Prediction of Reference Level for the Period 2013-2020 for Forest Management in Iceland

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SKÓGRÆKT RÍKISINS

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Preface

The author of this report works as a scientific specialist at the Icelandic Forest Research, which is the research division of the Iceland Forest Service, the official forest authority in Iceland. The directive to write this report came from the Ministry of Environment which is responsible for greenhouse gas reporting to the United Nations Framework Convention on Climate Change (UNFCCC).

Introduction

The intention of this report is to provide an estimate of predicted removals or emissions from forest land that would be defined as under forest management in Iceland. The work is in accordance with the decision of the COP 16/CMP 6 in Cancun, Mexico that states:

> "*The Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol,*
> *4. Requests* the Annex I Party to submit to the secretariat, by 28 February 2011, information on the forest management reference level inscribed in the appendix to Annex I of this decision, including any updates to replace the value, in accordance with the guidelines outlined in Part I of Annex II to this decision."

In this report the guidelines given by COP 16/CMP 6 in Part I of Annex II are followed as possible.

As Iceland did not elect Forest Management for the first commitment period of the Kyoto protocol, special efforts to estimate and report on its green house gas impact, other than the usual UNFCCC reporting, has not been processed before. Also it has to be taken into account that commercial forestry is very young in Iceland and of a little economic importance. Data availability and quality is not comparable to nations with an old and well developed forestry structure, as in many other European countries.

Definition of areas under forest management

All woodland defined as forest in the initial report from Iceland (Ministry for the Environment, 2006) and not part of Afforestation, Reforestation or Deforestation (ARD) activities under paragraph 3.3 of the Kyoto Protocol are classified as managed forest and as such reported in the National Inventory Report (NIR) and the Common Reporting Format (CRF) to the UNFCCC. In the initial report all woodlands that fulfill these requirements at maturity are defined as forest:

- minimum tree crown cover: 10 percent
- minimum land area: 0.5 hectare
- minimum tree height: 2 meters

Areas defined as being under Forest Management are from two separate forest classes in Iceland:

1. Afforestation up to year 1989 and reforestation.
2. The forest part of the natural birch woodlands.

The former forest class consists mostly of forest plantations of introduced and indigenous tree species. This class is referred to as cultivated forest. A small fraction of this class is direct seeded areas or self-seeded forest originating from planted or direct seeded forest.
The second forest class is the part of the natural birch woodland of Iceland that can reach at least 2 m height at maturity. These are dominated by just one species, the downy birch (*Betula pubescens*), and are referred to as natural birch forest.

Afforestation before 1990 and reforestation

It is possible to make a prognosis based on the age and species distribution for this class as the age and species distribution is known.
Rather good statistics are available for the number of planted seedlings through the first eleven decades of afforestation. This makes it possible to model the area, biomass and its derivatives for different time periods (see figure 1). These statistics have been published annually in the yearbook of the Icelandic Forest Association (Pétursson, 1999). Before 1940 plantation was very limited or under 10,000 seedlings per year. After 1940 the annual plantation started to increase slowly to the first peak in 1962 with decline down to 750,000 seedlings in the 1970s. In the 1980s annual plantation started to rise again with increasing afforestation on private farm land but an abrupt transition in greater annual planting was observed as of 1990 when two new afforestation projects were launched.

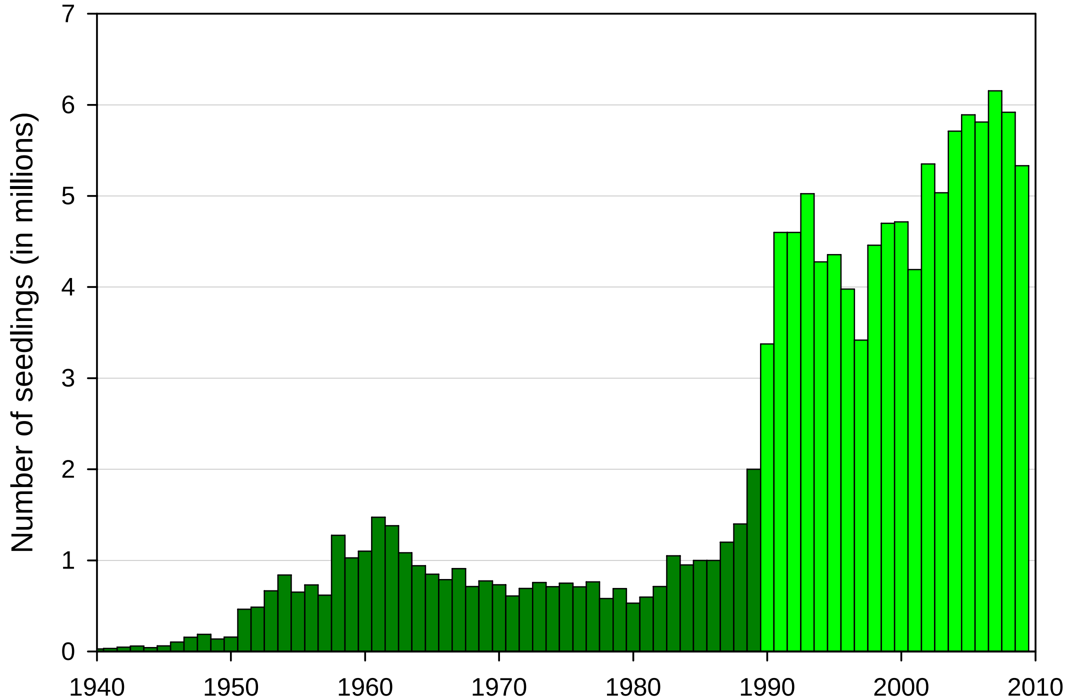

Figure 1. Annual plantation of forestry seedlings in Iceland.

The model that is used in this report was first introduced in 2006 and then used to make longtime prognoses for carbon sequestration of afforestation in Iceland (Snorrason, 2006). A predecessor to the model was used in one of first efforts to estimate the area and the C-stock of cultivated forest in Iceland (Sigurdsson et al., 2000).

National forest inventory (NFI) in Iceland was launched in 2001. Data sampling using a systematic grid of permanent field plot started in 2005 and was finished in 2009 (Snorrason, 2010b). The first NFI consists of field measurement of 663 plots in cultivated forest. The data sampling of the second NFI in cultivated forest has already started with re-measurement of the plots measured in 2005. The NFI data can be used to control the model represented and calibrate it upwards or downwards to levels of the NFI outcome.

Area estimation

For the area simulation the inputs into the model are annual planting of seedlings classified into eleven species groups. Seedling number needed to create one hectare of cultivated forest was assumed as follows:

1. For the period 1899-1989: 4000 seedlings are needed to create 0.75 ha of forest. To meet this objective, one would need 4000 seedlings per hectare (both initial and supplementary planting), with 25 % of each planting expected to fail and not grow up as forest.
2. For the period 1990-2009: 2350 seedlings are needed to create 0.75 ha of forest.

Each plot of cultivated forest measured in the NFI sample is age determined so that changes in area per annum can also be estimated roughly by the NFI data. Time series of the area can then be constructed.

When the first results from the NFI of the C-stock change and the area of the cultivated forest where estimated (Hallsdóttir et al., 2008) it was clear that the model was over-estimating the area (See figure 2). The area estimate was overestimating both the older cultivated forest, before 1990 and the afforestation since 1990 as shown in table 1.

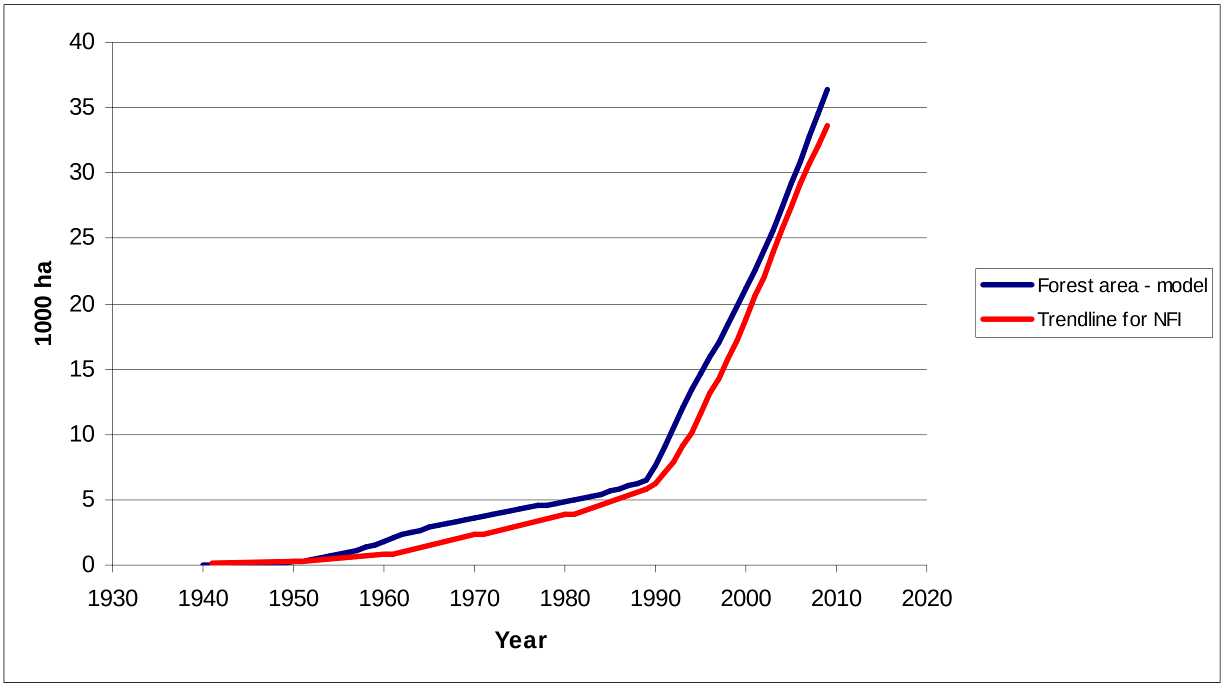

Figure 2. Differences in area estimate between the original growth model and NFI data for cultivated forest. The figure shows accumulated area of cultivated forest.

Table 1: Differences in area estimate between cultivated forest older than 1990 and since 1990.

	Model	NFI data	% dif.
Cultivated forest untill year 1989	6.600	5.800	14%
Cultivated forest from 1990-2009	29.900	28.800	4%
All cultivated forest	36.500	34.600	5%

The area of old cultivated forest in the model has to be calibrated before modeling the C-stock changes in different carbon pools. After the calibration the age distribution of plantations is as shown in figure 3.

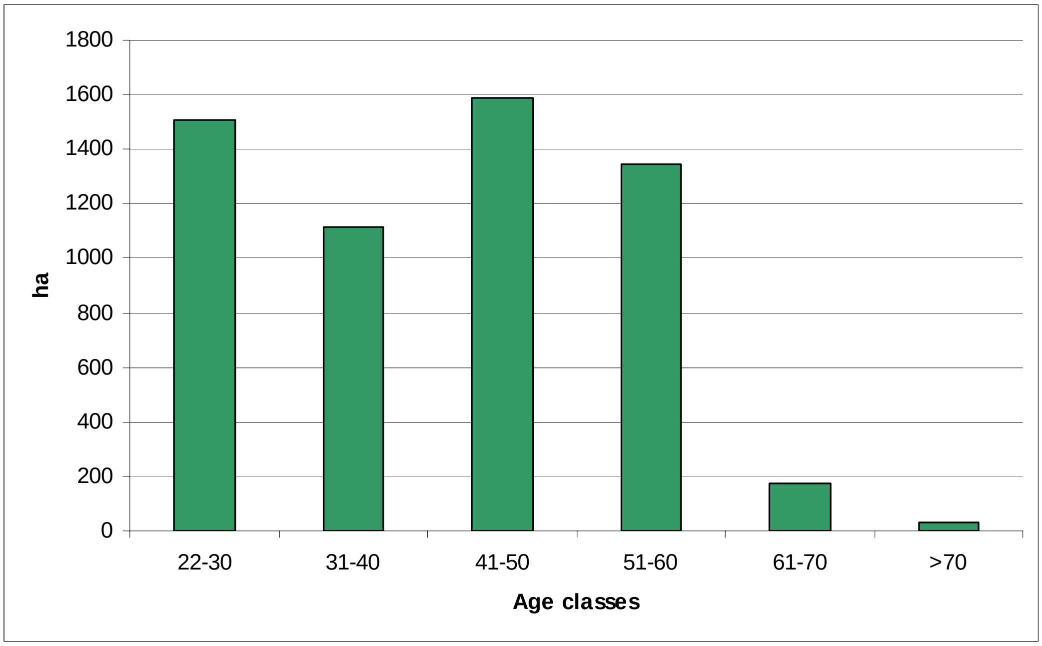

Figure 3. Size of age classes in area for cultivated forest before 1990 according to model used.

CO_2 removals to biomass in trees

The outputs of the model are annual biomass yields of trees in cultivated forest. This output can be converted to CO_2 removals to biomass of the trees in the forest. The biomass yield of other vegetation is excluded.

The inputs for the biomass yield part of the model are C-stock curves for eleven different species-groups. They are made from forest measurements performed around the turn of the century on plots evenly spread around the island (See figure 4). The reason for these measurements was to explore the growth potential in different regions of Iceland of the most commonly used species in Icelandic forestry. Further description of the measurements can be found in Snorrason et. al., (Snorrason et al., 2001a, Snorrason et al., 2001b, Snorrason et al., 2001c, Snorrason et al., 2002a, Snorrason et al., 2002b).

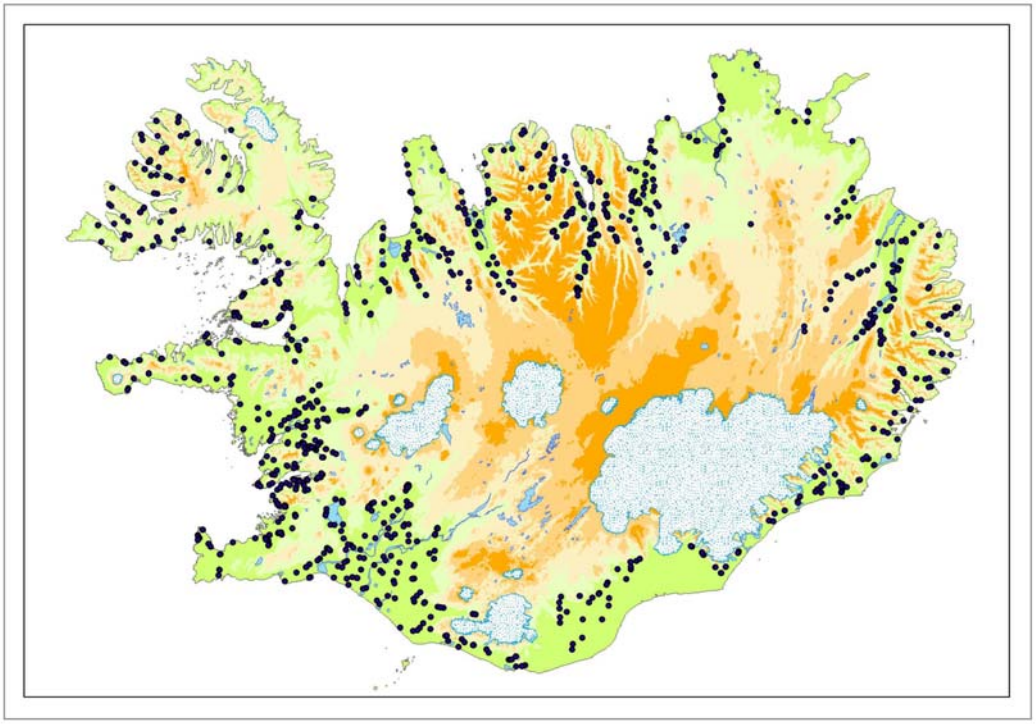

Figure 4: Map of Iceland showing the location of forest growth measurements conducted 1999-2001.

Measurements from 1,345 forest plots were used to graphically construct the growth curves. Main figures for the species groups are shown in table 2.

Table 2. Main growth figures for the species groups used in biomass growth model.

	Slow growing willow	Fast growing willow	Poplars	Engel-mann spruce	White spruce	Birches	Rowans	Norway spruce	Larches	Pines	Sitka spruce
Length of rotaton[1]	35	35	65	95	105	105	75	105	85	85	95
C-accumulation on rotation (ton C/ha)[2]	20	39	174	71	66	73	125	68	119	100	204
Mean CO_2 removal (ton/ha and yr)[2]	2.0	4.1	9.8	2.7	2.3	2.5	6.1	2.4	5.1	4.3	7.8

[1]Rotation length (in years) is defined when current annual increment gets smaller than the mean annual increment.
[2]C-accumulation and CO2 removals are only in above and below biomass of trees.

For forest planted before 1990 the output of the model shows a slow growth of biomass yield that reached a peak in 2004 and then slowly declined.
Figure 5 shows a comparison between CO_2 removals to living biomass in trees for the model, with and without calibration of the area, and the estimated CO_2 removals in 2009 from NFI data. The estimated CO_2 removals in 2009 from NFI are higher than the output from the model. Calibrated and uncalibrated figures for 2009 are 55% and 63% of the NFI estimate for the same year.

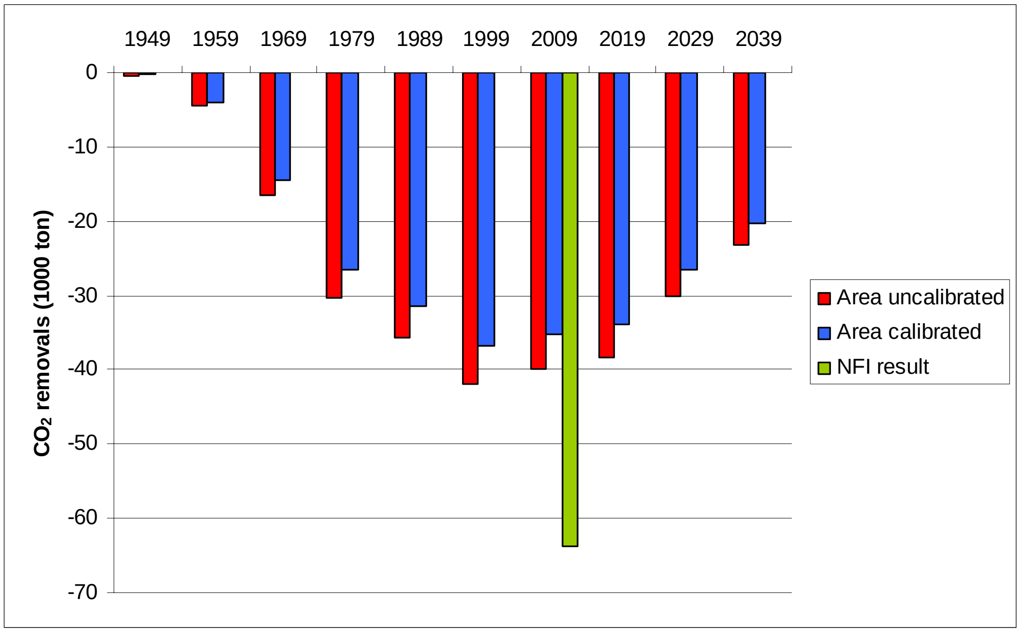

Figure 5. CO_2 removals to living biomass in trees for the model with and without calibration of area and the estimated CO_2 removals in 2009 from NFI data.

To justify the model the output for each year was calibrated in the same ratio as between the output figures of 2009 and the estimated results of the NFI for the same year. The result is shown in figure 6.

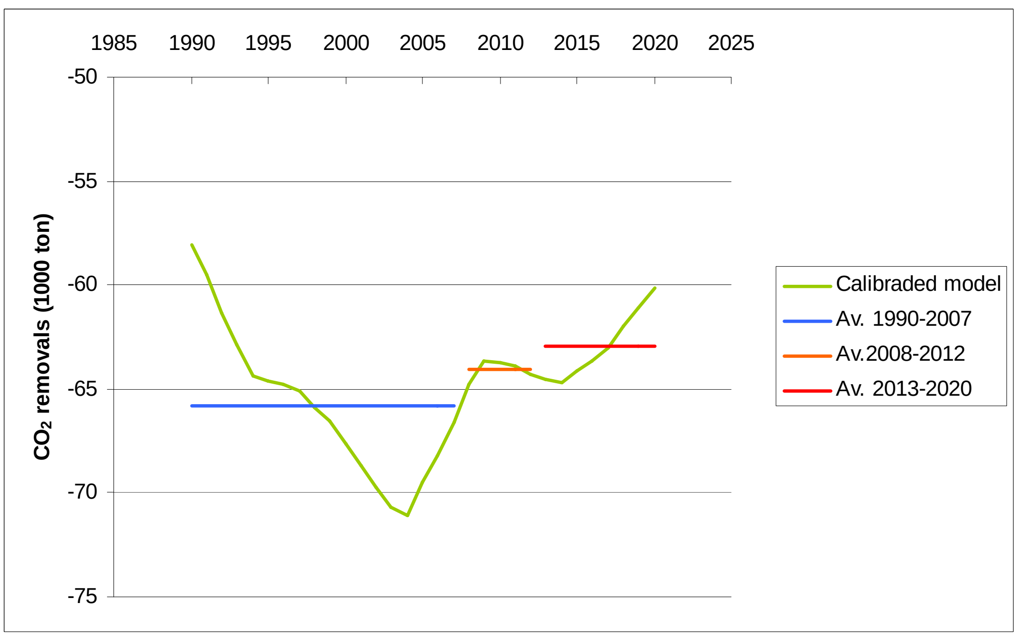

Figure 6. Modeled CO_2 removals to living biomass in old cultivated forest and reforestation. Green line: Annual estimate. Blue line: Average for the period 1990-2007. Brown line: Average for the period 2008-2012. Red line: Average for the period 2013-2020.

CO_2 and N_2O removals/emisssion to/from other pools than biomass

Other data for cultivated forests reported in the National Inventory Report (NIR) and the Common Reporting Format (CRF) of Iceland to the UNFCCC are:

1. CO_2-removals to mineral soil and litter up to 50 yrs after afforestation

2. CO_2- emissions from organic soil of drained wetland

3. N_2O- emissions from organic soil of drained wetland

4. N_2O- emissions from N-fertilizer used in forestry

N_2O- emissions from N-fertilizer used in forestry is not relevant for cultivated forests established before 1990. Fertilization in forestry in Iceland is limited to young plantations.

The other pools have in common to be area-dependent and can therefore be estimated by the area estimation of the NFI data and predicted by the area calibrated model. The removal factors to soil and litter that have been constructed from research measurements on afforestation areas (Sigurdsson et al., 2005, Bjarnadóttir, 2009) are only used for afforestation up to 50 years old as suggested in research cited. Thus the removals decline as more and more of the afforestation before 1990 reaches 50 years age. The emission from drained organic soils is supposed to be stable for a longer period than 50 years. Emission factors for N_2O and CO_2 are IPCC default factors. Further explanation of calculation of these removal/emission sources is to be found in NIR of 2010 (Hallsdóttir et al., 2010) and the NIR of 2011 (Hallsdóttir et. al., 2011). Figure 7 shows how removals/emissions from other pools than biomass are estimated/predicted from 1990 to 2020.

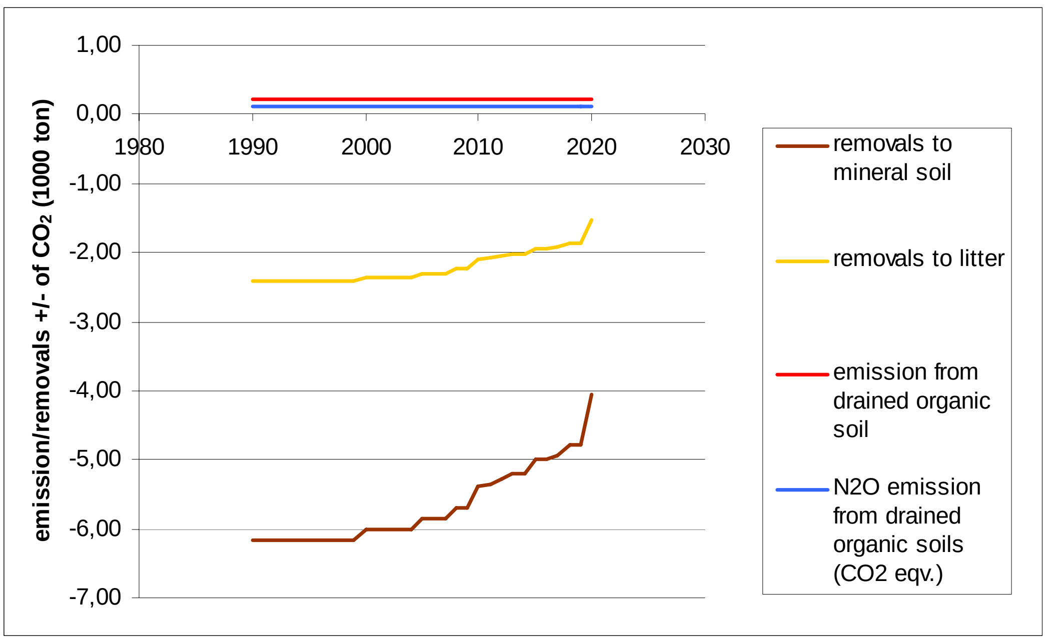

Figure 7. Estimated/predicted changes in removal/emissions from other pools than biomass.

The pool of dead wood is omitted as it has not yet been estimated because of lack of repeated measurement in the NFI. The effect of dead wood is reasonably very small. Both in the cultivated forest and the natural birch forest is dead wood meeting the size definition of dead wood occurring rarely on the field plot of the NFI. On the other hand one will expect increasing amount of dead wood following increased harvest activity especially in the cultivated forest.

The forest part of the natural birch woodlands

In the period 2005-2009 a sample plot inventory similar to the inventory of the cultivated forest was performed in the natural birch woodlands although with a much lower sampling intensity (Snorrason, 2010b). A total of 209 plots were measured. According to the most recent data from the NFI the total area of natural birch woodland is estimated to be 85,000 ha (+/- 7,400 ha 95% confidence interval) (Hallsdóttir et. al., (2011).
The natural birch woodland has been surveyed twice before, in 1972-1975 and in 1987-1991 (Sigurðsson et al., 1977, Aradóttir et al., 2001). These surveys are not comparable in method, data sampling and accuracy to the NFI 2005-2009 and can not be used to build a time series for the changes in area and C-stocks.

Since the beginning of settlement of Iceland (870 AD), natural birch woodland has been in steady decline (Sigurðsson, 1977). It is estimated that 95% of the natural birch woodland has been deforested. There are indications that the decline ceased late in the 20th century when the number of free-ranging sheep began to decline rapidly after it reached a maximum in the late 1970s (Jóhannesson, 2010). At that time the sheep stock fell from 900,000 sheep down to 550,000 in 1990. After 1990 this decline slowed down. The current stock is 470,000 sheep. There are indications that natural birch woodland have slightly recovered and this can be observed when condition assessments are compared between surveys made in 1972-75 and 1987-91.
Approximately 64%, or 54.500 ha, of the total area of natural birch woodland are 2 m or more in height or are estimated to reach that height at maturity. They are defined as forest, according to the country-specific definition of forest in the initial report to the UNFCCC (Ministry for the Environment, 2006).
Estimates of the CO_2-removals to the biomass of trees in the natural birch forest was completed this year and will be published and reported for the first time in the NIR and CRF of the year 2011(Hallsdóttir et. al., 2011). The gross annual biomass yield of trees in the natural birch forest is estimated to be - 112,000 tons expressed in CO_2-removals for the year of 2009. No modeling of the historical and future development of the natural birch forest exists. The increase in annual C-removal for the period of 2000 – 2009 reported in the 2011 CRF and NIR is simply estimated by backward calculation of the annual growth ratio estimated for 2009. As mentioned before there are indications that the natural birch woodlands have started slowly to recover after centuries of decline. How fast this process is accelerating is unknown but relatively high biomass yield figures strengthen this theory. On the other hand it is impossible to predict how the biomass yield will evolve so here it is assumed that the amount estimated for 2009 will stay unchanged in the future to the end of the prediction period.
As the natural birch forest is assumed to have occupied most of its current area for a very long time, removals to other pools such as soil and litter are probably not relevant. On the

other hand some natural mortality is occurring, leading to losses of biomass. In this report, dead biomass is assumed to decompose rapidly and emit to the atmosphere. In the NIR of 2011 these losses are estimated to be 23,100 tons in CO_2- emissions from biomass of trees. The same assumption as for the removals of unchanged level throughout the prediction period is also applied for this pool.

Harvest rate and its prediction

As mentioned before, commercial forestry is very young in Iceland. Until the year 2010, harvests from cultivated forest have been very restricted. Clearcutting has not yet occurred and the harvest reported is only from commercial thinning.

Fuel wood cutting in the natural birch forest has a long tradition but after the Mid-20th century the common use of fuelwood ceased and the remaining removals have been restricted to forests owned and managed by the Icelandic Forest Service (Umhverfisráðuneytið, 2007). Most of the wood from the natural birch forest is used for specialized cooking (such as pizza ovens) or as fuelwood for ornamental fireplaces.

Industrial wood use is beginning to emerge from the cultivated forest.

Rapid change in the economic situation in Iceland has occurred in the domestic market for wood following the economic crisis in late 2008. In the middle of the year of 2007 the ratio between the Euro and the Icelandic currency (ISKR) was 1:88. In February 2011 the ratio was 1:159. Furthermore, transactions with foreign currency are restricted. This situation has created a considerable demand for domestic wood for prices that make commercial thinning profitable. In fact, the demand for domestic wood production outstrips the supply.

Most of the thinning is occurring in forest owned by the Iceland Forest Service. A small proportion is procured from other forests in public ownership or under supervision of local forestry associations. Only precommercial thinning has begun in privately-owned forests (owned by farmers and other landowners) as the public schemes aimed at afforesting private land did not begin until in the 1990s. In precommercial thinning, trees cut down are left behind on the forest floor and become litter or dead wood.

Figure 8 shows the amount of annual commercial wood production (marketed) in the period 1986 to 2010. Data used in this graph and in the estimation of emission from wood removals are taken from the same sources as the data for annual plantation, i.e. from the yearbook of the Icelandic Forest Association that keeps a register of commercial wood production as well as annual plantation rate (Gunnarsson, 2010). Figures for 2010 are preliminary and not yet published.

In the prediction of the annual harvest in the future, the harvests of 2010 are assumed as business as usual (BAU). The argument for using 2010 as a baseline for BAU for the nearest future is that nothing in the economic situation in Iceland suggests that significant changes in the economy are imminent that will lead to similar currency rate as before the economic crisis. As long as the demand for wood will persist, the new level of wood removal will last. The only limitation and uncertainty is the possibility that the profitable thinning areas in forest founded before 1990 will be depleted before the end of the period. Taking into account that only a small fraction of the annual biomass yield is harvested, it is unlikely that this situation will occur (See Table 3).

Most of the wood harvested and removed from forest go to processes with very high decomposition rate that will return the CO_2 to the atmosphere either in the year when the wood is sold (e.g. ferro-silicate industries, local heating facilities) or few years after harvest (production of wood chips and shavings for animal bedding). Sawn wood production is only a small fraction of the total production.

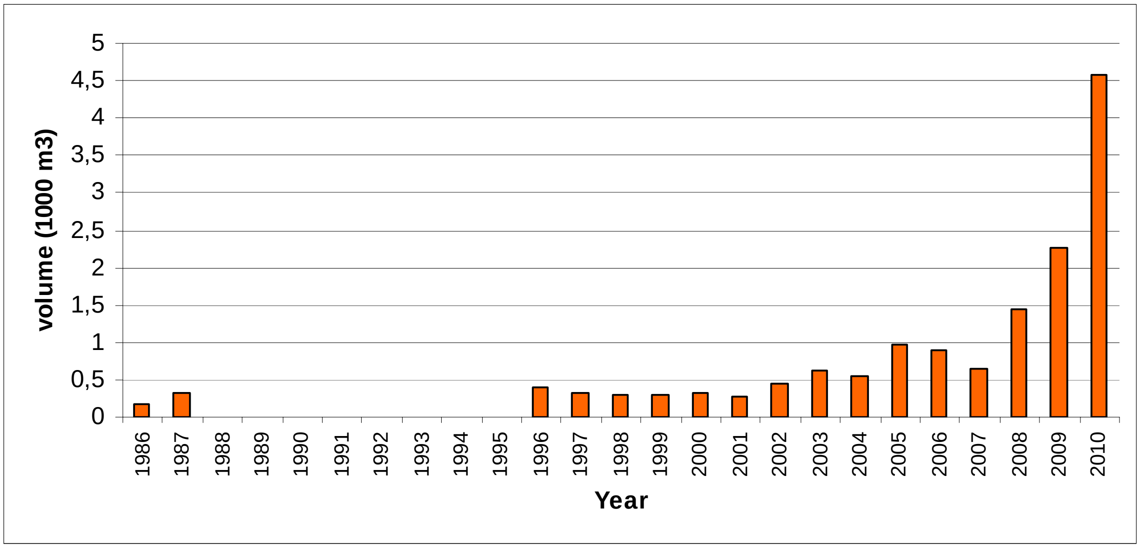

Figure 8. Amount of annual commercial wood production (marketed) registered in the period of 1986 to 2010. Data for the year 1988-1995 are lacking.

Natural disturbances and climate change effects

In modern time has the occurrence and effects of natural disturbances been barely measurable. Wildfires and insects outbreaks have occurred in woodland and forest but the frequency is low and the effect of each event little (Snorrason, 2010a). Windthrows are still very rare. However it has to be noticed that the probability for all three major incidence mentioned, will increase with increasing area, age, height and harvesting intensity of the new forest. In this report all effects of natural disturbances are excluded.
Factoring out of climate change effects of elevated CO_2 concentrations in the atmosphere and indirect nitrogen deposition has not been conducted in this report as evidences of these effects on all the carbon pools of forest are poorly known.

Final calculation of reference level

Figure 9 shows the estimated development of CO_2 removals from forest defined under forest management in Iceland. The main effect is due to the gross biomass yield of the natural birch forest that also covers the majority, or 90% of the area under forest management. The second main effect is due to gross biomass yield of the cultivated forest. Harvesting has a small impact on the final estimate. The amount of harvest is only 6% of the gross annual yield in the cultivated forest, which explains the minor effect it has towards changing the amount of annual cuttings in the reference period. In figure 9 the averages for three periods are also shown, the reference period of 2013-2020, the commitment period of the Kyoto Protocol of 2008-2012 and the period from the base year of the Kyoto Protocol of 1990-2007. Table 3 shows the relative effect of each source or pool for each of the periods.

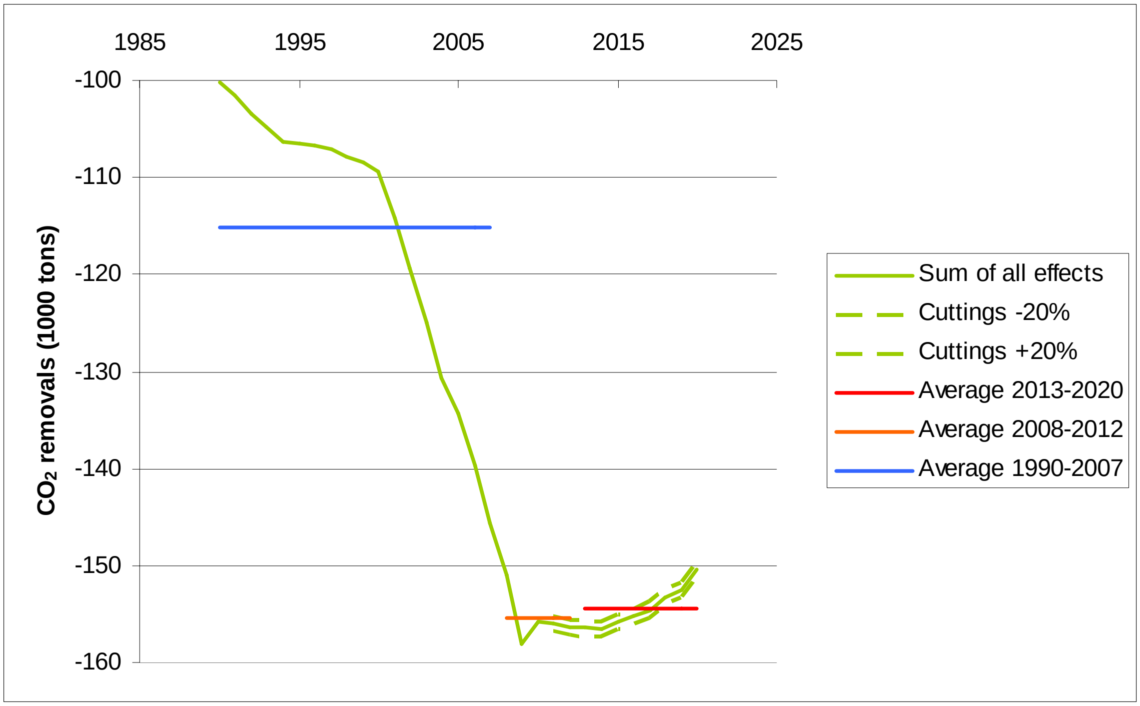

Figure 9. Annual CO_2 removals for all effects and pools estimated (Green solid line). Effect of modification of harvest by 20% is shown as green dotted lines. Annual averages for each period calculated are also shown.

Table 3: Amount and relative effect of each source or pool for each of the period estimated.

	1990-2007		2008-2012		2013-2020	
	kton CO_2	%	kton CO_2	%	kton CO_2	%
Removals to biomass in cultivated forest	-65,8	57,2%	-64,1	41,2%	-62,9	40,8%
Removals to mineral soil in cultivated forest	-6,1	5,3%	-5,5	3,5%	-4,9	3,2%
Removals to litter in cultivated forest	-2,4	2,1%	-2,1	1,4%	-1,9	1,2%
Emission from drained organic soil in cultivated forest	0,2	0,2%	0,2	0,1%	0,2	0,1%
N_2O emission from drained organic soils in cultivated forest (CO_2 eqv.)	0,1	0,1%	0,1	0,1%	0,1	0,1%
Emission from harvest of wood	0,4	0,4%	3,0	1,9%	3,9	2,5%
Removals to biomass in natural birch forest	-52,3	45,5%	-109,7	70,6%	-112,0	72,6%
Emission due to natural mortality in natural birch forest	10,8	9,4%	22,6	14,5%	23,1	14,9%
Total all effects	**-115,1**	**100%**	**-155,5**	**100%**	**-154,4**	**100%**

Final result as shown in table 3 is that **estimated reference level for Forest Management is – 0.154 Mt CO_2 –eq.**

Discussion

The lack of historical time series for the estimate of the carbon stocks in biomass, especially in the natural birch forest is obviously a major weakness of this estimate. Re-measuring of the permanent plots in the natural birch forest will not begin until 2015 and be completed in 2019. In the meantime Icelandic Forest Research has embarked upon remapping the natural birch forest. That work started in 2010 and will be completed in 2014. Improvement of time series for the natural birch forest will not be possible until by the end of the reference period. On the other hand, estimates for the other main source, the carbon stock in biomass in cultivated forest, will be improved annually as the re-measurements of the cultivated forest already started in 2010. The second inventory of cultivated forest will be finalized in 2014. New and more reliable data to estimate time series will by then be available. Although the wood harvest has little effect on predictions, this will depend on changes in demand for locally harvested wood, and is very difficult to predict, as the economic situation in Iceland is unpredictable over the foreseeable future. Possibilities to predict wood harvest will be enhanced once the economic situation has stabilized.

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