# Spatial distribution of forests and woodlands in Iceland in accordance with the CORINE land cover classification

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## ABSTRACT

This paper presents a united geographical database for all known forest and woodland areas in Iceland, both natural and planted. This first edition of the database follows forest and woodland classifications used in the European CORINE land cover program. According to the database, the total area of forests and woodlands in Iceland was estimated as being 156,800 ha, divided into natural downy birch (*Betula pubescens*) woodland (115,400 ha) and forest plantations (41,400 ha). The natural birch forests were estimated at 23,600 ha and shrubland (<2 m) 91,800 ha. The area of plantation forests was estimated to be 11,300 ha and afforested areas which had not yet reached a height of two meters as 30,100 ha. Accordingly forests and woodlands in Iceland cover 1.5% of the total land surface and 3.6% of the land below 400 m. It was also estimated that 4,000 ha of the forest plantations overlap the natural birch woodlands, amounting to 3.5% of the total natural birch coverage. This is an estimate of the area where natural birch woodlands have been replaced with forest plantations. The database overestimated the area of forest plantations, which indicates that the original mapping of new plantations should be improved.

**Keywords:** afforestation, forest plantation, geographical database, GIS, natural birch woodlands, plantation forests

## YFIRLIT

*Útbreiðsla ræktaðs skóglendis og náttúrulegs birkilendis á Íslandi samkvæmt skilgreiningum CORINE landgreiningaverkefnisins*

Á Rannsóknastöð Skógræktar ríkisins á Mógilsá hefur verið unnið að gerð landfræðilegs gagnagrunns sem inniheldur upplýsingar um skóglendi landsins, bæði birkilendi og ræktað skóglendi. Flokkun skóga í gagnagrunninum fylgir flokkun skóga í Evrópska CORINE landgreiningarverkefninu. Samkvæmt gagnagrunninum var heildarflatarmál skóglendis á Íslandi áætlað 156.800 ha, þar af var náttúrulegur birkiskógur og kjarr 115.400 ha og ræktað skóglendi 41.400 ha. Náttúrulegir birkiskógar og kjarr skiptust í 23.600 ha af skógi og 91.800 ha af kjarri. Heildarflatarmál ræktaðra skóga var áætlað 11.300 ha en gróðursetningar sem samkvæmt þessu mati höfðu ekki náð 2 m meðalhæð þöktu um þrefalt stærra svæði eða 30.100 ha. Hlutfall skóglendis af yfirborði landsins var 1,5% og 3,6% af landi neðan 400 m hæðar yfir sjávarmáli. Staðfræðilegur saman-

burður á þekju ræktaðra skóga og birkilenda leiddi í ljós að 4.000 ha sköruðust sem er 3,5% af heildarþekju birkilendis á Íslandi. Þetta er mat á hve víðtæk gróðursetning hefur verið í birkilendum. Ljóst er að stærð skógræktarsvæða er ofmetin í grunninum og bæta þarf til muna kortlagningu nýrra gróðursetninga.

## INTRODUCTION

### *Short history of forests and woodlands in Iceland*

Before the settlement in the late 9th century the Icelandic lowlands were dominated by downy birch (*Betula pubescens* Ehrh.) woodlands (Sigurðsson 1977), which is in accordance with the classification of Iceland as a part of the northern boreal zone (Tuhkanen 1993). At that time the birch woodland cover was estimated to be 28,000 km$^2$ or about 27% of the total land area (Sigurðsson 1977). After settlement severe deforestation took place due to human impact, mainly owing to land clearing for agriculture, grazing, cutting for cooking and house heating. Severe soil erosion followed, which was magnified by colder climate and natural catastrophes such as volcanic eruptions. Birch was used for heating houses until 1940, when the birch coverage was probably at its minimum (Ministry for the Environment 2007). In the late 20th century the area of birch woodlands was estimated to cover only 1.2% of the total land area (Snorrason et al. 2007).

Experiments with planting forests of exotic tree species started in Iceland in 1899 (Blöndal 1977). The area of forest plantations, both exotic and native species, increased slowly throughout the 20th century, with a sudden expansion in the 1950s and again in the 1990s (Pétursson 1999). Most of these forest plantations were located in deforested areas but in some cases the tree planting took place within the natural birch woodlands.

Until the 1990s, most of the tree planting in Iceland was on public land managed by the Iceland Forest Service or forestry associations (NGOs) (Blöndal & Gunnarsson 1999). Since 1990, afforestation of privately owned land has been encouraged by the government and plantations have expanded on private lands. Regional forestry projects have been established which provide grants to farmers and other landowners to plant trees on their land. The role of the Iceland Forest Service in expanding forest area has greatly diminished and in the last few years most of the annual forest plantings have been managed by regional forestry projects (Gunnarsson 2003, 2004, 2005, 2006, Pétursson 1999, 2000, 2001, 2002).

### *Former inventories of forests and woodlands*

The natural birch woodland was surveyed on a national level twice in the last century. In the former survey, carried out in 1972-1975, all woodlands were mapped on aerial photographs and divided into homogeneous units or polygons. For each unit a set of variables was collected, e.g. mean height and crown cover (Sigurðsson & Bjarnason 1977). Further analysis of the data and the first map of the natural birch woodlands were published in 1986 (Ministry of Agriculture 1986).

The latter survey was carried out in 1987-1991 and was a more in-depth field inventory of sampled transects (Aradóttir et al. 2001). A new inventory of the area was not completed, but the area data from the first inventory were partially improved with new data from vegetation maps and field mapping. A map of the woodlands was digitised and projected in an official geographical co-ordinate system for Iceland known as ISNET93 and published as part of a vegetation map of Iceland (Guðjónsson & Gíslason 1998). Further modification of the data sampled in the survey and rectification of the digital map was carried out in 2006 and a GIS database for the natural birch woodland was constructed, with most of the data sampled in the survey linked to the polygons in the digital map (Snorrason et al. 2007).

Statistics are available on the number of planted tree seedlings and the approximate location of plantations in Iceland (Pétursson 1999). These data have been used to estimate the area of plantations (Snorrason & Kjartans-

son 2004). On the other hand, information about the area and exact location of plantation sites varies in quality (Sigurdsson & Snorrason 2000).

A project called the Iceland Forest Inventory (IFI) was launched in 2001 at the Icelandic Forest Research. The main goal of the IFI is to sample data in order to make qualified estimates of the carbon stocks of forest areas in Iceland (Snorrason 2005). Other goals of the project are similar to the goals of national forest inventories in other countries. A priority task of IFI was initially to compile a geographical database covering the area, geographic location and contours of all plantation areas in Iceland. Both geographical and tabular data were aggregated from the different actors concerning forest plantations in Iceland. Part of the data was sampled directly by mapping and reporting in the field by IFI personnel. After the IFI started data sampling in the field in 2005 the database has been used as a sampling population for measurement plots. Although they served well as a sampling population, tabular data in the database were in many cases not standardized, or were badly defined or missing.

The field inventory is based on a grid-point system, 500x1000 m for the plantations and 1000x1500 m for the natural birch woodlands. The grid points are numbered 1-5 for each year in the 5 year cycle of field measurement. Grid points that intersect with the polygons of the forest database mark the location of plots to be measured. However, field visits revealed that some of the intersected grid points were located in nonforested areas, an indication of inaccurate mapping.

*United geographical forest and woodland database*

The aim of the work presented in this paper was to build a unified and standardized geographical database of both natural and cultivated forests and woodlands in Iceland.

This initiative was triggered by a request from the National Land Survey of Iceland (NLSI), which asked the IFI to prepare a geographical database for forests and woodlands to use in the integrated land-use database NLSI was making for the European Environment Agency as an input in the European CORINE Land Cover database (Bossard et al. 2000). The CORINE land cover program's main mission is to monitor and map changes in land use in Europe. Data for land use changes have to be sent to the European Environment Agency every five years.

The classification presented in the database mainly conforms to the classes of the CORINE land cover program.

## MATERIALS AND METHODS

*The CORINE land use classification*

Forests and woodlands are classified as class 3 out of five level I classes in the CORINE land use database (Heymann et al. 1994). Class 3 is subdivided into three level II classes and twelve level III classes, as shown in Figure 1. A tree-covered area is defined as class "3.1. Forests" if trees reach a minimum height of 5 m. Exemptions from this rule have been granted if country conditions and traditions in defining forested areas are special. In the case of Iceland it was decided to change the minimum height to 2 m and this was done with the full acceptance of the CORINE project leaders.

Only five of the twelve level III classes of classifying forest and woodland areas were used. These classes are marked with frames in

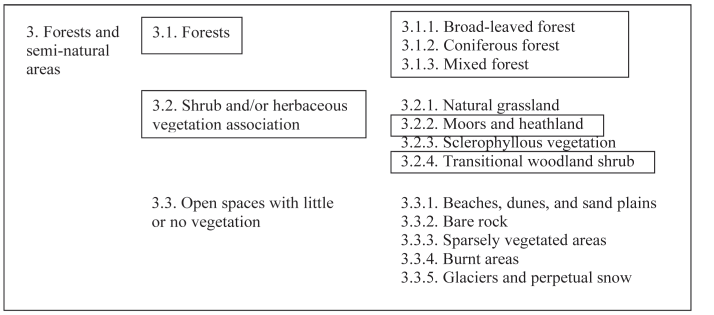


**Figure 1.** CORINE classifications of the main land use class of forests and semi-natural areas. Classes used for forests and woodlands in Iceland are marked with frames.

**Table 1.** Linkage between CORINE classification and country classification.

| CORINE classes | | Country classes | |
|---|---|---|---|
| **Number** | **Name** | **Name** | **Height** |
| 3.1.1 | Broad-leaved forests (more than 75% broadleaves) | Natural birch woodlands | ≥ 2 m |
| | | Broad leaved plantation forests | ≥ 2 m |
| 3.1.2 | Coniferous forests (more than 75% conifers). | Coniferous plantation forests | ≥ 2 m |
| 3.1.3 | Mixed forests (a mix of broad-leaved and coniferous trees.). | Mixed plantation forests or mixture of plantation and birch woodlands forests | ≥ 2 m |
| 3.2.2 | Moors and heathland | Natural birch woodlands | < 2 m |
| 3.2.4 | Transitional woodlands shrub | Young forest plantations | < 2 m |

Figure 1. The interpretation of the linkage between these five CORINE classes and the country classification is shown in Table 1. To make this classification possible it was necessary to add a new variable, height, to the database to be able to distinguish between natural birch forests (≥ 2 m) and natural birch shrubland (< 2m). Tree height and length measured in the second birch survey were used to define height classes for polygons or to divide polygons according to height classes.

*Sources*

The spatial database is based on two main sources, polygons of natural birch and polygons of afforested areas in Iceland. The polygons of afforested areas have been constructed of data originating from many sources. These sources were:

- Regional forestry projects (forest plantations with government funding on private land)
- The Icelandic Forestry Association, which samples data from the local and regional

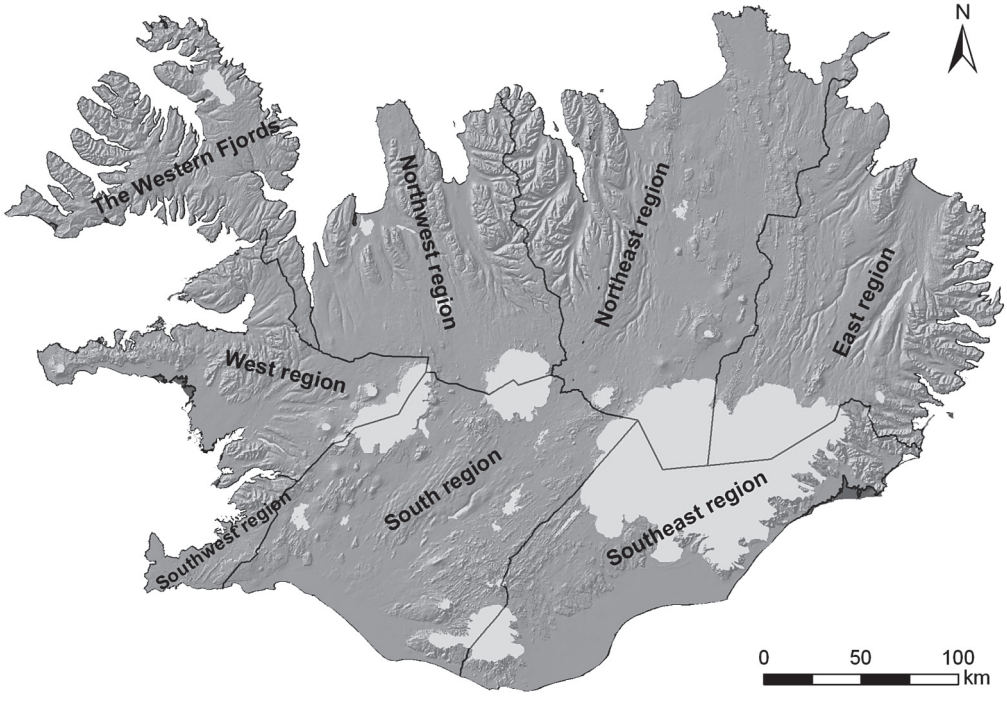


**Figure 2.** The 8 regional divisions of Iceland.

forestry associations throughout Iceland
- The IFI forestry database
- The Iceland Forest Service
- Municipalities
- Private forest owners

The main sources for young plantations were the regional forestry projects, which map all their plantations in the GIS database. In the IFI field visits, forests that are not already in the database are mapped visually in the GIS system. The Iceland Forest Service is responsible for national forests in Iceland. Many of them have been mapped and are already integrated into the IFI database.

*Analysis*

Iceland was divided into eight regions (Figure 2) following administrative boundaries. The Southwest region is smallest in terms of land area but contains the capital Reykjavik and its suburbs where 2/3 of Iceland's inhabitants live.

The area of all forests and shrublands in Iceland was calculated, based on area values in the attribute table of the database. The area was calculated for a) natural birch forests equal to or taller than 2 m, b) natural birch shrublands lower than 2 m, c) planted forests equal to or taller than 2 m, and d) forest plantations with a mean tree height lower than 2 m. Wooded area, i.e. all forests and woodlands, was calculated as a percentage of Iceland's total surface area and the area below the 400 m contour line. The reason for using the 400 m contour line as a criterion was linked to a goal which was set in a law about regional forestry projects to increase the area of cultivated forests to cover at least 5% of the lowland of Iceland which was defined as all land under 400 m a.s.l. (Alþingi 1999, 2006).

The two layers of polygons for natural birch and plantations rarely overlapped. The small are of overlap indicates plantations that have been established in birch woodlands. The overlap was analysed by calculating the area of afforested areas in birch woodlands by using the intersection function in GIS.

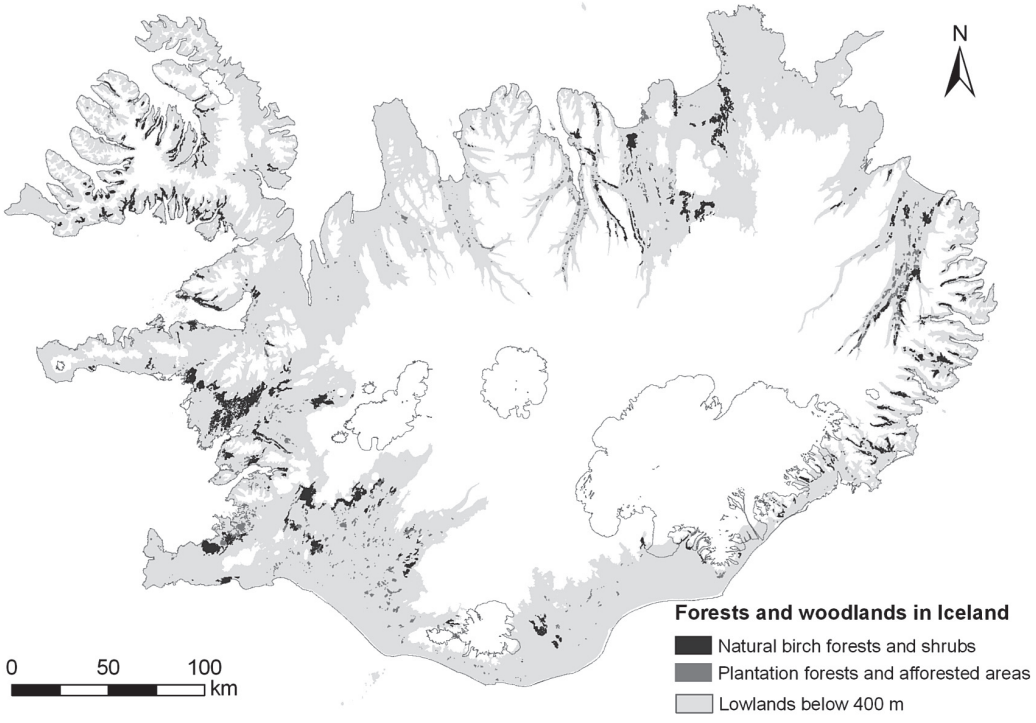


**Figure 3.** Distribution of forests and woodlands in Iceland.

**Table 2.** Area of wooded land in Iceland according to the CORINE classes.

| Number | Name | Size, ha | Ratio, % |
|---|---|---|---|
| 3.1.1 | Broad-leaved forests | 24,200 | 15 |
| 3.1.2 | Coniferous forests | 2,400 | 2 |
| 3.1.3 | Mixed forests | 8,300 | 5 |
| 3.2.2 | Moors and heathland | 91,800 | 59 |
| 3.2.4 | Transitional woodlands shrub | 30,100 | 19 |
| | Total (ha) | 156,800 | 100 |

**Table 3.** Area of wooded land according to mean tree height.

| Forest type | Size, ha | Ratio of total area, % | Ratio below 400 m, % |
|---|---|---|---|
| **Natural birch** | **115,400** | **1.1** | **2.6** |
| Forests > 2m | 23,600 | 0.2 | 0.5 |
| Shrubs < 2m | 91,800 | 0.9 | 2.1 |
| **Plantations** | **41,400** | **0.4** | **1.0** |
| Forests ≥ 2m | 11,300 | 0.1 | 0.3 |
| Broad leaved forests | 600 | 0.0 | 0.0 |
| Coniferous forests | 2,400 | 0.0 | 0.1 |
| Mixed forests | 8,300 | 0.1 | 0.2 |
| Plantations< 2m | 30,100 | 0.3 | 0.7 |
| **Total forested area in Iceland** | **156,800** | **1.5** | **3.6** |

## RESULTS

The total area of wooded land in Iceland came to 156,800 ha (Table 2). According to the CORINE land cover classification (Figure 3) natural shrubs and young plantations were the dominant classes. Wooded land covered 1.5% of the total area of Iceland and 3.6% of the lowlands below 400 m. Natural birch woodland covered 115,400 ha or 1% of the total area and 2.7% of lowlands below 400 m (Table 3). Natural birch shrubs accounted for approximately 60% of all wooded land in Iceland and 80% of all natural birch woodland. Plantations covered 41,400 ha, of which planted forests covered 11,300 ha. Young forest plantations constituted 20% of all wooded land and 70% of all plantations in Iceland.

*Area by regions*

The western region had the largest area of wooded land (Table 4) with 85% of natural birch woodlands, with natural birch woodland covering 93% of the forested area in the West Fjords region. In these regions natural shrublands were dominant (Table 5). In the eastern and southern regions approximately 60% were natural birch and 40% plantations. In the southwest region the proportion was the same but the area was smaller than in the other two regions.

The northwest region did have the smallest area of wooded land with 7% as nat-ural birch and 93% plantation areas. It was the only region where the area of plantations exceeded the area of natural birch woodland.

The area of plantations were largest in the southern and eastern regions (Table 5). The area of forest plantations ≥ 2m was largest in the southern region; however the area of young plantations were largest in the eastern region and slightly smaller in the south. The West Fjords and the southeast region had the lowest

**Table 4.** Area of forested land by land regions.

| Land regions | Area, ha | Ratio, % | Natural birch, % | Forest plantations, % |
|---|---|---|---|---|
| West region | 31,400 | 20 | 85 | 15 |
| West Fjords | 21,000 | 13 | 93 | 7 |
| Northwest region | 2,700 | 2 | 7 | 93 |
| Northeast region | 27,100 | 17 | 76 | 24 |
| East region | 27,100 | 17 | 65 | 35 |
| Southeast region | 9,600 | 6 | 83 | 17 |
| South region | 26,200 | 17 | 61 | 39 |
| Southwest region | 11,600 | 7 | 60 | 40 |
| Total | 156,800 | 100 | | |

**Table 5.** Area of natural birch woodlands and forest plantations by regions.

| Natural birch Land regions | Forests ≥2m, ha | Shrubs <2m, ha | Total area, ha |
|---|---|---|---|
| West region | 4,000 | 22,800 | 26,800 |
| West Fjords | 900 | 18,600 | 19,500 |
| Northwest region | 100 | 100 | 200 |
| Northeast region | 12,800 | 7,900 | 20,700 |
| East region | 4,000 | 13,400 | 17,400 |
| Southeast region | 700 | 7,200 | 7,900 |
| South region | 1,000 | 15,000 | 16,000 |
| Southwest region | 0 | 6,900 | 6,900 |
| **Total natural birch** | 23,600 | 91,800 | 115,400 |
| **Forest plantations Land regions** | **Forests ≥2m, ha** | **Plantations < 2m, ha** | **Total area, ha** |
| West region | 1,900 | 2,800 | 4,700 |
| West Fjords | 200 | 1,400 | 1,600 |
| Northwest region | 400 | 2,100 | 2,500 |
| Northeast region | 1,700 | 4,700 | 6,400 |
| East region | 1,200 | 8,500 | 9,700 |
| Southeast region | 400 | 1,300 | 1,700 |
| South region | 3,600 | 6,600 | 10,200 |
| Southwest region | 1.900 | 2,700 | 4,600 |
| **Total forest plantations** | 11,300 | 30,100 | 41,400 |

plantation areas. The area of birch forests was largest in the northeastern region.

*Forest plantations in natural birch woodlands*

Plantations in natural birch woodlands were estimated to cover 4,000 ha, of which 1,500 ha were in birch forests and 2,500 ha in birch shrublands (Table 6). Most of the plantations in birch woodlands occurred in the southern region, or 1,300 ha. Forest plantations equal to or taller than 2 m were dominant in the natural birch woodlands and covered 3,200 ha.

## DISCUSSION

The database contains information on the size and status of forest plantations and natural birch woodlands in Ice-

**Table 6.** Plantations in natural birch woodlands according to forest plantation overlap.

| Land regions | Plantations in birch forests, ha | Plantations in shrubs, ha | Total plantations in birch, ha | Ratio, % |
|---|---|---|---|---|
| West region | 500 | 300 | 800 | 20 |
| West Fjords | 0 | 100 | 100 | 3 |
| Northwest region | 0 | 0 | 0 | 0 |
| Northeast region | 300 | 100 | 400 | 10 |
| East region | 550 | 200 | 750 | 19 |
| Southeast region | 0 | 100 | 100 | 3 |
| South region | 150 | 1,200 | 1,350 | 34 |
| Southwest region | 0 | 500 | 500 | 13 |
| Total plantation | 1,500 | 2,500 | 4,000 | 100 |
| | **Planted forests ≥ 2m in birch, ha** | **Plantations < 2m in birch, ha** | **Total plantations in birch, ha** | **Ratio, %** |
| West region | 700 | 100 | 800 | 20 |
| West Fjords | 50 | 50 | 100 | 3 |
| Northwest region | 0 | 0 | 0 | 0 |
| Northeast region | 300 | 100 | 400 | 10 |
| East region | 450 | 300 | 750 | 19 |
| Southeast region | 100 | 0 | 100 | 3 |
| South region | 1,300 | 50 | 1,350 | 34 |
| Southwest region | 300 | 200 | 500 | 13 |
| Total plantations | 3,200 | 800 | 4,000 | 100 |

land. It includes data on afforestation which are important for the carbon reporting required by the Kyoto protocol, where the carbon budget of all afforested areas from 1990 have to be reported.

In the 1950s, when planting exotic tree species was initiated, birch woodlands were often used as a shelter for the young plantations. Since 1990 planting of exotics in these woodlands has decreased due to criticism of using birch woodlands as plantation sites (Sigurdsson & Snorrason 2000). Improved knowledge and experience on the use of appropriate tree species in non-forested land played a major role in these changes. The findings in the present project were in accordance with these historical trends.

The size of afforested areas in the database was overestimated. By comparing the area that was mapped as plantation and the grid points studied in the field data sampled in the IFI project, it was found that over 25% of the grid points that overlapped the plantation coverage turned out to be in non-forested areas. The reason is that some of the polygons added to the database and identified by regional forest projects as fully stocked were in reality only partly covered with trees. One possible explanation may be that the polygons which are the management units in the afforestation plans of the regional forestry projects are marked as planted at the initiation of planting instead of at the completion of planting of the whole area of each polygon. The approach used to map afforested areas is therefore too generalized and this fault must be taken into consideration in improving the mapping.

It is also clear that the map of natural birch woodlands in the database is rather coarse and must be improved in the nearest future. A new survey of natural birch woodlands is needed with the focus on the spatial distribution of the birch and new natural regeneration.

In integration the different surveys, attention must be paid to whether the parameters measured has changed over time. In this case the time gap from the birch survey and the plantation survey was 18 years and probably some of the natural birch woodlands changed between height classes. It is not possible with the data available to estimate these changes but when the newly begun sample inventory has been completed correction of this bias will be possible.

Although the classifications and different classes are thoroughly described in the CORINE technical report (Bossard et al. 2000) it was not obvious how to classify the different forest types. It was rather obvious that only five out of twelve level III classes were suitable for forests and woodland areas in Iceland. On the other hand definitions of what should be included or excluded in each of these five classes were often inconsistent. We were therefore forced to rely on our own interpretations and recommend that CORINE project leaders make the class definitions more consistent in the future.

This first version of the database includes novel and important information on the spatial distribution of wooded land in Iceland. With improved mapping and more consistent definitions, the data will become more accurate in the future.

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