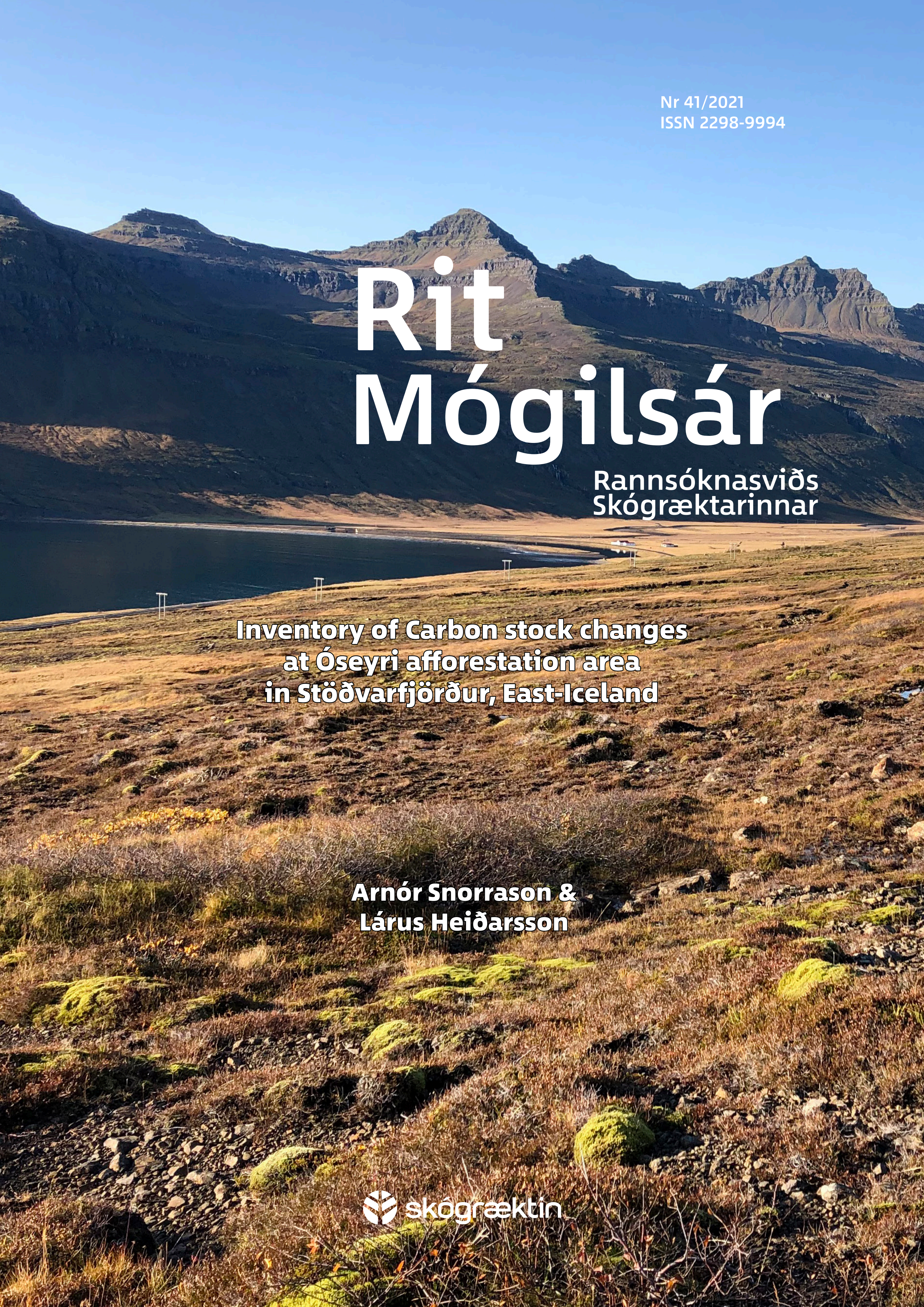

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## Inventory of Carbon stock changes at Óseyri afforestation area in Stöðvarfjörður, East-Iceland

Arnór Snorrason &
Lárus Heiðarsson

skógræktin

# Contents



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# Inventory of Carbon stock changes at Óseyri afforestation area in Stöðvarfjörður, East-Iceland

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# Introduction

The work addressed in this report is ordered and partly financed by Yggdrasill Carbon ehf.

The objectives of this report are:

1. To map the status of the afforested land and the afforestation on the farm Óseyri in Stöðvarfjörður, East-Iceland.
2. To estimate the current annual C-stock change of the plantations at Óseyri.
3. To project the C-stock changes of the afforested area for the next 70 years, with business-as-usual management (baseline management) of forest available for wood supply.
4. To make a projection of the C-stock changes of an alternative management plan with no utilization of wood in the same period for plantations classified as forest available for wood supply and compare it with the projection of business-as-usual.

# Materials and methods

## Historical afforestation activity

Afforestation started on the farm in 2006 with grants from the state. In this report we used data sampled in the field from the time when afforestation started and the management plan of the afforestation to see how they match to our inventory. Reported data about seedling number and species composition of planted seedling were also used.

### Data sampling for afforestation planning

The data used to make the afforestation plan for Óseyri were sampled in July 2006 (Benjamín Örn Davíðsson 2009). The area mapped and contracted with forestry authorities was estimated to be 194 ha. The border of the area is shown in Figure 2. 32% of the area was moss heath, 38% dwarf shrub heath, 25% *Betula nana* heath and the remaining area Kobresia/Juncus heath (2%) and grassland (3%). Moss, dwarf shrub and Kobresia/Juncus heath indicate infertility, especially on thin soils. *Betula nana* heath is usually with thicker soils and intermediate fertility. Grassland can be fertile on thick soils but on thin soils it is usually rather infertile. Generally, the afforestation area of Óseyri is infertile. It should be noted that natural birch shrubland with sparse canopy cover (roughly 10%) was present on 27 ha.

### Afforestation planning

The afforestation plan was completed in early 2009 (Benjamín Örn Davíðsson 2009), two years after planting started. Afforestation was planned on all areas except rock outcrops and wetland. Total planned afforested area was 191.6 ha. According to the afforestation plan, the total number of seedlings to be planted was 572,400, with an average density of 2987 seedlings per ha which is a seedling spacing of 1.8 m. Recommendation of seedling spacing varied from 1.3 m to 3.2 m depending on tree species.

### Reports of seedlings planted

Planting has been ongoing annually since 2007, apart from 2018 (Figure 1). The total number of seed-

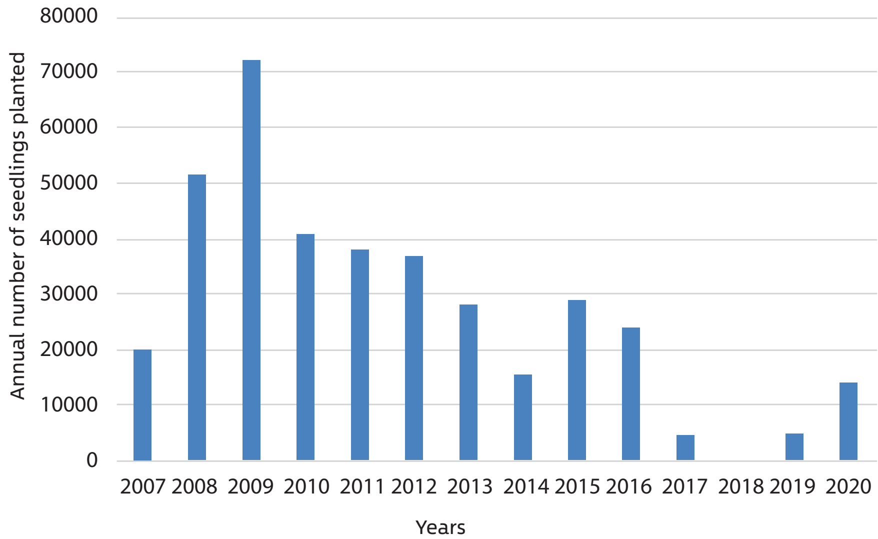


***Figure 1****. Annual number of forest tree seedlings planted at Óseyri afforestation area. Raw data from the regional office of forest advisory division of the Icelandic Forest Service in Egilsstaðir.*

***Table 1****. Number of forest tree seedlings according to the plan and planted at Óseyri afforestation area divided into species groups. Ratio of the planted main tree species within the species group is given in the last column.*

| PLANNED PLANTATION | | | PLANTED SEEDLINGS | | | |
|---|---|---|---|---|---|---|
| **Species group** | **Number of seedlings** | **% of total** | **Number of seedlings** | **% of total** | **Main species** | **% of group** |
| Poplar | 7600 | 1.3 | 3717 | 1.0 | Black cottonwood | 100 |
| Spruce | 143600 | 25.1 | 58933 | 15.5 | Sitka spruce | 90 |
| Pine | 74300 | 13.0 | 94140 | 24.8 | Lodgepole pine | 76 |
| Larch | 68800 | 12.0 | 71501 | 18.9 | Russian larch | 88 |
| Birch | 178900 | 31.3 | 120624 | 31.8 | Downy birch | 95 |
| Alder | 45200 | 7.9 | 11920 | 3.1 | Sitka alder | 52 |
| Rowan | 38300 | 6.7 | 17643 | 4.7 | Mountain ash | 100 |
| Other species | 15700 | 2.7 | 792 | 0.2 | Goat willow | 100 |
| **Sum** | **572400** | | **379270** | | | **100** |

lings planted as of 2020 is 380,270 or 66% of the planned number.

In Table 1, the number of seedlings is shown, both planned and reported. The planned number of seedlings was only given by species groups, but species reported are listed by main tree species.

Of the main tree species, the planned number of pine and larch seedlings have already been reached but only 41% and 67% of planned planting of spruce and birch, respectively.

Tree species yielding forest available for wood supply where only 39% and 41% of planned and planted number of seedlings, respectively. The main tree species available for wood supply at Óseyri are black cottonwood, Sitka spruce and lodgepole pine. Russian larch is too frequently damaged by spring frost dieback in localities near the coastline to develop wood reaching commercial size. The special cultivar Hrymur, which is a hybrid of Russian and European larch, does thrive rather well in Óseyri but has only been planted in small scale (8508 seedlings). Hrymur will most likely yield forest available for wood supply. Other species planted are often shrubby with many and/or crooked stems. Commercial use of the wood of these species is in many cases unrealistic. These species are birch, alder, rowan and willow. The goal of the afforestation at Óseyri must be only partially aimed at growing forest for wood utilisation as the majority of planned and planted seedlings are not available for wood supply.

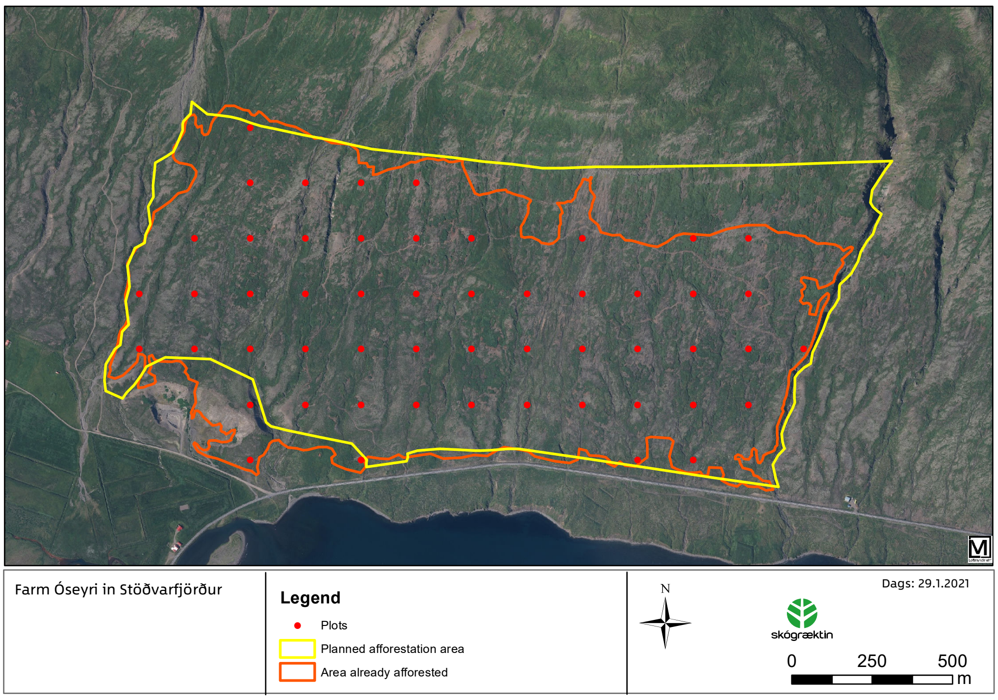


***Figure 2****. An aerial photo of the afforestation area at Óseyri. The planned afforestation area is marked with a yellow line and the area already afforested and inventoried is marked with a brown line. Sample plots are marked with red dots.*

# The inventory of 2020

To get a better picture of the status of the plantations and sample data on biomass and growth, a traditional plot sample inventory was conducted on the afforestation area in Óseyri (Van Lar et al. 2007).

## Sample design

Before the inventory plots were laid out, an outline of the area already planted was mapped and separated from land that was not yet planted. This work was done in the field by tracking the border with a GPS device (Figure 2). The area was estimated 170.26 ha.

It was clear from the start that the map of the afforestation plan and the reporting of plantation activity could not be used to stratify the afforestation. Therefore, measurement plots were laid out in a systematic sample grid, resulting with a square grid of 172x172 m yielding 53 plots on the demarcated area (Figure 2).

## Data sampling on plots

Field measurements on plots where managed with hardware and software from Field-Map (see https://www.fieldmap.cz/). Each plot is a circle with fixed size of 100 $m^2$. To find and set out the centre of a plot, a handheld GPS device was used. The plot centre was set out and marked with a red coloured iron rod. High precision GPS measurement was applied at the plot centre.

Vegetation class, vegetation cover, surface class, soil depth class, soil type class and bedrock class were assessed together with crown cover and mean height of natural birch and other native shrubs on every plot. This was done on a subplot level when plots where split into subplots as shown in Figure 3. The border of each subplot was mapped with the Field-Map device.

When planted trees were within plots, the plantation was described, and its age and species composition assessed. All planted trees were located and mapped with the Field-Map device. For each tree, the species was identified, the vitality, damage and height, dieback height and the diameter at root collar was measured. Both living and dead trees where measured (see Figure 3). Together, 779 living and 8 dead trees were measured on 44 plots.

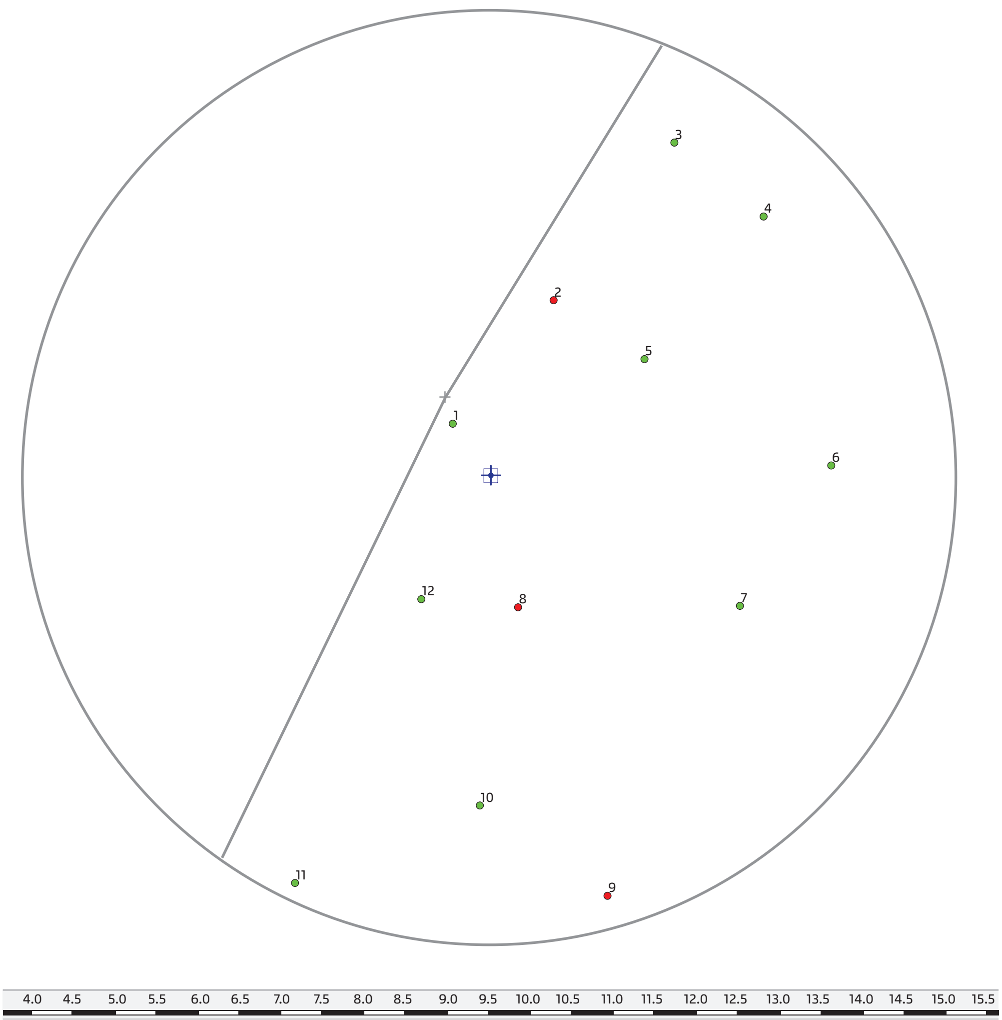


***Figure 3***. *A map of a plot divided into two subplots, one with trees and the other without trees. Trees are shown with numbered dots where green dots are living trees and red dots dead trees. The picture is drawn from a screenshot from the Field-Map software.*

# Data processing

Data processing and processing methods are described in this chapter according to the objectives of the report as listed in the introduction. Plot information was the basis for processing, calculation, and estimated results. Simple random sample statistics with exclusion were used, although plots were distributed systematically given that the coordinate of the first plot in the grid was randomly chosen (Van Lar et al. 2007). Standard error estimation of post stratification of classified variables was derived by:

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

where $n_i$ is the number of plots in post-strata i, and $n$ the number of plots in the sample (Husch et al. 1972). The upscaling factor was defined as the total area divided by the total number of plots.

## The status of the afforested land and the afforestation

The land was classified into plantation and land without plantation. To describe the status of the plantations, average height and max height was calculated for all living trees measured.

One of the most important variables, when assessing the quality of plantations, is the density of planted seedling.  We calculated tree-density of all plots and subplots and weighted area mean density of the plantation.

Vitality of each tree was visually assessed and divided into four classes: 1. Very healthy, 2. Moderately healthy, 3. Rather weak and 4. Very weak. Class 1 describes seedlings growing under good and normal condition. Classes 2 and 3 describe seedlings growing under stressful and harmful conditions but Class 4 signifies seedlings that are potentially dying in coming years. Damage was reported for each tree and described by different damage classes.

## Current annual C-stock change of the plantations

The biomass above ground stock for all trees with stump diameter more than 6 mm was calculated by:

$$b_{abg} = g_{stump} * 22.745 - 6.3406 \quad \text{Eq. (2)}$$

where $b_{abg}$ is the above ground biomass in grams, $g_{stump}$ is the basal area at stump height or root collar in cm$^2$. The equation is built on empiric linear regression of 41 harvested stems of planted birch ($R^2$=0.95) and is used in the calculation of the biomass trees under 1 m height in the annual National Inventory Report (NIR) of Iceland to the UNFCCC. Root/shoot ratio of 0.87 ($R^2$=0.94) from the same research was used to estimate biomass below ground (Keller et al. 2020).

To calculate C-stock change of trees, an initial biomass of each seedling measured was set at 0.63 g which is an average figure of unplanted seedlings. As the plantations at Óseyri were young (1 to 14 years old), relative annual growth rate was assumed to be constant. Annual growth rate was calculated for each tree by iteration.

C-stock change in soil and litter was estimated by the same removal factors as used in the NIR of Iceland to the UNFCCC (Keller et al. 2020) in the 50 years conversion period of Land converted to Forest land. These factors are for litter 0.141 ton C per ha and year, and in addition for soil in vegetated areas (≥30% vegetation cover); 0.365 ton C per ha and year, and for soil in sparsely vegetated areas (<30% vegetation cover); 0.513 ton C per ha and year.

## Baseline prediction of C-stock changes of afforested areas

Because it was not possible to use the growth rate of the plantations as an indicator of yield classification, a new tool "Skógarkolefnisreiknir" was used to define yield classes. (See: https://www.reiknivel.skogur.is). At Óseyri three yield curves that suites the species planted were available: a curve for Sitka spruce with top-height 8-11 m at age 50 years, for lodgepole pine with top height 10 m at age 50 and for birch with top height 8 m at age 50. Most commonly, dominant species on plots were birch, Russian larch, lodgepole pine and Sitka spruce. Sitka alder and mountain ash were dominant on two plots each, but goat willow and Swiss stone pine covered one subplot each. We decided to classify plots with other deciduous trees than birch together with the birch plots. The Swiss stone pine was classified with the lodgepole pine plots. In the "Skógarkolefnisreiknir" model, the East-coast of Iceland is defined as not suitable for Russian larch so choosing a growth curve for that species is not an option in the model. We decided to use yield class RL4 for the Russian larch as the max height on the plots was only 0.7 m at 10 years of age. Top height of the Russian larch in RL4 in the model is 0.9 m at age 10.

The age span of the species groups was from 4 years for Sitka spruce, up to 14 years for lodgepole pine. We decided to treat measurements for Sitka spruce, deciduous species and Russian larch together, but the lodgepole pine data was split into two age classes (see Table 3 on page 11 below).

Tree density affects the C-stock development, especially at young age. We estimated this effect by comparing the C-stock development of different initial tree densities for 50 years in a simulator called ARBOREX. The simulator was made by Professor Timo Pukkala at the University of Eastern Finland and uses growth models to do forecasts (Lárus Heiðarsson et al. 2012). The algorithm in the simulator used for the optimization is called "direct search" (Hooke et al. 1961). The relative differences between density classes were used to recalculate current annual increment of C-stock (CAI-C) in relation to age (see Figure 7 below). This was only done for species groups with density under 2000 trees per ha.

A similar method was used to estimate the loss of C-stock caused by thinnings for classes treated as forest available for wood supply. Considering rather low density and yield at Óseyri, we decided to let the ARBOREX simulator execute only one thinning over the rotation. Rotation length and strength and timing of thinnings was optimized using the simulator by maximizing the net present monetary value (NPV) of the cutting activity and rotation length with 3% interest. At the end of the rotation, reforestation with planting of same species was assumed.

We assumed that the stems of trees harvested in thinnings and final fellings will be used in production that leads to instant oxidation. We used the ratio between the stem C-stock and total C-stock at the age of thinning and final felling found in the ARBOREX output. Other components, branches, foliage, rootstock, and roots where assumed to decay with 30 years half-life which gives an annual decay factor of 0.023. 30 years half-life was referenced from a new article on the decay of deadwood and snags in Switzerland at different climate conditions (Hararuk et al. 2020). In this work the average annual temperature was set to 4.5°C, which was the last ten years average measured at the nearest weather station, Kollaleira.

### Baseline prediction compared to alternative management with no cuttings

The last phase in the work was to compare the baseline prediction described above with an alternative management without cutting activity. To do so we cut out the last step in the estimation of the baseline prediction, that is the "reducing" effect of the cutting activity.

# Results

### The status of the afforested land and the afforestation

Table 2 shows how the afforestation area is divided between landtypes. There was only one landtype with tree cover registered because none of the plantations measured reached more mean height than 1.3 m.

***Table 2***. *Landtype classification of the area under inventory. (SE = standard error).*

| Units = ha | Area | % | SE ± |
|---|---|---|---|
| Treeless area (500-5000 m$^2$) | 21.4 | 12.6 | 7.8 |
| Small rivers (< 4 m wide) | 2.2 | 1.3 | 2.7 |
| Vehicle tracks (< 4 m wide) | 1.5 | 0.9 | 2.2 |
| Small clearings (< 500 m$^2$) | 22.0 | 12.9 | 7.9 |
| Plantations (< 1.3 m height) | 123.2 | 72.4 | 10.6 |
| **Total area** | **170.3** | | |

Figure 4 shows the vegetation classification for all plots. Plots with plantations are shown separately. Dominant vegetation classes were moss heath and dwarf shrub heath that are generally infertile and *Vaccinium* heath which has medium fertility and can be classified with the two grassland classes. 60% of the moss heath had soil depth under 25 cm but 23% and 26% of the dwarf shrub heath and the *Vaccinium* heath respectively had soil depth under 25 cm. Soil depth in other vegetation classes was more than 25 cm.

To describe the status of the plantations, average and max height was calculated for each plot. In Figures 5 and 6, average height and max height is plotted against planting age. Trendlines show mean development over time. The equation for trendline and its $R^2$ are shown in the graphs.

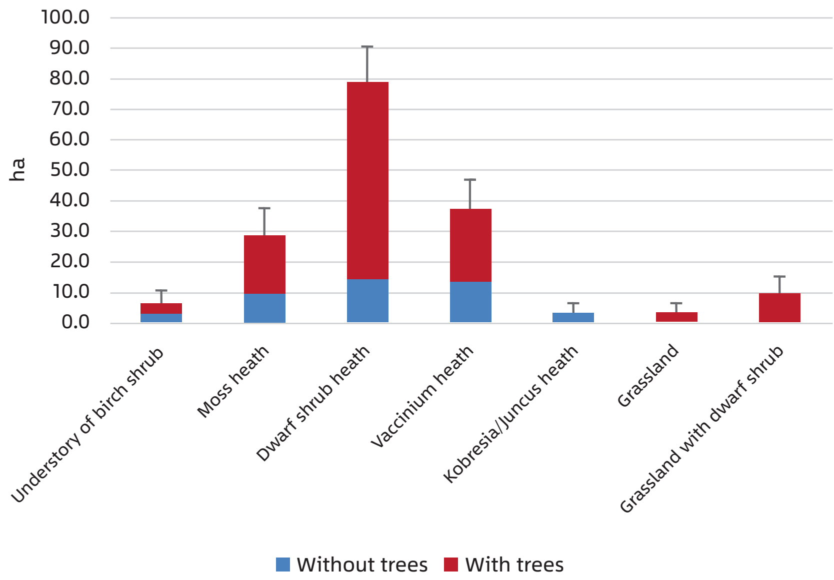


***Figure 4**. Vegetation classification on the inventoried area in Óseyri. Error bars are SE.*

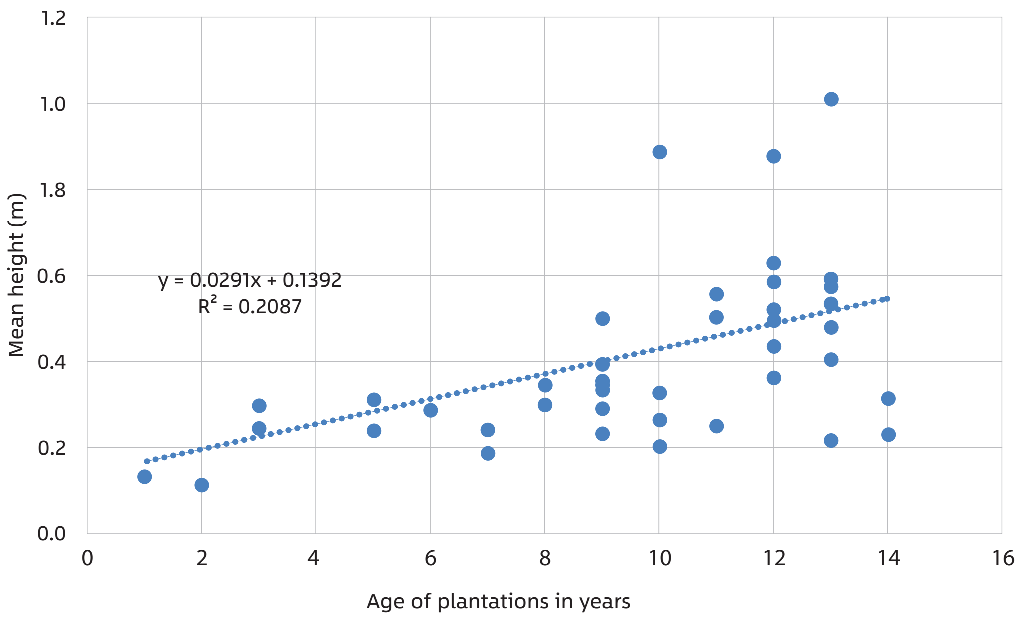


***Figure 5**. Mean height and plantation age of trees on measurement plots at Óseyri.*

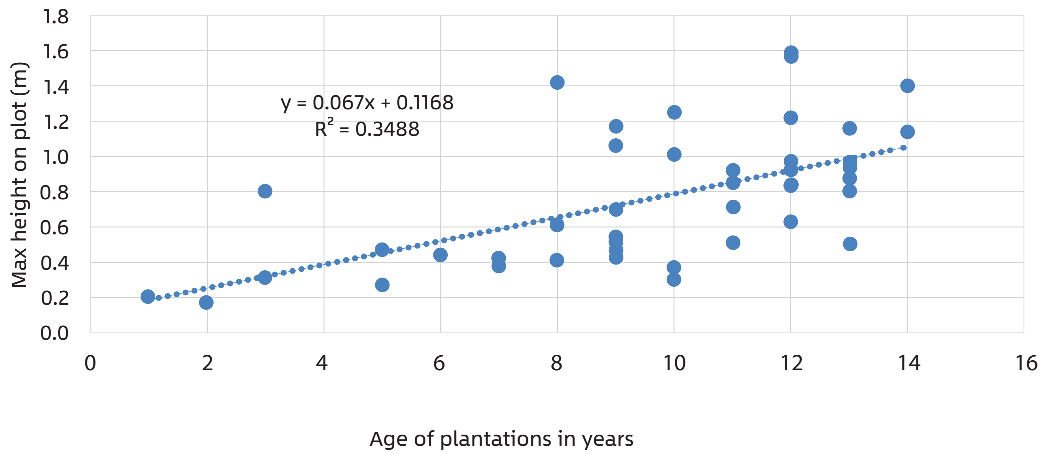


***Figure 6**. Max height and plantation age of trees on measurement plots at Óseyri.*

Mean annual growth was small or 3 cm per year for mean height and 7 cm per year for max height.

The tree density per plot varied considerably with an average of 2147 trees per ha, median density 2100 trees per ha and minimum and maximum density 200 and 6840 trees per ha, respectively. Considering area weight, the mean density was estimated at 2031 trees per ha and the number of living trees 250,000.

All together eight tree species were measured on the plots. All the species listed in Table 1 were measured except black cottonwood but instead a Swiss stone pine (*Pinus cembra*) was measured on one subplot.

Only three trees were assessed as being very healthy. The majority of the trees were classified as moderately healthy (81%), 17% were classified rather weak and 2% very weak. The majority of the trees (65%) were damaged, and the most common damage was old (not recent) top dieback (75%). Old top dieback is a severe dieback, older than from the current or last growth period, commonly causing multi-stem development. The second most common damage was top browsing (38%). In total, 94% of trees had some form of top damage. Top damage supresses the height development of the trees.

## Current annual C-stock change of the plantations

Not unexpectedly, the estimation of current C-stock and C-stock change of planted trees showed small figures. As trees with stump diameter below 7 mm were excluded from the biomass calculations, some of the plots (the most recently planted) were without C-stock calculation and in others, a number of trees were excluded due to small size. To get more complete C-stock calculation, the plantation has to grow into more measurable sizes of trees. C-stock per ha was estimated to be 66 kg C (SE: ±14) and the C-stock change per ha and year 23 kg C (SE: ±6). Summed for all plots and upscaled for the area of plantations the C-stock and C-stock change in trees was estimated 6.98 t C (SE: ±1.52) and 2.46 t C (SE: ±0.61) respectively. Figure 7 shows the development of C-stock in trees with increasing age of the plantations.

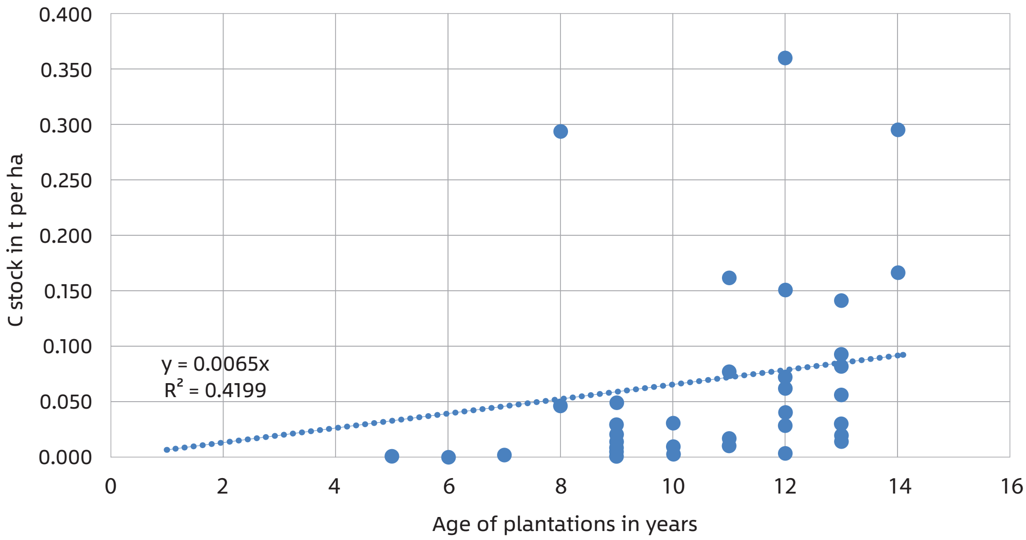


***Figure 7****. C-stock and plantation age of trees on measurement plots at Óseyri.*

Annual C-stock changes in litter and soil was estimated for the plantation area at 63.58 t C. Together, the estimated annual C-stock change in the year 2020 was 66.04 t C where the C-stock change in tree was only 4% of the total.

## Baseline prediction of C-stock changes of afforested areas

The treatment classes used are shown in Table 3 with age, density and C-stock change in litter and soil weighted by area. In the table the area and the defined yield are also shown.

As can be seen in Table 3, the C-stock change (CsC) factor of the classes was slightly different, which was caused by differences in the assessment of the initial vegetation coverage, where plots assessed with sparse vegetation coverage pre-afforestation affected the factors slightly differently from one class to another.

***Table 3***. *Treatment classification of the plantations.*

| Treatment classes | Mean age | Area ha | Density no/ha | Yield Class | Litter and soil CsC t/ha |
|---|---|---|---|---|---|
| Sitka spruce | 12 | 13.7 | 1521 | SG8-11 | 0.515 |
| Lodgepole pine old | 11 | 17.8 | 2567 | SF10 | 0.506 |
| Lodgepole pine young | 4 | 15.0 | 2276 | SF10 | 0.538 |
| Russian larch | 9 | 30.5 | 1631 | RL4 | 0.511 |
| Decidous species | 10 | 46.2 | 2161 | IB8 | 0.516 |

We decided that the density for the lodgepole pine classes and the deciduous class was satisfactory as density turned out to be more than 2000 trees per ha, and no reduction of the current annual increment curve was applied. The Sitka spruce and the Russian larch classes were evaluated with too low density to yield CSC at same level as the growth curves. Comparison between the C-stock development of Sitka spruce with 1521 and 2500 trees per ha was calculated in the ARBOREX simulator and the relative differences are shown in Figure 8 together with a fitted equation used to calculate reduction each year from year 12 (in 2021) to year 78 (in 2086). The same procedure was followed for Russian larch.

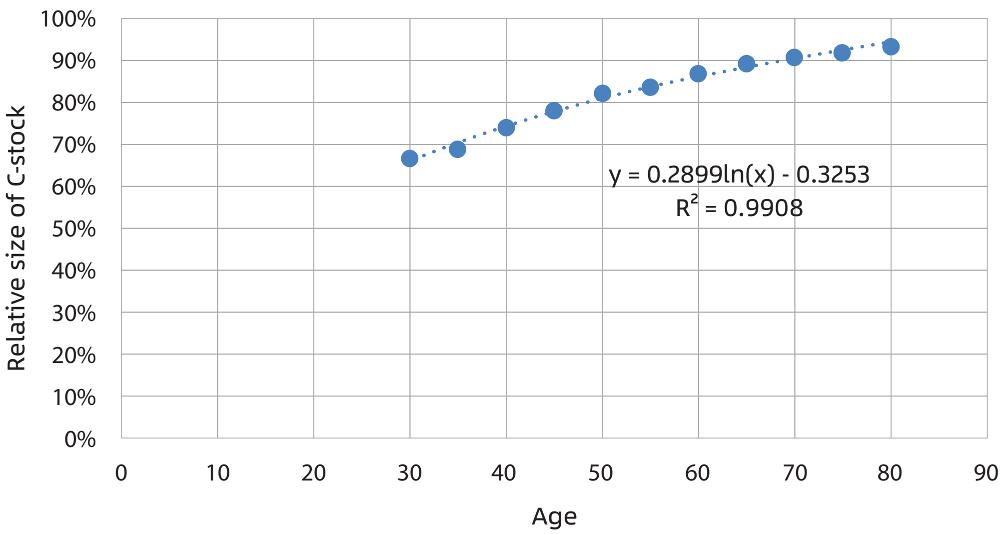


***Figure 8***. *Development of the relative size of the C-stock with age for Sitka spruce with 1521 trees per ha compared to 2500 trees per ha. The fitted equation for the relationship is also shown.*

Assessment of forest not available of wood supply (FNAWS) was applied in the field and followed the dominance of species. All deciduous dominant plots were considered FNAWS but all plots with coniferous dominance were considered as available for wood supply.

Comparison of managed (with cutting activity) and unmanaged forest showed very little differences in C-stock development before final cut. The relative difference of the C-stock between managed and unmanaged Sitka spruce is shown in Figure 9. The Sitka spruce was modelled to have light thinning at age 60.

For Sitka spruce, the impact on the current annual increment showed a relatively large emission in year 60 (year of thinning) and more annual growth than unmanaged forest in the years after age 60. No final cut occurred for Sitka spruce as the economical best fit of final cut was beyond the prediction period or at age 91 years. For the other three species classes

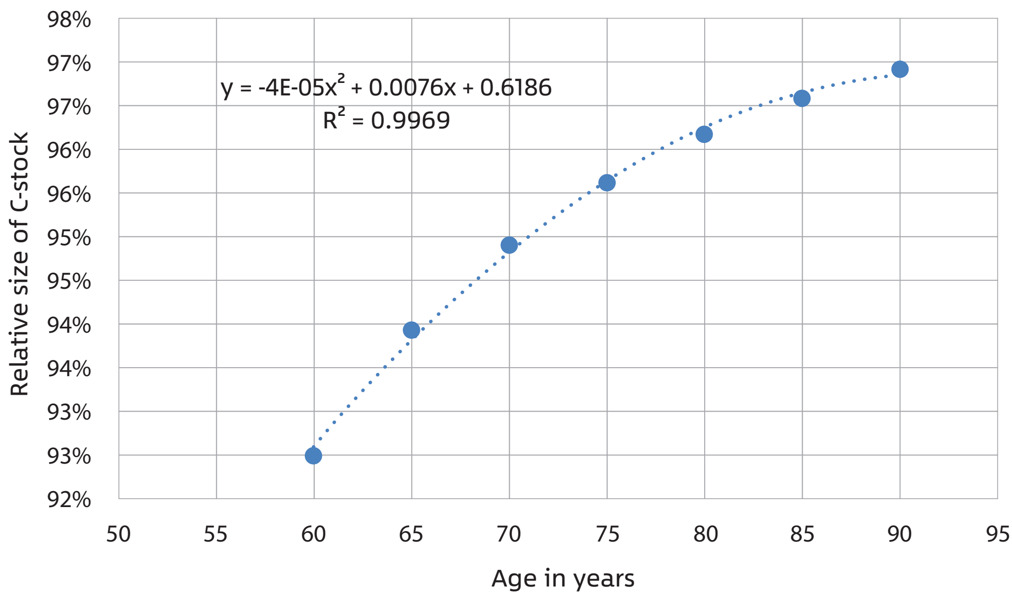


***Figure 9***. *Development of the relative size of C-stock with age for Sitka spruce thinned compared to no thinning. The fitted equation for the relationship is also shown.*

of conifers, the final cut occurred and had large impact in all cases and the thinnings a moderate effect (Figure 10).

Prediction of the total net $CO_2$ fluxes of the forest ecosystem is shown in Figure 10 for the period 2021-2090.

## Baseline prediction compared to alternative management with no cuttings

An illustrative comparison of the baseline prediction with cutting management of forest available for wood supply and an alternative prediction without any cutting management is shown in Figure 10. The

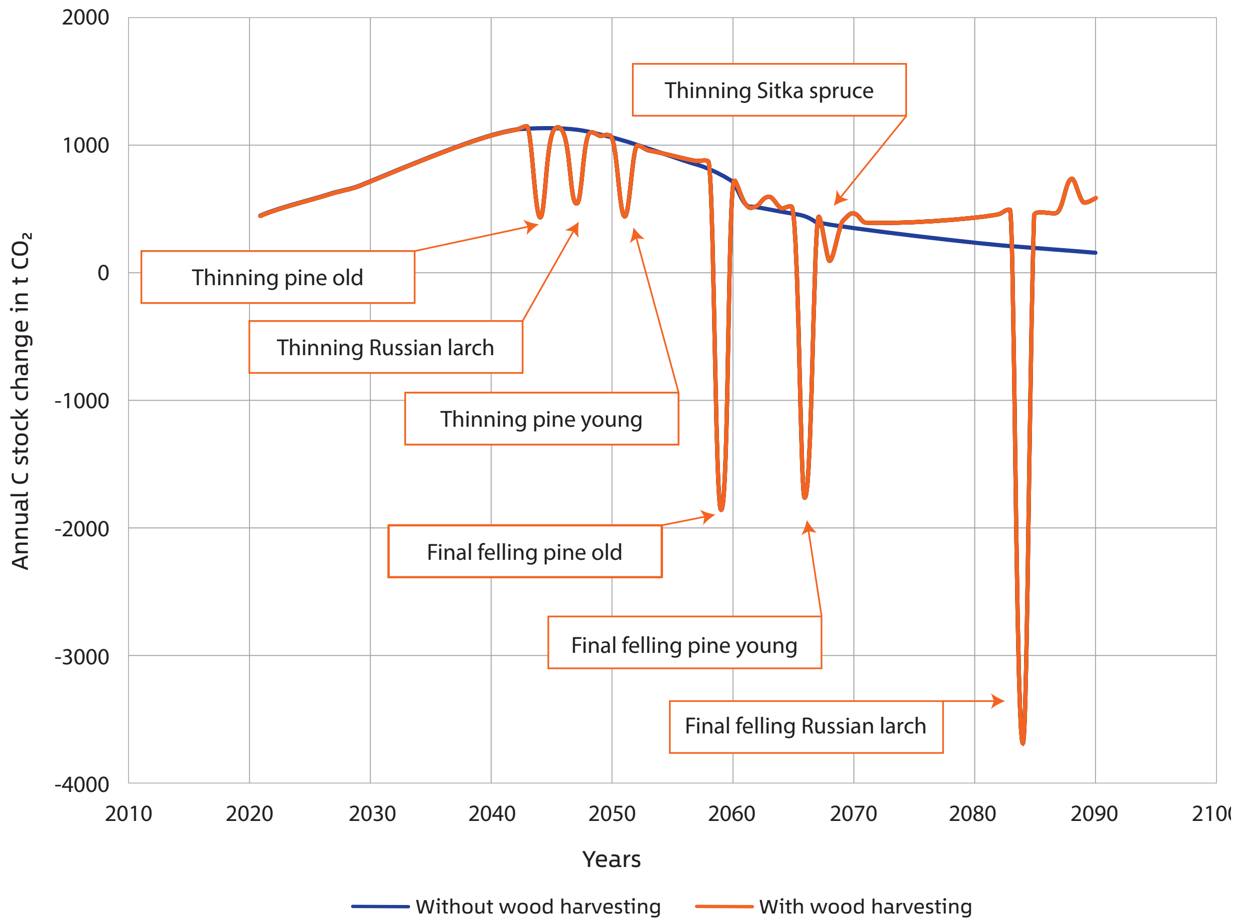


***Figure 10***. *Total net $CO_2$ fluxes at Óseyri for baseline prediction with wood harvesting of forest available for wood supply and for alternative prediction without wood harvesting. Positive values indicate net $CO_2$ sequestration. Negative values indicate $CO_2$ net release into the atmosphere (emission).*

differences between the two predictions do not always show beneficial results when choosing the no cutting management. After thinning, the diameter growth of the remaining trees increases because they have more space than before thinning. This is even more clear after final cutting as the pioneer tree species, such as Russian larch and lodgepole pine, grow much faster in the early years of their rotation compared to the growth at post rotation age. The difference between the two predictions is shown in Figure 11. Table A in Appendix I shows numeric values for each class and year and the difference between the two predictions.

At the end of the 70 year period, total carbon sequestration in the business as usual (baseline with thinning, felling and replanting) scenario was 38,219 tons $CO_2$-e, while the total sequestration under the alternative (no thinning, felling or replanting) scenario was 44,715 tons $CO_2$-e. In other words, the baseline scenario yielded 6,497 tons less $CO_2$-e sequestration than the scenario with no forest management.

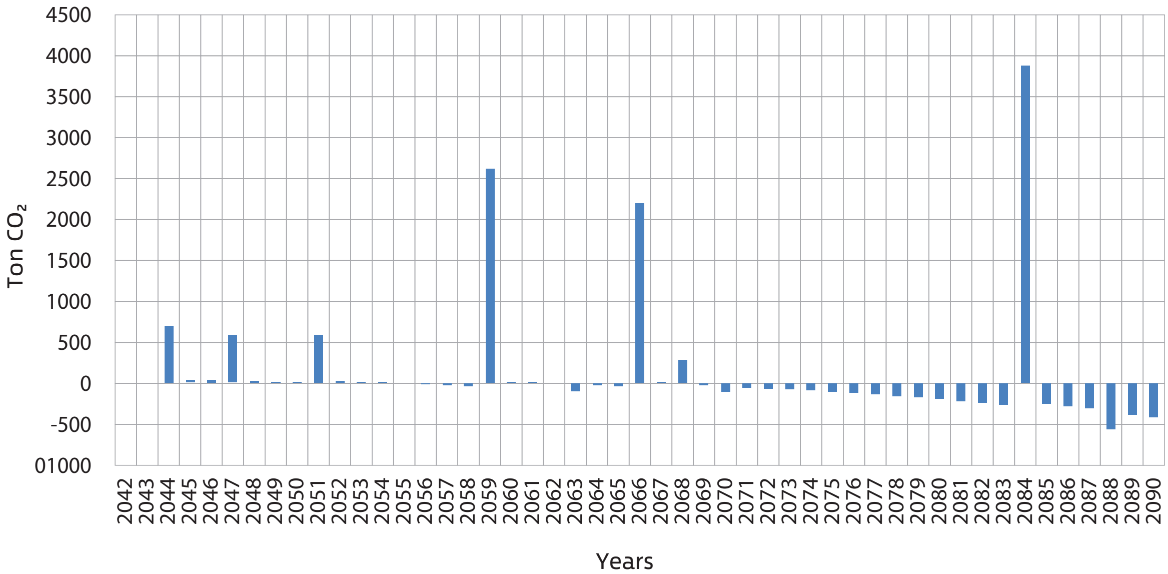


***Figure 11***. *The difference between alternative prediction without wood harvesting and baseline prediction with wood harvesting of forest available for wood supply. Positive values are $CO_2$ emissions avoided with alternative scenario. Negative values are reduction of $CO_2$ removal to forest with alternative scenario.*

# Discussion

## The status of the afforestation

Comparison of the planned and reported plantation in Óseyri shows that the afforestation project is still ongoing as only about 66% of planned number of seedlings has been planted. Species composition in the management plan has mostly been followed but planting of poplars, spruce, birch, and alder have not been finished. Accordingly, the gross area with plantations did not cover the entire planned forest land. The gross area planted was 170.3 ha (Table 2), or 89% of total planned area (191.6 ha). It should be noted that a small part of the afforested area is located outside the planned afforestation as can be seen on the map in Figure 2. The net area of plantations was estimated to be 123.2 ha, or 64% of the total planned area (Table 2). In the long run the net area will increase with bigger size of trees growing into small treeless clearings and narrow tracks and rivers. Despite that, the clearings can be defined as afforestation areas that are still not planted and will be afforested in the future. Notice that the ratio of the number of planted seedlings and plantation area of the total are very alike, or 66% and 64% respectively, which indicate that density recommendations of the plan have been generally followed.

Both species composition and vegetation classification on sample plots did not show the whole spectrum of planted tree species or mapped vegetation, which is a usual and expected situation when working with sample inventories.

Nevertheless, the consistency between mapped and sampled vegetation was rather convincing. The very low stature birch (*B. pubescens*) was most likely mistaken for *Betula nana heath* (25%) at the basic mapping before the planning as in the plots no *Betula nana* heath was found but instead *Vaccinium* heath (see Figure 4) which is often the understory of natural birch shrubland.

It was rather obvious when plotting mean height, max height and C-stock against age (Figures 5, 6 and 7) that most of the plantations measured were still in growth stagnation. Very common damage of top dieback supports that conclusion. Having such a high frequency of top browsing damage was surprising, as afforestation areas at the juvenile stage are supposed to be protected against grazing of domestic animals. Under "normal" conditions, the old plantation should have similar top height and C-stock in trees as given in the curves in the "Skógarkolefnisreiknir" model. Such a stagnation or time lagging of growth is on the other hand not uncommon, but it makes the fitting of growth curves difficult.

Average tree density was satisfactory. Comparison of estimated number of trees and reported number of planted seedlings indicated a survival rate (68%) similar as found in special survival inventories on North and East Iceland (70% and 73%) (Reynisson 2007, Þórsson 2008). Nevertheless, we decided to reduce the C-stock development of Sitka spruce and Russian larch because of low density (see Table 3 and Figure 8). The other classes defined were considered to have sufficient density.

## Growth predictions

The main challenge in our work was the choice of growth curves to use for the plantations at Óseyri. Because of young age of part of the plantations and the stagnation in growth of the rest, we were not able to directly choose growth curves by measurement statistics on plots. To be able to do so real tree growth has to start, and that will most likely happen after 5 to 10 years.

Another challenge was to decide whether the plantations will grow into forest available for wood supply or not. This was especially difficult in the case of Russian larch which tends to be having more and more growth problems with increasing winter temperature caused by ongoing climate change. Today, Russian larch is generally not recommended at the fjord area in East-Iceland, which was not the case 10-15 years ago. We decided to define the Russian larch as available for wood supply which is a highly debatable decision.

Uncertainty is a key word in the estimation and calculation introduced in this paper. We calculated standard error (SE) for the estimation of area classes showing a coefficient of variation of 36% for classes around 20 ha (see Table 2). Note that the classes used in prediction were from 14 to 46 ha in size. We did not try to calculate variation intervals to the predictions. It must be highlighted that both the models used are in the first stage of development and has to be used carefully if they are not to produce erroneous results. The growth stagnation of the plantations really adds to this uncertainty as previously described.

This paper should be handled as the first attempt to predict C-stock changes of different management schemes in afforestation.


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# Appendix 1

***Table A***. *Total net $CO_2$ fluxes at Óseyri for alternative prediction without wood harvesting and baseline prediction with wood harvesting of forest available for wood supply and the differences between the two scenarios.*

| Year | A Alternative prediction | B Baseline prediction | A - B Difference | Year | A Alternative prediction | B Baseline prediction | A - B Difference |
|---|---|---|---|---|---|---|---|
| 2021 | 461 | 461 | 0 | 2056 | 885 | 902 | -18 |
| 2022 | 493 | 493 | 0 | 2057 | 855 | 881 | -26 |
| 2023 | 516 | 516 | 0 | 2058 | 826 | 860 | -33 |
| 2024 | 541 | 541 | 0 | 2059 | 774 | -1851 | 2625 |
| 2025 | 568 | 568 | 0 | 2060 | 716 | 700 | 16 |
| 2026 | 596 | 596 | 0 | 2061 | 548 | 541 | 7 |
| 2027 | 627 | 627 | 0 | 2062 | 526 | 526 | 0 |
| 2028 | 659 | 659 | 0 | 2063 | 505 | 607 | -102 |
| 2029 | 693 | 693 | 0 | 2064 | 486 | 514 | -28 |
| 2030 | 728 | 728 | 0 | 2065 | 468 | 503 | -35 |
| 2031 | 764 | 764 | 0 | 2066 | 450 | -1751 | 2201 |
| 2032 | 802 | 802 | 0 | 2067 | 404 | 401 | 4 |
| 2033 | 840 | 840 | 0 | 2068 | 389 | 102 | 287 |
| 2034 | 878 | 878 | 0 | 2069 | 374 | 396 | -23 |
| 2035 | 916 | 916 | 0 | 2070 | 359 | 472 | -113 |
| 2036 | 954 | 954 | 0 | 2071 | 345 | 401 | -56 |
| 2037 | 991 | 991 | 0 | 2072 | 332 | 400 | -68 |
| 2038 | 1025 | 1025 | 0 | 2073 | 319 | 400 | -81 |
| 2039 | 1057 | 1057 | 0 | 2074 | 307 | 401 | -94 |
| 2040 | 1085 | 1085 | 0 | 2075 | 295 | 403 | -109 |
| 2041 | 1108 | 1108 | 0 | 2076 | 283 | 407 | -124 |
| 2042 | 1126 | 1126 | 0 | 2077 | 272 | 413 | -140 |
| 2043 | 1138 | 1138 | 0 | 2078 | 262 | 420 | -158 |
| 2044 | 1144 | 446 | 698 | 2079 | 252 | 429 | -177 |
| 2045 | 1144 | 1105 | 39 | 2080 | 242 | 440 | -198 |
| 2046 | 1138 | 1107 | 32 | 2081 | 232 | 452 | -220 |
| 2047 | 1128 | 546 | 581 | 2082 | 223 | 467 | -244 |
| 2048 | 1112 | 1087 | 25 | 2083 | 215 | 483 | -269 |
| 2049 | 1092 | 1076 | 16 | 2084 | 206 | -3677 | 3883 |
| 2050 | 1068 | 1061 | 7 | 2085 | 198 | 453 | -255 |
| 2051 | 1040 | 453 | 587 | 2086 | 191 | 473 | -283 |
| 2052 | 1011 | 986 | 25 | 2087 | 183 | 493 | -310 |
| 2053 | 979 | 966 | 13 | 2088 | 176 | 741 | -565 |
| 2054 | 947 | 945 | 2 | 2089 | 170 | 565 | -396 |
| 2055 | 916 | 924 | -8 | 2090 | 163 | 584 | -421 |

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