be actualized first.

The collection of data that is required for estimation on soil carbon stocks has been developed in a number of steps according to the Good Practice Guidance on LULUCF:
Step 1: Collect of data concerning climate (1a) and soil types (1b);
Step 2: Collect of data concerning land use and - management in the time;
Step 3: Collect of data concerning the impact of changes in land use and country management on the carbon stock in the soil and carbon flux from the soil;
Step 4: Calculation of the carbon stock of the soil in the Netherlands in 1990, and next years;
Step 5: Calculation and treasures of the annual changes in the carbon stocks;
Step 6: Recommendations for future adaptations and more details of data, databases and calculations.

These steps are passed through for two methods, FAO-map in combination with LGN-3 and the NSSP/soil map 1:50,000 in combination with HGN.

The methodology to determine the carbon stock on the basis of the NSSP and LGN-3 estimated the carbon stock in the top 30 cm at 286000 Gg C. The default IPCC methodology the carbon stock was estimated at 244000 Gg C. The first methodology is more time consuming (20 days and 5 days respectively).

The quality of the default method has not been determined. The inaccuracy of the carbon stock calculation with the NSSP/LGN-3 methodology is (at 95% confidence) only 2.1% which relates to the precision of the estimate of the organic matter content. The larger time effort led in any case to a considerably better quantified result. If we include the estimate for carbon stock in organic soils from the NSSP/LGN-3 methodology to the estimate from the default methodology (66000 GgC) the total stock of carbon amounts to 310000 Gg C. This is 8% higher than the earlier calculation of 286000 Gg C. We have not calculated any changes of carbon stock with either methodology. For NSSP/LGN – 3 this would not be possible for data on changes of soil carbon stock are not available. We have chosen not to use the default factors for changes of soil carbon stock as provided by the IPCC GPG of 2003.

The total carbon stock in the soil with the method NSSP/HGN is calculated at 336450 Gg C in 1990. This stock had decreased to 336073 Gg C in 2000. This means an annually net flux of 34 Gg C (125.8 Gg CO_2). The C stock calculated with this method is much higher than with the default method (FAO) or compared to the earlier calculations with NSSP/LGN-3. For large enclaves of the soil map (urban area) a carbon stock has now been determined by extrapolation. The area for which the carbon stock is calculated has increased from 2.8 to 4.1 million ha. We have selected to use the NSSP/HGN methodology because of the use of the combination of using the best quality of available soil- and land use data in the Netherlands.

As we know now soil types and characteristics of soils in the Netherlands have changed over time and are likely to change in the future as well as a direct result of soil and water management. If one then calculates the carbon stock by using a single (old) soil map not all changes of carbon will be recognized and taken into account. This would require frequently updating of the soil map.

Differences in carbon stock are distinguished with difficulty in the short term (5 years). That also becomes clear from the precision with which can be measured. It is very important to take account for the influence of the changing soil map (disappear of peat layers) when calculating carbon fluxes.

Monitoring of the carbon stock in the Netherlands can be carried out with a new sampling scheme. Alternatively modeling in combination with measurements of C changes at several representative locations for validation purposes is a good option. Then extrapolation of this knowledge and accounting to the total area of the Netherlands is feasible. This deterministic approach leads likely to a better understanding on impact (of changes) of land use. With such a modeling methodology, one may expect that the impact of regulations to diminish carbon losses and emissions or carbon gains and sequestration could be established.

Determining the carbon stock of the Netherlands can be carried out more accurate in future by measuring bulk density, determining carbon content instead of organic matter and a stratification of the soil map which aims exclusively at differences in carbon stock between soils.

Annex D: Location and surface of afforestations carried out domestically for CO2 credits under the Groenfonds.

Table 1: List of parcels with carbon credits registered at the National Groenfonds. The Dutch National Groenfonds links companies buying carbon credits and land owners planting new forest. The registration of the location and surface of the parcels is one of the possibilities to go to a spatially explicit estimate of afforestation.

Projectnumberr	X	Y	Surface (ha)	Year of establishment
B2001-002	137.4	373.9	6.00	2002
B2001-003	235.6	471.8	5.49	2001
B2001-004	199.9	350.8	6.33	2002
B2001-005	189.3	336.8	10.40	2002
B2001-006	226.8	517.6	22.86	2003
B2001-007	89.6	387.4	10.72	2002
B2001-014	182.7	313.8	14.33	2004
B2002-001	244.3	557.2	42.61	2001
B2002-008	229.8	537.1	20.30	2001
B2002-009	226.9	547.6	35.88	2002 en 2003
B2002-010	243.2	556.6	15.65	2001
B2002-011	226.7	455.6	10.21	2002
B2002-012	185.7	507.7	10.00	2001
B2002-016	252.1	526.7	10.90	2003
B2002-018	204.9	350.4	5.38	2002
B2002-019	200.9	354.2	9.23	2002
B2002-020	206.1	501.8	7.48	2001
B2002-021	260.6	559.4	17.95	2002
B2002-022	246.9	555.8	7.41	2002
B2002-023	196.8	376.4	7.76	2002
B2002-024	236.9	534.5	5.08	2003
B2002-027	245.2	543.9	7.95	2001
B2002-028	212.4	439.4	5.00	2002
B2002-029	239.3	550.7	5.44	2002
B2002-030	207.7	500.6	8.77	2000
B2002-031	205.4	498.1	6.64	2002
B2002-032	218.4	533.7	5.50	2002
B2002-033	210.3	382.8	5.29	2002
B2002-035	179.1	309.3	7.26	2003
B2002-036	180.6	362.5	5.58	2005
B2002-037	270.6	562.8	7.03	2003
B2002-038	196.6	365.8	4.55	2003
B2002-039	188.2	342.8	3.61	2004
B2002-040	203.6	373.4	3.63	2003
B2002-041	189.5	366.2	4.90	2003
B2002-042	138.3	414.5	19.72	2003
B2003-043	149.8	446.8	4.04	2001
B2003-044	116.2	383.3	7.11	2003
B2003-046	186.6	351.8	7.96	2003
B2003-047	224.4	447.8	5.62	2004
B2003-050	221.5	440	22.58	2004
B2003-052	183.9	359.9	5.22	2004
B2003-053	224.2	509.1	4.65	2003
B2003-055	187.2	311.7	6.94	2004
B2003-056	136.5	379.3	3.35	2004
B2003-057	175.2	367.5	6.81	2004
B2003-059	153.7	434.9	6.04	2004
B2003-060	235.9	568	5.21	2004
B2003-061	236.9	537.7	5.23	2004
B2003-063	214.6	493.2	4.17	2004
B2003-064	210.5	391.5	6.04	2005
B2003-065	270.8	543.6	6.92	2004
B2003-066	257.9	485.3	6.00	2005
B2003-067	211.1	536.4	7.17	2003 / 2005
B2004-069	255.5	541.7	16.56	2003
B2004-070	255.9	539.1	4.32	2003
B2004-071	218.5	484.8	5.00	2005
B2004-072	161.8	408.5	5.50	2004
B2004-073	233.5	536.6	12.78	2005
B2004-074	200.3	321.3	8.65	2003
B2004-075	213.7	466.5	5.15	2002
B2004-076	273.9	560.8	20.13	2003
B2004-077	235.9	535.4	21.49	2004
B2004-084	171.8	415.6	6.36	2005
B2004-086	182.5	318.4	3.41	2004
B2004-091	186.4	309.7	8.80	2005
B2004-092	193.2	323.1	6.00	2005
B2004-093	191.5	375.4	5.00	2004
B2004-094	187.7	311.8	4.41	2004
B2004-095	197.3	376.4	7.57	2004
B2004-096	202.5	323.5	12.99	2004
B2004-099	179.4	355.9	9.58	2004
B2004-100	197.8	365.5	5.54	2005
B2004-101	254.2	536.8	15.29	2005
B2004-102	167.4	453.8	4.86	2005
B2004-103	205.6	541.7	15.29	2005
B2004-104	222.3	445.3	5.61	2005
B2004-105	196.6	365.8	5.48	2001/2005
B2004-106	28.1	399.5	12.29	2004
B2004-107	189.3	343.9	4.44	2004
B2004-108	187.3	339.9	2.65	2004
B2004-110	266.8	485.3	4.19	2005
B2004-111	220.7	464.9	4.24	2005
B2004-112	174.2	409.8	12.06	2005
B2004-114	255.3	535.9	11.71	2005
B2004-115	191.1	342.5	6.72	2004/2005
B2004-116	266.9	534	6.85	2005
B2004-117	241.7	490.5	14.37	2005
B2004-122	260.3	473.5	4.85	2005
B2005-125	189	393.9	5.21	2005
B2005-126	195.1	367.2	4.98	2005
B2005-129	224.3	516.8	15.63	2005
B2005-131	224.9	515.7	26.70	2005
B2005-132	264.5	566.7	30.61	2005
B2005-133	242.5	548.6	16.62	2005
B2005-134	185.8	338.5	4.35	2005
B2005-135	192.4	375.3	10.83	2005
B2005-141	245.9	476.3	10.11	2005
B2005-142	161.4	408.2	11.46	2005
B2005-144	202.2	539.5	4.42	2005
B2005-145	237.4	549.9	54.81	2005
B2005-154	196.7	388.7	47.22	2005
B2005-155	197.4	378.6	16.40	2005
		Opp. totaal	1063.3912	

Annex E: Methodology to distinguish between regular harvesting of forests and deforestation

The amount of wood harvested in the Netherlands is recorded annually. Using the average standing volume at harvest an estimate could be made of the surface harvested. However, it is not possible to distinguish between harvests from thinnings, clearcuts in regular forest cycle or clearcuts from land use change. To establish the surface of land that looses its forest function another approach is needed.

Since the installation of the so called Forest Law (20 July 1961, Stbl 256/1961) the fate of forested parcels is closely monitored. Forest owners have to request permission before clearcutting a plot and have the obligation to replant it. In some cases it is possible to request permission to plant instead another surface located elsewhere, that at least equals the harvested plot in surface and soil quality and is located in the same region (4 regions in The Netherlands). Replanting has to be carried out within 3 years and lost plant material has to be replaced again within the same time interval (Decree of 20 June 1962; adapted 12 June 1998). Lately, the State Forestry Service and "Rijkswaterstaat" have gained partial release of the legal restrictions and the time period for replanting has been extended to 10 years for some forest types. LASER (National), an organisation of the Ministry of Agriculture, Nature and Fisheries is responsible for the permissions and registration of harvests and replanting under the Forest Law.

The forest Law is not applicable for tree stands inside built-up areas or meeting some other restrictions (e.g. on size, tree species, but also officially approved changes in development plans) and cutting of these stands usually only requires permission from the local administration. As there is no central registration, data about tree stand loss are not (easily) accessible. However, this would concern mostly individual trees to very small patches. Where it concerns slightly larger areas (e.g. change of the official land use in the development plan of an area), the change of forest into other land use types can also be derived from the Dutch topographic maps. The recorded loss of forest area on aerial photographs is checked on the ground and details are added. Based on the state of the location on the ground it is assessed whether the area has really experienced a change in land use (e.g. if houses are being built) or will proceed to the next forest cycle.

The information contained in the official registration, combined with the topographic maps, provides an opportunity to make an estimate of the area undergoing deforestation as land use change, independent of the amount of wood harvested.