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Aboveground woody biomass of natural birch woodland in Iceland – Comparison of two inventories 1987-1988 and 2005-2011

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ABSTRACT
The only native tree species in Iceland forming woodland is the mountain birch. Since human settlement in the 9th century AD, natural birch woodlands have decreased from around 28% to 1.5% of the terrestrial area. In this paper we estimated and compared aboveground woody biomass stocks of two sample inventories from 1987-1988 and 2005-2011. Total above- ground woody biomass stocks in 1987-1988 and 2005-2011 were 1503 Gg (SE = 175, n= 272) and 1455 Gg (SE = 180, n= 181), respectively, for the woodland already existing in 1987-1988. The biomass estimates in 2005-2011were not significantly different from the 1987-1988 estimates in the < 2 m height class (P = 0.282) nor in the 2 - 4 m height class (P = 0.673). We concluded that the aboveground woody biomass of the natural birch woodland already existing in 1987-1991 had not changed between the two inventories. Additionally, we estimated an aboveground woody biomass increment of 37 Gg for the woodland expansion occurring between these two inventories.

Keywords: aboveground biomass, Betula pubescens, biomass stock change, mountain birch, woody biomass stock.

YFIRLIT
Lífmassi ofanjarðar í trjágróðri náttúrulegra birkiskóglenda á Íslandi – samanburður á tveimur úttektum frá 1987-1988 og 2005-2011.
Ilmbjörk er eina trjátegundin sem myndar skóga og kjarr á Íslandi. Frá landnámi hefur skóglendi minnkað mikið eða frá því að þekja um 28% niður í 1,5% af flatarmáli Íslands samkvæmt úttekt sem gerð var 2010 - 2014. Við bárum saman og mátum lífmassa ofanjarðar í trjágróðri í tveimur úrtaksúttektum í náttúrulegum birkiskógum á Íslandi m.a. til að leggja mat á hvort lífmassinn hefur aukist eða minnkað á milli úttekta. Við notuðum tvær úttektir sem framkvæmdar voru með 20 ára millibili á síðustu þremur áratugum. Þar sem þessar úttektir voru töluvert frábrugðnar varðandi t.d. úrtakseiningar, úrtaksflokkun og skilgreiningu skóglendis, varð að vanda alla kvörðun og útreikninga þannig að gögnin yrðu samanburðarhæf. Lífmassi trjágróðurs ofanjarðar í flokkaðri úrtaksúttekt sem gerð var 1987-1988 var metin 1503 Gg (SE = 175, n= 272) en 1455 Gg (SE 180, n= 181) í óflokkaðri úrtaksúttekt sem gerð var á árunum 2005-2011 fyrir sama skóglendi. Tölfræðilegur samanburður á lífmassa trjágróðurs á flatareiningu í könnunum tveimur sýndi ekki marktækan mun í hvorugum hæðarflokki < 2 m (P=0,282) og 2 – 4 m (P=0,673). Okkar niðurstaða var því að ofanjarðar lífmassi trjágróðurs í náttúrlegu birkilendi á Íslandi, sem þegar var fyrir hendi 1987-1988, hafi ekki breyst marktækt. Þar fyrir utan mátum við aukningu í lífmassa í trjágróðri ofanjarðar sem 37 Gg í náttúrulegum nýgræðslum birkis á milli úttektanna tveggja.

INTRODUCTION

In Iceland, the mountain birch (*Betula pubescens* Ehrh.) is the only native woodland-forming tree species (Kristinsson 1995). At the time of the human settlement in the 9th Century AD, birch woodlands might have covered a land area of 2,800,000 ha (Sigurðsson 1977, Aradóttir & Arnalds 2001). Presently, birch woodland covers only 150,600 ha (Snorrason et al. 2016), only 1.5% of the land area of Iceland.

The Kyoto Protocol to the United Nations Framework Convention on Climate Change as well as later international agreements demand that signatories monitor, report and manage their terrestrial carbon pools, including forests and other vegetation (United Nations 1997). The reported statistics are subject to transnational auditing.

Forest carbon stocks are usually derived from biomass inventories. The Kyoto Protocol defined the year 1990 as the baseline for national reporting of carbon stocks and fluxes. Accurate and verifiable inventory-based biomass estimates are required for the baseline year as well as for more recent periods, covering the entire native birch population.

In 1972-1975, the natural birch woodlands of Iceland were demarcated and classified. In this comprehensive mapping survey, polygons of homogeneous woodland units were drawn on aerial photographs that were later projected optically onto topographic maps. Unique reference numbers were assigned to woodland units and the characteristics of each visually scored according to classes of canopy cover, overall tree height (elevation of canopy), general conditions, regeneration and site characteristics (Sigurðsson and Bjarnason 1977).

During the years 1987-1991, a second nation-wide inventory of natural birch woodlands was conducted, with emphasis on objective tree measurements. The inventory project was in three parts:

(1) A study of aboveground biomass based on a stratified random sample of single trees from the entire native birch population that was carried out in 1987-1988 (Jónsson 2004). Data from this study are used in this paper and are further described in the next section.

(2) An update, alignment with existing vegetation maps and digitization of revised woodland maps from the 1972-75 survey (Aradóttir et al. 1995, Aradóttir et al. 2001).

(3) A comprehensive inventory of birch woodlands was performed. In this part of the inventory, sample units were located along transects lines laid out in woodland blocks, recording measured tree sizes, regeneration and site characteristics. In total, about 10,000 trees were measured along 560 km long transects (Aradóttir et al. 1995, Aradóttir et al. 2001). The data were linked to the revised birch maps forming a geographic information system (GIS) and were used to split the woodland units by canopy height classes (Traustason & Snorrason 2008). Later these maps were rectified (Snorrason et al. 2007) and used to determine an official estimate of natural birch woodland areas and in international land use reports such as the European CORINE land cover program (Traustason & Snorrason 2008).

In 2005, a periodic national forest inventory (NFI) was launched, covering separately forest plantations and natural birch woodland (Snorrason 2010). The inventory of natural birch woodland took place in 2005-2011. Data from this inventory were used in this paper and are described in more detail in the next section.

From 2010 to 2014, Icelandic Forest Research re-mapped the natural birch woodland and combined the new maps with the existing birch woodland database. Snorrason et al. (2016) used the database to estimate woodland areas in 1989 and 2012. Respectively, the areas were 137,700 ha and 150,600 ha, an increase in the total area from 1989 of 12,900 ha.

The 1987-1988 biomass study and the 1987-1991 map update are close in time to the 1990 reference year of the Kyoto Protocol. The first commitment period of the Kyoto-protocol, 2008-2012, almost coincides with the 2005-2011 periodic national forest inventory of natural birch woodland. The two decades between 1987-1988 biomass study and the first periodic national birch inventory (2005-2011) essentially define the baselines for national carbon accounting. The objectives of our present paper were to estimate: (1) aboveground woody biomass stocks of natural birch woodland during the two periods 1987-1988 and 2005-2011, (2) stock change between the two periods in woodlands already existing in 1987; as well as (3) biomass stock in areas colonized by birch between the two periods.

MATERIALS AND METHODS

We compared the means of aboveground biomass densities per unit area (Mg ha^{-1}) in the two inventories of 1987-1988 and 2005-2011 by canopy height strata used in the 1987 survey.

Inventory of 1987-1988

A stratified random sample of 300 trees of mountain birch was drawn from the entire population of natural birch woodland, stratified into the three canopy height classes used in the inventory of 1972-75. The height classes were < 2 m, 2-4 m and > 4 m with 55, 81 and 149 trees sampled, respectively, in each class. The trees were harvested and measured in the dormant period of September 1987 to April 1988. All stems of trees sampled were measured for stem length (height), diameter at ground level ($d_{0.0}$) and 0.5 m distance from ground level ($d_{0.5}$). The stem with greatest diameter was felled and weighed in the field. Subsamples from the stem and branches were taken for dry mass estimations (Jónsson 2004, Jónsson & Snorrason 2018).

Distance to the third nearest tree was measured and used to estimate point density by the Equation 1 given by Philip (1994):

$$N = \frac{(3-0.5)10^4}{\pi k^2} \qquad \text{(Eq. 1)}$$

where N is the number of trees per hectare and k the distance from the measured tree to the third nearest tree. Aboveground biomass was calculated for each stem using biomass functions described in Jónsson & Snorrason (2018). Aboveground biomass for each tree was the sum of the biomass estimates for all stems arising from a single root system plus dry mass of stump sprouts weighed in the field. Biomass on a unit area basis was estimated as the product of tree biomass and respective point density (N) estimated by Equation 1. For each stratum, we calculated average biomass per hectare.

Inventory of 2005-2011

Covering the whole of Iceland, a 1.5 x 3.0 km grid was laid out with permanent 200 m^2 circular plots centred at each grid intersection overlapping the 1987-91 natural birch woodland map. Plots were established where the forest margin was within 24 m of the intersection coordinates (24 m buffer zone). Within the birch woodland boundaries, the minimum requirement to register a plot was that the birch trees, at perceived maturity, had a canopy cover of at least 10%. A plot inside a woodland could be without trees if the treeless area was smaller than 0.5 ha or non-wooded corridors of less than 20 m in width. Plots were mapped, splitting the plot areas into sections with and without tree cover (gaps), defining gross and net woodland cover. In the case where plots situated on the woodland perimeter extended outside the borderline, the mapped treeless area beyond the woodland margin was excluded from the woodland area (Snorrason 2010).

A total of 310 permanent sample plots were established and visited. About one third of visited plots were deemed outside of birch woodland although plot coordinates were situated inside the 1987-1991 woodland map with later corrections (Table 1). This mismatch had been caused by projection errors explained in the area subsection below. Of 210 valid plot locations, 201 plots had trees within plot boundaries, whereas an additional 25 plots were missing some observations and excluded from the dataset.

Plots of the 2005-2011 inventory were designed with a spatial hierarchy of sub-plots at three levels: (1) the circular main plot of 200 m^2, (2) concentric circular sub-plot of 50 m^2; and (3) one to three circular sub-plots of 4 m^2 each

Table 1. Number of plots visited and measured in the plot inventory of 2005-2011.

	Year of field inventory							
Number of plots	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Sum**
Measured	13	59	34	53	43	6	2	210
Outside woodland	8	23	23	14	25	3	4	100
Visited	21	82	57	67	68	9	6	310

at a 4 m distance from the centre of the main plot. On the 200 m^2 main plots, trees reaching the forest canopy and with a stem diameter of ≥10 cm at $d_{0.5}$ were measured, recording tree height, stem length and $d_{0.5}$. All trees on the 50 m^2 sub-plots more than 2 m high but with stems less than 10 cm at $d_{0.5}$ were measured, recording stem length, $d_{0.0}$ and $d_{0.5}$. On each of the 4 m^2 sub-plots, an apparently representative tree less than 2 m tall was chosen; its stem length and $d_{0.0}$ were measured and the number of all trees less than 2 m tall was recorded (Snorrason 2010). Outside the sample plot, substitute trees were identified of similar size and growth habit to those measured on the 4 m^2 and the mean stem at 50 m^2. Stem length and $d_{0.0}$ were measured and the tree harvested for biomass analysis and age determination. Age determination of bigger trees was done by cores from stems sampled right above ground and at a height of 0.5 m. Age analysis of samples was conducted at the Icelandic Forest Service Tree-ring Laboratory.

Area

We used measurements of current mean tree heights to assign inventory plots to canopy height classes of < 2 m, 2-4 m and > 4 m used in the 1987 inventory. Plots were also categorized by National Forest Inventory classification by perceived height at maturity, < 2 m, 2-5 m and > 5 m.

We used the estimated area of native birch woodland by Snorrason et al. (2016) to define national total area in 1987 and 2007. The mean annual increase in area of 563 ha occurred in the period 1989 to 2012. The expansion in area between 1989 to 2007 was therefore estimated to be 10700 ha.

Snorrason et al. (2016) identified an important mismatch between the maps of the 1987-1991 and 2010-2014 mapping surveys. The main reason for this misalignment was inaccurate projection of mapped woodland, in the first phase when projecting woodland borders from air photos to hard copy maps and in the second phase when digitizing woodland borders from hard copy maps. Due to this misalignment sample plots did not entirely cover the area of the woodland. To correct for this loss of sampling area the expansion factor of each plot was calibrated by a factor of 1.61, the ratio of total area of the 2010-2014 remapping project (137,700 ha) divided by the total area of the 2005-2011 inventory (85,600 ha) based on the number of plots coinciding with the 2005-2011 inventory map.

Birch woodland areas by different canopy height classes were estimated by Equation 2 (Husch et al. 1972):

$$A_i = \frac{n_i}{n} A \qquad \text{(Eq. 2)}$$

where A_i is the estimate of the area of class *i*, n_i the number of plots in area class *i*, n the number of plots in the sample, and *A* is the total sampled area estimated by Snorrason, et al. (2016). A standard error of the area estimate for class *i* (SE_i) was derived by:

$$SE_i = \sqrt{\frac{\left(\frac{n_i}{n} * \left(1 - \frac{n_i}{n}\right)\right)}{(n-1)}} \qquad \text{(Eq. 3)}$$

Aboveground biomass

We used single tree biomass functions derived for the entire Icelandic birch population (Jónsson & Snorrason 2018) to estimate tree biomass aboveground from diameters measured in the 1987-1988 and 2005-2011 inventories.

Biomass for small stems up to 60 mm in $d_{0.0}$ were estimated by the function:

$$dm = bd_g{}^c \qquad \text{(Eq. 4)}$$

denoted M2 in Jónsson & Snorrason (2018), where *dm* is the dry biomass in grams (g), d_g is the diameter of the circle of the true basal area at ground level in millimetres (mm), and *b* and *c* are constants, 0.0786 and 2.5609, respectively. When using $d_{0.0}$ measured with diameter calliper a factor of 0.9299 given by Jónsson & Snorrason (2018) was used to convert the calliper measurement to d_g.

Biomass for stems larger than 60 mm were estimated by the function:

$$wm = a + bd_g{}^c \qquad \text{(Eq. 5)}$$

denoted M11 in Jónsson & Snorrason (2018), where *wm* is the wet in-field biomass in g, d_g is the diameter in mm of the circle of the true basal area at 0.5 m, and *a*, *b* and *c* are constants, 92.4779, 0.3932 and 2.4771, respectively. When using $d_{0.5}$ measured with a diameter calliper a factor of 0.9346 given by Jónsson & Snorrason (2018) was used to convert the calliper measurement to d_g. To convert wet biomass into dry biomass we used the factor of 0.5372 given by Jónsson & Snorrason (2018).

Total aboveground biomass for all trees on each plot and sub-plots was calculated, adjusted by appropriate area fractions and totalled to derive biomass per hectare.

Total biomass stock was estimated for each canopy height sub-population as the product of average biomass per unit area and total area of the stratum.

We fitted linear regression, with intercept set to zero, to data of woody aboveground biomass by estimated stand age based on cores from mean stems and substitute stems sampled in the field on 128 plots in the 2005-2011 inventory. We used the slope of the regression line to estimate annual biomass increment of an area recently colonized by birch. We used the observed average annual rate of woodland expansion of 563 ha yr^{-1} (Snorrason et al. 2016) to adjust national total woodland area to specific years. The rates of biomass increment and woodland area expansion were used to estimate total biomass by 2007 in an area colonized by birch since 1987.

Statistical analyses

We used Shapiro-Wilkinson to test normality of the biomass density data by canopy height. Mann-Witney two sample rank test (Zar 1998) was used to compare woody biomass density data between 1987-1988 and 2005-2011 surveys.

RESULTS

Biomass per hectare

The median values of aboveground biomass per hectare of birch scrub (<2 m) were 4.41 Mg ha^{-1} and 5.77 Mg ha^{-1} in the 1987-1998 inventory and the 2005-2011 inventory, respectively. For the canopy height class 2-4 m, the median values were 12.89 Mg ha^{-1} and 12.26 Mg ha^{-1} the 1987-1998 inventory and the 2005-2011 inventory, respectively. In the 2005-2011 inventory, 66%, 33% and 1% of plots were categorised by canopy height classes, < 2 m, 2-4 m and >4 m, respectively. There were insufficient observations for analysis of the >4 m canopy height sub-population.

The Shapiro-Wilkinson test for normal distribution of the data failed for both canopy height classes < 2 m and 2 – 4 m. The Mann-Witney two sample rank test differences did not show significance between inventories, with P values 0.282 and 0.673 for the canopy height classes <2 m and 2-4 m, respectively.

In the 1987-1988 inventory, the average biomass density weighted by canopy height class was 15.40 Mg ha^{-1} and 10.91 Mg ha^{-1} per net and gross area, respectively (Table 2). The mean for the 2005-2011 inventory was 10.57 Mg ha^{-1} per gross area. Calibrated according to the estimated initial total area of 137,700 ha, the woody biomass stock above ground of natural birch woodland in 2005-11 was estimated at 1455 Gg (SE = 180, Table 3).

Biomass stocks were estimated for the 1987-

Table 2. Aboveground woody biomass of mountain birch in natural birch woodland in Iceland according to the 1987-1988 inventory.

	Biomass per net area			Biomass stock		Biomass per gross area	
Stratum	**Mean**	**SE**	**Area**	**Stock**	**SE**	**Area**	**Mean**
	Mg ha^{-1}	**Mg ha^{-1}**	**ha**	**Gg**	**Gg**	**ha**	**Mg ha^{-1}**
< 2m	11.23	2.38	60,100	675	143	92,200	7.32
2-4m	20.99	2.85	35,300	740	100	43,300	17.11
> 4m	40.01	5.30	2,200	87	12	2,200	40.01
All strata	15.40	1.80	97,600	1,503	175	137,700	10.91

Table 3. Area and the aboveground woody biomass according to the 2005-2011 inventory. Area is classified by height at maturity in net woodland area and area of gaps in the woodland. Calibrated area is also shown for net woodland area of each class and for the gross woodland area as sum of net woodland and gaps in each class.

	Uncalibrated area and biomass						Calibrated area and biomass			
	Area (ha)				Biomass (Gg)		Area (ha)		Biomass (Gg)	
Height at maturity	**Net area**	**Gaps**	**Sum**	**SE**	**Stock**	**SE**	**Net**	**Gross**	**Stock**	**SE**
< 2 m	18,700	11,400	30,200	3,300	189	77	30,100	48,500	304	124
2 - 5 m	35,700	13,400	49,100	3,800	583	71	57,400	79,000	938	113
≥ 5 m	6,200	100	6,300	3,200	133	21	10,000	10,100	213	34
All classes	**60,600**	**24,900**	**85,600**	**3,900**	**904**	**112**	**97,600**	**137,700**	**1455**	**180**

1988 survey separately for each stratum of actual height class and for all strata. The relative value of the standard error (standard error divided by the mean) of the estimate was from 14% for all strata to 26% for the < 2 m stratum where the number of measurements was lowest. For the 2005-2011 inventory, the relative SE estimate was for the total 12%, but considerable higher or 41% for the < 2 m height classes at maturity. The other two classes were in line with actual height classes in the 1987-1988 survey or 12% and 16% for 2-5 m and > 5 m classes respectively.

Woodland expansion

The slope of a regression line of biomass by age forced to pass through origin was 0.343 Mg ha^{-1} yr^{-1} and highly significant ($P < 0.0001$, $R^2=0.314$). In the period 1989 to 2012, natural birch woodlands colonized an area of previously open ground of 12,900 ha (Snorrason et al. 2016), a mean annual rate of 563 ha yr^{-1}. Based on this rate, biomass stock by the year 2007 on area colonized by birch since 1987 was estimated at 37 Gg.

DISCUSSION

In the Initial Report under the Kyoto Protocol, the Icelandic government decided to define forests by minimum value at maturity of 2 m height and 10% crown cover (Ministry for the Environment 2006). For this study we estimated aboveground biomass stocks and stock changes separately for birch scrub less than 2 m and taller woodlands. In Iceland, natural birch woods with dominant trees taller than 2 m account for 71% of the total area of forest, including both natural woodlands and plantations (Hellsing et al. 2016). Birch scrub, on the other hand, is classified under Grassland and not reported under the Kyoto Protocol. Nevertheless, both birch scrub and woodlands taller than 2 m are important for biomass and carbon stock accounts even though registered differently in greenhouse gas bookkeeping.

Accuracy of our biomass stock and stock change estimates depend on: (1) the woodland area estimates, (2) quality of the two inventories, and (3) accuracy of the single tree biomass models employed. The early birch maps of the 1972-1975 survey had some errors. These were partially corrected in the 1987-1991 map update and edited further in the National Forest Inventory (Snorrason et al. 2007). Nevertheless, considerable mismatch remained between boundaries of woodland map units and true forest margins. In the 2010-2014 remapping project, woodland boundaries were carefully redrawn with extensive ground proofing (Snorrason, et al. 2016). Our currently presented biomass stock estimates are based on the more accurate 2010-2014 woodland maps with a calibration factor to scale up biomass estimates from the 2005-2011 inventory.

The two inventory datasets of 1987-1988 and 2005-2011 are of unlike design, a stratified random sample and systematic plot sample, respectively. Both are by design representative samples of the entire natural birch population. Our statistical comparison of the two inventories of unlike design was at the expense of precision but not accuracy. Accuracy of our estimates is critically important and dependent on the use of unbiased and representative single tree biomass functions.

The native birch woodlands and scrub are mostly of low stature with small diameter trees (Jónsson 2004). For these woodlands, biomass stock estimates are sensitive to bias at the small diameter end of allometric biomass functions. Therefore, careful choice of unbiased single stem biomass functions was essential for temporal stock comparisons.

Snorrason & Einarsson (2006) published a two-parameter single stem biomass function of $d_{0.5}$ and stem length for plantation grown birch and rowan (*Sorbus aucuparia* L.) in Iceland. This two-species model was based entirely on plantation grown trees and is thus not representative of natural birch woodlands. Furthermore, stem length added insignificantly to model fit (Snorrason and Einarsson 2006). Natural mountain birch trees are commonly leaning, contorted or procumbent (Jónsson 2004). Stem length is difficult and tedious to measure non-destructively and adding variables beyond diameters might be inefficient.

Hunziker et al. 2014 put forward single parameter biomass models for mountain birch in Iceland, but their data were only from a few stands in South Iceland. Tested on two independent samples representative of the entire natural birch population in Iceland, their model derived by linear regression of log-transformed power function (Baskerville 1972) proved accurate (Jónsson & Snorrason 2018). However, their model was based on $d_{0.5}$ only, and thus did not cover the smallest diameter stems.

Jónsson & Snorrason (2018) derived unbiased single stem single parameter biomass models for natural birch in Iceland, based both on $d_{0.0}$ and $d_{0.5}$. These models cover the entire range of tree sizes and were derived from a representative sample of the entire natural birch population in Iceland and tested on an independent and representative sample. We used these models to estimate aboveground biomass for trees in both our 1987-1988 and 2005-2011 inventories.

Bylund and Nordell (2001) estimated the aboveground biomass in natural birch woodlands in Abisko in North Sweden as 9.6 Mg ha^{-1} with the foliage biomass included and estimated at 12.8% of total aboveground biomass. Aboveground woody biomass of natural mountain birch in the transatlantic mountain birch ecosystem has been estimated from 11.0 Mg ha^{-1} in Kevo in Northern Finland (Kjelvik and Kärenlampi 1975) to 54.9 Mg ha^{-1} in Eqaluit in South-West Greenland (Elkington and Jones 1974). In both cases foliage was included, an estimated 0.595 and 1.2 Mg ha^{-1} respectively. Our results do fall well between these estimates.

In Iceland, the native birch woodland is in a continuous cycle of regeneration, growth and tree mortality (Jónsson 2004). For the 1987-1988 sample, Jónsson (2004) estimated median life expectancies of dominant birch stems; 32, 44 and 56 years in birch scrub (<

2 m), scrub woodland (2-4 m) and forest sub-populations (> 4 m), respectively. Both annual biomass increments and turnover rates are low percentages of standing biomass stock. Our present study was not sensitive to small changes in biomass stocks. Thus, in the 20-year period, we would not expect significant biomass stock change in the natural birch woodland.

A second round of re-measurements of the permanent systematic plots of the 2005-2011 inventory started in 2015 and is to be finished by 2019. The 2015-2019 inventory will provide an estimate of the biomass changes in the interim period between 2005-2011inventory and the 2015-2019 inventory. The second round will include new plots established based on the 2010-2014 natural birch woodland maps. In old established woodlands, repeated measurements of the same permanent plots might provide more precise estimates of biomass change. Also, re-measurement of existing plots as well as addition of new plots on land recently occupied by birch will further clarify recent changes in the above biomass stocks.

CONCLUSIONS

In the 20 years period between the 1987-1988 inventory and the 2005-2011 inventory, woody aboveground biomass of natural birch woodlands did not change significantly but woodland expansion added 37 Gg to the total biomass stock. Overall, the difference between the two estimates was only 11 Gg or a 0.7% decrease during the period, and statistically not significant.

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