P-04-315

Estimation of biomass and primary production of birch

Birch biotopes in Forsmark and Oskarshamn

Vanja Alling, Petter Andersson,
Georg Fridriksson, Charlotta Rubio Lind

December 2004

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

ISSN 1651-4416
SKB P-04-315

Estimation of biomass and primary production of birch

Birch biotopes in Forsmark and Oskarshamn

Vanja Alling, Petter Andersson,
Georg Fridriksson, Charlotta Rubio Lind

December 2004

Abstract

The aim of the study is to estimate the biomass and net primary production (NPP) of birch in SKB's two investigation sites Forsmark and Oskarshamn. Several studies of biomass production of birch have been conducted both in Sweden and abroad, though no one with focus on all parts of young birches. The aim of the study is to estimate the biomass and yearly net primary production (NPP) of young birch (*Betula sp*) forests in Forsmark and Oskarshamn. The results from the biomass estimation were from Oskarshamn: stem biomass 497 g/m^2, living branches 240 g/m^2, dead branches 30 g/m^2, coarse roots 79 g/m^2, fine roots 11 g/m^2, leaves 308 g/m^2 and for Forsmark: stem biomass 495 g/m^2, living branches 214 g/m^2, dead branches 28 g/m^2, coarse roots 78 g/m^2, fine roots 11 g/m^2 and leaves 161 g/m^2.

What we can see when our study is compared with /Johansson, 1999/ and /Alriksson, 1998/ is that the leaf biomass in our study is in the same range of what were found in the two other studies, but stem and branches had much higher biomass values in the other two studies and differed with up to a factor of 10. This is though expected when the trees in the other studies were much older than in our study, and the mean weight of stem and branches must be much higher in old stands of trees.

In all results from biomass estimation, Oskarshamn had higher biomass per m^2. One explanation to this could be that Forsmark is situated about 300 km north of Oskarshamn, and other biomass production studies have also shown that the county Småland, where Oskarshamn is situated, has higher production than the county Uppland, where Forsmark is situated.

Total net primary production for Oskarshamn was 679 g/m^2/yr and for Forsmark 322 g/m^2/yr. This is in the range of Johanssons study, where he estimated NPP to 413 g/m^2/yr.

Contents

1 Introduction

SKB (Swedish Nuclear Fuel and Management Co) performs a siting program for deep repository of spent nuclear fuel. Main interest is spent on two sites, Oskarshamn and Forsmark. In order to predict the possible outcomes or scenarios, in the event of a leakage from nuclear waste material capsules stored deep underground, the vegetation above the storage facility plays a significant part. It is of importance to be able to quantify both the productivity of the area in terms of carbon assimilation or sequestration as well as the true biomass of the area. Both factors are critical when assessing the results/outcomes of a possible leakage.

Several studies of biomass and net primary production on birch have been conducted both in Sweden and abroad. Most of them are either made on old trees, /e.g. Alriksson et al. 1998/ or on cultivated bioenergy forests /e.g. Johansson, 1999/. Johanssons studies of birch growth in Finland show differences in production depending on latitude /Johansson, 1999/.

/Marklund, 1988/ studied the biomass of birches in Sweden without making discrimination between *B. pendula* and *B. pubescens*. By measuring birch in several places and soil quality in Sweden he could present a function for stems on and under bark, for living and dead twigs and stem bark. Marklund's rapport will serve as a basis for our study, but as he only made formulas for above-ground parts, some formula are taken from other studies. In one case, for fine rootpart, the ratio is taken from another species, *Fagus sylvatica* /DeAngelis et al. 1981/ when no such ratio was found in any birch report.

Birch species are effective in colonising due to the fact that their seed is dispersed by wind and may form seed banks /Leckie et al. 2000/. Birch can also produce ramets and there by spread laterally by the root system (in the report we use the term individuals for all birch trees). Birch is therefore common in new open areas in early succession such as clear-cut forests or in newly planted coniferous tree forests. Therefore such localities were used in the present study because of the high birch abundance.

2 Method and materials

2.1 Site description

The studies took place in Forsmark situated in Uppsala county and in Oskarshamn (Simpevarp) in Kalmar county in Sweden. The areas are characterized by extensive forestry and is predominated by conifer evergreens as Pine (*Pinus sylvestris*) and Spruce (*Picea abies*). After harvesting conifers, the harvested areas are left unattended for some years, making establishment of young birches possible. The woody species most prone to succession of harvested areas is birch (*Betula pendula* and *B. pubescens, B. pendula* dominating). For maps over the areas see Appendix Ia and Ib.

2.2 Sampling strategy

To assess the biomass of birch on previously harvested forestry areas, transects were laid out and used as representative for the whole harvested area. When being chosen, the harvested forestry areas were spread as much as possible in the two sites in order to avoid homogeneity in sampling. All these localities were birch dominated and characterized by being rather old forestry areas. All localities were chosen from a GSD-Fastighetskarta and their coordinates were noted in field using a GPS instrument.

Within each chosen locality, a transect of 30×2 m was laid out. The transects were all placed in a North-South course with the aid of a compass. Since some of the localities were quite densely regrown with birch, sticks were placed with an interval of 10 m along each transect to assist in keeping the transect straight and at the right course. Each locality was photographed facing north and then documented (see Appendix IIa and IIb).

All birch trees within each transect were counted and ten individuals in Forsmark and Oskarshamn were sampled for the assessment of biomass. The individuals subjected to sampling were chosen at an interval of 3 m lengthwise along the transect or as close to it as possible. The stems of the individuals were measured in both diameter and length. The diameter was measured at the base, at 0.5 m height and at 1.3 m height (breast height).

Out of these individuals/ramets, three sub-samples with a total height of more than 1,3 m were chosen and an approximately 0.5 cm thick section cut out of those individuals/ramets stem at 1.3 m height. The sections were used to estimate their yearly biomass increase. From these sub samples the leaf biomass were collected, dried in 60°C for 24 h and weighed.

2.3 Calculations

Using functions from already published work, the biomass and volume were calculated for stem, living and dead branches /Marklund, 1988/, coarse roots /Alexeyev et al. 1994/ and fine roots /DeAngelis et al. 1981/ and leaves separately.

2.3.1 Biomass calculations

Following formula were used to calculate biomass for single trees. For extrapolating the biomass per tree to area specific values, formula (8) was used.

Stem (kg/tree): $\ln(B) = 11.0735*d/(d+8))–3.0932$ (1)
/Marklund 1988, B1/

Living branches (kg/tree): $\ln(B) = 10.2806*d/(d+10)–3.3633$ (2)
/Marklund, 1988, B11/

Dead branches (kg/tree): $\ln(B) = 7.9266*d/(d+5)–5.9507$ (3)
/Marklund, 1988, B15/

where B is biomass and d is stem diameter at 130 cm for the tree in question.

LMR (Leaf Mass Ratio) was calculated for all trees.

LMR = Leaves DW (kg) sampled/B_{stem} for current tree (4)

Leaf biomass (kg/tree): $B = LMR*B_{stem}$ (5)

The mean LMR were used for a specific site (O1, O2 etc) or for an area (Oskarshamn or Forsmark) if the leaves had not been collected at that site. B_{stem} is the stem biomass for the tree in question. For trees that had been sampled, the actual measurement was used.

Coarse roots (kg/tree): $B = B_{stem} *0.18*0.88$ (6)

where 0.18 is RMR (root mass ratio) for *Betula sp* from /Alexeyev et al. 1994/ and 0.88 is the fraction coarse roots of the total root biomass, taken from a study by /DeAngelis et al. 1981/ in a *Fagus sylvatica* stand in southern Sweden.

Fine roots (kg/tree): $B = B_{stem} *0.18*0.12$ (7)

where 0.18 is RMR /Alexeyev et al. 1994/ and 0.12 is the fraction of the root biomass that is fine root biomass /DeAngelis et al. 1981/.

All results for biomass are also recalculated to g/m^2 in Table 3-2 from formula:

$B_{part\ of\ tree}*10^3$*number of trees in transect/transect area (8)

where 10^3 is the conversion factor for kg to g.

2.3.2 Net primary production calculations

Net primary production was calculated using yearly diameter increment and the biomass functions 1–8.

Stem growth (cm): Was estimated using the mean of five years growth (less in some very young trees) of the stem of each sampled tree.

Diameter (D) at year 0 (cm): d_0 = d–(Mean growth/locality/year*5) (9)

Biomass for each part of tree at year 0 was calculated according to formula (1), (2) and (6), but with d_0 instead of d. That generated $\mathbf{B_0}$. B_1 that represented the biomass today was calculated using d.

Stem (g/m²/year): $NPP = (B_{1stem} – B_{0stem})/years*(8)$ (10)

Living branches (g/m²/year): $NPP = (B_{1liv.branch} – B_{0\ liv\ branch})/years*(8)$ (11)

Coarse roots (g/m²/year): $NPP = (B_{1coarse\ roots} – B_{0coarse\ roots})/years*(8)$ (12)

Fine roots and leaf biomass were assumed to regenerate each year.

Total NPP_{birch} (g/m²/year): $NPP = ((B_{1total} – B_{0total})/years + (5) + (7))*(8)$ (13)

2.3.3 Coverage of other broad leaf trees in transect

Coverage of any other woody broadleaf successors within each transect was assessed by visually estimating the area covered by bushes and trees in m^2 and translating that into percentage of the transects.

3 Results

3.1 Birch biomass

The results for the biomass estimation for birch at the sites Forsmark and Oskarshamn are represented in Table 3-1 and 3-2. The mean values for biomass differ much between both localities and sites. In locality O4, the nr of trees in the transect was more than 4 times higher than the mean. This has an effect on all results for this locality and for the means from Oskarshamn in Table 3-2 and 3-3.

Table 3-1. Biomass represented as mean values per tree at each locality, median, mean and standard deviation for each site and grand mean for both sites. Standard deviation is calculated for all samples from each site.

Locality	Transect (m^2)	Nr trees in transect	Stem (g/tree)	Liv. branches (g/tree)	Dead branches (g/tree)	Coarse roots (g/tree)	Fine roots (g/tree)	Leaves (g/tree)
O1	60	33	799.3	313.4	41.3	126.6	17.3	560.6
O2	60	32	521.9	225.6	29.8	82.7	11.3	268.2
O3	60	94	964.2	365.4	48.3	152.7	22.8	565.5
O4	60	450	653.6	268.6	35.6	103.5	14.1	383.4
O5	60	98	304.5	146.6	18.3	48.2	6.6	184.7
Median		94	653.6	268.6	35.6	103.5	14.1	383.4
Mean		141	651.7	264.9	34.8	103.6	14.1	398.8
Stdv		175	636.0	211.9	29.0	101.7	13.9	406.0
F1	60	57	521.1	225.2	29.6	82.5	11.3	180.7
F2	60	45	303.9	146.0	18.2	48.1	6.6	124.2
F3	60	22	995.8	386.5	52.1	157.7	21.5	440.3
F4	60	48	978.0	368.7	48.5	154.9	21.1	339.2
F5	60	84	492.7	216.0	28.4	78.0	10.6	90.0
Median		48	521.1	225.2	29.6	82.5	11.3	180.7
Mean		51	658.3	268.5	35.4	104.3	14.2	234.9
Stdv		22	610.6	202.9	27.8	96.7	13.2	243.6
Grand mean		96	653.5	266.2	35.0	103.5	14.3	313.7

Table 3-2. Biomass represented as mean values per m² at each locality, median and mean for each site and grand mean for both sites.

Locality	Transect (m²)	Nr trees in transect	Stem (g/m²)	Liv. branches (g/m²)	Dead branches (g/m²)	Coarse roots (g/m²)	Fine roots (g/m²)	Leaves (g/m²)
O1	60	33	439.6	172.4	22.7	69.6	9.5	308.3
O2	60	32	278.4	120.3	15.9	44.1	6.0	143.0
O3	60	94	1,510.6	572.5	75.6	239.3	35.8	624.8
O4	60	450	4,902.3	2,014.8	267.2	776.5	105.9	2,991.1
O5	60	98	497.4	239.5	30.0	78.8	10.7	301.7
Median		94	497.4	239.5	30.0	78.8	10.7	308.3
Mean		141	1,525.6	623.9	82.3	241.7	33.6	873.8
F1	60	57	495.0	214.0	28.1	78.4	10.7	223.1
F2	60	45	228.0	109.5	13.7	36.1	4.9	93.1
F3	60	22	365.1	141.7	19.1	57.8	7.9	161.4
F4	60	48	782.4	294.9	38.8	123.9	16.9	187.9
F5	60	84	689.7	302.5	39.8	109.3	14.9	126.0
Median		48	495.0	214.0	28.1	78.4	10.7	161.4
Mean		51	512.1	212.5	27.9	81.1	11.1	158.3
Grand mean			1,018.9	418.2	55.1	161.4	22.3	516.1

3.2 Net primary production

The yearly net primary production in young birch forests at the sites Forsmark and Oskarshamn is presented in Table 3-3. The extreme value received from locality O4 resulted in that the median and mean differ in Oskarshamn.

Table 3-3. Net primary production represented as mean values per m² and year at each locality, median and mean values for each site and grand mean for both sites.

Locality	Transect (m²)	Nr trees in transect	Stem (g/m²/year)	Liv. branches (g/m²/year)	Coarse roots (g/m²/year)	Fine roots (g/m²/year)	Leaves (g/m²/year)	Total (g/m²/year)
O1	60	33	38.3	13.3	6.1	9.5	308.4	377.3
O2	60	32	33.2	12.5	5.3	6.0	143.0	201.7
O3	60	94	141.2	47.7	22.4	35.8	624.8	869.3
O4	60	450	504.3	182.3	79.9	105.9	2,991.1	3,773.4
O5	60	98	68.6	29.0	10.9	10.7	301.7	425.1
Median		94	68.6	29.0	10.9	10.7	308.3	425.1
Mean		141	157.1	56.9	24.9	33.6	873.8	1,129.4
F1	60	57	87.0	34.4	13.8	10.7	223.1	322.5
F2	60	45	37.9	15.7	5.9	4.9	93.1	158.9
F3	60	22	67.8	24.8	10.7	7.9	161.4	276.2
F4	60	48	145.6	51.5	23.1	16.9	187.9	515.5
F5	60	84	103.5	40.1	16.4	14.9	126.0	332.4
Median		48	87.0	34.4	13.8	10.7	161.4	322.5
Mean		51	88.2	33.3	14.0	11.1	158.3	321.1
Grand mean			122.7	45.1	19.4	22.3	641.0	725.2

3.3 Leaf Mass Ratio

Leaf Mass Ratio (LMR) was calculated from field sampling of birch leaf (Table 3-4). LMR was also used to calculate leaf biomass for trees and localities that have not been sampled, and those values are presented as leaves in Table 3-1, 3-2 and 3-3. In Table 3-4 is the actual measured leaf biomasses presented. That is why the mean values differ from those previously presented in this report.

Table 3-4. Calculations of Leaf Mass Ratio (LMR) from measured leaves dry weight. Three localities at each site have been sampled with three trees at each locality. Mean and standard deviation for each locality, site and for both sites are also calculated.

Locality	D 10 (cm)	D 50 (cm)	D 130 (cm)	Tot H. (m)	Stem (kg)	Leaves DW (g/tree) from field sampling	LMR
O1	3.2	2.8	1.6	2.99	0.29	177.9	0.62
O1	4.4	3.6	2.6	3.87	0.69	554.1	0.81
O1	3.2	2.5	1.8	3.7	0.35	229.7	0.66
Mean						320.6	0.70
Stdv						203.9	0.10
O2	4.4	3.4	2.8	4.03	0.80	378.4	0.47
O2	3.1	2.1	1.4	2.63	0.24	114.4	0.48
O2	5.4	3.8	3.4	4.09	1.23	694.5	0.56
Mean						395.7	0.51
Stdv						290.4	0.05
O5	3.8	2.8	2.3	3.35	0.54	244.6	0.45
O5	3.7	2.8	1.7	2.7	0.32	198.0	0.63
Mean						221.3	0.54
Stdv						33.0	0.12
Mean Osk						323.9	0.59
Stdv Osk						203.4	0.12
F2	3.6	4.05	2.9	5.2	0.86	150.7	0.17
F2	2.6	2.465	1.7	3.23	0.32	164.6	0.52
F2	2	2	1	3	0.16	114.0	0.73
Mean						143.1	0.48
Stdv						26.1	0.28
F3	4.2	3.50	3.0	4.00	0.93	373.8	0.40
F3	4.4	4.05	3.4	4.7	1.23	489.3	0.40
F3	4.9	4.11	3.1	5.12	1.00	300.6	0.30
Mean						387.9	0.37
Stdv						95.1	0.06
F5	2.6	2.965	1.6	4.33	0.29	80.8	0.28
F5	4.3	4.455	3.2	5.71	1.07	108.1	0.10
F5	3.3	3.575	2.5	4.65	0.63	132.9	0.21
Mean						107.2	0.20
Stdv						26.1	0.09
Mean Fors						212.7	0.35
Stdv Fors						141.8	0.19
Grand mean						265.1	0.46
Stdv						177.3	0.20

3.4 Coverage of other broad leaf trees in transect

Table 3-5. Coverage of other broad leaf trees in the transect sampled for birch. Number of birches in each transect is shown to see if any correlation or reverse correlation is present between birch cover and coverage of other broad leaf trees.

Locality	Transect (m^2)	Nr birches in transect	Coverage of other (%)
O1	60	33	12
O2	60	32	10
O3	60	94	28
O4	60	450	0
O5	60	98	0
Median		94	10
Mean		141	10
Stdv		175	11
F1	**60**	**57**	**0**
F2	60	45	0
F3	60	22	7
F4	60	48	0
F5	60	84	1
Median		48	0
Mean		51	2
Stdv		22	3
Grand mean		96	5.8

4 Discussion

4.1 Biomass

When no other study on natural growing young birch forest could be found, the results obtained from this study are hard to verify. Most usual is that the studies on broad leaf trees are either made on old trees, /e.g. Alriksson et al. 1998/ or on cultivated bioenergy forests /e.g. Johansson, 1999/. This study was made as a part of SKBs investigation of vegetation in their sites Forsmark and Oskarshamn, and the current biomass in different vegetation types are of interest. When no former study presented all formula needed for this study, calculations for different parts of trees, and biomass versus NPP were taken from different studies. In Table 4-1 some of our results are compared with two other studies, /Johansson, 1999/ and /Alriksson et al. 1998/. Johansson studied trees growing on former cultivated land in order to estimate the outcome for bioenergy and the age of the trees varied from 8 to 32 years, and growing sites spread over middle and north of Sweden. In Alrikssons study, the trees were all 27 years old, and grown in Northern Sweden. This is factors that highly influence the results of the studies. What we can see from the comparison is that the leaf biomass in our study is in the same range of what were found in the two other studies, but stem and branches differ with up to a factor of 10. This is though expected when the trees in the other studies were much older than in our study, and the mean weight of stem and branches must be much higher in old stands of trees.

In all results from biomass estimation, Oskarshamn had higher biomass per m^2. This is partly explained by the higher abundance of trees in the transects in Oskarshamn.

The variance (and standard deviation) is very high in almost all variables from the study. Sometimes is the standard deviation as big as the mean or median value. This is a natural consequence of sampling in heterogeneous environment. The trees sampled differed also much in height (range 1.45–8.23 m). The aim of the study was to estimate the biomass of all birch in this specific environment, and this was a consequence that was hard to avoid.

Table 4-1. Comparison between results from this study and two other studies of birch in Sweden. Values from Oskarshamn and Forsmark are median values, from /Johansson, 1999/ and /Alriksson et al. 1998/ they are mean values.

Data from	Stem (g/m^2)	Branches (g/m^2)	Leaves (g/m^2)	NPP ($g/m^2/yr$)
Oskarshamn	497	269	308	679
Forsmark	495	242	161	322
/Johansson, 1999/	6,328	500	312	413
/Alriksson et al. 1998/	9,600	1,500	310	

4.2 Net primary production

Johanssons result from net primary production /Johansson, 1999/, 413 $g/m^2/yr$ is in the range of what were found in the two sites of this study, 679 in Oskarshamn and 322 $g/m^2/yr$ in Forsmark (Table 4-1). The NPP was calculated from yearly increase in stem diameter, and this was, as an exception, a variable that did not differ much between different trees, locality and sites (0.177cm/yr ± 0.04 at all localities and sites). The number of trees in each locality had though high influence also on the net primary production at each locality, and the yearly production at each locality differed with as much as a factor of 10.

One explanation to this could be that Forsmark is situated about 300 km north of Oskarshamn. A biomass and NPP study from Swedish University of Agricultural Science (SLU) showed that Spruce (*Picea abies*) had a bigger annual growth in the Swedish county Småland, where Oskarshamn is situated, than in the county Uppland, where Forsmark is situated /Berggren et al. 2004/. They concluded that this is a consequence of both a longer growing season and a higher Nitrogen status in the county of Småland. If both of these two arguments are applicable on Forsmark and Oskarshamn are not known, but at least the difference in growing season is likely to be an explanation. This could be expected in maybe higher degree for broad leaf trees such as birch.

4.3 Leaf Mass Ratio

Foliage and the leaf mass ratio of young birches have not been sampled and calculated before, and because of that we want to put some extra attention to this part of our study. Young birch forests, growing on forested land are a common environment in Sweden. The mean value for dry weight of leaves in Oskarshamn was 323.9 g/m^2 (Table 3-4). When extrapolated into all localities and trees the median was 308.3 g/m^2 (Table 3-2). In Forsmark the mean from sampled trees was 212.7 g/m^2 and the extrapolated median was 161 g/m^2. These means generated LMR values that differed between Oskarshamn and Forsmark. LMR for Oskarshamn was 0.59 and for Forsmark it was 0.35. This means that the trees in Oskarshamn generally had leaf masses of 0.59 times the stem mass, and in Forsmark 0.35 times the stem mass. The value from Forsmark correspond well to /Johansson, 1999/ calculations for percentage leaf mass of total biomass for *B. pendula* with diameters at breast height less than 2.0 cm, but the leaf from Oskarshamn are a greater part of the total mass of the trees. Johansson calculated that between 15 and 20% of total dry weight should be leaf, and translating our LMR to percentages of total weight the trees from Oskarshamn has 29.8% leaves of total mass and in Forsmark is the same value 19.6%.

4.4 Coverage of other broad leaf trees in transect

The estimation of other broad leaf trees in each transect was made to see if any correlation or reverse correlation is present between birch cover and coverage of other broad leaf trees. As can be seen in Table 3-5, no such relationship is present. Maybe the estimation process was to rough, or if more transects had been tested, a relationship would have been found. This study can though not recommend that the coverage percent found here is used to any extrapolations for bigger areas.

5 References

Alexeyev V A, Birdsey R A, 1994. (Cited Gribov 1967; Pozdnyakov et al. 1969). Results In Li Z, Kurz W A, Apps M J, Beukema S J, 2003. Belowground biomass dynamics in the Carbon Budget. Model of the Canadian Forest Sector: recent improvement and implications for the estimation of NPP and NEP. Canadian Journal of Forest Research 33: 126–136.

Alriksson A, Eriksson H M, 1998. Variations in mineral nutrient and C distribution in the soil and vegetation compartments of five temperate tree species in NE Sweden. Forest Ecology and Management 108: 261–273.

Berggren D, Bergkvist B, Johansson M-B, et al. 2004. A description of LUSTRA's common field sites. Department of Forest Soils, Swedish University of Agriculture Sciences, Uppsala, Report 87.

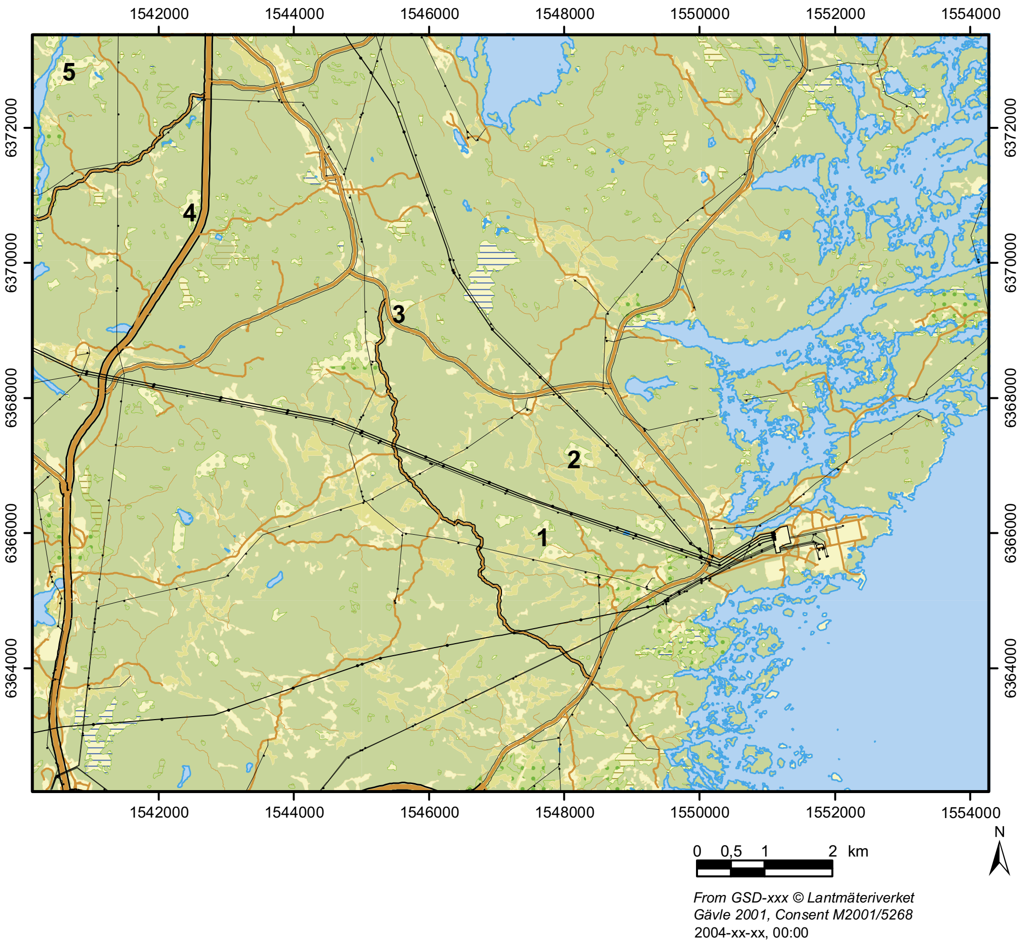
DeAngeli D L, Gardner R H, Shugart H H, 1981. Productivity of forest ecosystems studied during the IBP: The woodlands data set. Pages 567–672 *in* Dynamic properties of forest ecosystems. D.E. Reichle, editor. Cambridge University Press, New York, New York, USA.

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

Leckie S, Vellend M, Bell G, Waterway M J, Lechowicz M J, 2000. The seed bank in an old-grown temperate decidious forest. Can. J. Bot. 78: 181–192.

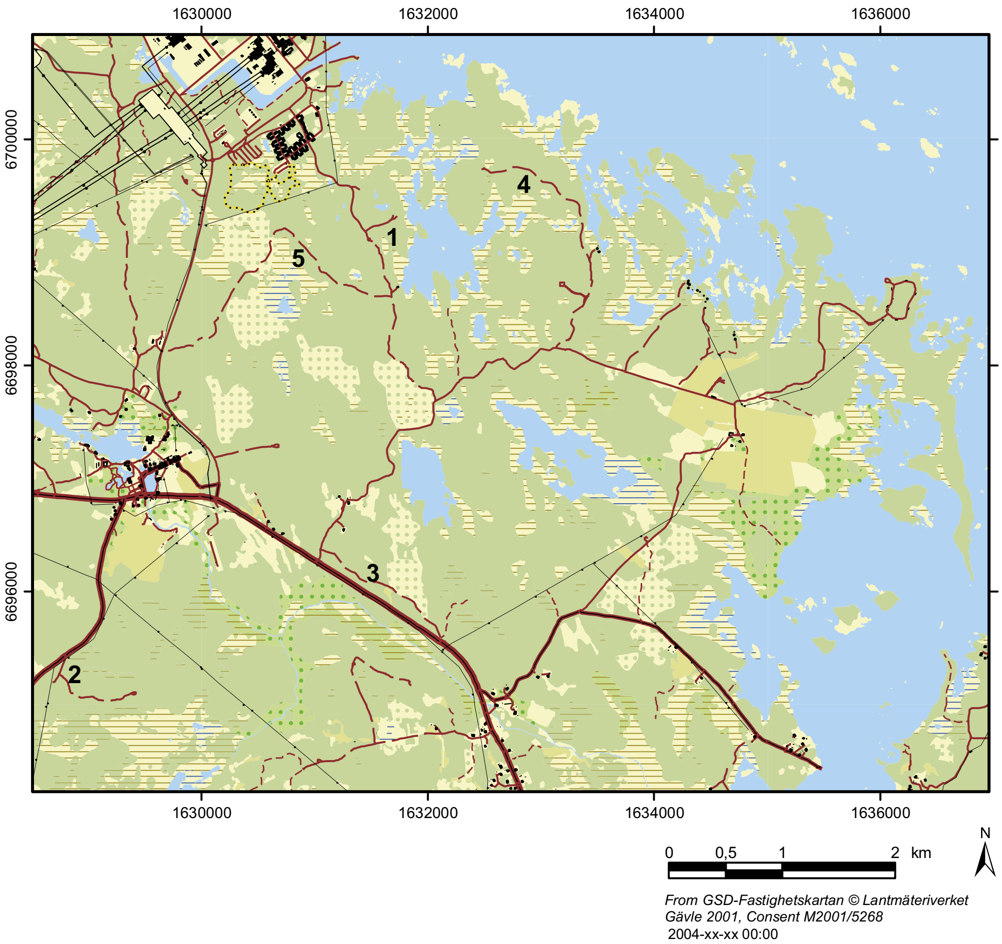
Marklund L G, 1988. Biomass functions for pine, spruce and birch in Sweden. Institutionen för skogstaxering. Rapport 45, SLU, Umeå.

The map shows the Oskarshamn area and the sampling localities (O1–O5)



Coordinates for the sampling sites:
1: 6 366 047, 1 547 668
2: 6 367 092, 1 548 157
3: 6 369 228, 1 545 633
4: 6 370 746, 1 542 384
5: 6 372 949, 1 541 168

The map shows the Forsmark area and the sampling localities (F1–F5)



Coordinates for the sampling sites (some of the coordinates have low accuracy):
1: 6 698 903, 1 630 986
2: 6 695 274, 1 628 863
3: 6 696 179, 1 631 344
4: 6 696 124, 1 631 349 (low accuracy)
5: 6 698 904, 1 630 984

Appendix IIa

Photos of the birch sites in Oskarshamn

1. 

2. 

3. 

4. 

5. 

Photos of the birch sites in Forsmark

1. 

2. 

3. 

4. 

5.