R-04-08

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ISSN 1402-3091
SKB Rapport R-04-08

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Keywords: Carbon, Forsmark, GIS, Nitrogen, pH, Soil hydrology, Soil inventory, Soil type, Texture, Uppland.

Summary

Investigations to give prerequisites for long-term storage of nuclear waste are made by the Swedish Nuclear Fuel and Waste Management Ltd (SKB AB). Ecosystem functions are crucial in this management. The range of the scope is wide including bedrock, regolith, hydrosphere and biosphere. The interface between deep geological formations and surface systems is then considered very important. This would be the top of the regolith, where soils are developed. Special attention has been paid to these layers with fairly comprehensive investigations. Field investigations were made for one of the candidate areas, the Forsmark area, in 2002 by the Department of Forest Soils, Swedish University of Agricultural Sciences.

In these ecosystem functions, the upper part of the regolith is one crucial component and the focus in the investigations was on the upper metre of the soil. Variables determined include vegetation, hydrology, soil parent material, textural composition, soil type and physical and chemical properties of relevant soil layers. Methods used in the investigation coincide with those of the Swedish Forest Soil Inventory, which provide possibilities to compare properties in the Forsmark area with those of total Sweden and regions of the country.

Soil properties were determined thoroughly on eight site types in two replicates to provide statistical significance. However, this meant that the investigation did not have a total spatial coverage. Instead, the spatial distribution of soils in the area was determined from a GIS based on the inventory made and information on vegetation types, distribution of Quaternary deposits and a hydrological index. From this GIS, distributions were compared with other parts of the country.

The geographical location of the Forsmark area (N 60°22'; E 18°13') is on the northeast coast of central Sweden bordering to the Bothnian Sea. The area is low-lying, reaching only up to 15 m above the sea, which means that the soils are young and therefore fairly undeveloped. Climate is characterised by an annual precipitation of c 700 mm, mean annual temperature of c +5°C and a semi-arid condition during the vegetation period.

Determinations on sites include a site survey over the 30 m x 30 m plots and eight soil profile investigations on each plot. Properties determined were ground vegetation, site hydrology, drainage and stoniness together with profile conditions such as horizons, parent material, texture, humus form, soil type and peat humification degree. Added to this was soil sampling from top soil layers (0–20 cm) and of the parent material on 0.6 m depth. Soil samples were analysed on pH, total C and N.

The investigation resulted in the overall impression that the Forsmark area exhibit similarities concerning land types with large parts of Sweden, with a dominating forest type and soil parent material not differing to any major extent. But, the young soils has resulted in more or less immature soil types, to a large extent being Regosols but also six other classes occurred. The considerable influence of calcareous soil material furnishes nutrient rich conditions that in these fairly summer-warm conditions provide a rich and diversified flora.

In the Forsmark area the soils are young, mainly less than 1500 years. Till soils dominate. The impacts of sea waves have redistributed the material and left coarse water washed tills in large parts with in low-lying areas sorted sediments and in higher locations thin soils and bare bedrock. Site hydrology variations on investigated plots ranged mainly over fresh to wet types while the class dry mainly occurred on local small hills, where also the bedrock outcrops existed. Sea bays have been cut off and now form inland lakes partly being in transgression to swamps and peatlands.

Typical soils for Sweden would be Podzols but these are poorly developed in the Forsmark area and only a few locations were identified. Instead immature soils such as Regosols and soils influenced by water, such as Gleysols and Histosols, occur frequently.

The fairly rich nutrient conditions together with climate and hydrology provided properties for mull and moder humus forms to develop, being more frequent as compared to most other parts of Sweden. Also the O horizon pH was in general high with values around six while Sweden on average show values between four and five. The humus layer are influenced by the underlying mineral soil and pH values there reached 6.5 on average to be compared with values around 5 for most of Sweden.

Carbon concentrations in the humus layer agree with Swedish ordinary conditions but in the mineral soil the influence of $CaCO_3$ makes the concentration higher as compared to the general values for Sweden. There exist also increasing concentrations with depth, which mainly would be attributed to the $CaCO_3$ content, and deviating from ordinary forest soil conditions.

Nitrogen concentrations in the soil agree fairly well with most parts of Sweden. However, the values are lower than the region IV and Uppsala county to which regions the Forsmark area belongs.

Sammanfattning

Undersökningar genomförs för att klargöra förutsättningar och fastställa förhållanden inför långtidslagring av utbränt kärnbränsle. Svensk Kärnbränslehantering (SKB AB) undersöker ekosystemförhållanden i de två områdena Forsmark och Oskarshamn. Särskilda platsundersökningar har stor omfattning, alltifrån det djupa berget upp till de lösa avlagringarna ovan berg samt vatten- och biosfärssystemen. Känsliga delar i hela systemet är övergången från geosfär till biosfär, där de övre marklagren och jordmånsskiktet är avgörande för de ytliga ekosystemen. Fältundersökningar av Forsmarksområdet jordar genomfördes 2002 av Institutionen för skoglig marklära, SLU.

De särskilda jordmånsundersökningar, som har genomförts omfattade vegetationsförhållanden, markhydrologi, jordartsgeologi, pedologi och inbegrep också markprovtagning för laboratorieanalyser av fysikaliska och kemiska förhållanden. Inkluderat i dessa var främst textur, skrymdensitet, pH, total C och N.

Undersökningarna följde gängse metoder för Riksinventeringen av Skogsmarkinventering. Detta medför att de egenskaper som bestämts för Forsmarksområdet kan jämföras med förhållanden i hela Sverige eller delar därav. En avvikelse från markinventeringen, som är spatiellt täckande för lite större områden, är att sådan täckning inte eftersträvades för Forsmarksområdet. Istället var avsikten att söka nå statistisk spridning för egenskaper inom utvalda enhetliga marktyper. För att kunna applicera dessa över hela Forsmarkområdet så användes GIS i en areell skattning av marktyper över området. Denna kartläggning baserades på vegetations-, jordarts- och hydrologiska digitala kartor. Från detta material kunde den spatiella utbredningen av marktyper bestämmas och jämföras med markinventeringens uppgifter.

De undersökta marktyperna fastställdes till åtta varianter och varje sådan inventerades i två upprepningar. Varje lokal utgjordes av en 30 m x 30 m yta, där ståndortegenskaper fastställdes och åtta markprofiler undersöktes avseende jordmån, jordart, textur, humusform och för torv nedbrytningsgrad. Markprover för laboratorieanalyser togs från humuslagret, de övre 0,2 m av mineraljorden och från modermaterialet på 0,6 m djup.

Det geografiska läget för Forsmarksområdet (N 60°22'; E 18°13') är vid Bottenhavskusten i NO Uppland. Området ligger strax ovan havsytenivån med högsta höjder upp till ca 15 m. Detta medför att jordarna är relativt unga och att jordmånsutvecklingen endast pågått kort tid. Klimatet karaktäriseras av ca 700 mm årsnederbörd, en årsmedeltemperatur av ca +5°C och ofta relativt torra och varma vegetationsperioder.

Undersökningarna visar i stort på relativt stora likheter mellan Forsmarksområdet och stora delar av Sverige såsom varande ett skogklätt område på tämligen vanliga jordarter. Men, de unga jordarna har endast nått ett stadium av begynnande jordmånsbildning, så jordmånen blev till stor del bestämd till Regosol men det förekom också sex andra typer. En inte obetydlig inverkan av kalciumkarbonat i marken medför tämligen

näringsrika betingelser och med ett fördelaktigt klimat har en rik och diversifierad flora utvecklats.

De unga jordarna, flerstädes mindre än 1500 år över havsnivån, utgörs av morän och moränliknande typer över stora områden. Bearbetning och omlagring genom havsvattnets försorg medför att de mer moränliknande jordarterna finns i de högre belägna delarna där också renspolade hällar förekommer frekvent. I lägre liggande lägen har jordmaterialet bearbetats mer och där förekommer också vattensorterade sediment. Innehållet av ler är relativt stort.

Under strandförskjutningen (landhöjningen) har havsvikar blivit avsnörda från havet och utgör ofta grunda sjöar i överföring till våtmarker med torvbildande miljöer, som succesivt omförs till torvmarker och myrar. I dessa låga lägen förekommer grunda torvmarker med jordmåner utvecklade till Histosoler. I närmast angränsande marker är fortfarande vattenpåverkan stor och sumpjordmåner, Gleysoler, förekommer. I strandnära delar finns också sandjordar, Arenosoler, även om Regosolerna är mer frekvent förekommande. I högre lägen påträffas den för Sverige vanligaste jordmånstypen, Podsoler, men endast på ett mindre antal platser.

Den näringsrika miljön har bidragit till humusformer främst av typerna mull till moder, som i detta område är klart vanligare än i stora delar av övriga Sverige. De bördiga förhållandena speglas också av relativt höga pH-värden, som i O-horisonten ligger nära 6 medan de i mineraljorden når ca 6,5. Dessa värden är någon pH-enhet högre än i Sverige överlag.

Kolinnehållet i humuslagret är normalt för Sverige medan innehållet i mineraljorden är högre än normalt genom den inverkan som kalciumkarbonatet ger. Detta gör också att halterna ibland ökar med djupet i marken, något som vanligen inte gäller organiskt bundet kol.

Kväveinnehållet i jordarna överensstämmer i stora drag med Sverige överlag. Men, just för region IV och Uppsala län, där ju Forsmark ligger, så är halterna klart lägre.

Content

1 Introduction

Comprehensive investigations related to management for long-term storage of nuclear waste are carried out by The Swedish Nuclear Fuel and Waste Management Ltd (SKB AB). These investigations concern ecosystem properties and functions in tentative areas of bedrock storage. In this work, the soil and site type survey is one important part. One of the candidate areas is the Forsmark area where soil and site conditions were investigated in 2002. Information of regolith properties is necessary to provide possibilities to model possible transport of leaching nuclides as well as determine impacts of the preparatory work for the storage compartment building.

The survey was made by the Department of Forest Soils, Swedish University of Agricultural Sciences in Uppsala and relates, by using mainly similar methods, to the Swedish National Survey of Forest Soils and Vegetation (from 2003 named "The Swedish Forest Soil Inventory"). This combination provides possibilities to compare the conditions in the Forsmark area with national and regional conditions. The variables included in the investigation are mainly the same as in the soil inventory.

The upper part of the soil is one of the more crucial components for ecosystem functions. Clarification of the conditions in the upper metre of the soil was the main focus in this investigation. The general approach in the work has been to classify the land into the typical soil types of the area based on spatial information on vegetation, Quaternary deposits and a topographical index of soil wetness. This work was carried out in GIS environment. Variables determined include vegetation, hydrology, soil parent material and textural composition, soil profile type and physical and chemical properties of the relevant soil layers.

The project results are reported in this written document and also presented in a GIS of a soil map of the Forsmark area. The results from the field investigation formed the basis for the soil classes suitable to characterise the Forsmark area. A further development has been to extrapolate this information and give the geographical distribution of the defined soil classes in the area.

Soil here refers to the upper part of the regolith, which is characterised by horizons with certain physical and chemical properties. The soil is developed as a result of the interaction of many different factors, such as typically influences of *soil parent material, climate, hydrology* and *organisms*, being integrated over *time*. The aim of soil classification is to define soils of similar characteristics, i.e. soil types. By mapping soil types it is possible to assign properties collected in well-described soil profiles to other locations with the same soil type. Since soils are the result of many different processes, they are a sensitive component of the ecosystem and may serve as indicators for changes induced by disturbances. In the Forsmark area, it is of interest to be able to trace any short- or long-term changes induced by the actions taken in relation to the possible long-term bedrock storage of nuclear waste material. Short-term changes may involve changes induced by e.g. a changing ground water surface, whereas the long-term changes that might occur are unknown.

2 Investigation area

The Forsmark area is located on the southwest Bothnian Sea coastline in the centre east part of Sweden (Figure 2-1). The area is c 20 km^2 and located approx. N 60°22’ and E 18°13’, southeast of the Forsmark nuclear fuel plant. The altitudes of the area ranges from coastal sea level up to c 15 m above mean sea level. The main land cover is forest on till soils, together with partly open land on wet soils, i.e. partly peatlands, and three lakes in sizes around 0.5 km^2 and c 20 smaller lakes. There is also one area of arable land, c 0.7 km^2 and in the Northeast a small esker elongates.

The climate of the region is characterised by a snow covered winter period during four months in 80% of the years, ranging approximately from first of December to beginning of April, c 125 days. Average maximum snow depth is 50 cm. The vegetation period extends over 180 days, mainly May to September. Hydrology is characterised by fairly dry summers, autumn rain with increasing runoff and a spring snowmelt period also with relatively high streamwater discharges. Annual precipitation amounts to c 700 mm and evapotranspiration reaches c 400 mm resulting in a runoff of c 300 mm. The mean annual temperature is c +5°C.

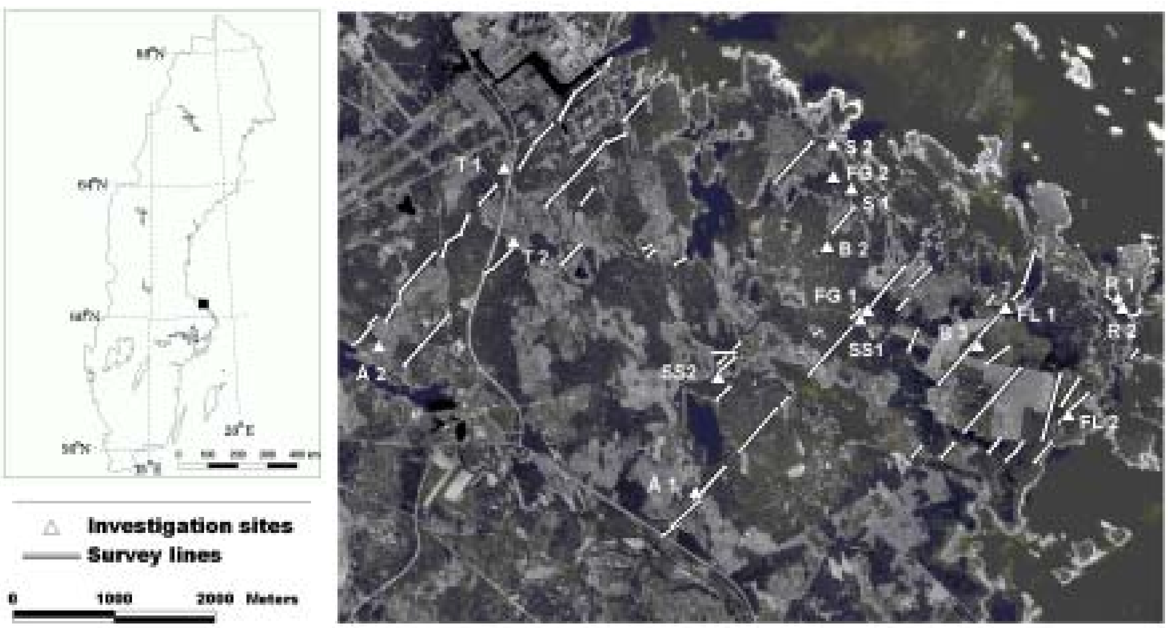


Figure 2-1. *Geographical location of the Forsmark area in the east part of South Sweden and the study area with survey lines and investigation plots.*

The soils of the Forsmark area are very young; in most of the area, the soils are less than 1500 years. The soil material is of till origin, which has been affected by the action of sea waves during the transgression of the Baltic Sea. This redistribution of soil material has left course water washed tills in large parts and in higher locations thin soils and bare bedrock. Elsewhere, in depressions the redistributed fine material has been deposited as sorted sediment soils. During the transgression, sea bays have been cut off and now forms inland lakes. Many of these lakes are slowly being turned into swamps and peatlands with shallow peat cover, which is also a characteristic feature of the area.

3 Methods

3.1 Investigation design

The investigations on site and soil conditions are linked, by mainly using similar methods, to the Swedish National Survey of Forest Soils and Vegetation (from 2003 the Swedish Forest Soil Inventory). Results from the investigated sites are extrapolated to give conditions in an spatial coverage map. This was reached by use of additional GIS project data, i.e. vegetation, Quaternary deposits and wetness conditions.

Conditions and properties of the Forsmark area was classified from the plots investigated and compared with other parts of Sweden. Four areas were used for this comparison, i.e. the total Sweden being the national scale, the Swedish National Forest Inventory region IV as region scale including the Svea- and Götaland part of Sweden excluding Scania, the West coast, Blekinge and the island Gotland. This would be the main part of Southeast Sweden /RT, 2002/. The third comparison was with the county of Uppsala and on local scale the community of Östhammar was used. However, the national inventory statistics would be weak on small areas such as most communities, i.e. in this case the community of Östhammar.

The primary interest in the soil inventory is to identify characteristic land types and for each of these determine statistically based values on a number of properties, especially chemical elements. These values would in a repeated investigation provide possibilities to detect changes over time. Another interest is the possibility to compare the Forsmark area conditions with the "Swedish Soil Inventory" national and regional conditions to show distributions of properties for the Forsmark area in comparison with all of Sweden and also a few other relevant regions.

With respect to this the initial stage of the investigation was to get an overview of the area. Two methods were used;

1) available maps were studied,
2) a site land surface survey along lines covering parts of the area was made. However, a total coverage of the survey area was too time consuming. Instead selected parts, stratified from maps, was selected to direct interest on anticipated sites.

From these preparatory stages eight site types were selected and representative plots thoroughly investigated. The plots were selected based on five criteria:

- The plots should be representative for typical sites in the area, primarily with respect to hydrology and vegetation.
- The sites should have representative soil material and humus forms.
- The plots should be homogeneous with respect to topography, soil moisture class, vegetation, humus form and soil patent material composition.
- Elevation differences inside the plot should not exceed one metre.
- There should inside the Forsmark area exist a similar site, not belonging to the same biotope, to be used as replicate.

Each of the eight types had two replicates, which makes up 16 investigated plots. On each plot, being 30*30 m, a 10*10 m grid was established and used to select the exact soil profile locations. These were selected based on a systematic approach, where the first location was intended for a deep profile, second used as a reserve and third for a profile for upper horizons (0–0.5 m) and then a reserve for this and after this the same consecutive four locations repeated. Reasons for not using pre-set locations could be trees, boulders or deviating water levels. A deep profile could be changed to an upper layer pit if there would be problems to go deeper and then the reserve or next location was chosen as next pit.

The investigations were carried out according to Activity Plan SKB AP PF 400-02-17 (SKB internal control document). The data have been incorporated in the SICADA database under field note no "Forsmark 121".

3.2 Site survey methods

At each of the plots a site description was made including type of field- and bottom layer vegetation, hydrology, subsurface water flow, drainage activities, frequency of stones and boulders and the thickness of the humus layer.

Vegetation

Vegetation types and dominating species within the list of species used in the "Forest Soil Inventory" and percentage of coverage were determined.

Vegetation types included in the bottom layer:
1 lichen type
2 lichen-moss type
3 lichen rich type
4 *sphagnum* type
5 wet moss type
6 mesic moss type

Field layer:
01 tall herbs without shrubs
02 tall herbs with shrubs/bilberry
03 tall herb type with shrubs/vitis idea
04 low herbs without shrubs
05 low herbs with shrubs/bilberry
06 low herbs with shrubs/vitis idea
07 without field layer
08 broad leaved grass
09 narrow leaved grass
10 tall sedge
11 low sedge
12 horse tail type
13 bilberry type
14 vitis idea/whortleberry , marsh rosemary type
15 crowberry/heather type
16 poor shrubs type

The species identified relates to the number of types in the “Soil and Vegetation Survey Manual” /Lundin et al, 2002/.

Site hydrology – Soil moisture class

This variable reflects the average distance from the ground surface to the groundwater table during the vegetation period. Estimations are made from geophysiographical conditions.

1 dry
2 fresh
3 fresh/moist
4 moist
5 wet

Probability of subsurface water flow

This variable mainly refers to the slope and length of this uphill from the plot studied. Estimations are made from topography and slope length.

1 Missing/rare
2 Shorter periods
3 Longer periods

Drainage

Estimations reflect effect of ditches on the plot where 20 m considers to be the largest distance of influence.

0 not drained
1 drained

Stones and boulders

Statement on possibility to perform the stoniness inventory. The special determination means pushing a 10 mm steel rod into the soil until a stone or boulder is hit with max. depth 30 cm. This was made in 36 points over the 30x30 m plot. At the same locations also the thickness of the humus layer was measured. The average stoniness depth is used in a function to estimate the volumetric content of stones and boulders in the soil.

0 measurements not possible to make
1 measurement made

Aspect

Indicates the plot facing direction.

1 north	12 northeast
2 east	14 northwest
3 south	32 southeast
4 west	34 southwest

3.3 Methods for soil inventory on profile level

Soil profile

Thickness of the genetic horizons was estimated. This refers to common designations of the horizons /Lundin et al, 2002/. Values are given as depth from the soil surface. When depth values is followed by a plus-sign (+), this means that the horizon continuous deeper then the value given.

Humus layer, deepest border
A-horizon, deepest border
AB-horizon, deepest border
E-horizon, deepest border
B-horizon, deepest border

Soil parent material in the profile

Soil material composition is determined at 20 cm depth in the mineral soil and as peat if the organic surface layer is thicker than 30 cm.

1 Well sorted sediments
2 Poorly sorted sediments
3 Till
4 Bedrock
5 Peat

Soil material texture

Textural conditions were determined in the field using common methods by working the material /Lundin et al, 2002/. Determinations were made on a sample from a depth of 20 cm in the mineral soil.

0 Boulders in the profile
1 Stone/Boulder/Bedrock
2 Gravel/Gravely till
3 Coarse sand/Sandy till
4 Sand/Sandy silty till
5 Fine sand/Silty sandy till
6 Coarse silt/Coarse silty till
7 Fine silt/Fine silty till
8 Clay/Clayish till/Gyttja
9 Peat

Also special laboratory textural determinations were made on selected samples. Analysis was made very thoroughly with pre-treatment to eliminate organic material and mitigate $CaCO_3$ influence. Organic content was removed by hydroxy peroxide treatment. To avoid flucculation from abundant Ca^{2+}-ions, Calgon (sodiumhexametaphospate and sodium carbonate) was used as dispersing agent. The suspension was agitated over-night before the hydrometer method revealed the results.

Despite the careful preparations and consecutive analysis, the importance of sampling may not be neglected. The fixed sampling depths mixed in some cases genetical horizons giving a less distinct result.

Soil type

Classification on soil types refers to the international World References Base system (WRB) /WRB, 1998/. The system used is a simplified version including the appropriate types for Sweden and with field determinations, which actually is not totally correct while a thorough classification needs chemical analysis. However, the simplified determination would reflect an almost correct classification.

1 Histosol
2 Leptosol
3 Gleysol
4 Podzol
5 Umbrisol
6 Cambisol
7 Arenosol
8 Regosol
9 Unclassified (could be caused by too much water, etc)

Additional features in the soil profile

There are a number of specific features that are of decisive interest in the soil profile and some of these have been determined. Most special for the Forsmark area is the presence of $CaCO_3$, which deviates from large parts of Sweden.

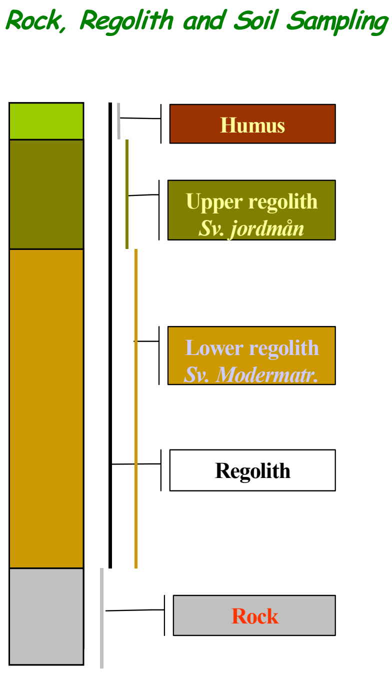
The calcium carbonate content could occur as discrete particles of calcite but also as cementing agent and in the latter case it should be removed by treatment with 2% hydro chloric acid. When calcite particles are present this treatment should be avoided and this was the case here. The calcium carbonate content has been determined by a volumetric method according to Passon /Talme and Almén, 1975/.

0 None
1 Culture influence (especially ploughing)
2 Disturbances (soil scarification, wind thrown trees, etc)
3 Spodic B horizon (determining the Podzol soil type)
4 Calcium carbonate (frequently found in Forsmark area)
514 Combination of 1 and 4
34 Combination of 3 and 4

Soil sampling

Soil was sampled from the profiles and the system was adopted both to international conditions and the traditional Swedish system to give the possibility to compare with the ongoing Swedish "Forest Soil Inventory". The horizon from which soil was sampled was recorded and the soil parent material and texture determined on the deepest sample, belonging to the C-horizon. This determination used the classes given above for soil parent material and texture in the soil parent material. Sampling of the soils was made according to the soil type with the basic sampling related to:

Humus layer was sampled separately and mineral soils mainly in three layers (Figure 3-1).
Mineral soil layers: 0–10 (H10 sample under mull and mull like moder), 10–20 and 55–65 cm.
In Podzols: 0–5 and 5–20 cm in the B-horizon and 55–65 cm.
In Histosols: 0–30 and 40–60 cm.



Sampling depths, cm

Main types	Podzols	Peat
0-30	0-30	0-30
0-10	0-5	
10-20	5-20	40-60
55-65	55-65	

Figure 3-1. *The regolih over the bedrock with soil sampling depths in three categories of soils.*

Sampling for bulk density

Volumetric mineral soil samples were taken to determine dry bulk density. Two profiles on each plot were sampled, if possible, in the depths: 0–10, 10–20, 20–30, 30–40, 40–50 and 50–60 cm. The steel cylinder size used had the height 5 cm and radius 3.6 cm.

Mineral soil material underlying peatlands

The composition of the parent material underlying peat deposits were determined according to:

1 Clay
2 Silt
3 Sand
4 Gravel
5 Stone
6 Non-sorted material
7 Boulder or bedrock

Peat humification degree

The degree of peat humification, according to the von Post scale /von Post and Granlund, 1926/ was determined in two depths in the peat, i.e. 10 cm and 50 cm. Decomposition degree:

1 Undecomposed or very weakly, von Post H1-2
2 Weakly, von Post H3-4
3 Moderately well, von Post H5-6
4 Strongly, von Post H7-8
5 Almost completely, von Post H9-10

3.4 GIS map class methods

Geographical input data

The principal method to construct the soil map was to use secondary geographical information to classify the area into soil types. The input data used for this were digital geographical information on vegetation, quaternary deposits and topography (Figure 3-2–3-6). The classes for each input data set can be found in Appendix II. The vegetation data was from a classification based on remote sensing /Boresjö et al, 2002/ and included data on the tree, field and ground layer. It was in vector format with an approximate scale of 1:50 000. Vegetation served as indicator of site conditions, which could be used to identify different soil types. The data of quaternary deposits (SGU, serie Ae) were vector data at the scale 1:50 000, and was used to outline areas where the soil classes could be derived based on soil texture and genesis, e.g. the peatland class (HI), shallow soils (LP) and the esker area (RG). In addition, topographical information was used in the form of a high-resolution digital elevation model /Holmberg, 2002/ with 10 m raster cell size. The elevation data was used to calculate a topographical index of soil moisture, which could be used to differentiate between forest soils with similar vegetation.

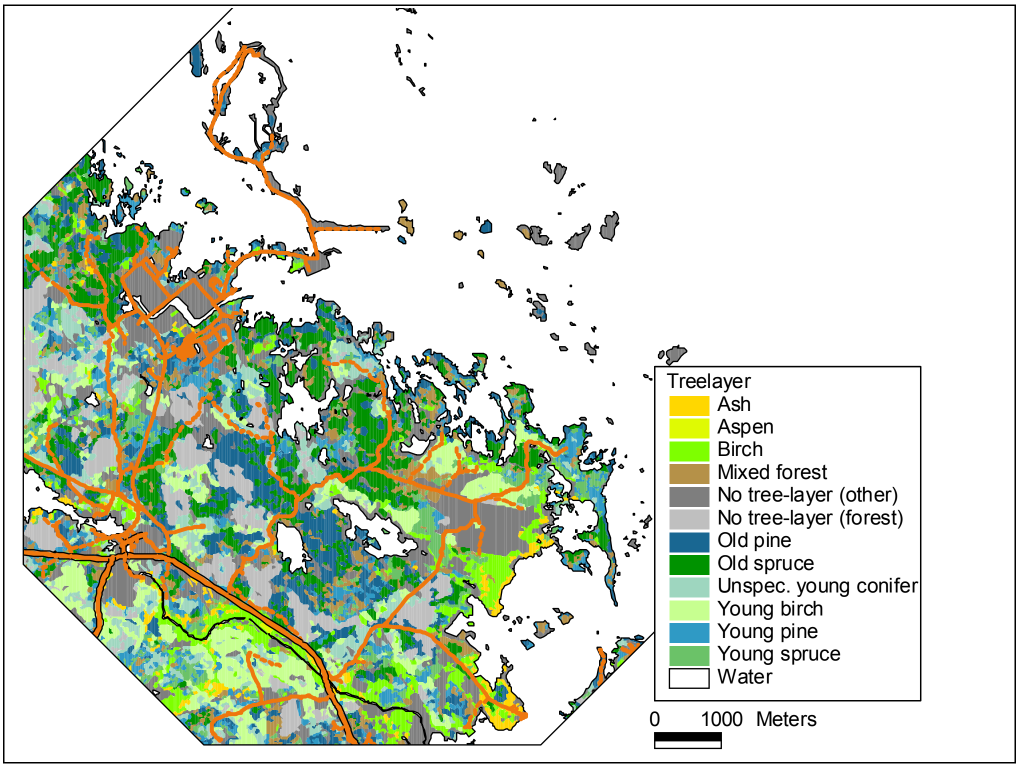


***Figure 3-2.** The tree layer vegetation map of the Forsmark area /Boresjö et al, 2002/.*

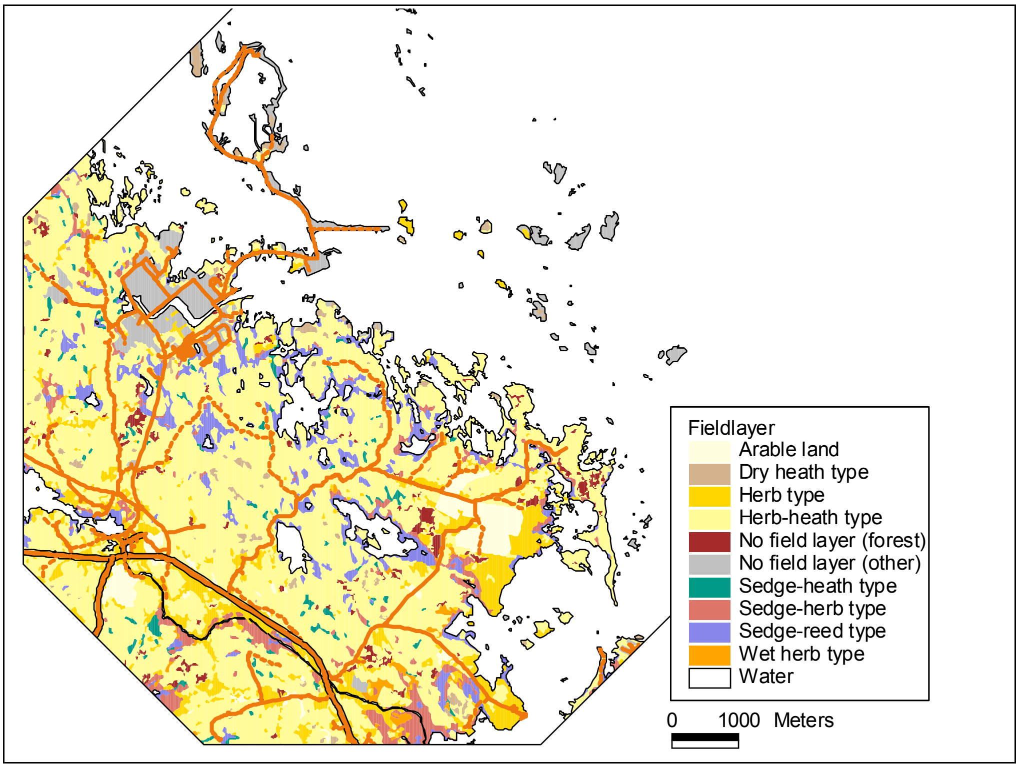


***Figure 3-3.** The field layer vegetation map of the Forsmark area /Boresjö et al, 2002/.*

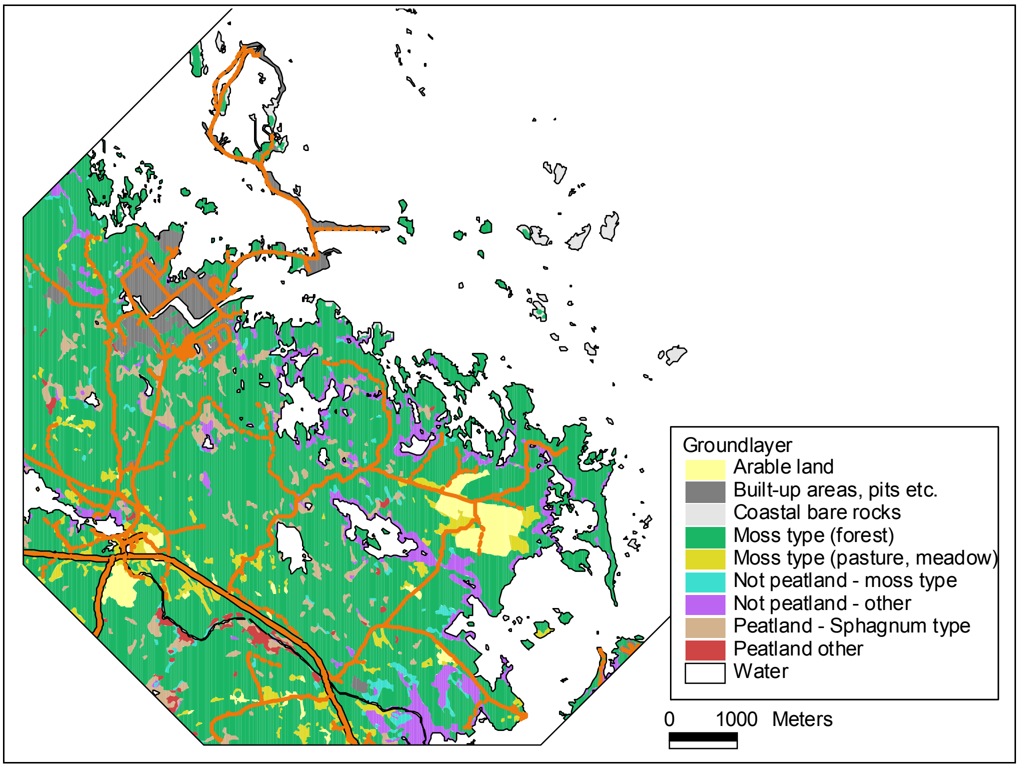


***Figure 3-4.** The ground layer vegetation map of the Forsmark area /Boresjö et al, 2002/.*

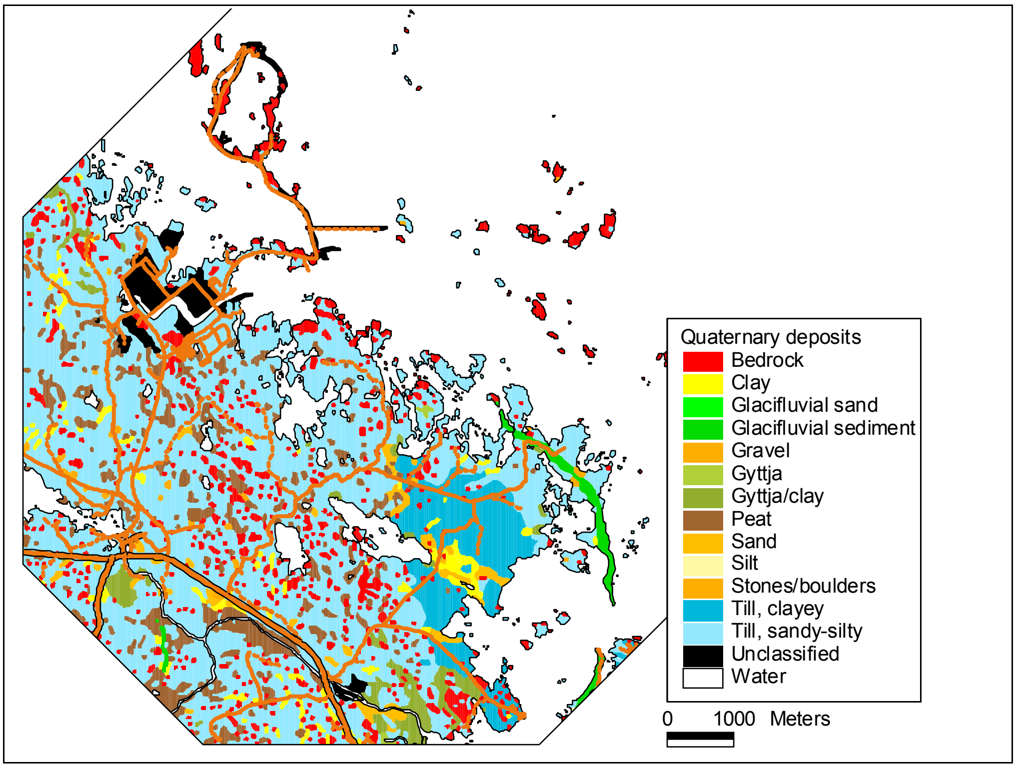


Figure 3-5. *Quaternary deposits map of the Forsmark area (SGU, serie Ae).*

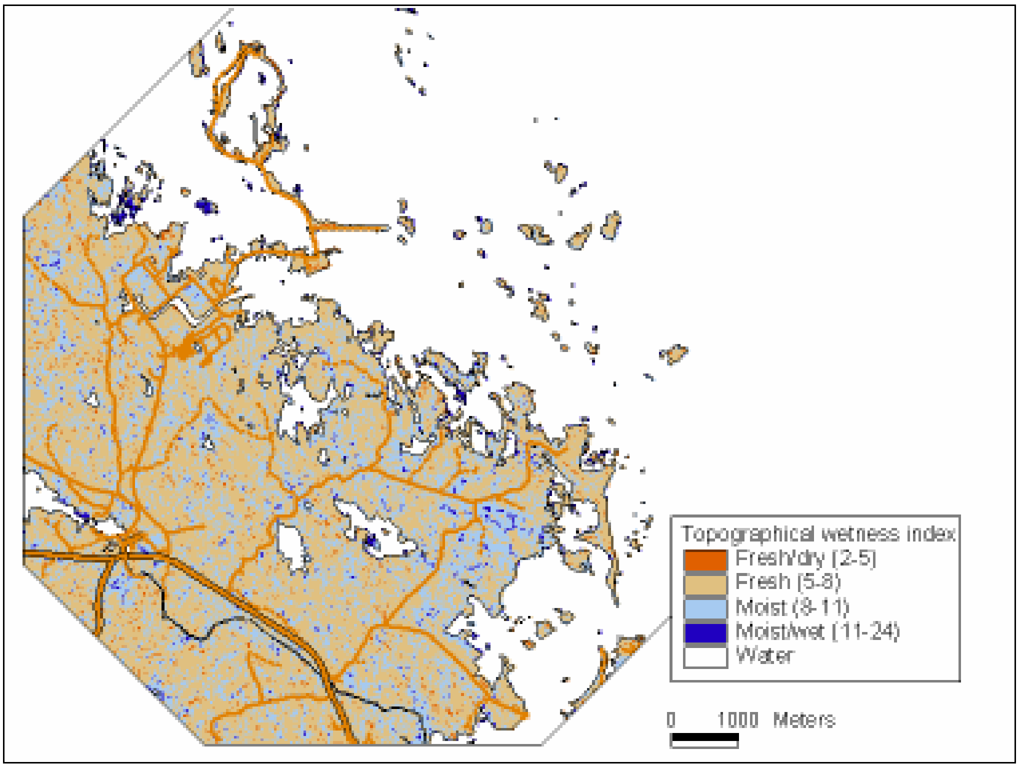


Figure 3-6. *Map of the topographical wetness index modelled by TOPMODEL.*

Topographical modelling

Soil moisture is to a large extent dependent on topography, or rather, the hydrological conditions given by the topography. Generally upland areas are drier than lower parts of the landscape. The wetness in a certain location relates to its specific catchment area, i.e. the upslope area draining through that location, and the slope. Since soil moisture condition is an important variable in the soil formation it can give rise to different soil types under otherwise equal conditions.

The topographical wetness index (TWI) was calculated using the TOPMODEL hydrological model /Beven and Kirkby, 1979; Seibert et al, 1997/. The index attempts to describe the spatial distribution of the depth to the groundwater table, which reflects the soil moisture in the upper part of the soil. The index is valid as long as the groundwater surface varies according to the topography and the soil transmissivity is constant. In the Forsmark area the first prerequisite could be considered valid but a constant transmissivity is an unavoidable simplification. The index (TWI) in a point is a non-linear function of the upslope area (α) and slope (β), which can be derived from the digital elevation model:

$TWI = \ln (a/\tan \beta)$.

A large index indicates wet soil conditions and low index dry conditions. When the accumulated flow reaches a certain threshold the soil becomes saturated and a stream is formed, which discharges the water. The calculated TWI data was smoothened, before it was used further, by calculating a local mean value in a three by three cell (30 by 30 m) neighbourhood. The limit chosen to differentiate between fresh and moist soils was a TWI value of 8.

Processing of geographical data

All input data were converted into raster format with a common cell size (10 m) origin, and outer bounds to facilitate overlay analysis in a GIS. In addition, the closeness to the sea was derived by spatial neighbourhood analysis (Expand operation of the class Water in Arc/Info GRID) and used as input data. The input data layers formed a spatial database of the Forsmark area, which could be used to classify the area into soil classes. The principle method to assign the defined soil classes was by Boolean logic operations on the input grid layers in Arc/Info GRID (the batch script can be found in Appendix I).

4 Results

4.1 Short summary on results

The overall impression is that the Forsmark area exhibit similarities concerning land types with large parts of Sweden, with a dominating forest type and soil parent material not differing to any major extent. But, the land is low-lying and comparably young, as it has been sea covered much longer time then most other parts of Sweden. This has resulted in more or less immature soil types, to a large extent being Regosols but also six other classes occurred. The considerable influence of calcareous soil material furnishes nutrient rich conditions that in these fairly summer-warm conditions provide a rich and diversified flora.

In the Forsmark area the soils are young, mainly less than 1500 years. Till soils dominate. The impacts of sea waves have redistributed the material and left coarse water washed tills in large parts with in low-lying areas sorted sediments often with fairly high clay content and in higher locations thin soils and bare bedrock. Site hydrology variations on investigated plots ranged mainly over fresh to wet types while the class dry mainly occurred on local small hills and where also the bedrock outcrops existed. Sea bays have been cut off and now form inland lakes partly in transgression to swamps and peatlands.

Typical soils for Sweden would be Podzols but these are poorly developed in the Forsmark area and only a few examples were identified. Instead immature soils such as Regosols and soils influenced by water, such as Gleysols and Histosols, occur frequently. In the fresh and moist locations also Cambisols exist. On a few sites there are also Arenosols.

The fairly rich nutrient conditions together with climate and hydrology provided properties for good humus forms to develop, with mull and moder types being more frequent as compared to most other parts of Sweden. Also the O-horizon pH was in general high with values around six while Sweden on average show values between four and five. The humus layer are influenced by the underlying mineral soil and pH values there reached 6.5 on average to be compared with values around five for most of Sweden.

Carbon concentrations in the humus layer agree with Swedish ordinary conditions but in the mineral soil the influence of $CaCO_3$ makes the concentration higher as compared to the general values for Sweden. There exist also increasing concentrations with depth, which mainly would be attributed to the $CaCO_3$ content, and deviating from ordinary forest soil conditions.

Nitrogen concentrations in the soil agree fairly well with most parts of Sweden. However, the values are lower than the region IV and Uppsala county to which regions the Forsmark area belongs.

4.2 Properties and spatial coverage

Variables identifying properties of the soil were determined on a representative plot scale with eight site types in two replicates. The plots were chosen in a stratified selection to cover the major occurring land types and to achieve good statistically based information from these types. The spatial coverage of land types is provided from the GIS mapping of the area.

A combination of the plot determinations and the spatial coverage was used in the comparisons of areal distributions of properties in the Forsmark area with relevant areas of Sweden to reflect similarities and deviations of the Forsmark land types for Swedish land area conditions.

GIS map classes

Eight classes were defined to characterise the main soil conditions in the Forsmark area. This was made as part of the field investigation of soil and site conditions at plots and along transects. The class names are in accordance with the soil classification /WRB, 1998/, although the classes in many cases have been slightly modified or extended to cover the characteristics of the Forsmark area. The names and definitions of the classes are given and the criteria for the map classification are summarised below.

HI: Histosol
This class covers the peatland soils and includes open mires as well as forest covered peatland. The dominant soil class is Histosol, which comprises organic soils of at least 40 cm depth. In the Forsmark area the Histosol soil are typically covered with a sparse tree layer of birch, pine and alder. The definition of Histosols has been extended to include reed areas surrounding many of the lakes.

Map classification
This class was assigned to areas with ground layer of type "Peatland" or of type "Not peatland (Wetland)" in case field layer was sedge-reed. Furthermore, the areas that were peat according to the map of quaternary deposits were included.

LP: Leptosol
This class covers shallow soils typically found in upslope locations. Leptosols, which dominates this class, has a soil depth of less than 25 cm overlaying the bedrock or soil material of very course texture. This soil class has been expanded to also include bedrock outcrops. Other soil types found are Gleysol, Podzol, Cambisol and Regosol. The tree layer is dominated by pine and some spruce, and the field layer is mainly of heath type. Data that were collected at site level refers to adjacent soils of some depth (at least 0.60 m), which were chosen to enable sampling in a soil profile. Therefore this data may deviate somewhat from the expected values for this class.

Map classification
This class was assigned to areas with thin soil or bedrock according to the map of quaternary deposits. Areas with the field layer "Dry heath" were also included.

GL: Gleysol
This class include moist soils that are not peatland such as swamp forests. The predominant soil class is Gleysol, which represent soils that are periodically saturated with water. This leads to reduced conditions and gives rise to the typical gley properties, which should be found within 50 cm depth. The soil wetness is moist and the parent material is course textured mineral soil. The humus type is peaty mor. Forests include spruce and deciduous trees, and herbs dominate the field layer.

Map classification
This class was assigned to areas with ground layer of type “Not peatland (Wetland)”. Peat areas according to the quaternary deposits map were excluded as well as areas where field layer was sedge-reed.

GL/CM: Gleysol/Cambisol
This class covers fertile forest soils on fine texture parent material often located low in the landscape. The prevalent soil types include the periodically saturated Gleysol and Cambisol soils. The Cambisol is a young soil that develops on fine textured material and has no clear horizons in the topsoil. Below the topsoil the mineral soil has developed into a distinct B-horizon. The humus form is of mull type. The tree layer is dominated by deciduous trees (mainly ash and alder) and herbs dominate the field layer.

Map classification
This class was assigned to areas where the tree layer consisted of deciduous trees and where the field layer was of herb or herb-heath type. Areas with forest type dominated by spruce, mixed forest, young birch, or without tree layer (possible clear-cuttings) were included in this class if they had a *high* topographical wetness index (TWI 8). Further, all areas of the previously mentioned forest types were included if they were located on clayey till. All areas in this class had a ground layer of moss type (i.e. no wetlands).

AR/GL: Arenosol/Gleysol
This class is found along the sea shoreline and is influenced by the closeness to water. The Arenosol and Gleysol soils dominate along with some Regosols. The Arenosol soils are formed on sandy material of sediment origin, which has been deposited in different stages of shoreline transgression. In places, that are periodically inundated, the soil type becomes a Gleysol. The humus forms are peaty mor.

Map classification
This class was assigned to shoreline areas along the coast and formed a 10 m wide (one pixel) zone. Shoreline areas located on bedrock (LP) or on organic soil (HI) were excluded from this class.

RG/GL: Regosol/Gleysol
This class is forest soils found in upslope locations with fresh soil moisture class. The Regosol soil, which dominates the class, are formed on unconsolidated course textured parent material and are characterised by a minimal soil profile development as a consequence of young age. A soil type also present is Gleysol. Humus forms are mor or moder. The mixed coniferous forests are dominated by spruce with herbs and heath in the field layer.

Map classification
This class was assigned to areas with young or old pine forest and a field layer of herb or herb-heath type. Further, forest types dominated by spruce, mixed forest, young birch, or without tree layer (possible clear-cuttings) were included in this class if they had a *low* topographical wetness index (< 8). Areas located on clayey till were excluded. All areas in this class had a ground layer of moss type (i.e. no wetlands).

RG/GL-a: Regosol/Gleysol, arable land
This class covers arable land, pasture and abandoned arable land. The Regosol soils and Gleysol soils dominate. This class also includes fertile arable land located on clayey till with soils of Cambisol type, although these areas were not represented among the sampling sites due to ongoing agricultural activities. The soil moisture class is fresh or fresh-moist and the humus form is mainly of mull type. Broad-leafed grass and cereal crops dominates the field layer.

Map classification
This class was assigned to areas with ground layer of arable land type, pasture or meadows.

RG: Regosol
This class in found on the esker in the eastern part of the area. The soil is mainly a Regosol, rich in stones and boulders. The soil moisture class is mainly fresh or partly dry. The humus forms are mull or mull-like moder. Occasional Arenosols are also present. The tree layer is sparse and the field layer is dominated by grass.

Map classification
This class was assigned to areas located on an esker according to the map of quaternary deposits.

The map classification was based on one or several of the input raster layers of the vegetation (tree, field and ground layer), the quaternary deposits, the topographical wetness index, and closeness to the sea (Table 4-1).

Table 4-1. Classification scheme of the soil types based on vegetation, quaternary deposits and topographical index. Alternative determination groups (Alt.) and existing shoreline (Y=yes). For details on the class codes see Appendix II.

Class	Alt.	Input data					
		Tree layer	Field layer	Ground layer	Quat. deposits	TWI	Shore-line
HI Histosol, peatland	1			21,22			
	2				75		
	3		23	24,25			
GL Gleysol, swamp forest	1		<>23	24,25	<>75		
CM Cambisol, deciduous forest	1	1,2,11,12, 17,22,30	<>12	12		≥8	
	2	21,23,26	15,16	12			
	3	1,2,11,12, 17,22	<>12	12	94,96		
GL/RG-a Regosol/Gleysol, arable land	1			31,32			
RG/GL Regosol/Gleysol, coniferous forest	1	1,2,11,12, 17,22,30	<>12	12	<>94,96	<8	
	2	13,14	15,16	12			
AR/GL Arenosol/Gleysol, shoreline	1			<>21,22			Y
RG Regosol, esker	1				50,56		
LP Leptosol, thin soil & bedrock	1		12				
	2				890		

4.3 The soil map of the Forsmark area

Most of the Forsmark area is characterised by a mosaic of four soil types (Figure 4-1), i.e.

1) two forest soils of different soil moisture conditions (GL/CM and RG/GL),
2) peatland soils (HI),
3) thin soils (LP).

The main soil types are distributed in the whole area. Exceptions are first, the RG class being concentrated to the area around the esker in the eastern part. Second, the only large areas of arable land are found in two places, east and west in the area. Third, along parts of the shoreline and on the islands the thin soil and bedrock (LP) is the dominant soil type.

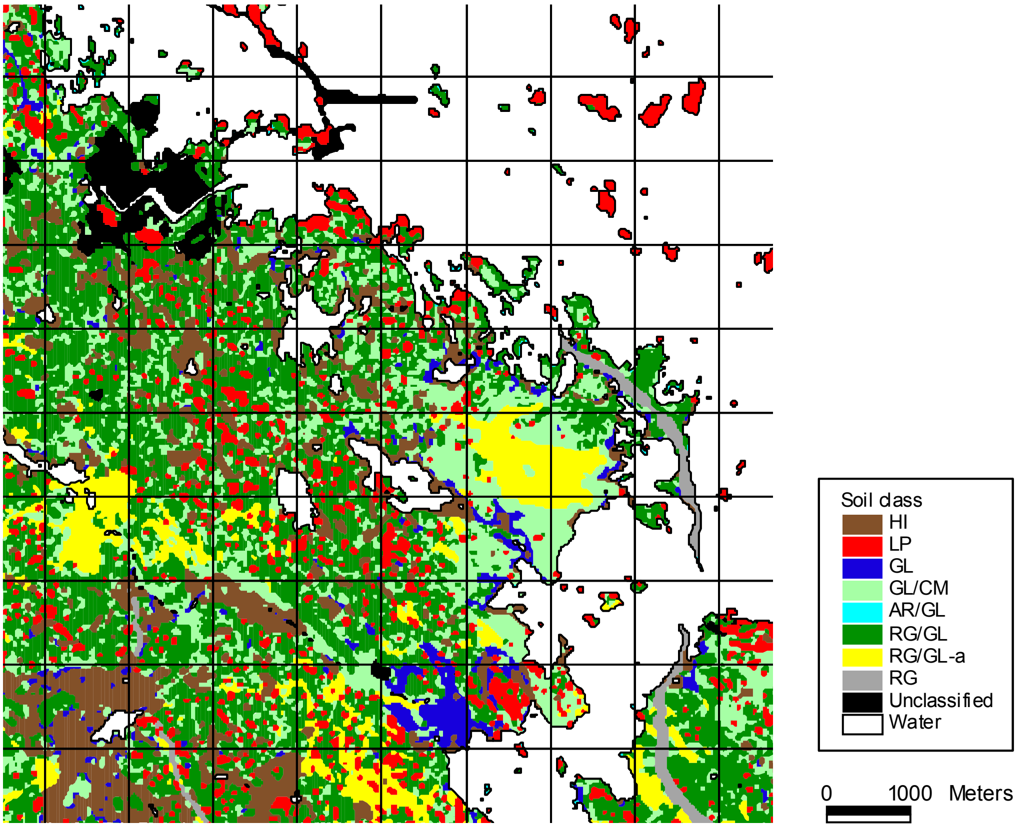


Figure 4-1. *The soil map of the Forsmark area.*

The introductory and preliminary map studies and field inventory of the area along transects gave information contributing to identify the typical soil types of the area. These were then investigated in detail at the 16 sampling sites. However, these few sites were not sufficient to give the spatial coverage to serve as a basis for soil mapping. The intention was not to survey the distribution of soil types within the Forsmark area. Instead, the purpose of collecting the field data was to statistically determine properties for the relevant plots.

Instead, a soil map was created based on secondary sources of information such as vegetation, quarternary deposits and the index of soil moisture, which all provide information with high spatial resolution. The spatial uncertainty with this approach is thus much better than an approach based only on the field data. However, there is an additional source of uncertainty in how well these secondary features can describe the soil types. The eight site map classes identified for the Forsmark area ranged from upslope sites down to the shoreline and could be characterised from the field inventory (Table 4-2 and 4-3).

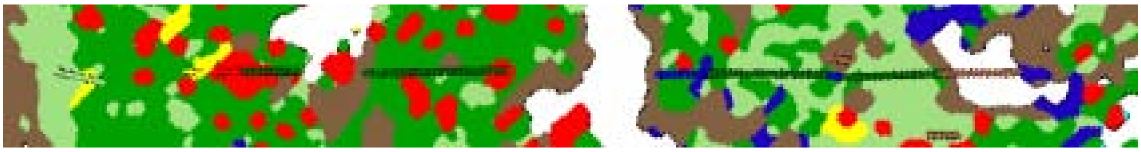
Table 4-2. Characteristics of the identified GIS map soil types of the Forsmark area with distributions of soil types, soil parent material, humus forms, soil wetness classes and ground vegetation.

Map ID	Sampling ID	Soil type	Soil parent material	Humus form	Site hydrology	Prevailing ground-layer vegetation	Prevailing field-layer vegetation
LP	B	Regosol-32%; Podzol-25%; Cambisol-19%; Gleysol-12%; Non-classified-12%	Till-94%; Well sorted sediment-6%	Mull-44%; Mor-1-25%; Mor-2 and Moder-12%; Mull-like moder-7%	Fresh-100%	Mesic mosses type	Low herbs without shrubs
RG/GL	FG	Gleysol-50%; Regosol-44%; Podzol-6%	Till-81%; Missing inform.-19%	Moder-75%; Mor-2-25%	Fresh-50%; Fresh-moist-50%	Mesic mosses type	Tall herbs without shrubs and narrow leafed grass
GL/CM	FL	Gleysol-75%; Regosol-13%; Cambisol-6%; Non-classified-6%	Poor sorted sediment-88%; Well sorted sediment-6%; Missing inform.-6%	Mull-100%	Fresh-100%	Mesic mosses type	Tall and low herbs without shrubs
RG	R	Regosol-76%; Arenosol-12%; Non-classified-12%	Poor sorted sediment-100%	Mull-75%; Mull-like moder-25%	Fresh-100%	Mesic mosses type	Narrow leafed grass
AR/GL	S	Arenosol-44%; Gleysol-37%; Regosol-19%	Well sorted sediment-56%; Till-44%	Mull-like moder-44%; Peaty mor-44%; Humus missing-12%	Wet-100%	Non-classified	Non-classified
GL	SS	Gleysol-75%; Non-classified-25%	Well sorted sediment-44%; Till-37%; Poor sorted sediment-19%	Peaty mor-100%	Moist-100%	Mesic mosses type	Low herbs without shrubs
HI	T	Histosol-100%	Peat-100%	Peat-100%	Wet-100%	Wet mosses type (not *Sphagnum*)	Broad leafed grass
RG/GL-a	A	Regosol-50%; Gleysol-25%; Non-classified-25%	Poor sorted sediment-81%; Well sorted sediment-13%; Till-6%;	Mull-81%; Mull-like moder-19%	Fresh-50%; Fresh-moist-50%	Mesic mosses type	Broad leafed grass

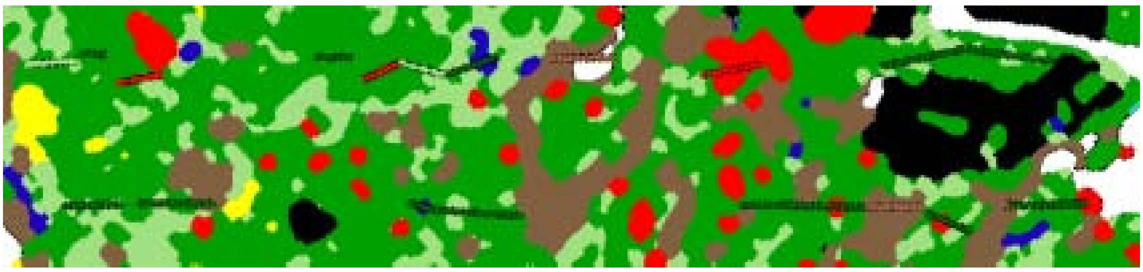
The topographical wetness index (TWI) was used to differentiate between forest soils, which could not be separated based solely on the vegetation data. The forest types were typically spruce forest or mixed forest that may be found on both the dry poor Regosol type (RG/GL) and on rich soil with higher soil moisture (GL/CM). The threshold value used (TWI = 8) to separate the two soil types based on the borders found in the transect data and by field control. The modelling of the TWI produced a highly detailed image of the soil wetness, which was smoothened by calculating a floating mean value in order to generalise the spatial distribution. This was necessary in order to get data of similar spatial resolution as the other information sources.

To evaluate the soil map, the transect data was used as well as field controls in selected locations. A control of the result was made by overlaying transect data and the final soil map (Figure 4-2). The result shows partly good agreement between the two data sets, especially for peatland soil (HI) and for arable land soil (RG/CM-a). However, in some areas there is less good agreement. Some Leptosol soils along the transects, for example, are found just outside areas mapped as Leptosol (Figure 4-2b), while others are not found at all in the map. This may indicate that the map underestimates the coverage of the Leptosol class. Influences could come from the selection of exact plot sites in the field inventory, where the thinnest soils were avoided for the reason to collect deep soil samples. The agreement between the map of quaternary deposits and other maps was not totally perfect. Transects classified as RG/GL soils (Figure 4-2) also include some GL/CM soils, which may explain the great abundance of the RG/GL along the transects.

So far no fully quantitative validation was made and only brief field controls have been carried out. Thus, the quality of the soil map could be enhanced by further investigations and field controls.



a.



b.

Figure 4-2a and b. *Examples on validation of the soil map by plotting three transects from the field inventory as an overlay on the soil map. Similar colours on transect lines and soil map represent the same class (red=LP, blue=GL, light green=GL/CM, dark green=RG/GL, yellow=RG/GL-a).*

4.4 Properties of the Forsmark area land types

The Forsmark area was represented by the eight land and soil type classes selected for the inventory to represent the majority of the area. However, these rather few plots did not give possibilities to reach a representative spatial coverage that was better presented in the GIS map. Based on this, the distributions of the soil types were compared with prevailing conditions for the total Sweden, the middle part of south Sweden and with the Uppsala County (Table 4-3). Forest land and peatland were rather well represented as compared with the region and also Sweden as a country. Arable land agreed rather well with Sweden but is much less than in Uppsala County.

Table 4-3. Spatial distribution (%) of land use classes in the Forsmark area compared with national and regional areas.

Class	Sweden	Svealand region	Uppsala county	Forsmark area
Forest land	62	67	54	75
Pasture	1	1	2	4
Arable land	7	11	26	4
Peatland	16	11	8	12
Other land	14	10	10	5

Site types and investigated plots

Eight site types with two replicates were investigated. These types were selected on basis of the most frequent site types in the area determined from map studies and field observations. The eight types were designated B, FG, FL, R, S, SS, A and T (Table 4-4). In this section a brief description is made of the plots. The two replicates had sampling identities (ID; both related to soil type class and the SKB Id-codes) and these plots were later related to the map classification soil types (Table 4-4).

Table 4-4. Sample plots in relation to the map soil type classes and SKB Id-codes.

Map soil type class		Sample plot ID	SKB Id-codes
Histosols,	HI	T1, T2	AFM001078, AFM001079
Leptosols,	LP	B2, B3	AFM001066, AFM001067
Gleysols,	GL	SS1, SS2	AFM001076, AFM001077
Regosol/Gleysol,	RG/GL	FG1, FG2	AFM001068, AFM001069
Gleysol/Cambisol	GL/CM	FL1, FL2	AFM001070, AFM001071
Regosol	RG	R1, R2	AFM001072, AFM001073
Arenosol/Gleysol	AR/GL	S1, S2	AFM001074, AFM001075
Regosol/Gleysol-arable	RG/GL-a	A1, A2	AFM001080, AFM001081

B 2 and B3 – Thin soil layers in upslope locations – "LP map class"

Shallow soil layers on fresh, partly dry soils, in upslope locations indicate similarities to the Leptosol soil type. However, the plots were located on slightly thicker soils to furnish possibilities for deep (0.75 m) soil sampling. This mean that the soils could not be Leptosols but reflects conditions close to such sites and representing the map class Leptosol "LP". The humus forms were mainly mull and mull-like moder and the soil types ranged over Gleysols, Podzols, Cambisols and Regosols (Table 4-5). On both plots there were sandy-silty till overlying silty till. Vegetation was in the tree layer dominated by spruce including some birch. Field layer was of low herb types without shrubs.

Table 4-5. Distribution of soil types, parent material and soil horizons in the B2 and B3 plots both separately (a) and together (b).

a)

LP	**B2 – AFM 001066**						**B3 – AFM 001067**					
Number of profiles, n	4		2		2		3		3		2	
Soil	Podsol -50%		Gleysol -25%		Regosol -25%		Cambisol -37.5%		Regosol -37.5%		Non-classified -25%	
Soil material	Till		Till		Till		Till		Till		Till, well sorted sediment	
Soil leyer depth, cm	Average	Min-max	Average	Min-max	Average	Min-max	Average	Min-max	Average	Min-max	Average	Min-max
O layer, cm	11	6–14	11	11	11.5	5–18	23	17–28	15	13–18	14	10–18
A layer, cm	4	0–10	3	2–3	2	0–4	23	17–28	15	13–18	14	10–18
AB layer, cm									2	0–7		
E layer, cm	5	0–7										
B layer, cm	8	6–14	21	17–>24	32	32–>50	20	0–24	15	>10–23	14	5–22

b)

LP	**B**									
Number of profiles, n	5		4		3		2		2	
Soil	Regosol -32%		Podsol -25%		Cambisol -19%		Gleysol -12%		Non-classified -12%	
Soil material	Till		Till		Till		Till		Till, well sorted sediment	
Soil leyer depth, cm	Average	Min-max	Average	Min-max	Average	Min-max	Average	Min-max	Average	Min-max
O and H layer, cm	13	5–18	11	6–14	23	17–28	11	11	14	10–18
A layer, cm	8	0–18	4	0–10	23	17–28	3	2–3	14	10–18
AB layer, cm	2	0–7								
E layer, cm			5	0–7						
B layer, cm	24	10–>50	8	6–14	20	0–24	21	17–>24	14	5–22

FG 1 and FG2 – Fresh and Fresh-moist upslope sites – "RG/GL map class"
The mainly fresh soil type in coniferous forests provided a mor and moder humuslayer. Most frequent soil types were Gleysols and Regosols on the mainly silty till (Table 4-6). The forest is dominated by spruce and vegetation in the field layer varied between tall herb types without shrubs and also narrow leafed grass type.

Table 4-6. Distribution of soil types, parent material and soil horizons in the FG1 and FG2 plots both separately (a) and together (b).

a)

RG/GL	FG 1 – AFM 001068		FG 2 – AFM 001069			
Number of profiles, n	8		7		1	
Soil	Gleysol -100%		Regosol -87.5%		Podzol -12.5%	
Soil material	Till		Till		Till	
Soil leyer depth, cm	Average	Min-max	Average	Min-max	Average	Min-max
O layer, cm	15	11–18	11	9–20	11	
A layer, cm	6	0–11	2	0–5	6	
AB layer, cm			3	0–7		
E layer, cm						
B layer, cm	17	0–28	10	4–22	6	

b)

RG/GL	FG					
Number of profiles, n	8		7		1	
Soil	Gleysol -50%		Regosol -44%		Podsol -6%	
Soil material	Till		Till		Till	
Soil leyer depth, cm	Average	Min-max	Average	Min-max	Average	Min-max
O layer, cm	15	11–18	11	9–20	11	
A layer, cm	6	0–11	2	0–5	6	
AB layer, cm			3	0–7		
E layer, cm						
B layer, cm	17	0–28	10	4–22	6	

FL 1 and FL 2 – Fresh-Fresh-moist soils – "GL/CM map class"
These sites indicated more fertile soils with the humus form being a mull and the trees dominated by deciduous types (ash and alder). Field vegetation showed similarities with tall herb types without shrubs and the soil type was influenced by reduced conditions mainly forming Gleysols with at a few locations also Regosols and a Cambisol (Table 4-7). Sorted sediments of fine sand, silt and partly clay dominated soil texture.

Table 4-7. Distribution of soil types, parent material and soil horizons in the FL1 and FL2 plots both separately (a) and together (b).

a)

GL/CM	FL 1 – AFM 001070						FL 2 – AFM 001071			
Number of profiles, n	6		1		1		6		2	
Soil	Gleysol -75%		Cambisol - 12.5%		Non-classified - 12.5%		Gleysol -75%		Regosol -25%	
Soil material	Poor and well sorted sediment		Poor sorted sediment				Poor sorted sediment		Poor sorted sediment	
Soil leyer depth, cm	Aver-age	Min-max	Aver-age	Min-max	Average	Min-max	Average	Min-max	Average	Min-max
H layer, cm	16	12–21	19		19		14	11–15	12	12
A layer, cm	12	7–18					12	10–15	10	10
AB layer, cm	7	4–9					5	0–7	5	5
E layer, cm										
B layer, cm	15	0–29	28		>22		19	7–38	22	>18–25

b)

GL/CM	FL							
Number of profiles, n	12		2		1		1	
Soil	Gleysol -75%		Regosol -13%		Cambisol -6%		Non-classified -6%	
Soil material	Poor and well sorted sediment		Poor sorted sediment		Poor sorted sediment			
Soil leyer depth, cm	Average	Min-max	Average	Min-max	Average	Min-max	Average	Min-max
H layer, cm	15	12–21	12	12	19		19	
A layer, cm	12	7–18	10	10				
AB layer, cm	6	0–9	5	5				
E layer, cm								
B layer, cm	17	0–38	22	>18–25	28		>22	

R1 and R2 located on an esker – "RG map class"

The soil moisture class was mainly fresh, partly also dry, and stoniness rich. Humus forms were mull or mull-like moder on Regosols and a few Arenosols (Table 4-8). Soil parent material were poorly-sorted sediments of sand and coarse sand types. Vegetation was partly sparse in the tree layer where pine and birch were common and with dominating narrow leafed grass types in the field layer.

Table 4-8. Distribution of soil types, parent material and soil horizons in the R1 and R2 plots both separately (a) and together (b).

a)

RG	R 1 – AFM 001072						R 2 – AFM 001073			
Number of profiles, n	5		2		1		7		1	
Soil	Regosol - 62.5%		Arenosol -25%		Non-classified - 12.5%		Regosol -87.5%		Non-classified - 12.5%	
Soil material							Poor sorted sedment		Poor sorted sedment	
Soil leyer depth, cm	Aver-age	Min-max	Average	Min-max	Average	Min-max	Average	Min-max	Average	Min-max
H layer, cm	10	10	19	15–22	12		8	7–10	11	
A layer, cm	10	10	19	15–22	12		8	6–9	8	
AB layer, cm							2	0–5	14	
E layer, cm										
B layer, cm	36	28–40	19	18–20	28		39	20–61	>26	

b)

RG	R					
Number of profiles, n	12		2		2	
Soil	Regosol -76%		Arenosol -12%		Non-classified -12%	
Soil material	Poor sorted sedment					
Soil leyer depth, cm	Average	Min-max	Average	Min-max	Average	Min-max
H layer, cm	9	7–10	19	15–22	12	
A layer, cm	9	6–10	19	15–22	10	
AB layer, cm	2	0–5				
E layer, cm						
B layer, cm	38	20–61	19	18–20	>26	

SS1 and SS2 – Downslope forest sites – "GL map class"

Mainly moist site types characterised by peaty mor humus forms and a vegetation of low herb types without shrubs. The tree layer is dominated by spruce. Soil type was Gleysol (Table 4-9) and the soil material had a large content of clay with clayey tills on one plot and a sorted sediment on the other, i.e. clay.

Table 4-9. Distribution of soil types, parent material and soil horizons in the SS1 and SS2 plots both separately (a) and together (b).

a)

GL	SS 1 – AFM 001076		SS 2 – AFM 001077			
Number of profiles, n	8		4		4	
Soil	Gleysol -100%		Gleysol -50%		Non-classified -50%	
Soil material	Till and well sorted sediment		Well and poor sorted sediment		Well and poor sorted sediment	
Soil leyer depth, cm	Average	Min-max	Average	Min-max	Average	Min-max
O and H layer, cm	12	7–19	13	8–18	19	12–34
A layer, cm					3	0–12
AB layer, cm						
E layer, cm						
B layer, cm	12	3–24	9	2–19	15	8–25

b)

GL	SS			
Number of profiles, n	12		4	
Soil	Gleysol -75%		Non-classified -25%	
Soil material	Till, and well and poor sorted sediment		Well and poor sorted sediment	
Soil leyer depth, cm	Average	Min-max	Average	Min-max
O and H layer, cm	12	7–19	19	12–34
A layer, cm			3	0–12
AB layer, cm				
E layer, cm				
B layer, cm	10	2–24	15	8–25

T1 and T2 – peatland – "HI map class"

The peatland type constituted phragmites fens with a sparse cover of birch, pine and alder over broad leafed grass types on wet soils. The organic layer is peat with low degree of decomposition in the upper layers (H1–H2 (von Post)) but higher in deeper layers (H3–H6 (von Post)). Thickness of the peat is c 0.9 m with wet gyttja over a gravely mineral soil. Thereby the soil type is Histosol (Table 4-10).

Table 4-10. Distribution of soil types, parent material and soil horizons in the T1 and T2 plots both separately (a) and together (b).

a)

HI	T 1 – AFM 001078		T 2 – AFM 001079	
Number of profiles, n	8		8	
Soil	Histosol -100%		Histosol -100%	
Soil material	Peat		Peat	
Soil leyer depth, cm	Average	Min-max	Average	Min-max
H layer, cm	94	87–102	91	78–102

b)

T		
Number of profiles, n	16	
Soil	Histosol -100%	
Soil material	Peat	
Soil leyer depth, cm	Average	Min-max
H layer, cm	92	78–102

S1 and S2 – shoreline sites – "AR/GL map class"

This site type was influenced by water, occasionally even inundated, and mainly of wet type with a few moist profiles. Sandy-silty and clayey tills were mixed with sorted sediments of sand. Soil types were Gleysols, Arenosols and a few Regosols mainly with a peaty mor but also gyttja occurred (Table 4-11). There was a considerable variation in plants and vegetation types, i.e. broad and narrow leafed grass types.

Table 4-11. Distribution of soil types, parent material and soil horizons in the S1 and S2 plots both separately (a) and together (b).

a)

AR/GL	S 1 – AFM 001074				S 2 – AFM 001075			
Number of profiles, n	7		1		5		3	
Soil	Arenosol -87.5%		Gleysol -12.5%		Gleysol -87.5%		Regosol -12.5%	
Soil material	Well sorted sediment		Well sorted sediment		Till and well sorted sediment		Till	
Soil leyer depth, cm	Average	Min-max	Average	Min-max	Average	Min-max	Average	Min-max
H and O/H layer, cm	3	0–5	5		7	4–9	4	2–6
A layer, cm	2	0–5	5				2	0–3
E layer, cm								
B layer, cm					7	0–10	14	10–17

Table 4-11 b)

AR/GL	S					
Number of profiles, n	7		6		3	
Soil	Arenosol -44%		Gleysol -37%		Regosol -12.5%	
Soil material	Well sorted sediment		Till and well sorted sediment		Till	
Soil leyer depth, cm	Average	Min-max	Average	Min-max	Average	Min-max
H and O/H layer, cm	3	0–5	6	4–9	4	2–6
A layer, cm	2	0–5	5		2	0–3
B layer, cm			7	0–10	14	10–17

A1 and A2 – pasture or terminated arable land – "RG/GL-a map classes"

Soil parent material is poorly sorted sediments of mainly fine sand but deeper in the Gleysol or Regosol profile types there is also included clay (Table 4-12). The content of stones and boulders are considerable. Soil moisture class is fresh to fresh-moist and the humus form mainly mull. Broad-leafed grass type dominates the vegetation field layer.

Table 4-12. Distribution of soil types, parent material and soil horizons in the A1 and A2 plots both separately (a) and together (b).

a)

RG/GL-a	A1 – AFM 001080				A 2 – AFM 001081	
Number of profiles, n	4		4		8	
Soil	Gleysol -50%		Non-classified -50%		Regosol -100%	
Soil material	Poor and well sorted sediment, till		Poor sorted sediment		Poor and well sorted sediment	
Soil leyer depth, cm	Average	Min-max	Average	Min-max	Average	Min-max
H layer, cm	25	20–30	20	18–22	17	14–20
A layer, cm	25	20–30	20	18–22	12	10–20
AB layer, cm					11	0–20
E layer, cm						
B layer, cm	8	0–16	20	18–>22	23	7–46

b)

A						
Number of profiles, n	8		4		4	
Soil	Regosol -50%		Gleysol -25%		Non-classified -25%	
Soil material	Poor and well sorted sediment		Till, and poor and well sorted sediment		Poor sorted sediment	
Soil leyer depth, cm	Average	Min-max	Average	Min-max	Average	Min-max
H layer, cm	17	14–20	25	20–30	20	18–22
A layer, cm	12	10–20	25	20–30	20	18–22
AB layer, cm	11	0–20				
E layer, cm						
B layer, cm	23	7–46	8	0–16	20	18–>22

4.5 Characteristics of the site types

Properties related to the site types in the Forsmark area varied concerning soil type mainly between six classes, with Regosols most common. Soil had developed partly on sorted sediments and partly on till with site hydrology variations on investigated plots being fresh to wet while the class dry mainly occurred on local small hills and where bedrock outcrops existed. The fairly nutrient rich parent material provided nutrient demanding vegetation and resulted in humus forms often being moder to mull (Appendix IIIa and b).

Similarities or differences for the map classification soil types could be visualised by a tree diagram showing Euclidean distances. Most of the replicates were found to be close. Largest differences were found for the type RG/GL, RG/GL-a and AR/GL (Figure 4-3). Mainly one of the plots in each type was slightly more moist as compared to the other, making up somewhat larger distances. On the overall, the picture showed fairly good correlations between the replicates and plot distribution set related plots rather close. The largest class was RG/GL including Regosols and Gleysols on till or poorly sorted sediments and fresh site hydrology. Lowest distribution was for AR-GL and RG soil types.

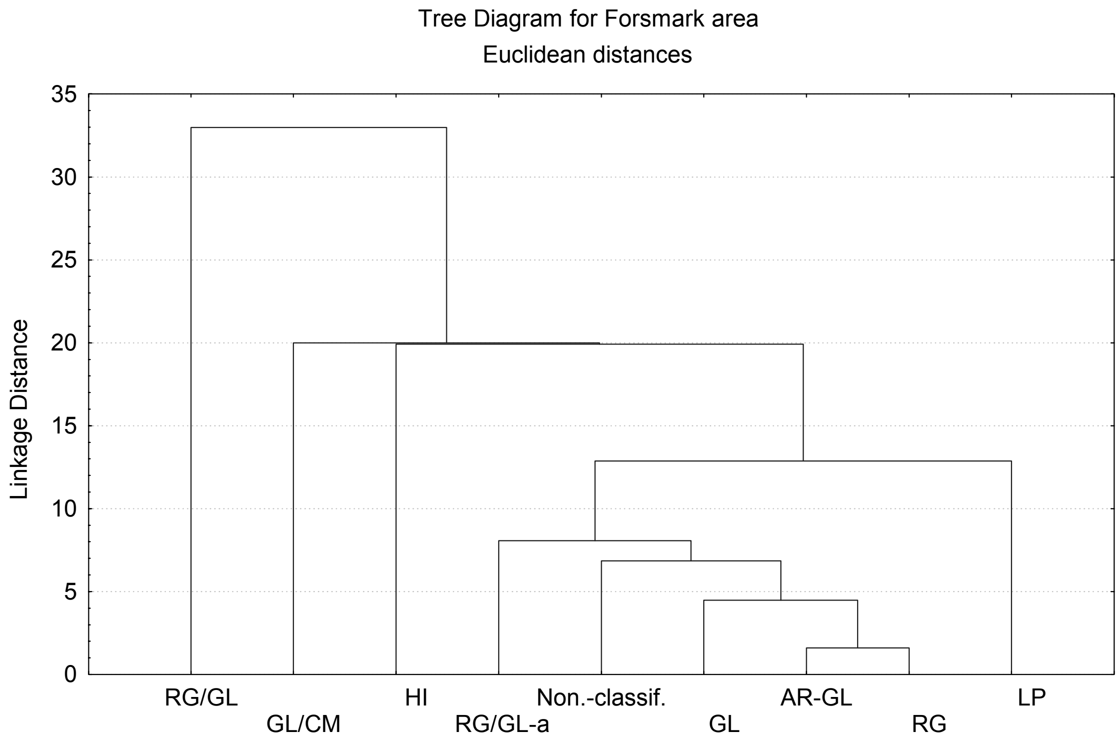


Figure 4-3. *Tree cluster diagram showing relations between sites. The area distribution is shown on the Y-axis and the similarities are related to distances on the x-axis. The relations depend on a combination of soil parent material, soil type and wetness class.*

Site hydrology

The soil moisture conditions of the Forsmark area are dominated by rather well-drained soils of fresh site types (Figure 4-4, Table 4-13). Areas of dry type is missing dependent on selection of areas to be investigated reflecting soils close to bedrock outcrops and thin soils. The actual thin soil areas were unsuitable for soil sampling and thereby excluded. Such areas covers less than 12% of the area (LP map class), though parts of this is fresh types. The distribution of moist and wet areas show similarities to Sweden total but the wet class is higher than the region of Sweden and Uppsala County.

The distribution of soil wetness on GIS map classes shows the dominating fresh types but also areas of fresh-moist and moist classes in map classes RG/GL and GL. Wet soils are found in peatlands (HI) and shoreline areas (AR/GL) (Figure 4-5). Deviation from expected wetness class could be noticed for the GL/CM map soil type.

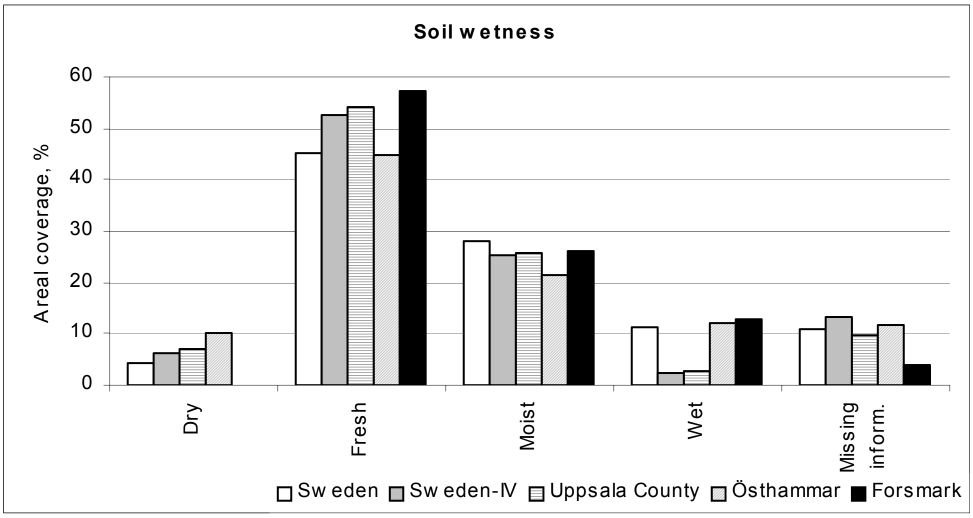
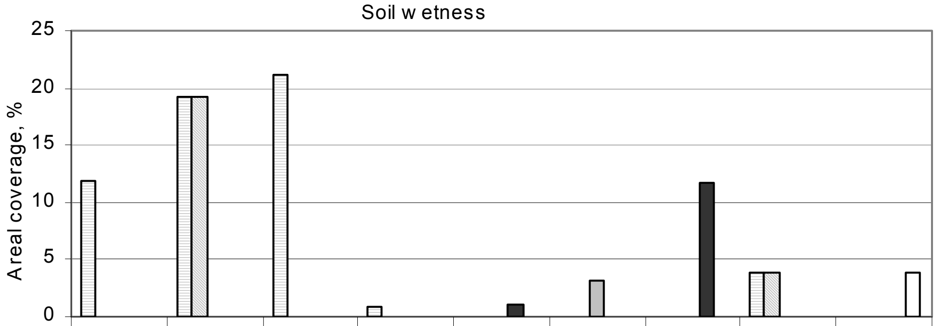


Figure 4-4. *Soil moisture classes, wetness, with frequency distribution for the Forsmark area and in comparison with conditions of four relevant Swedish areas.*

Table 4-13. Soil moisture class frequencies (%) of Forsmark area and four other parts of Sweden.

Class, %	Region				
	Sweden	**Sweden-IV**	**Uppsala County**	**Östhammar**	**Forsmark**
Dry	4.4	6.2	7.2	10.1	0.0
Fresh	45.0	52.7	54.3	44.7	57.1
Moist	28.2	25.5	25.8	21.6	26.2*
Wet	11.4	2.4	2.8	12.0	12.8
Missing inform.	11.0	13.2	9.9	11.6	3.9

* incl. 23.1% of ‘Fresh-moist’ soils



	LP	RG/GL	GL/CM	RG	AR/GL	GL	HI	RG/GL-a	Non-classif.
Fresh	11.9	19.3	21.2	0.9				3.8	
Fresh-moist		19.3						3.8	
Moist						3.1			
Wet					1.0		11.8		
Non-classif.									3.9

__Figure 4-5.__ Soil wetness conditions in the Forsmark area presented as distribution on GIS map soil classes.

Soil parent material

Tills and poorly sorted sediments (Figure 4-6 and Table 4-14) dominate the soil parent material in the Forsmark area. The latter group has higher frequencies as compared to total Sweden and selected regions. A comparably large influence from the sea contributes in this. However, in the area also well-sorted sediments and peat occur. Bedrock outcrops are excluded while the regolith is missing on such sites. However, bedrock outcrops are fairly common in the area and might cover some 8–10%.

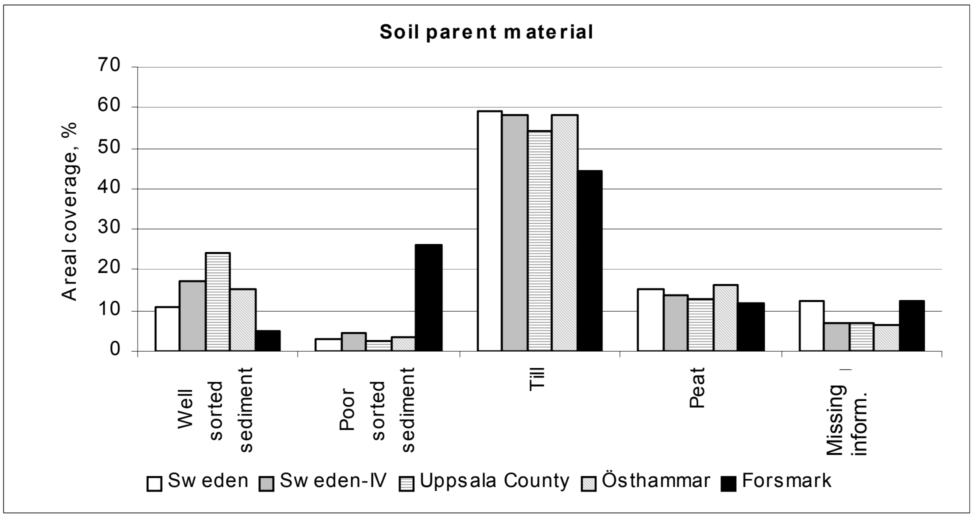
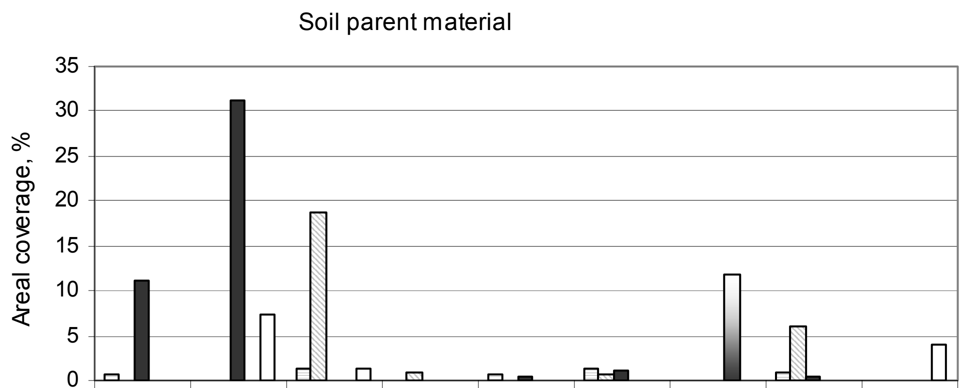


__Figure 4-6.__ Soil parent material distribution in the Forsmark area and in comparison with conditions of four relevant Swedish areas.

Table 4-14. Soil parent material frequencies (%) in Forsmark area and for four other parts of Sweden.

Class, %	Region				
	Sweden	Sweden-IV	Uppsala County	Östhammar	Forsmark
Well sorted sediment	10.9	17.3	24.0	15.4	4.9
Poorly sorted sediment	2.8	4.2	2.5	3.4	26.3
Till	59.0	58.1	54.1	58.1	44.5
Peat	15.2	13.7	12.6	16.5	11.8
Missing inform.	12.1	6.7	6.8	6.6	12.5

The distribution of soil parent material and peat for GIS map classes shows the domination for till soil but also c 25% poorly sorted sediments. Till occur on LP and RG/GL types while poorly sorted sediments are common on GL/CM, RG and RG/GL-a types. Well-sorted sediments could mainly be found on AR/GL and GL site types (Figure 4-7).

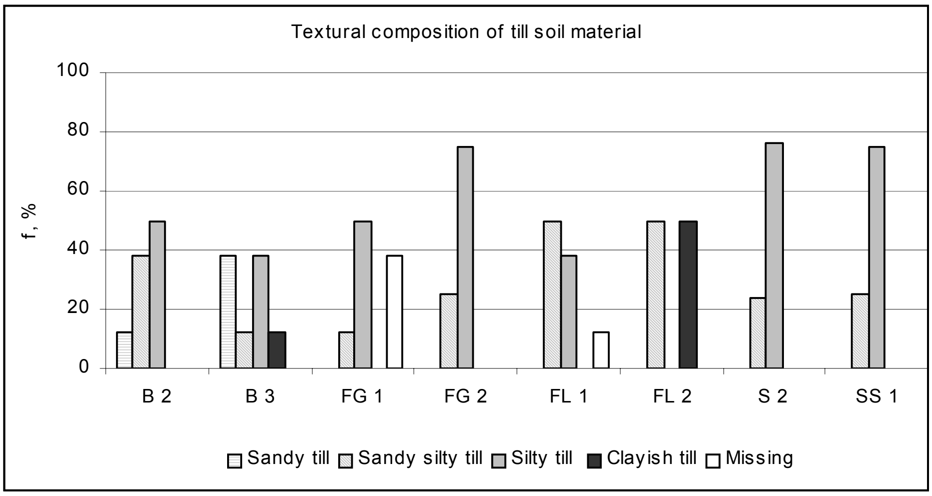


	LP	RG/GL	GL/CM	RG	AR/GL	GL	HI	RG/GL-a	Non-classif.
Well sorted sediment	0.7		1.3		0.6	1.4		1.0	
Poor sorted sediment			18.7	0.9		0.6		6.1	
Till	11.2	31.3			0.4	1.1		0.5	
Peat							11.8		
Missing inform.		7.3	1.3						3.9

Figure 4-7. *Soil parent material in the Forsmark area presented as distribution on GIS map soil classes.*

Soil texture

The soil textural compositions of the selected plots, field determination, show dominating fairly ordinary sandy-silty material, partly as poorly sorted sediments or as till soils. Also clay and especially clayey tills exist on comparably large part of the area. Peat covers totally the two site representing peatlands (Figure 4-8 and Table 4-15). On plots with thin soils and on the esker, the soils are somewhat coarser grained as compared to the locally more low-lying sites and shorelines.



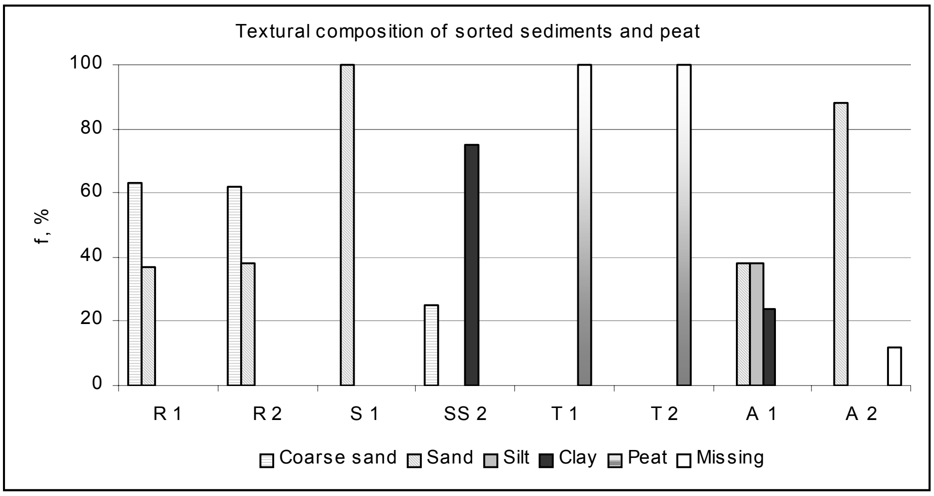


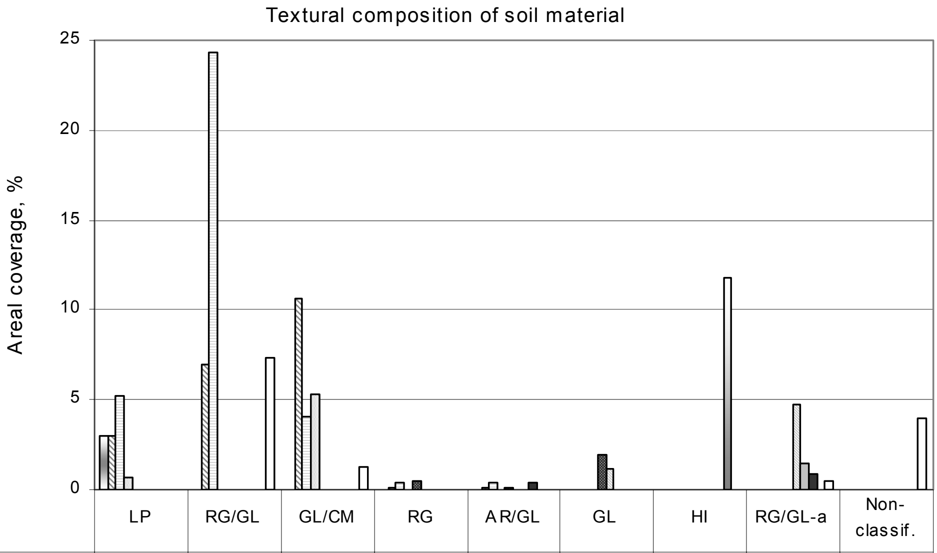
Figure 4-8. *Soil textural composition at the 16 investigated plots in the Forsmark area. Above the till soils and below sorted sediments and peat.*

Table 4-15. Spatial distribution (%) of soil textural composition in the Forsmark area based on the selected 16 plots and 124 profiles compared to conditions in forest soils of Sweden and Uppsala County. Sorted sediments and till soils – Δ = till.

	Coarse sand Sandy Δ	Medium Sa Sandy-silty Δ	Silt Silty Δ	Clay Clayish Δ	Peat	Missing
Sweden	6	23	57	4	10	–
Uppsala County	7	16	39	27	11	–
Forsmark area	5	27	36	7	12	13

The distribution of soil textural composition on the GIS map soil classes shows dominating till soils in LP, RG/GL, GL/CM and RG classes while sorted sediments exist in GL and RG/GL-a classes. The area distribution is dominated by sandy-silty and silty till soils showing common but slightly more fine grained soils as compared to large parts of Sweden (Figure 4-9).

Special texture laboratory analysis was made on 42 selected samples from the Forsmark sites. The gravimetrical content of grain sizes shows dominating content of fine sand and sand. The gravel fraction reaches up to over 40% in a few plots (one extreme sample on 83%) but the fraction is lacking on other sites such as sorted sediments in a shoreline site. Clay content reaches as high as 75% (one extreme) but is mainly between 10% and 20% but in some sites also zero content occur (Appendix IVa–d).



	LP	RG/GL	GL/CM	RG	AR/GL	GL	HI	RG/GL-a	Non-classif.
Sandy till	3.0								
Sandy silty till	3.0	6.9	10.6	0.1	0.1				
Silty till	5.2	24.3	4.0	0.3	0.4				
Clayish till	0.7		5.3						
Coarse sand				0.4	0.1	1.9			
Sand						1.2		4.8	
Silt								1.4	
Clay					0.4			0.9	
Peat							11.8		
Missing		7.3	1.3					0.5	3.9

Figure 4-9*. Soil textural composition in the Forsmark area presented as distribution on GIS map soil classes.*

Nine textural types were identified in the Forsmark area, sandy till, clayey sandy till, coarse boulder clay, sand with high clay content, glacifluvial sand, outwashed sand, coarse sorted sediments, heavy clay and a mixture between sand and clay.

Starting with till deposits, they are usually by definition well graded and thus presenting a quite smooth S-shaped curve or nearly a straight line on the semilogaritmic paper. This is especially evident for the samples represented by analyses numbers Sml 33, 59, 125, 127, 129, 157, 467, 513 and 515, respectively. This type of regolith is represented by Figure 4-10, showing the curve for Sml 33. It is the most common till types in Sweden and is classified as sandy till. The cumulative S-shaped texture curve implying obvious similarities to till occurred mainly in upslope location on LP and RG/GL soils. From these curves, these soils could be interpreted by a quite high possibility to be till deposits. They also represent the deepest sampling depth.

Another category is composed of soils, which show a similar grain-size distribution to normal tills but where the clay content is raised above 15%. The sample numbers Sml 59, 125, 127, 157, 221, 259, 263 and 465 represents these and are found in slopes on RG/GL and GL/CM soil types. When the clay content is restricted to 5–15% by weight they are called clayey tills. Based on the matrix composition they could be specified to clayey sandy tills, represented by analyses Sml 125. When the clay content is raised above 15% these soils are classified as coarse boulder clay, which are till deposits with clay content between 15–25% by weight. In the Forsmark area, the grain size distribution (Figure 4-10) revealed the existence in GL/CM soils. This is exemplified by analyses SML 263 (Figure 4-10).

These clay rich tills are rather unusual for Swedish conditions but are quite frequent in the northeastern most part of the province of Uppland bordering the Gulf of Gävle, where the bottom within a large area is composed of shale and limestones from the Cambro-Silurian Period. Otherwise, they are chiefly restricted to areas where shales occur in the bedrock. Such areas are found in connection to Palaeozoic bedrock in the Lake Storsjön region, the province of Jämtland; in the Lake Siljan area, the province of Dalarna; in the agricultural planes of the provinces of Närke and Östergötland; also in the vicinity of the table mountains of the province of Västergötland; on the great islands in The Baltic, Gotland and Öland. Finally, similar bedrock occurs in the province of Skåne, where even younger sedimentary rock types from the Mesozoic Era exist.

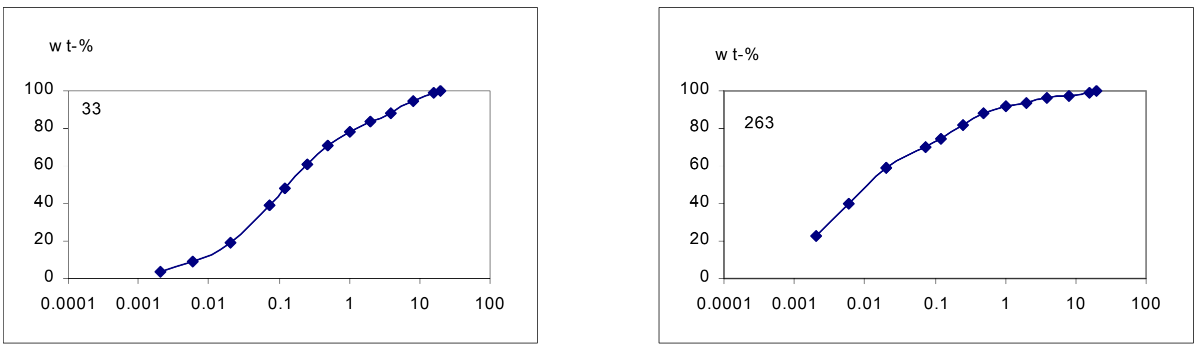


Figure 4-10. *Texture curves of till soil type (33) and coarse boulder clay type (263).*

Of course, there are deviations from these rules and boulder clays have been found at deep excavations, e.g. in the northern part of the Stockholm area. One explanation to these anomalies of boulder clay outside areas with shale bedrock is the existence of water laid clays in low lying plain areas before the latest glaciation period where those sediments could have been reworked by the inland glacier and inherited in the till deposit.

As earlier stated the investigation area has been subjected to wave washing in connection to the prevailing land uplift. This has resulted in transition states between primary deposited well graded tills to more or less well sorted water-lain sediments. This could be exemplified from the surface horizons represented by the analyses numbers Sml 29, 31 and 57 characterised by a till shaped cumulative curve with a more or less pronounced bulge in the sand fraction (Figure 4-11). The restricted thickness and the rather high clay content of 10% gives the deviation from a typical out-wash deposit as found in LP soil types.

Better-sorted deposits are represented, especially in RG soils, and the analysis numbers Sml 153, 155, 309, 311 and 339. However these are still deviating from well-sorted glaciofluvial sediments or eolian deposits. These types of soil are classified as outwash deposits and a rather bad sorting and low clay content characterise them. They have been reworked and deposited after the primary material has been exposed to intense wave washing.

If the primary deposited materials make up eskers, the exposure to wave washing result in a surface cover with outwash sand exemplified by analyses Sml 309 (Figure 4-11) found in a RG soil type. In this case, it is quite difficult to determine only from the cumulative curves whether or not the regolith should be classified as glaciofluvial sand or outwash sand. However, underneath the surface horizon a typical sorted sediment is found, which is classified as glaciofluvial sand.

In connection to the esker, that is traversing the NE part of the investigation area, typical glaciofluvial material has been found. These soils, found in RG and AR/GL soil types with close connection to the sea, are represented by the analysis numbers Sml 313, 339, 341, 369, 371 and 373. In this case, one or two fraction classes, either sand or gravel dominates the grain-size distribution curve but clay is lacking. Especially the curves Sml 313 (Figure 4-12), 369 and 373, dominated by medium sand have a

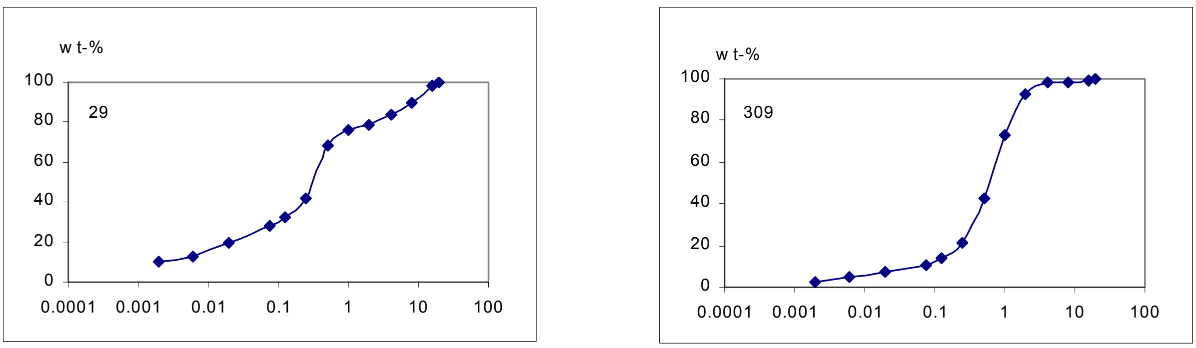


Figure 4-11. *Texture curves of slightly wave washed soil type (29) and an outwashed sand type (309).*

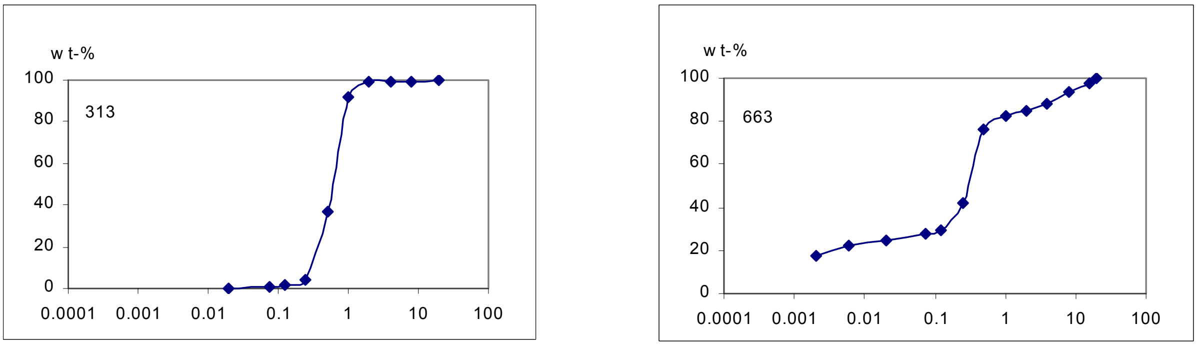


Figure 4-12. *Texture curves of a well sorted coarse sand (313) and a mixed coarse clay and gravelly sand (663).*

close resemblance to dune sands, but the occurrence of coarse sand will not approve a wind blown origin. In these cases, the well-sorted esker material could very well be covered by a layer of outwash material.

Well-sorted clay deposits, found in GL and RG/GL-a soil types, are represented by analyses Sml 583, 585, 667 where Sml 667 represents a very heavy clay with 75% clay. In the arable area the soil has been used as farmland and the samples Sml 723 and 725 indicate that an outwash sand deposit has been mixed with clay by ploughing because it is underlain by a very heavy clay (Sml 727). Other samples which carry evidence about mixing are Sml 663 (Figure 4-12) and 665, where coarse clay is supposed to have been mixed with outwash gravelly sand.

This also indicate about a quite complex formation environment and it can be impossible to determine from a grain-size distribution curve solely whether the regolith should be classified as a boulder clay, a glacial clay or a mixture of outwash gravelly sand with water-lain clays.

Volumetric content of soil particles

Texture analysis, both as field and laboratory determinations, often only consider grains finer than 2 cm (fine soil material is considered as being < 2 mm). However, in most Swedish soils considerable contents of stones and boulders (> 2 cm) exist. These grain size fractions constitute parts of the soil material but contribute negligible to e.g. chemical concentrations and properties but makes the chemical contents lower as compared to if the soil only was made up by fine material (< 2 mm). Therefore, estimation of the stone and boulder content were made according to the Viro method /Viro, 1958/ modified by Melkerud and Lundin (unpublished).

$Z = 71.7 – 2.39\ X$, Z: volumetric content, %, X: penetration depth, cm

Further research in this topic is needed to confirm the validity of the method and investigations are ongoing. However, two estimations of the volumetric content of soil particles (clay – boulders) were so far made for the Forsmark area. The stoniness index is determined as one value for a plot and relates primarily to the upper 0.3 m but was used for also deeper horizons. In Forsmark area it seems as if the fine material constitute rather small part of the total soil volume (Table 4-16).

Table 4-16. Volumetric content, %, of soil material distributed on grain size fractions. "Fine sand": 0.02–0.06 mm; "Silt": 0.002–0.02 mm.

Location	Stones and boulders	Gravel	Sand	"Fine sand"	"Silt"	Clay
B2:9						
0–10 cm	55.7	2.5	4.7	2.0	1.1	1.1
10–20 cm	55.7	2.1	6.9	5.9	2.7	3.8
55–65 cm	55.7	4.7	7.3	11.2	4.4	1.0
FG1:10						
0–10 cm	43.5	3.4	8.1	8.1	5.5	3.7
10–20 cm	43.5	4.0	7.6	11.0	8.6	4.9
55–65 cm	43.5	7.4	13.9	14.6	8.3	2.1

Soil bulk density

Dry bulk density in the Forsmark area show the common picture for Swedish forest soils with low values in the upper layers with 0.4 g/cm^3 to 1.5 g/cm^3. The density increases with depth and reaches 1.4 g/cm^3 to 2.3 g/cm^3 in depths of 0.6 m (Appendix V).

Humus form

Dominating humus forms for Sweden are mor types with almost 40% of the sites. In Forsmark area these types make up only 14%. Instead the mull together with mull-like moder and moder are more frequent with c 35% and c 30%, respectively. In Sweden mull types and moder constitute c 8% and 6%, respectively. Peat and peaty mor reach c 15% in Forsmark but over 20% for Sweden. (Figure 4-13 and Table 4-17).

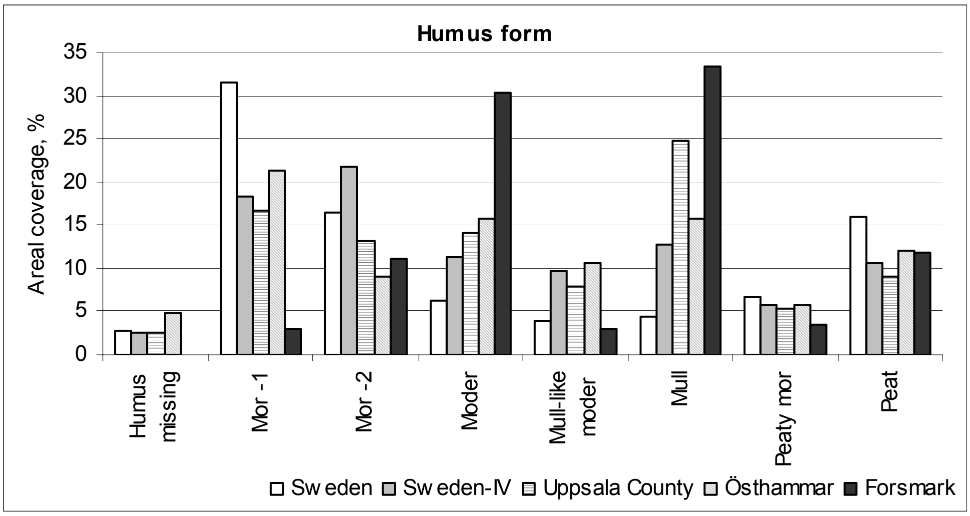
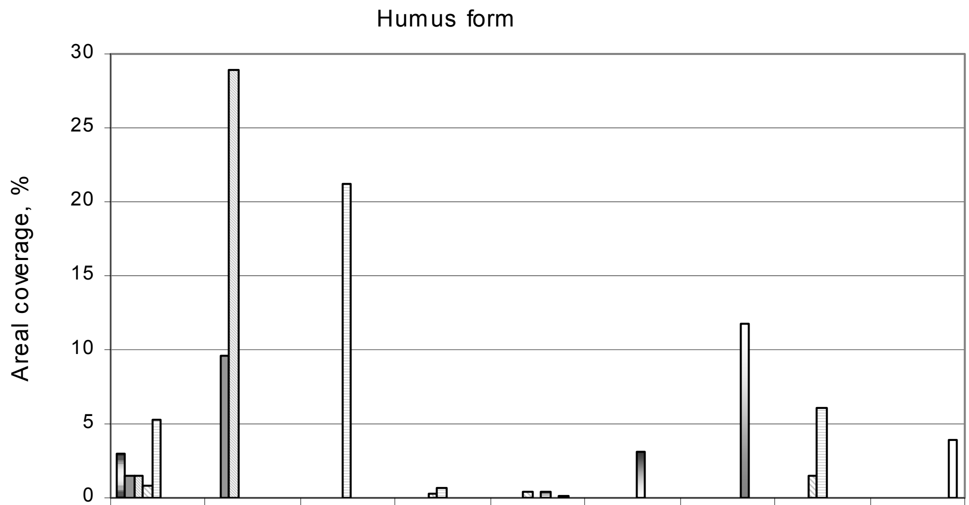


***Figure 4-13.** Humus form distribution for the Forsmark area and in comparison with conditions of four relevant Swedish areas.*

Table 4-17. Humus form frequencies of Forsmark area and four other parts of Sweden.

Class, %	Region				
	Sweden	Sweden-IV	Uppsala County	Östhammar	Forsmark
Humus missing	2.8	2.6	2.5	4.9	0.1
Mor-1	31.5	178.4	16.8	21.4	3.0
Mor-2	16.4	21.9	13.1	9.0	11.1
Moder	6.2	11.4	14.1	15.7	30.4
Mull-like moder	3.9	9.7	7.8	10.7	2.9
Mull	4.5	12.8	24.8	15.7	33.3
Peaty mor	6.7	5.8	5.3	5.7	3.5
Peat	15.9	10.7	19.1	12.0	11.8
Other	12.1	6.7	6.5	4.9	3.9

The distribution of humus forms on the map soil type classes shows dominating moder type in RG/GL type, mull in GL/CM type and, of course, peat in HI type (Figure 4-14).



	LP	RG/GL	GL/CM	RG	AR/GL	GL	HI	RG/GL-a	Non-classif.
Mor-1	3.0								
Mor-2	1.4	9.6							
Moder	1.4	28.9							
Mull-like moder	0.8			0.2	0.4			1.4	
Mull	5.2		21.3	0.7				6.1	
Peaty mor					0.4	3.1			
Peat							11.8		
Humus missing					0.1				
Non-classif.									3.9

Figure 4-14. *Soil parent material in the Forsmark area presented as distribution on GIS map soil classes.*

Soil type

Soils classified from a reduced WRB system /WRB, 1998/ includes eight types representing almost all soils to be found in Sweden, i.e.

- Histosols with a thick organic layer.
- Leptosols with thin soils on bedrock or skeletal soils with very high stone and boulder content.
- Gleysols with chemically reduced conditions in rather shallow soil layers and thereby limited amount of precipitated elements.
- Podzols with the typical bleached horizon and a Spodic B horizon with precipitated iron and aluminium.
- Umbrisols on fairly well drained sites with an organic topsoil layer and high content of organic matter in the top mineral soil with a clear structure.
- Cambisols with a humus form being a mull or mull-like moder, high content of organic matter in the mineral soil and very good structure in these layers.
- Arenosols on sand with weak development of soil layers.
- Regosols having immature soil profiles lacking most of the diagnostic horizons.

Ordinary Swedish forest soils include a large proportion of Podzols being overestimated in the Swedish classification system as compared to the international WRB system. In the Forsmark area with rather young soils, profile development is partly weak and Regosols are common (Figure 4-15 and Table 4-18).

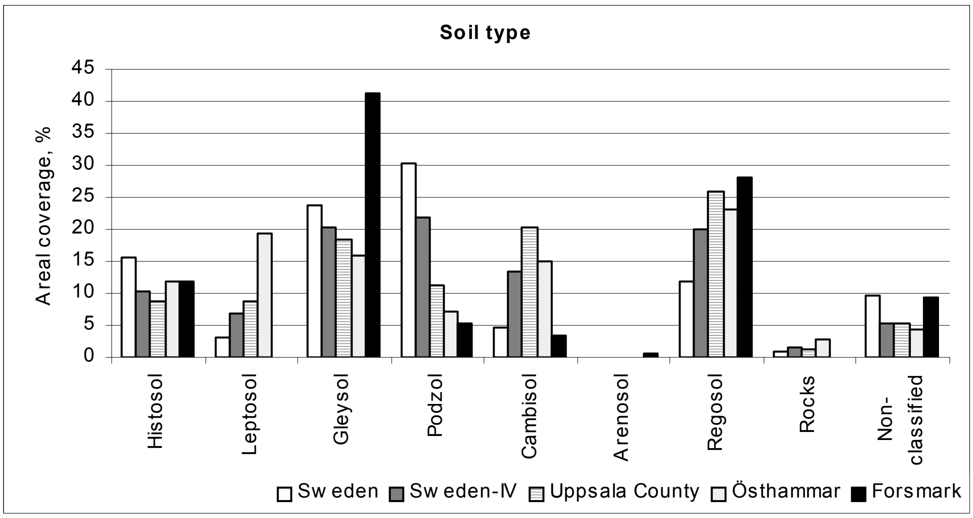


Figure 4-15. *Soil type distribution for the Forsmark area and in comparison with conditions of four relevant Swedish areas.*

Table 4-18. Soil type frequencies (%) of Forsmark area and four other parts of Sweden.

Class, %	Region				
	Sweden	Sweden-IV	Uppsala County	Östhammar	Forsmark
Histosol	15.6	10.2	8.7	12.0	11.8
Leptosol	3.1	7.0	8.8	19.5	0.0
Gleysol	23.8	20.3	18.5	15.9	41.2
Podzol	30.3	22.0	11.1	7.2	5.3
Cambisol	4.7	13.5	20.2	15.1	3.5
Arenosol					0.6
Regosol	11.9	20.0	26.0	23.1	28.2
Rocks	0.8	1.5	1.2	2.9	
Non-classified	9.8	5.4	5.5	4.3	9.4

There were also a variation of soil types within the investigated plots and for upland dry plots up to four classes were identified while in some moist and wet plots, there where only one soil type, e.g. peat types, HI with 100% Histosols (Figure 4-16).

The area distribution of soil types within the map soil classes (Figure 4-1) showed several types in the LP class, dominating Gleysols and Regosols, especially in RG/GL and GL/CM classes (Figure 4-17).

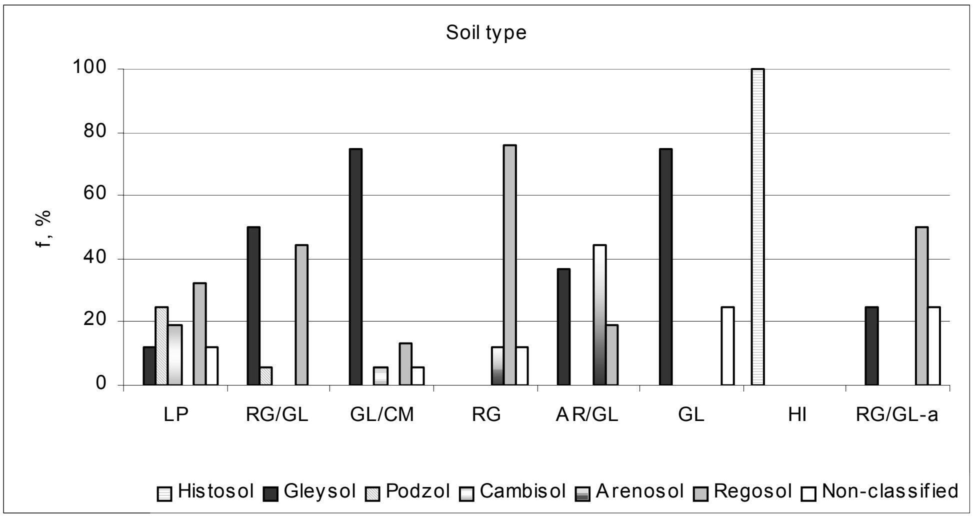
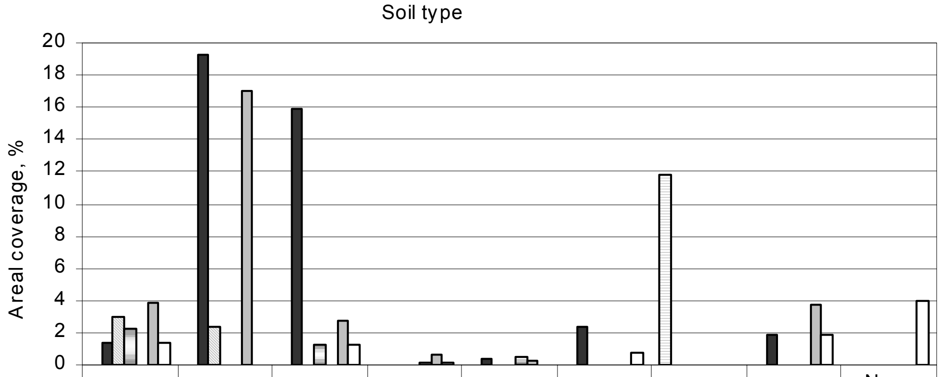


***Figure 4-16.** Distribution of soil types within and between the sites of the Forsmark area.*



	LP	RG/GL	GL/CM	RG	AR/GL	GL	HI	RG/GL-a	Non-classif.
Histosol							11.8		
Gleysol	1.4	19.3	15.9		0.4	2.3		1.9	
Podzol	3.0	2.3							
Cambisol	2.3		1.3						
Arenosol				0.1	0.4				
Regosol	3.8	17.0	2.8	0.7	0.2			3.8	
Non-classified	1.4		1.3	0.1		0.8		1.9	3.9

Figure 4-17. *Soil types spatial coverage (%) as distributed over the GIS map soil classes in the Forsmark area.*

Ground layer vegetation

The ground vegetation of the bottom layer was dominated by mesic mosses on most of the plots but with wet mosses, not being *Sphagnum* mosses on the wet plots (Figure 4-18 and Table 4-19).

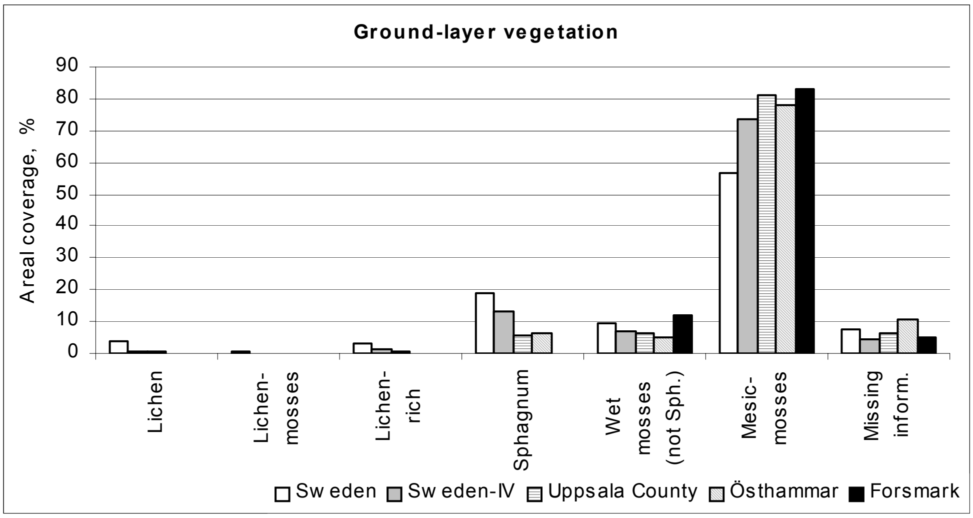


Figure 4-18. *Ground layer vegetation of the Forsmark area in comparison with relevant parts of Sweden. Parts of the missing information in Forsmark reflect no vegetation on the shoreline plots.*

Table 4-19. Ground vegetation distribution, %, on the Forsmark area plots. Missing data reflects no vegetation on the shoreline plots.

Class, %	Region				
	Sweden	Sweden-IV	Uppsala County	Östhammar	Forsmark
Lichen	3.6	0.7	0.4		
Lichen-mosses	0.4	0.2			
Lichen-rich	3.1	1.1	0.4		
Sphagnum	18.9	13.5	5.7	6.6	
Wet mosses (not *Sph.*)	9.4	6.6	6.2	4.9	11.8
Mesic-mosses	56.8	73.3	81.2	77.9	83.3
Missing inform.	7.7	4.6	6.0	10.7	4.9

The dominance of mesic mosses is in accordance with conditions in other parts of Sweden. For Forsmark area plots did not cover the driest parts resulting in absence of lichen types, however, these exist close to the bedrock outcrops. In wet sites, in Sweden, typical *Sphagnum* mosses, did not occur. Instead other *Bryophytes* existed there.

Field layer vegetation

The field layer vegetation in the Forsmark area was dominated by low herbs with bilberry shrubs, broad and narrow leafed grasses and, in an area with coniferous and deciduous forests, there were tall herbs and shrubs (Figure 4-19 and Table 4-20).

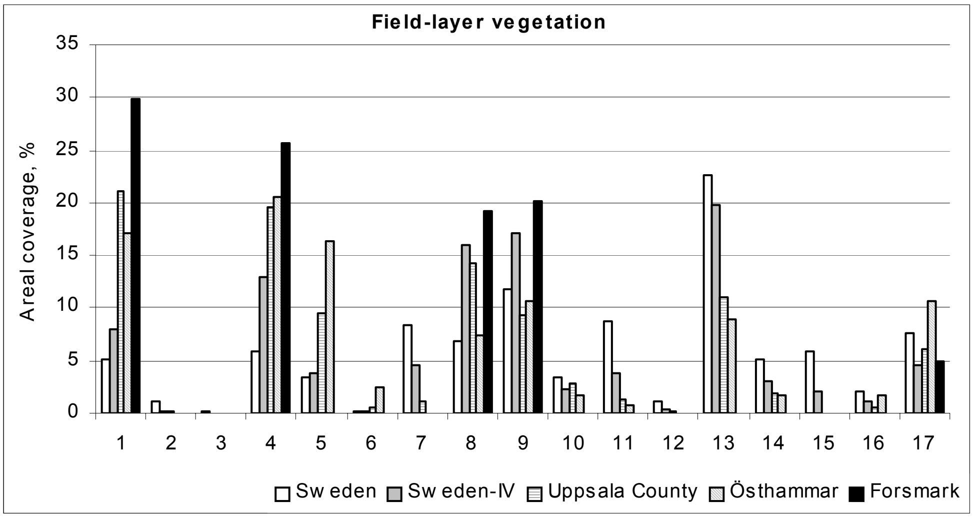


Figure 4-19. *Distribution of field layer vegetation types in the Forsmark area. Missing information is mainly no vegetation on the shoreline plots. The vegetation classes are defined in Table 4-20.*

Table 4-20. Field layer vegetation frequencies in the Forsmark area. Missing information is no vegetation on the shoreline plots.

Class, %	Region Sweden	Sweden-IV	Uppsala County	Östhammar	Forsmark
1. Tall herbs without shrubs	5.1	7.9	21.2	17.2	29.9
2. Tall herbs with shrubs/bilberry	1.1	0.2	0.2		
3. Tall herbs with shrubs/lingonberry	0.2	0.0			
4. Low herbs without shrubs	6.0	13.0	19.6	20.5	25.7
5. Low herbs with shrubs/bilberry	3.5	3.9	9.5	16.4	
6. Low herbs with shrubs/lingonberry	0.3	0.1	0.7	2.5	
7. Without field layer veg.	8.3	4.6	1.1		
8. Broad leafed grass	6.9	15.9	14.3	7.4	19.3
9. Narrow leafed grass	11.7	17.1	9.3	10.7	20.2
10. Tall sedge	3.5	2.3	2.9	1.6	
11. Low sedge	8.8	3.9	1.3	0.8	
12. Horse tail	1.0	0.3	0.2		
13. Bilberry	22.7	19.8	11.0	9.0	
14. Lingon-/whortle berry, marsh rosemary	5.0	3.0	2.0	1.6	
15. Crowberry/heather	5.9	2.1			
16. Poor shrubs	2.1	1.2	0.7	1.6	
17. Missing inform.	7.7	4.6	6.0	10.7	4.9

4.6 Soil chemistry

Soils of the Forsmark area were sampled on eight locations in the 16 plots constituting two replicates of eight plots. Determinations concerned pH, total C and total N.

Soil pH

The overall picture showed rather high pH values of 6 to 7 but in one site type pH values were lower, c 5. In the O-horizon the pH was on average 6.2 to be compared with pH between 4 and 5 for most parts of Sweden (Table 4-21). However, mor types and moder distributed on large parts of the area provide a picture of pH values between five and six (Figure 4-20). Discrepancies in presented pH values depend mainly on the change in inventory and sampling technique from the "Swedish Forest Soil Survey" to the modern international sampling made in this inventory. For the map, calculations on humus forms of mull and mull-like moder have been considered as mineral soil but in the "Soil survey" these horizons were considered as humus layers. Comparisons to the "Soil survey" had to include all humus forms. The distribution of pH values in the area showed high frequencies (62%) for pH over 6 (Figure 4-21 and Appendix VI–VIII).

Table 4-21. The Forsmark area plots pH values in the O-horizon in comparison with forest soils in four Swedish regions.

Survey area	Valid N	Average	Min	Max	Std	Cv, %
Sweden	6429	4.2	3.0	7.8	0.7	16.7
Sweden-IV	2662	4.2	3.1	7.3	0.7	16.7
Uppsala County	173	4.8	3.4	7.1	0.9	18.8
Östhammar	44	4.6	3.4	6.2	0.8	17.4
Forsmark (H 0–30)	68	6.2	3.8	7.8	1.1	17.7

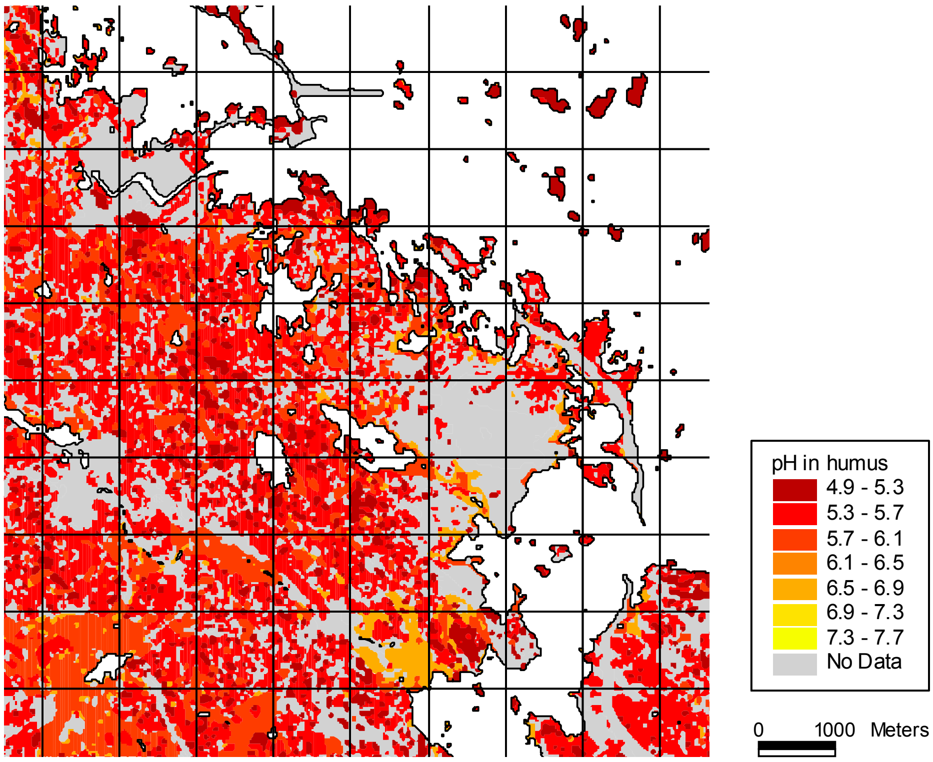


Figure 4-20*. Humus layer* pH_{H2O} *in the Forsmark area. The class "No Data" include unsampled areas and areas without humus layer.*

Also in the mineral soil, pH was fairly high with on average 6.5 in the upper 0–10 cm (Table 4-22) and a distribution with 80% of the locations having a pH over 5 (Figure 4-22 and 4-23 and Appendix VI–VIII).

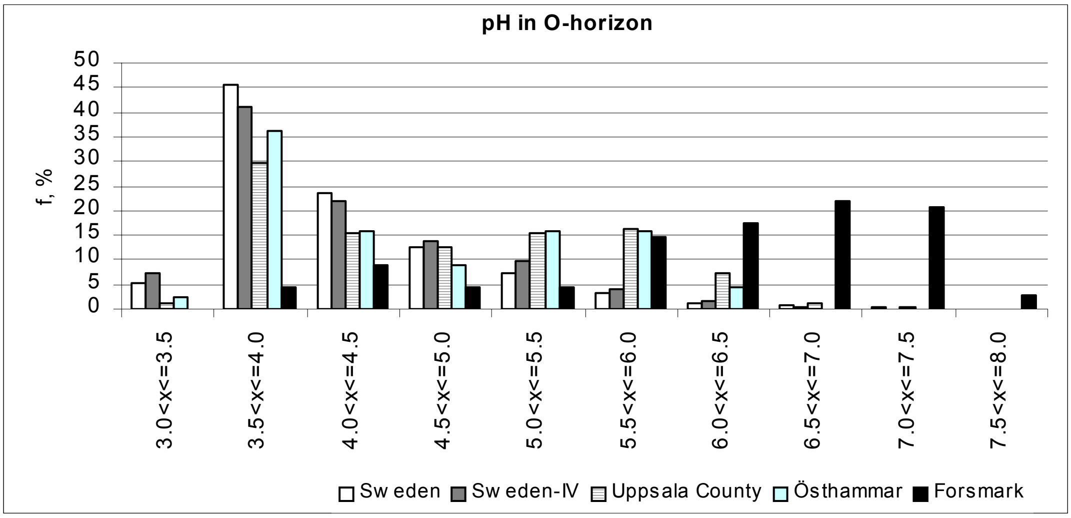


Figure 4-21. *Distribution of O-horizon pH (H_2O) in the Forsmark area and four regions of Sweden.*

Table 4-22. The Forsmark area plots pH values in the upper B-horizon in comparison with forest soils in four Swedish regions.

Survey area	Valid N	Average	Min	Max	Std	Cv, %
Sweden	1842	4.9	3.8	8.6	0.5	10.8
Sweden-IV	696	4.9	3.8	8.4	0.5	11.1
Uppsala County	48	5.4	4.1	8.4	0.9	16.5
Östhammar	12	5.4	4.1	6.7	0.9	17.0
Forsmark (M 0–10)	111	6.5	4.2	8.5	1.0	15.5

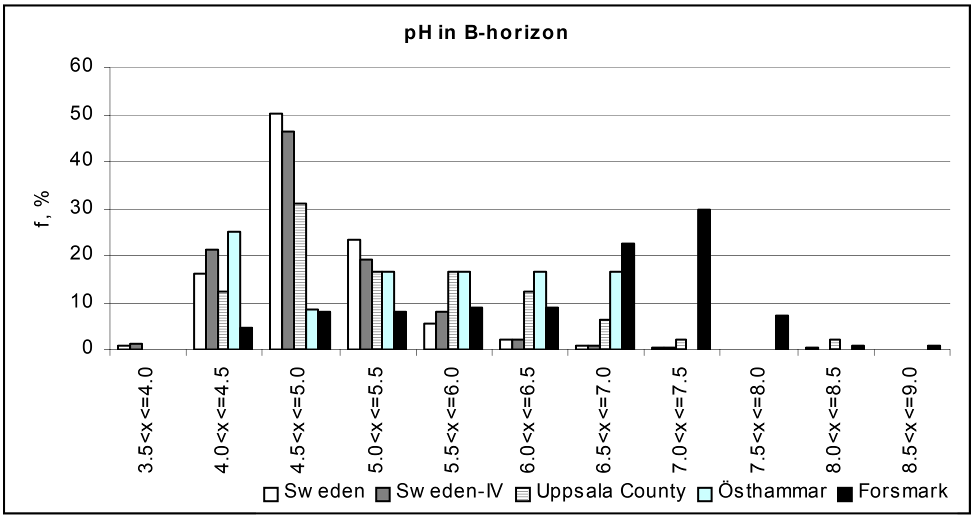


Figure 4-22. *Distribution of B-horizon pH (H_2O) in the Forsmark area and for forest soils in four regions of Sweden.*

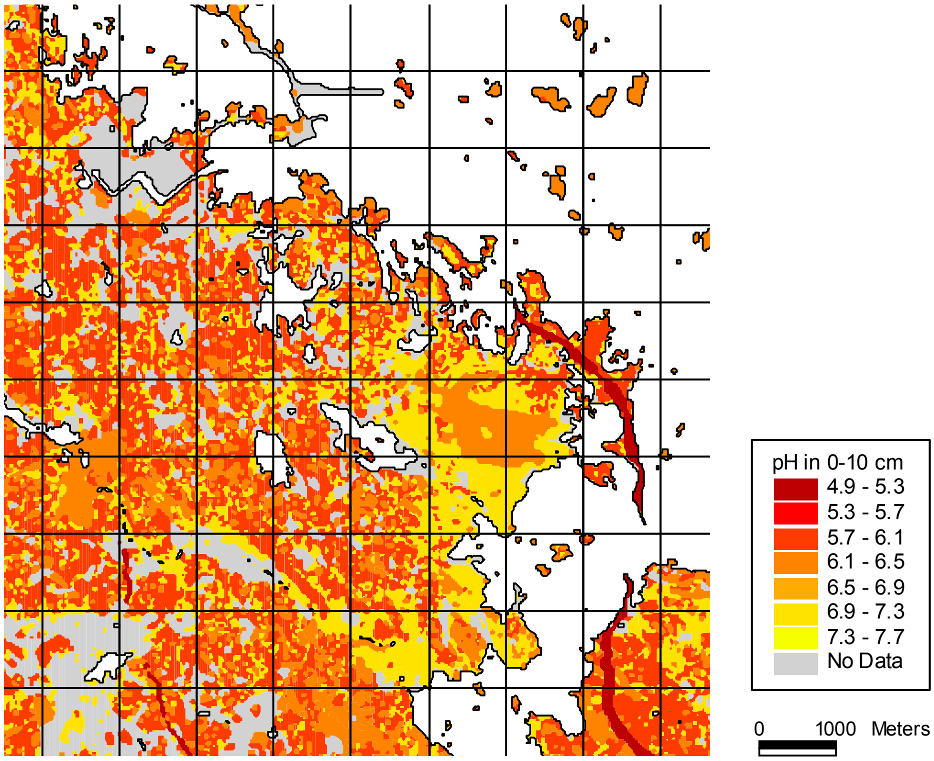


Figure 4-23. *Mineral soil (0–10 cm) pH values in the Forsmark area. The class "No Data" include non-sampled areas and areas with organic soils.*

In slightly deeper horizons (10–20 cm), pH was 6.7 on average (Table 4-23 and Figure 4-24) and similar distribution as in the topsoil (Figure 4-25 and Appendix VI–VIII). In the underlying C-horizon (55–65 cm), pH was even higher with on average 7.2 (Table 4-24 and Figure 4-26) and a distribution with 87% of locations over pH 6 while this value for Sweden would be 9% (Figure 4-27 and Appendix VI–VIII).

Table 4-23. The Forsmark area plots pH values in the B-horizon (10–20 cm) and comparison with forest soils in four Swedish regions.

Survey area	Valid N	Average	Min	Max	Std	Cv, %
Sweden	1842	4.9	3.8	8.6	0.5	10.8
Sweden-IV	696	4.9	3.8	8.4	0.5	11.1
Uppsala County	48	5.4	4.1	8.4	0.9	16.5
Östhammar	12	5.4	4.1	6.7	0.9	17.0
Forsmark (M 10–20)	110	6.7	4.5	8.7	0.8	11.9

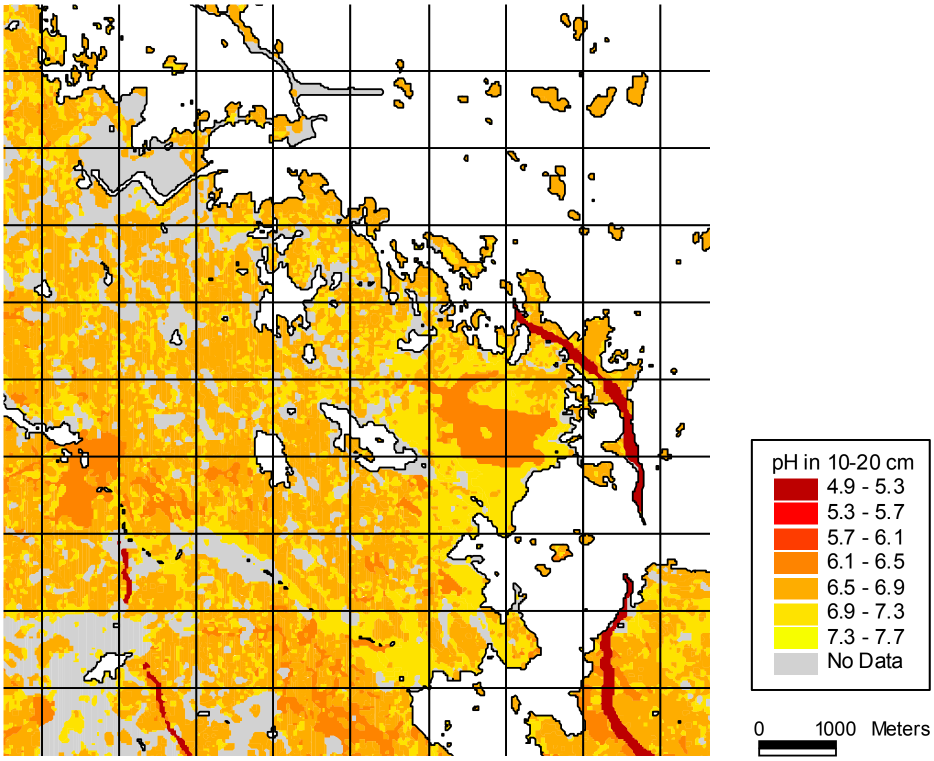


Figure 4-24. *Mineral soil pH in the 10–20 cm layer in the Forsmark area. The class "No Data" include not sampled areas and areas with organic soils.*

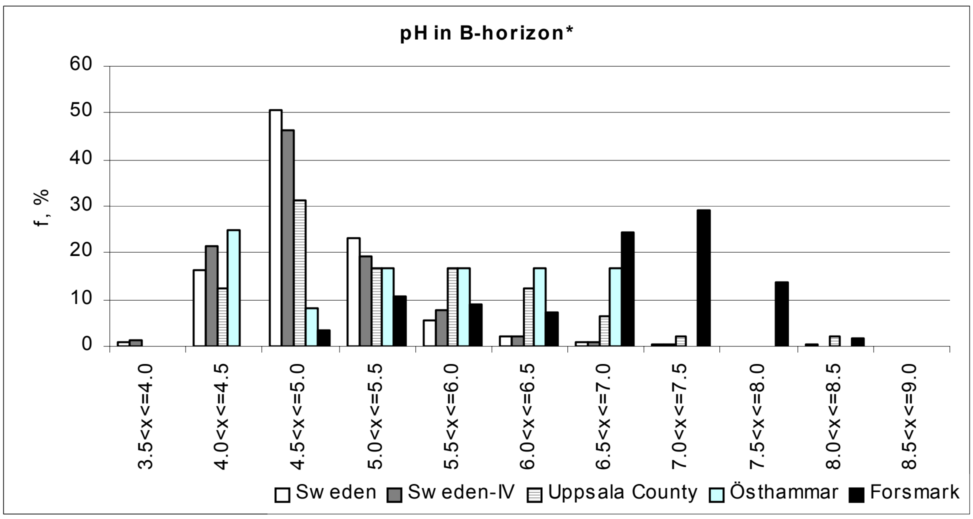


Figure 4-25. *Distribution of B-horizon pH (H_2O), 10–20 cm, in the Forsmark area and for forest soils in four regions of Sweden.*

Table 4-24. The Forsmark area plots pH values in the C-horizon and comparison with forest soils in four Swedish regions.

Survey area	Valid N	Average	Min	Max	Std	Cv, %
Sweden	1484	5.3	3.5	9.2	0.6	11.3
Sweden-IV	544	5.3	4.5	8.9	0.6	11.3
Uppsala County	33	6.3	4.7	8.9	1.1	17.5
Östhammar	7	6.4	4.7	8.1	1.2	18.8
Forsmark (M 55–65)	56	7.2	5.2	8.7	0.9	12.5

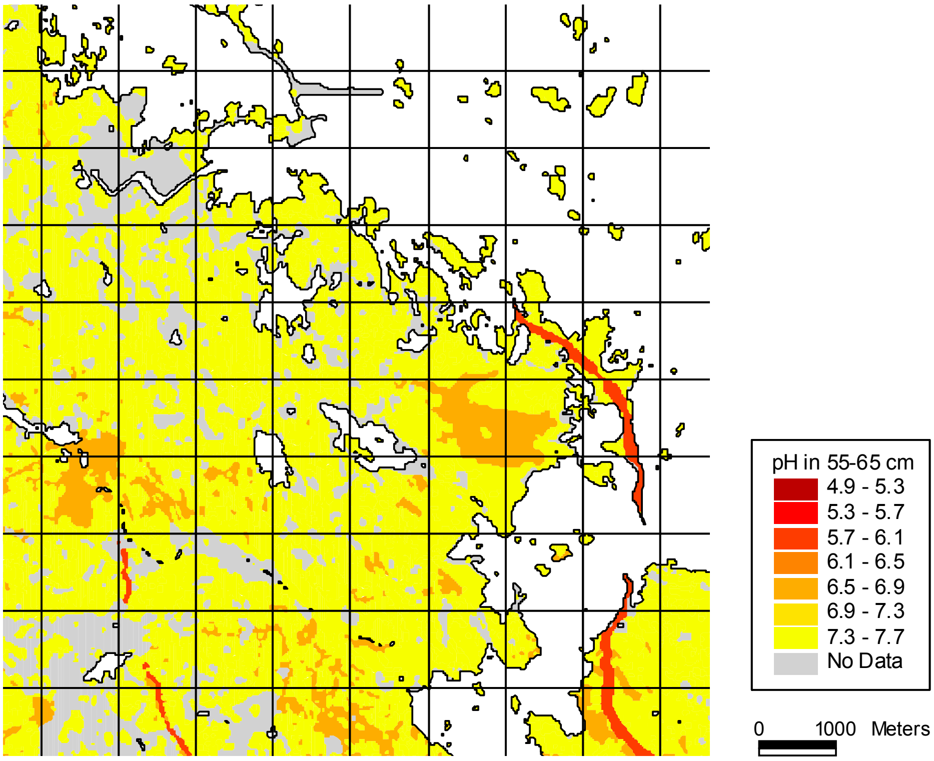


Figure 4-26. *Mineral soil pH in the 55–65 cm layer in the Forsmark area. The class "No Data" include not sampled areas and areas with organic soils.*

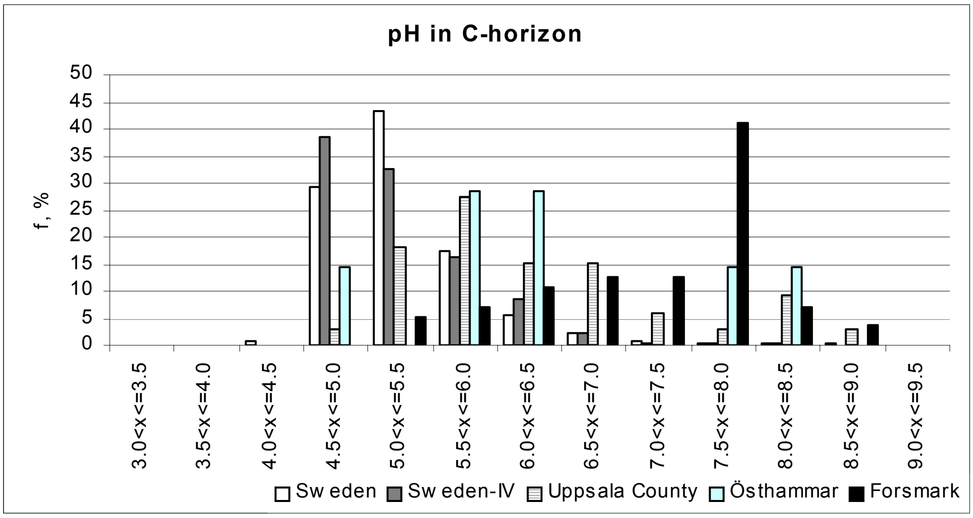
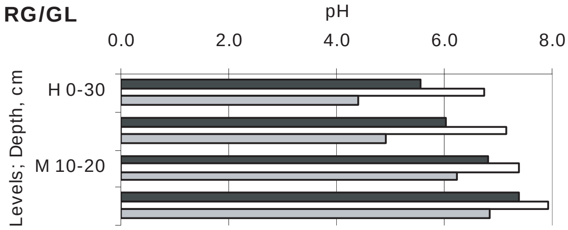
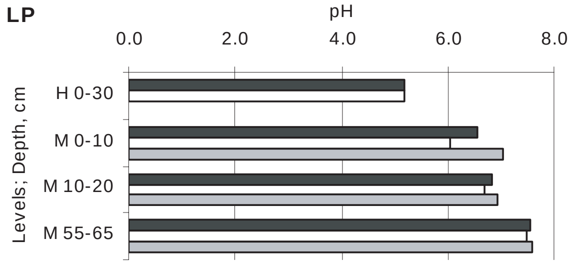


Figure 4-27. *Distribution of C-horizon pH (H_2O) in the Forsmark area and for forest soils in four regions of Sweden.*

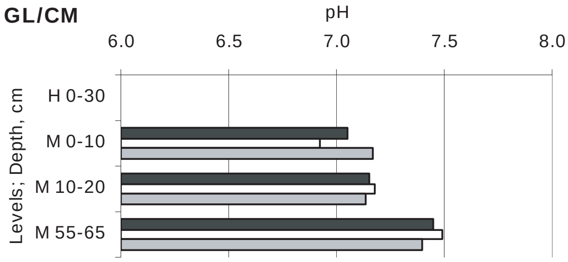
There could also be seen a stratification from upper soil layers with low pH to deeper layers with higher pH. This was most evident on fresh sites with mor layers while pH in moist soils and the young shoreline soils showed less stratification and mainly higher pH throughout the profile. In the peat plots the pH was c 6 with only small variations (Figure 4-28 and Appendix VII and VIII). However, the pH values in the peat soils in the region were considerably higher than the common pH in ordinary peat on salic soils where values around four are common. Mainly the replicates of site types were similar but with one exception on fresh to fresh moist soils with coniferous forests where the slightly drier site of the two showed somewhat lower pH values.



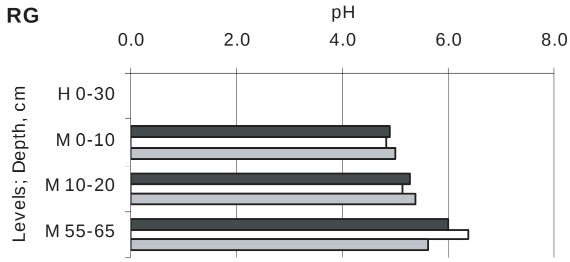
	M 55-65	M 10-20	M 0-10	H 0-30
FG	7.4	6.8	6.0	5.6
FG 1	7.9	7.4	7.2	6.7
FG 2	6.8	6.2	4.9	4.4



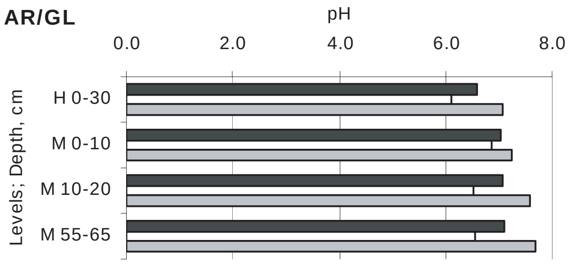
	M 55-65	M 10-20	M 0-10	H 0-30
B	7.5	6.8	6.5	5.2
B 2	7.5	6.7	6.0	5.2
B 3	7.6	7.0	7.0	



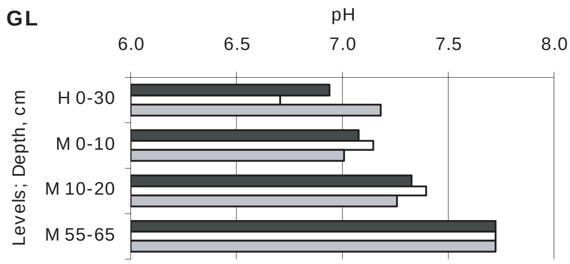
	M 55-65	M 10-20	M 0-10	H 0-30
FL	7.4	7.2	7.0	
FL 1	7.5	7.2	6.9	
FL 2	7.4	7.1	7.2	



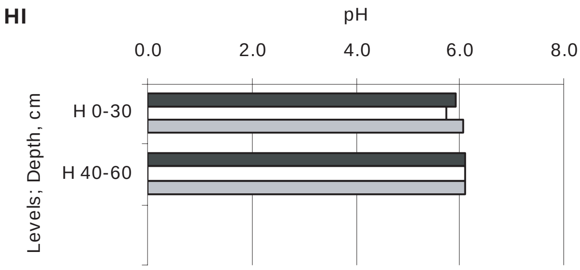
	M 55-65	M 10-20	M 0-10	H 0-30
R	6.0	5.3	4.9	
R 1	6.4	5.1	4.8	
R 2	5.6	5.4	5.0	



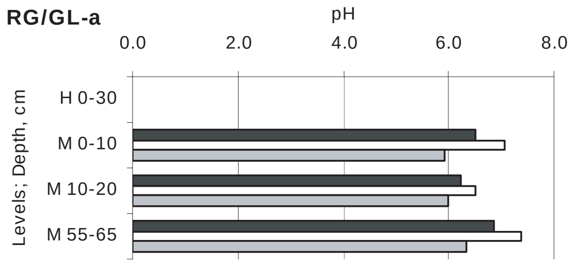
	M 55-65	M 10-20	M 0-10	H 0-30
S	7.1	7.1	7.1	6.6
S 1	6.6	6.5	6.9	6.1
S 2	7.7	7.6	7.2	7.1



	M 55-65	M 10-20	M 0-10	H 0-30
SS	7.7	7.3	7.1	6.9
SS 1	7.7	7.4	7.1	6.7
SS 2	7.7	7.3	7.0	7.2



		H 40-60	H 0-30
T		6.1	5.9
T 1		6.1	5.8
T 2		6.1	6.1



	M 55-65	M 10-20	M 0-10	H 0-30
A	6.9	6.2	6.5	
A 1	7.4	6.5	7.1	
A 2	6.3	6.0	5.9	

Figure 4-28. *The pH values in the Forsmark sites distributed on GIS soil map classes and depth. Black bar shows the mean value.*

Carbon

The carbon content in the humus layer is fairly similar to Swedish conditions with a concentration in the humus layer of 27.6% (Table 4-25 and Figure 4-29 and 4-30). Slightly higher concentrations were found in the mineral soil with 2.3–5.7% compared with c 2% in the B-horizon for Sweden (Table 4-26 and 4-27) and in the C-horizon 1.7% compared with 0.7% (Table 4-28).

Table 4-25. The Forsmark area plots carbon concentrations in the O-horizon and comparison with forest soils in four Swedish regions.

Survey area	Valid N	Average	Min	Max	Std	Cv, %
Sweden	5449	33.7	0.0	56.4	15.0	44.5
Sweden-IV	2345	26.1	0.0	56.4	18.4	70.5
Uppsala County	154	21.8	0.0	53.4	17.1	78.4
Östhammar	40	27.7	0.0	53.4	16.3	58.8
Forsmark (H 0–30)	69	27.6	1.7	49.1	14.1	51.1

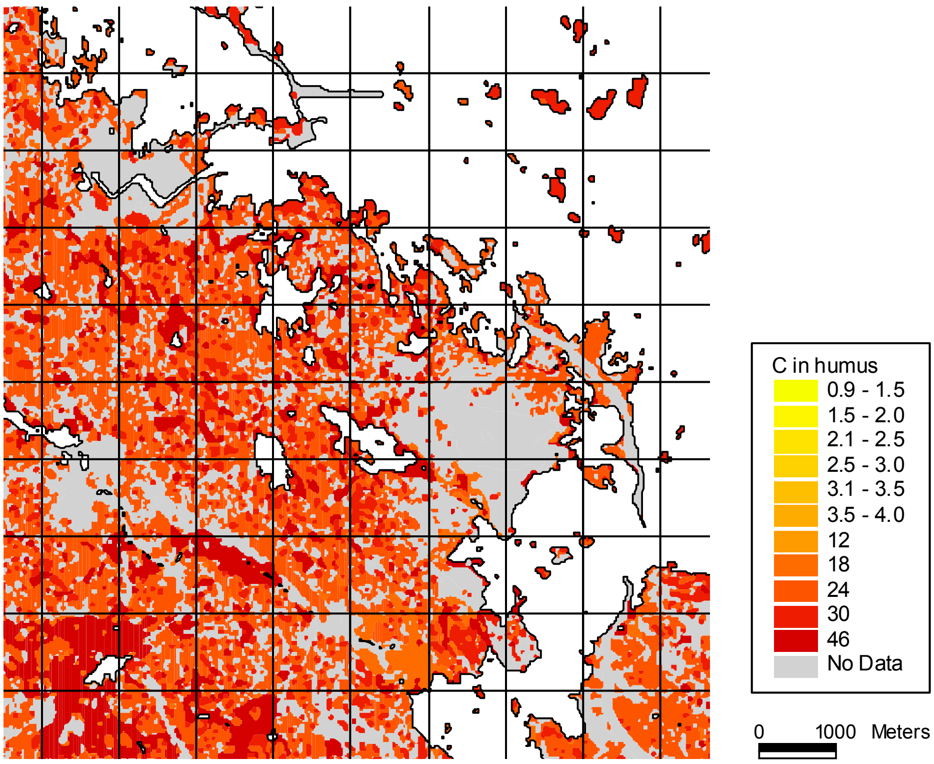


***Figure 4-29.** Soil carbon content (%) in the humus layer of the Forsmark area. The class "No Data" include not sampled areas and areas without humus layer.*

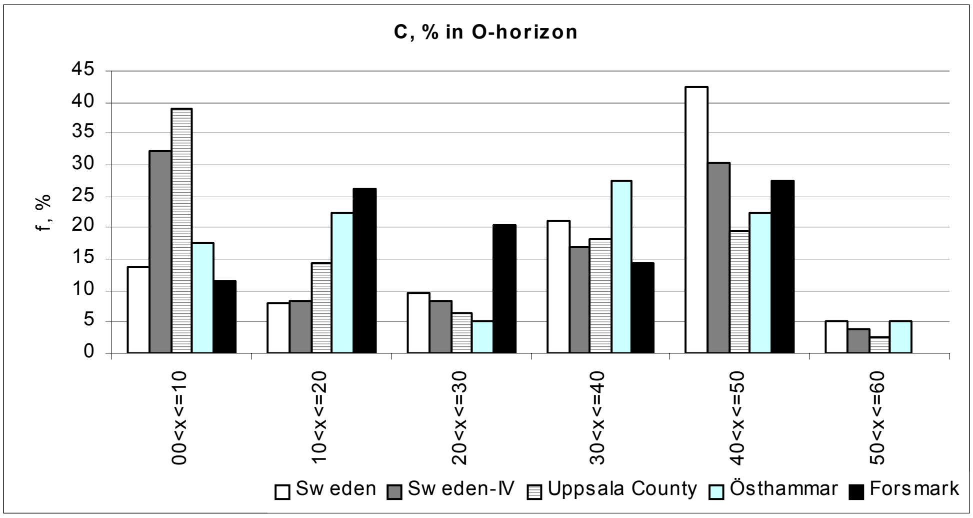


Figure 4-30. Distribution of carbon concentrations in the O-horizon in the Forsmark area and for forest soils in four regions of Sweden.

Table 4-26. The Forsmark area plots carbon concentrations in the upper B-horizon and comparison with forest soils in four Swedish regions.

Survey area	Valid N	Average	Min	Max	Std	Cv, %
Sweden	1509	2.3	0.0	42.8	2.0	87.0
Sweden-IV	588	2.0	0.0	16.3	1.9	95.0
Uppsala County	42	1.6	0.0	5.3	1.2	75.0
Östhammar	11	1.8	0.0	4.0	1.2	66.7
Forsmark (M 0–10)	110	5.1	0.1	24.0	4.7	92.2

Table 4-27. The Forsmark area plots carbon concentrations, (%) in the B-horizon (10–20 cm) and comparison with forest soils in four Swedish regions.

Survey area	Valid N	Average	Min	Max	Std	Cv, %
Sweden	1509	2.3	0.0	42.8	2.0	87.0
Sweden-IV	588	2.0	0.0	16.3	1.9	95.0
Uppsala County	42	1.6	0.0	5.3	1.2	75.0
Östhammar	11	1.8	0.0	4.0	1.2	66.7
Forsmark (M 10–20)	111	2.3	0.1	9.2	1.6	70.0

Table 4-28. The Forsmark area plots carbon concentrations (%) in the C-horizon and comparison with forest soils in four Swedish regions.

Survey area	Valid N	Average	Min	Max	Std	Cv, %
Sweden	1213	0.7	0.0	46.5	1.7	242.9
Sweden-IV	450	0.5	0.0	7.0	0.8	160.0
Uppsala County	28	0.9	0.0	6.0	1.2	133.3
Östhammar	7	1.4	0.2	6.0	2.1	150.0
Forsmark (M 55–65)	56	1.7	0.1	3.1	0.7	41.2

In the humus layer, the distributions of frequencies showed similar patterns with other regions (Figure 4-30 and Appendix IX). In the B-horizon there were larger frequencies for concentrations over 6% (Figure 4-31–4-34 and Appendix IX). In the C-horizon, carbon concentrations between 2% and 4% were higher than for other regions, probably dependent on $CaCO_3$ but apart from this the concentrations were rather low (Figure 4-35 and 4-36 and Appendix IX). The vertical stratification with depth was obvious even though $CaCO_3$ mitigated a pronounced pattern (Figure 4-37 and Appendix X).

The calcareous influence on the north Uppland soils is evident and partly this is reflected in increasing carbon content with depth in the mineral soil. Already, in the field determinations $CaCO_3$ was indicated on many locations. A small study on this revealed the influence of $CaCO_3$-C on the soil. Contents of 2–3% $CaCO_3$-C could make up the total carbon content and influenced the CN-ratio to be over 40, even as high as over 100 (e.g. 126). Further investigation and analysis on carbon content would be desired.

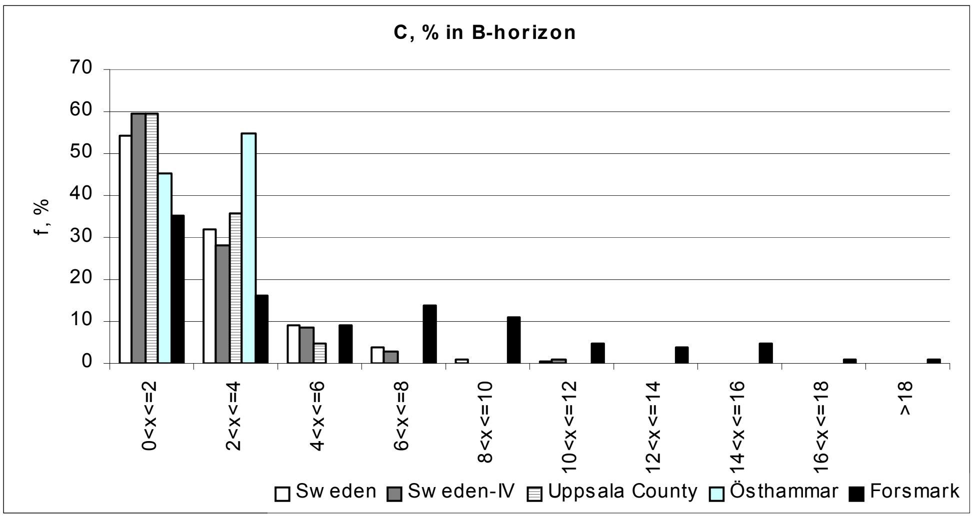


Figure 4-31. Distribution of carbon concentrations in the upper B-horizon in the Forsmark area and for forest soils in four regions of Sweden.

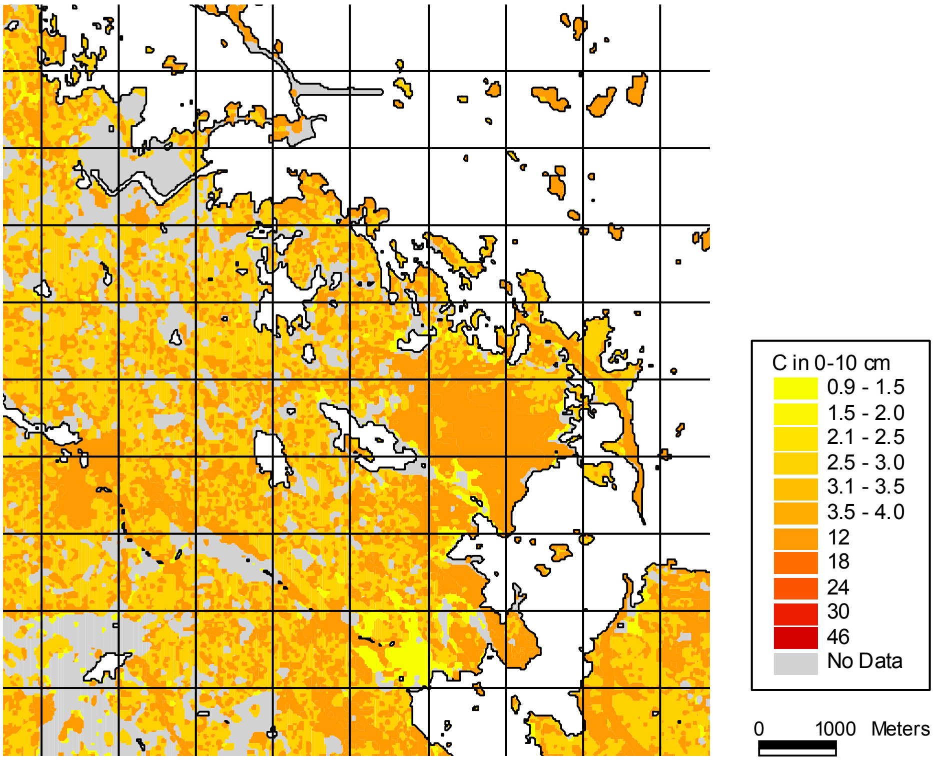


Figure 4-32. *Soil carbon content (%) in the 0–10 cm of the mineral soil layer of the Forsmark area. The class "No Data" include not sampled areas and areas with organic soils.*

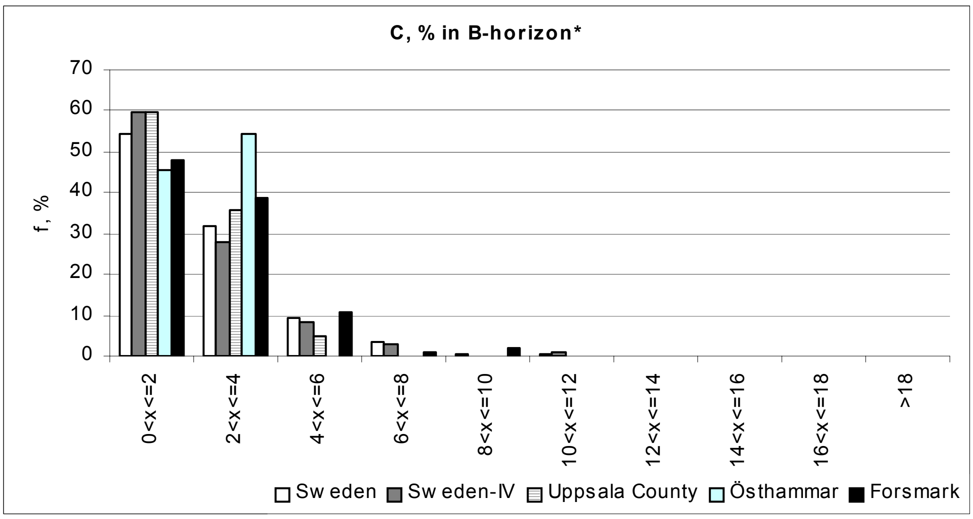


Figure 4-33. *Distribution of carbon concentrations in the B-horizon, 10–20 cm, in the Forsmark area and for forest soils in four regions of Sweden.*

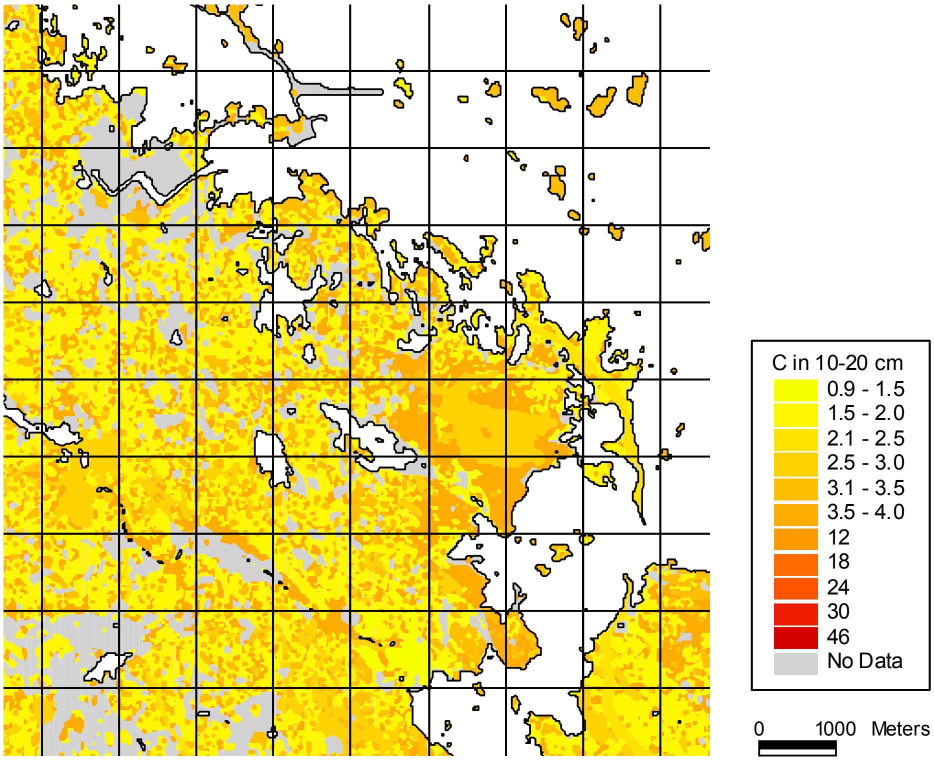


Figure 4-34. *Soil carbon content (%) in the in the 10–20 cm for the Forsmark area. The class "No Data" include not sampled areas and areas with organic soils.*

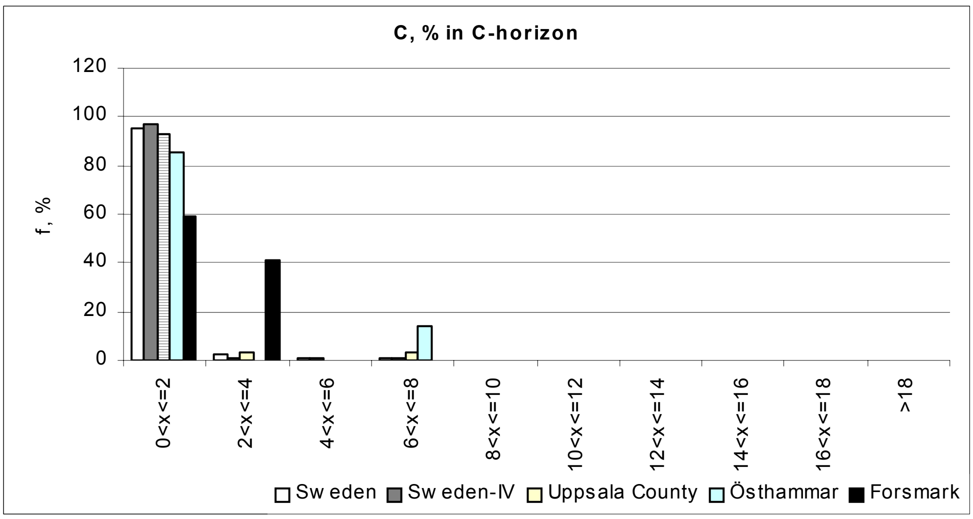


Figure 4-35. *Distribution of carbon concentrations in the C-horizon in the Forsmark area and for forest soils in four regions of Sweden.*

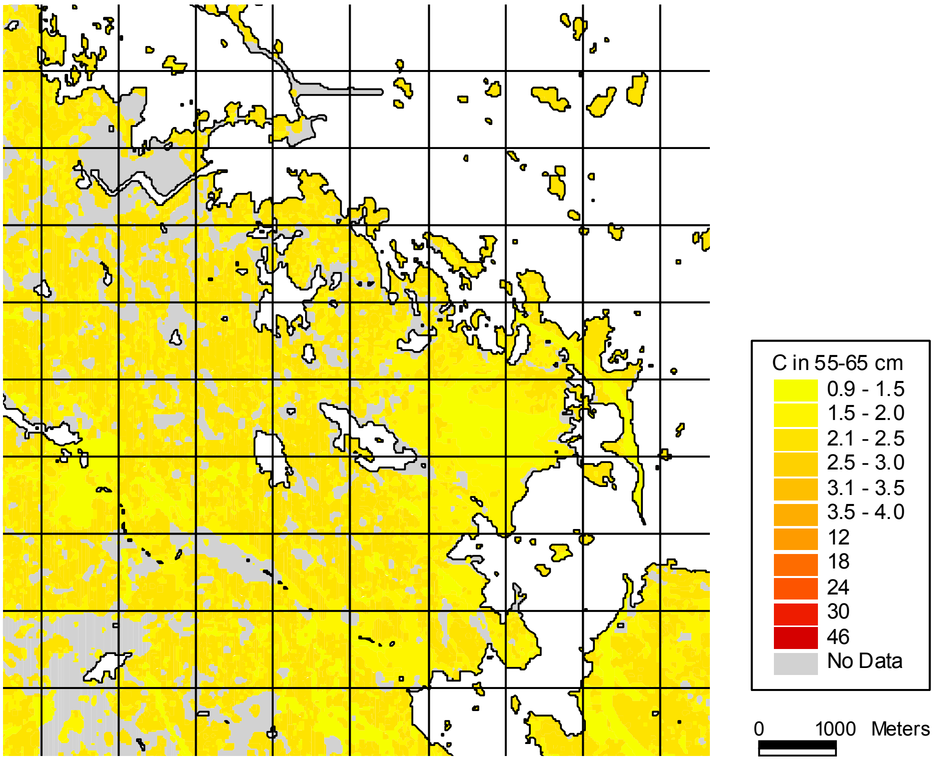
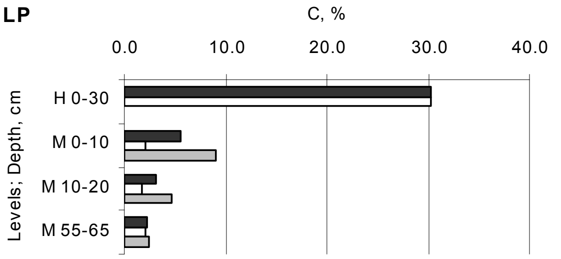


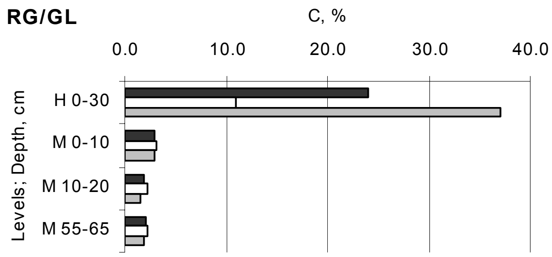
Figure 4-36. *Soil carbon content (%) in the C-horizon 55–65 cm for the Forsmark area. The class "No Data" include not sampled areas and areas with organic soils.*

The results from the analysis of calcium carbonate or limestone content are presented in Appendix IVd and the content could almost reach as high as 25% by weight of the material < 2 mm. In several investigations the distribution of limestone material from the Gulf of Gävle to the northeastern part of the province of Uppland has been discussed /Gillberg, 1967a,b; Ingmar and Moreborg, 1976; Palmqvist, 1989/. However, the investigations by Gillberg is attached with a systematic analytical error because the lime content is based on analyses of acid extactable calcium and not the carbonate content.

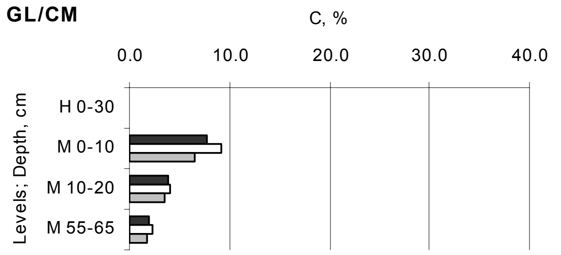
The influences from the sedimentary limestone area /Axberg, 1980/ to the north of Forsmark have resulted in considerably calcareous soils along the coastline but the lime content is gradually decreasing turning inlands. Looking in separate soil profiles it is evident that the original lime content of the till has been changed by leaching but the variation of lime by depth could also be a result of primary deposition by different ice movement directions or even by inclusions from calcareous glacial clay. The quite deep leaching resulting in a lime limit at 2 metres suggested by /Ingmar and Moreberg, 1976/ is not quite realistic according to the time during which the soils have been exposed to weathering. The results from the soil inventory also give evidences that the lime content is still left quite close to the soil surface. Stones and boulders lying on the surface of the ground also verify the occurrence of limestone material in the regolith.



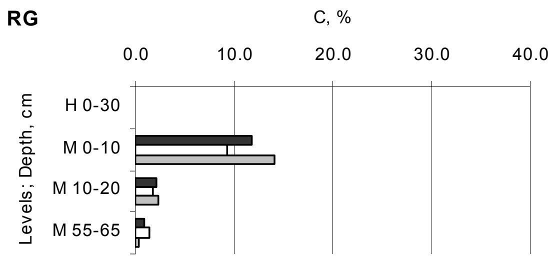
	M 55-65	M 10-20	M 0-10	H 0-30
B	2.3	3.2	5.6	30.2
B 2	2.1	1.7	2.0	30.2
B 3	2.5	4.7	9.1	



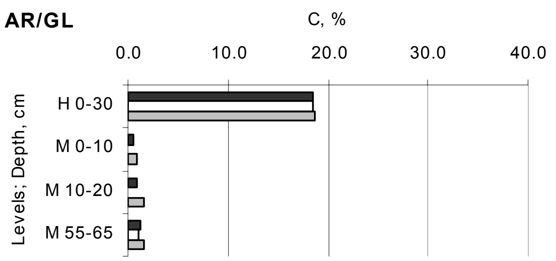
	M 55-65	M 10-20	M 0-10	H 0-30
FG	2.1	1.9	3.0	24.0
FG 1	2.3	2.3	3.1	10.9
FG 2	2.0	1.5	2.9	37.1



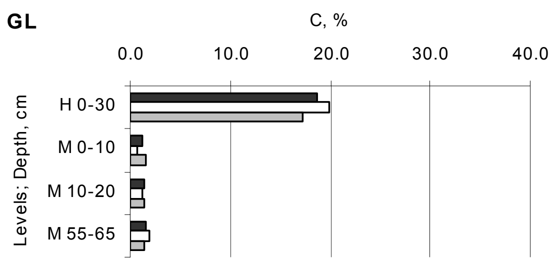
	M 55-65	M 10-20	M 0-10	H 0-30
FL	2.0	3.8	7.8	
FL 1	2.2	4.1	9.1	
FL 2	1.7	3.5	6.5	



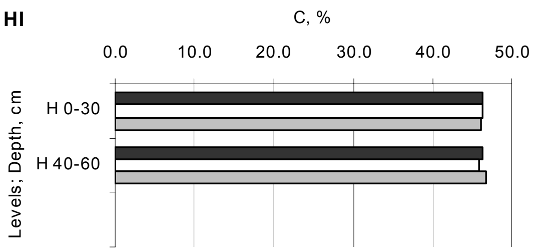
	M 55-65	M 10-20	M 0-10	H 0-30
R	0.9	2.1	11.8	
R 1	1.4	1.8	9.3	
R2	0.4	2.3	14.2	



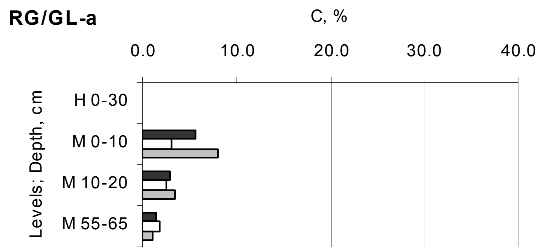
	M 55-65	M 10-20	M 0-10	H 0-30
S	1.3	0.9	0.5	18.5
S 1	1.0	0.2	0.2	18.4
S 2	1.7	1.5	0.8	18.6



	M 55-65	M 10-20	M 0-10	H 0-30
SS	1.6	1.4	1.2	18.6
SS1	1.9	1.3	0.7	19.9
SS 2	1.4	1.4	1.6	17.3



		H 40-60	H 0-30
T		46.3	46.2
T 1		46.0	46.4
T 2		46.7	46.1



	M 55-65	M 10-20	M 0-10	H 0-30
A	1.5	2.9	5.6	
A1	1.8	2.5	3.0	
A2	1.2	3.4	8.1	

Figure 4-37. *Carbon concentrations in the Forsmark sites distributed on GIS soil map classes and depth. Black bar shows the mean value.*

Nitrogen

The nitrogen content in the humus layer of the Forsmark area was fairly similar, perhaps somewhat low (1.3%) compared to main Swedish conditions (Table 4-29 and Figure 4-38 and 4-39). Also concerning the mineral soil layers concentrations were fairly similar but in the lower range (Tables 4-30 and 4-31 and Figure 4-40–4-43). Deviations were especially pronounced compared to region IV of Sweden and Uppsala County where nitrogen contents were higher.

The distribution of frequencies mainly showed low concentrations compared to other regions of Sweden with most values in the low range, however a strange bimodal distribution in the upper B-horizon (Figure 4-40 and Appendix XIa–d).

Spatial distribution of nitrogen over the Forsmark area was fairy even with comparably low values (Figure 4-44). The stratification with depth was though similar with values of 1.3% in the topsoil but only 0.4% in the C-horizon which was rather similar to common values for Sweden (Table 4-32 and Figure 4-45). One deviation with common values was in the upper B-horizon where the Forsmark area often showed fairly high values reflecting partly fertile soils. The peatland sites of course have high concentrations throughout the profile (Figure 4-45 and Appendix XII).

Table 4-29. The Forsmark area plots nitrogen concentrations (%) in the O-horizon and comparison with forest soils in four Swedish regions.

Survey area	Valid N	Average	Min	Max	Std	Cv, %
Sweden	5449	1.1	0.0	13.3	0.6	54.5
Sweden-IV	2345	5.1	0.0	55.2	11.8	231.4
Uppsala County	154	3.6	0.1	47.0	9.6	266.7
Östhammar	40	1.2	0.2	7.7	1.2	100.0
Forsmark (H 0–30)	69	1.3	0.2	2.4	0.5	38.5

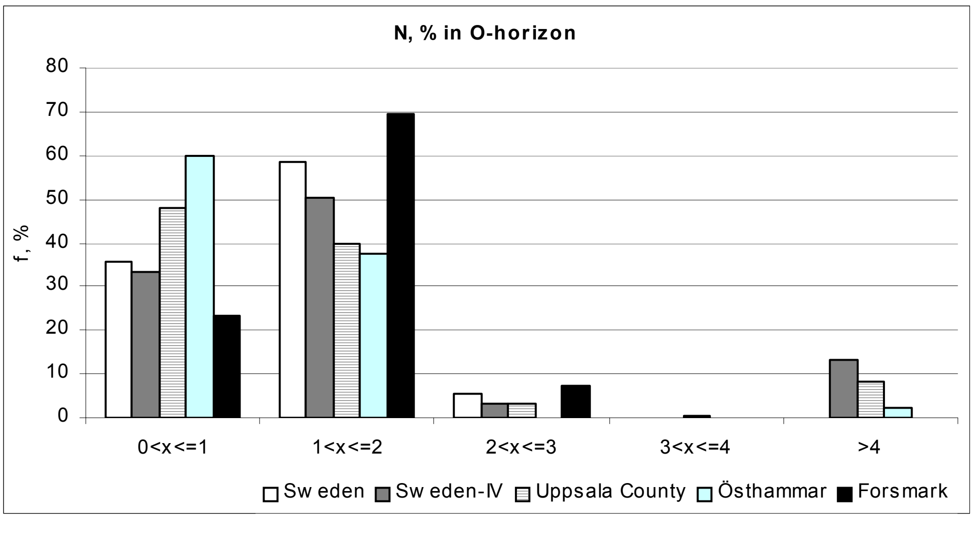


Figure 4-38. Distribution of nitrogen concentrations in the O-horizon in the Forsmark area and for forest soils in four regions of Sweden.

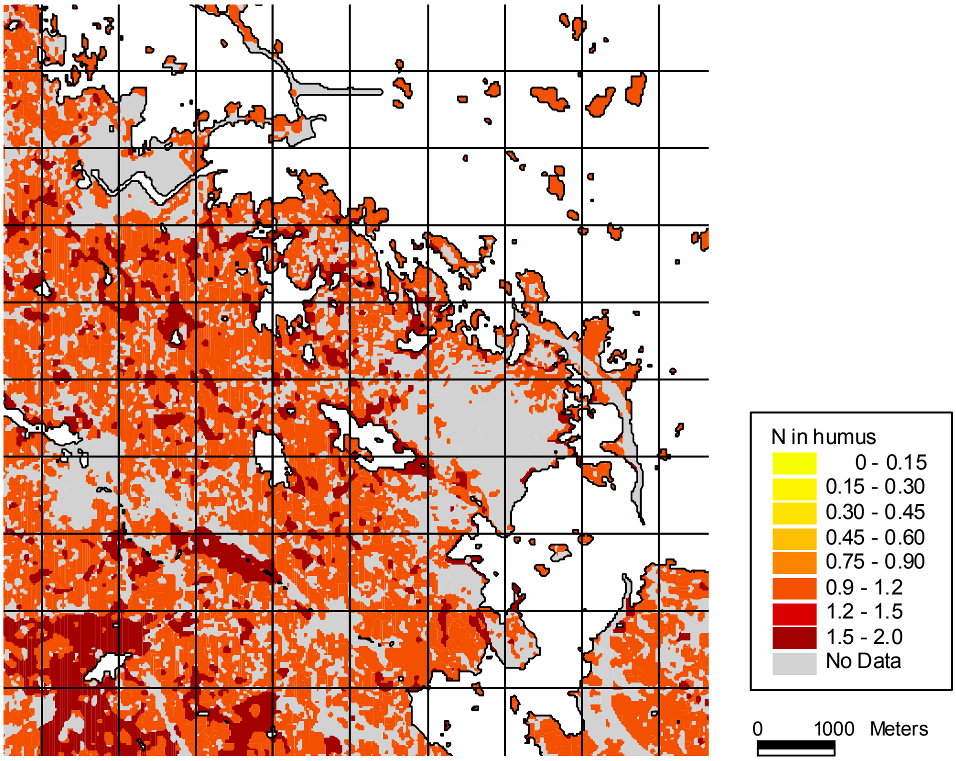


Figure 4-39. *Soil nitrogen content (%) in the humus layer in the Forsmark area. The class "No Data" include not sampled areas and areas without humus.*

Table 4-30. The Forsmark area plots nitrogen concentrations (%) in the upper B-horizon and comparison with forest soils in four Swedish regions. (Depths do not totally agree between the two inventories.)

Survey area	Valid N	Average	Min	Max	Std	Cv, %
Sweden	1509	0.1	0.0	1.5	0.1	100.0
Sweden-IV	589	0.5	0.0	18.1	1.5	300.0
Uppsala County	42	0.4	0.0	3.3	0.7	175.0
Östhammar	11	0.2	0.0	1.8	0.5	250.0
Forsmark (M 0–10)	110	0.3	0.0	1.2	0.3	100.0

Table 4-31. The Forsmark area plots nitrogen concentrations (%) in the B-horizon (10–20 cm) and comparison with forest soils in four Swedish regions. (Depths do not totally agree between the two inventories.)

Survey area	Valid N	Average	Min	Max	Std	Cv, %
Sweden	1509	0.1	0.0	1.5	0.1	100.0
Sweden-IV	589	0.5	0.0	18.1	1.5	300.0
Uppsala County	42	0.4	0.0	3.3	0.7	175.0
Östhammar	11	0.2	0.0	1.8	0.5	250.0
Forsmark (M 10–20)	111	0.2	0.0	0.6	0.1	50.0

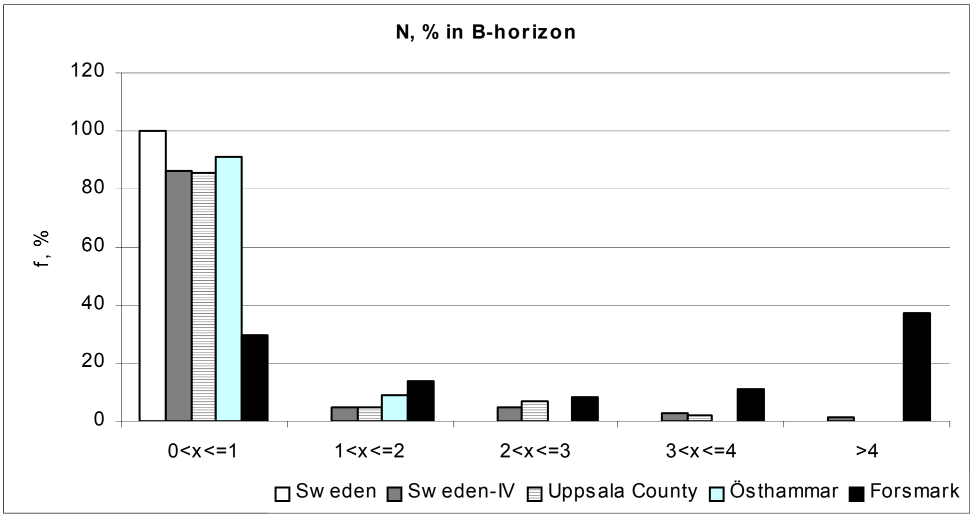


Figure 4-40. *Distribution of nitrogen concentrations in the upper B-horizon in the Forsmark area and for forest soils in four regions of Sweden.*

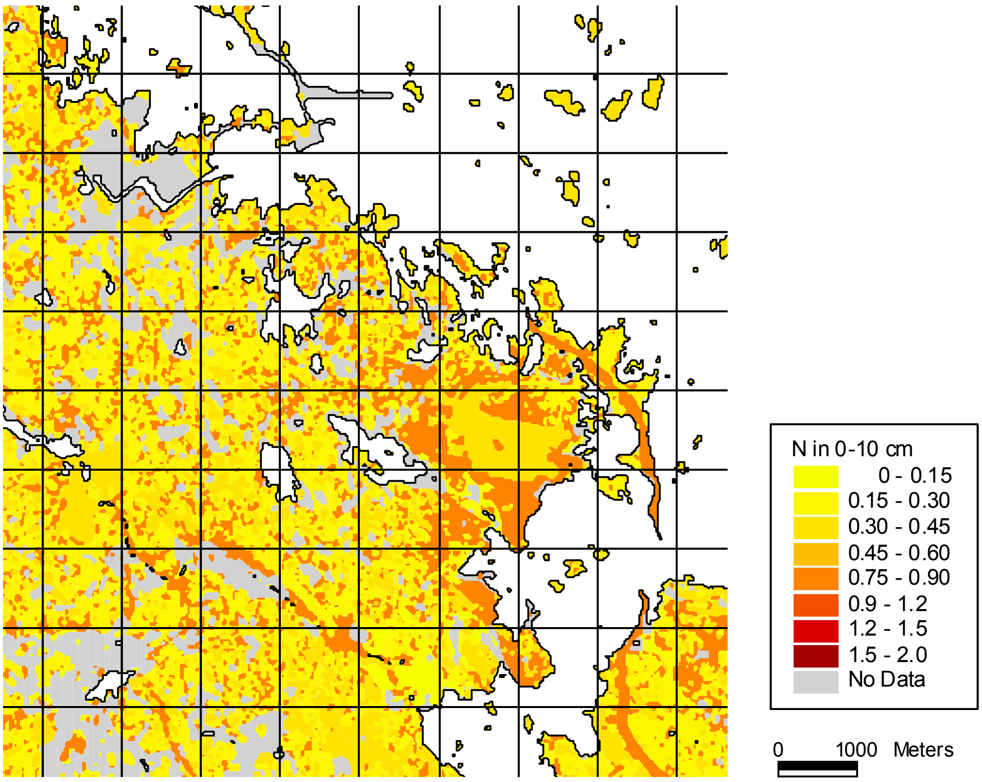


Figure 4-41. *Soil nitrogen content (%) in the 0–10 cm of the mineral soil in the Forsmark area. The class "No Data" include not sampled areas and areas with organic soils.*

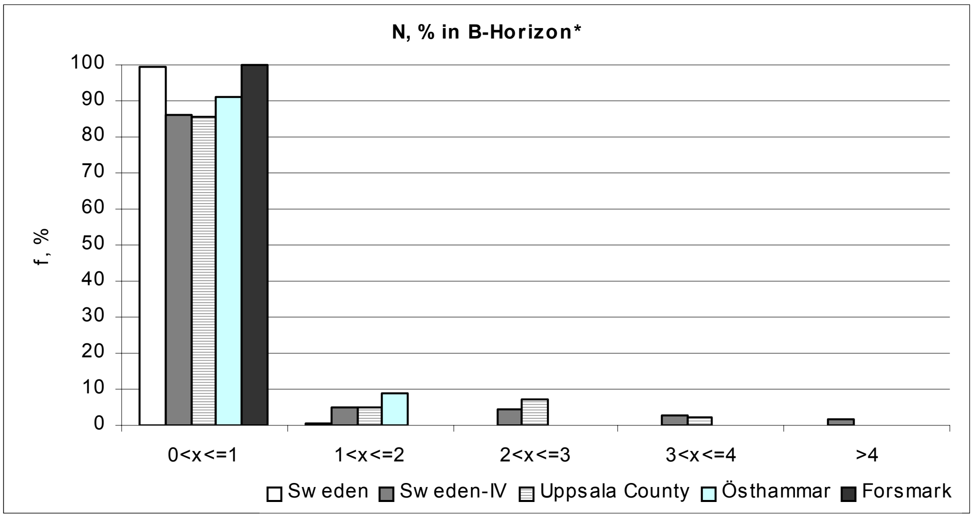


Figure 4-42. *Distribution of nitrogen concentrations in the B-horizon, 10–20 cm, in the Forsmark area and for forest soils in four regions of Sweden.*

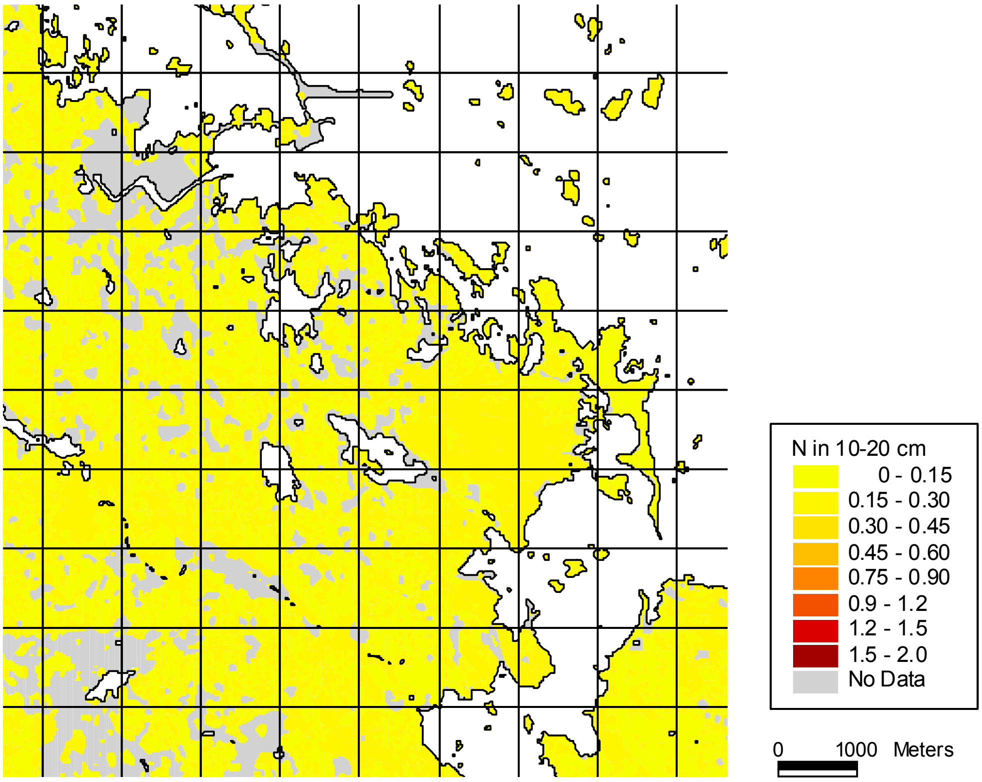


Figure 4-43. *Soil nitrogen content (%) in the B-horizon 10–20 cm of the mineral soil in the Forsmark area. The class "No Data" include not sampled areas and areas with organic soils.*

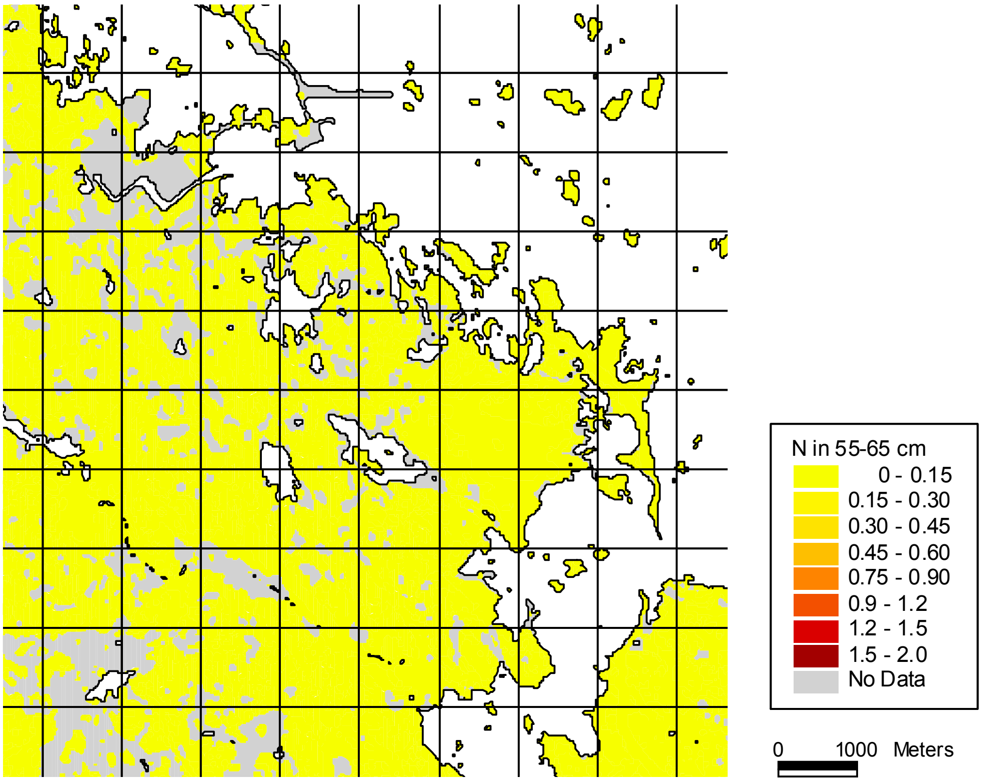
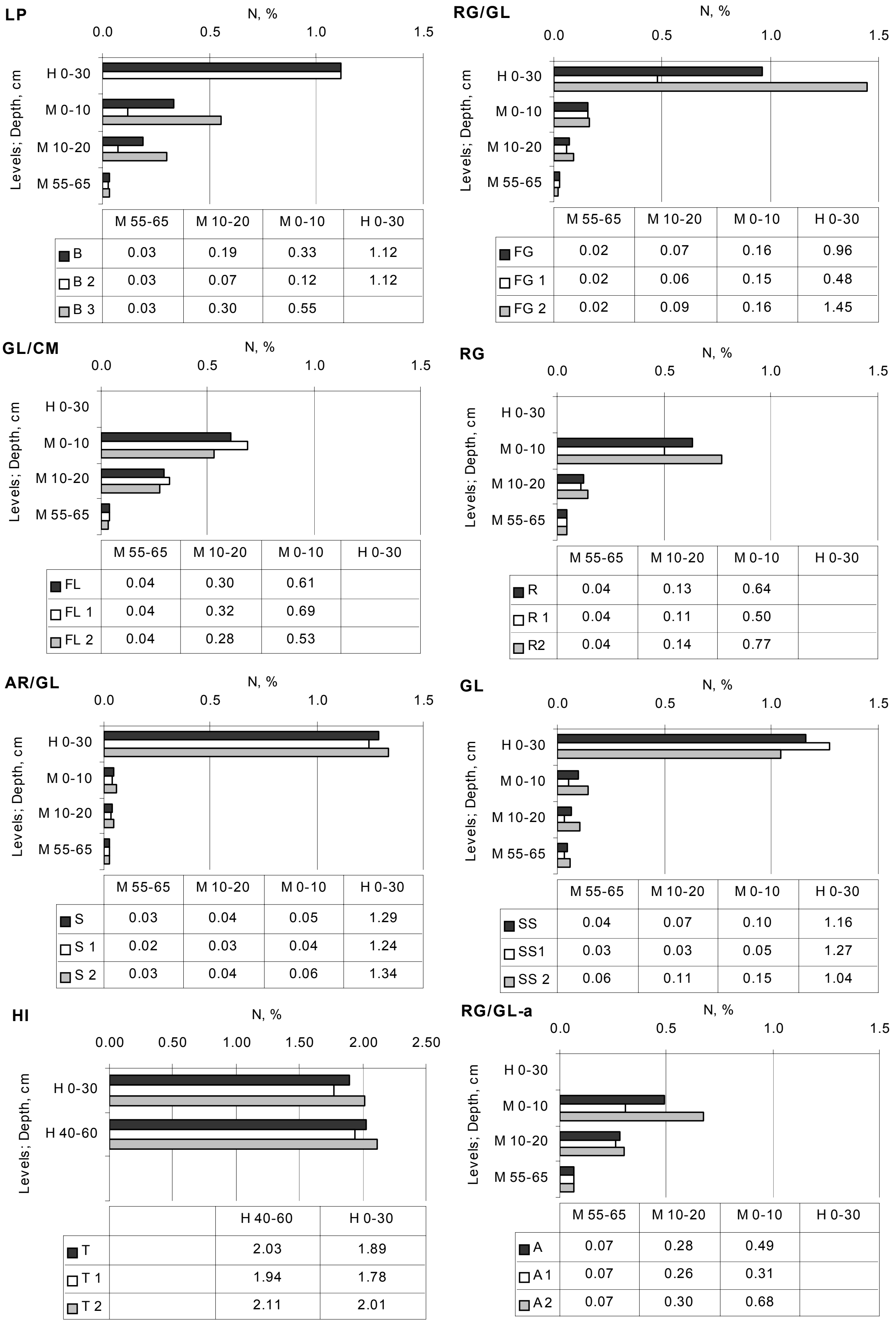


Figure 4-44. Soil nitrogen content (%) in the C-horizon at the 55–65 cm of the mineral soil in the Forsmark area. The class "No Data" include not sampled areas and areas with organic soils.

Table 4-32. The Forsmark area plots nitrogen concentrations (%) in the C-horizon and comparison with forest soils in four Swedish regions.

Survey area	Valid N	Average	Min	Max	Std	Cv, %
Sweden	1213	0.04	0.00	2.00	0.11	275.0
Sweden-IV	451	0.12	0.00	2.21	0.26	216.7
Uppsala County	28	0.07	0.02	0.29	0.07	100.0
Östhammar	7	0.06	0.02	0.29	0.10	166.7
Forsmark (M 55–65)	56	0.04	0.01	0.10	0.02	50.0



LP

	M 55-65	M 10-20	M 0-10	H 0-30
B	0.03	0.19	0.33	1.12
B 2	0.03	0.07	0.12	1.12
B 3	0.03	0.30	0.55	

RG/GL

	M 55-65	M 10-20	M 0-10	H 0-30
FG	0.02	0.07	0.16	0.96
FG 1	0.02	0.06	0.15	0.48
FG 2	0.02	0.09	0.16	1.45

GL/CM

	M 55-65	M 10-20	M 0-10	H 0-30
FL	0.04	0.30	0.61	
FL 1	0.04	0.32	0.69	
FL 2	0.04	0.28	0.53	

RG

	M 55-65	M 10-20	M 0-10	H 0-30
R	0.04	0.13	0.64	
R 1	0.04	0.11	0.50	
R2	0.04	0.14	0.77	

AR/GL

	M 55-65	M 10-20	M 0-10	H 0-30
S	0.03	0.04	0.05	1.29
S 1	0.02	0.03	0.04	1.24
S 2	0.03	0.04	0.06	1.34

GL

	M 55-65	M 10-20	M 0-10	H 0-30
SS	0.04	0.07	0.10	1.16
SS1	0.03	0.03	0.05	1.27
SS 2	0.06	0.11	0.15	1.04

HI

		H 40-60	H 0-30
T		2.03	1.89
T 1		1.94	1.78
T 2		2.11	2.01

RG/GL-a

	M 55-65	M 10-20	M 0-10	H 0-30
A	0.07	0.28	0.49	
A 1	0.07	0.26	0.31	
A 2	0.07	0.30	0.68	

Figure 4-45. *Nitrogen concentrations in the Forsmark sites distributed on GIS soil map classes and depth. Black bar shows the mean value.*

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Appendix I

Batch script for soil classes

```
/**************************************************************************
/* Batch run to create soil map for the Forsmark area for nuclear waste
/* storage. The input file are raster files for vegetation (tree, field
/* and ground), quarternary deposit (jord2), and TOPMODEL topographic
/* index (twi_ed). The rasters were created with 10 meter cell size from
/* vector files.
/*
/* The batch file will execute in Arc/Info GRID.
/**************************************************************************

/***** 1. HI, Peatland

torv_1 = con(ground in {21,22},1)
torv_2 = con(field eq 23 and ground in {24,25},1)
torv_jord1 = con(jord2 eq 75 and slope_ed lt 75,1)

t_1 = merge(torv_jord1,torv_1,torv_2)

kill torv_1 all
kill torv_2 all
kill torv_jord1 all


/***** 2. GL, Gleysol

ss_1 = con(ground in {24,25} and jord2 ne 75 and field ne 23,2)


/***** 3. GL/CM, Gleysol/Cambisol

tmpjord1 = con(jord2 in {94,96},1,0)
tmpjord2 = con(isnull (tmpjord1), 0, tmpjord1)
tmpveg1 = con(ground eq 12 and field ne 12 and tree in {1,2,11,12,17,22,30} and twi_ed ge
8,3)
tmpveg2 = con(ground eq 12 and field in {15,16} and tree in {21,23,26}, 3)
tmpveg3 = con(ground eq 12 and field ne 12 and tree in {1,2,11,12,17,22,30} and tmpjord2 eq
1,3)

fl_1 = merge(tmpveg1,tmpveg2,tmpveg3)


/***** 4. RG/GL, Regosol/Gleysol

tmpjord1 = con(jord2 in {94,96},1,0)
tmpjord2 = con(isnull (tmpjord1), 0, tmpjord1)
tmpveg1 = con(ground eq 12 and field ne 12 and tree in {1,2,11,12,17,22,30}
          and twi_ed lt 8 and tmpjord2 eq 0,4)
tmpveg2 = con(ground eq 12 and field in {15,16} and tree in {13,14}, 4)

fg_1 = merge(tmpveg1,tmpveg2)
```

```
/***** 5. RG/GL-a, Regosol/Gleysol, arable land

a_1 = con(ground in {31,32},5)


/***** 6. AR/GL, Arenosol/Gleysol

tmp1 = expand(field, 1, list, 100)
s_1 = con(tmp1 eq 100 and field <> 100 and dst_to_sea lt 20 and ground ne 41,6)


/***** 7. RG, Regosol (esker)

r_1 = con(jord2 in {50,56} and field ne 100, 7)


/***** 8. LP, Leptosol

tmpveg1 = con(combv2.value in {3,2},8)
tmpjord1 = con(jord2 eq 890, 8)

b_1 = merge(tmpjord1,tmpveg1)


/***** 0. Unclassified

o_1 = con(field ne 100,0)


/***** Merge layers into final map, soil_forsm, and
/***** assign code 99 to water:

tmp1 = merge(b_1,t_1,s_1,r_1,ss_1,fl_1,fg_1,a_1,o_1)

soil_forsm = con(isnull(tmp1),99,tmp1)
```

The class code definitions for the vegetation data (tree, field and ground layer) and for quaternary deposits

Class code	Tree layer
0	Outside mapping area
1	No tree-layer (< 30 % crown coverage) within forest land
2	No tree-layer (< 30 % crown coverage) outside forest land
11	Old spruce
12	Young spruce
13	Old pine
14	Young pine
17	Unspecified young conifer
21	Birch
22	Young birch (thicket on clear-cut)
23	Aspen (one area, manually edited)
26	Ash
30	Mixed forest
100	Water

Class code	Field layer
0	Outside mapping area
1	No field layer - forest land
2	No field layer - other land
4	Arable land (according to T5)
12	Dry heath type
15	Herb type
16	Herb-heath type
20	Sedge-heath type
22	Sedge-herb type
23	Sedge-reed type
25	Wet herb type
100	Water

Class code	Ground layer
0	Outside mapping area
12	Moss type (Forest)
21	Peatland - Sphagnum type (Wetland)
22	Peatland other (Wetland)
24	Not peatland - moss type (Wetland)
25	Not peatland - other (Wetland)
31	Arable land (Other)
32	Moss type (pastures and meadow) (Other)
41	Built-up areas, pits etc. (Other)
42	Coastal bare rocks (Other)
100	Water (Other)

Class code	Quaternary deposit
200	Filling material, unclassified
49	Glacial course silt
40	Glacial clay, non-specified
46	Glacial silt, layered with clay
6	Gyttja
50	Glacifluvial sediment, course silt – boulders
56	Glacifluvial sediment, sand – course sand
14	Unclassified
16	Clayey gyttja -
94	Till, clayey sandy
96	Till, clayey sandy – silty
95	Till, sandy
97	Till, sandy – silty
28	Postglacial fine sand
25	Postglacial course sand
17	Postglacial clay, unspecified
29	Postglacial sand – course sand
32	Postglacial gravel
34	Washed sediment, stones – boulders
75	Peat
890	Bedrock
91	Water

Properties of the site types in the Forsmark area

Appendix IIIa. Properties of the site types in the Forsmark area: Map and sample ID, positions, soil types, soil parent material, humus form and soil wetness.

Map ID	ID	Altit., m a.s.l.	X-position	Y-position	Number of smaples	Soil type	Soil parent material	Humus form	Soil wetness
LP	**B 2**	5	6698777	1633163	8	Podzol-50%; Gleysol-25%; Regosol-25%	Till-100%	Mor -1-50%; Mor -2-25%; Moder-25%	Fresh-100%
	B 3	7	6697808	1634653	8	Cambisol-38%; Regosol-38%; Non-classified-24%	Till-88%; Well sorted sediment-12%	Mull-88%; Mull-like moder-12%	Fresh-100%
RG/GL	**FG 1**	3	6698152	1633558	8	Gleysol-100%	Till-62%; Missing inform.-38%	Moder-100%	Fresh-moist-100%
	FG 2	3	6699465	1633226	8	Regosol-88%; Podzol-12%	Till-100%	Moder-50%; Mor-2-50%	Fresh-100%
GL/CM	**FL1**	1	6698178	1634928	8	Gleysol-76%; Cambisol-12%; Non-classified-12%	Poor sorted sediment-75%; Well sorted sediment-12%; Missing inform.-13%	Mull-100%	Fresh-100%
	FL2	2	6697118	1635547	8	Gleysol-75%; Regosol-25%	Poor sorted sediment-100%	Mull-100%	Fresh-100%
RG	**R1**	6	6698263	1636042	8	Regosol-63%; Arenosol-25%;Non-classified-12%	Poor sorted sediment-100%	Mull-75%; Mull-like moder-25%	Fresh-100%
	R2	6	6698179	1636086	8	Regosol-88%; Non-classified-12%	Poor sorted sediment-100%	Mull-75%; Mull-like moder-25%	Fresh-100%
AR/GL	**S1**	1	6699344	1633408	8	Arenosol-88%; Gleysol-12%	Well sorted sediment-100%	Mull-like moder-62%; Humus missing-25%; Peaty mor-13%	Wet-100%
	S2	1	6699785	1633223	8	Gleysol-62%; Regosol-38%	Till-100%	Peaty mor-75%; Mull-like moder-25%	Wet-100%
GL	**SS1**	3	6698060	1633495	8	Gleysol-100%	Till-75%; Well sorted sediment-25%	Peaty mor-100%	Moist-100%
	SS2	5	6697488	1632088	8	Gleysol-50%; Non-classified-50%	Well sorted sediment-62%; Poor sorted sediment-38%	Peaty mor-100%	Moist-100%
HI	**T1**	5	6699549	1629978	8	Histosol-100%	Peat-100%	Peat-100%	Wet-100%
	T2	4	6698818	1630070	8	Histosol-100%	Peat-100%	Peat-100%	Wet-100%
RG/GL-a	**A 1**	6	6696357	1631866	8	Gleysol-50%; Non-classified-50%	Poor sorted sediment-76%;Well sorted sediment-12%; Till-12%	Mull-62%; Mull-like moder-38%	Fresh-moist-100%
	A 2	16	6697798	1628742	8	Regosol-100%	Poor sorted sediment-88%; Well sorted sediment-12%	Mull-100%	Fresh-100%

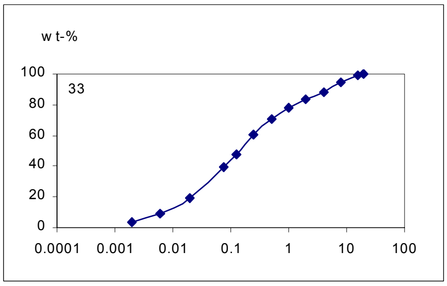
Appendix IIIb. Dominating ground vegetation in Forsmark area: Map and sample ID.

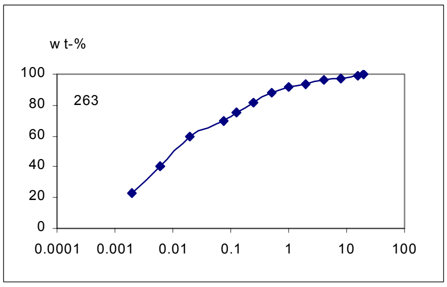
Map ID	ID	Ground-layer vegetation	Field-layer vegetation
LP	**B 2**	Mesic mosses type: incl. *Hylocomium splendens*, *Dicranum scoparium*, *Pleurozium schreberi*, *Rhytidiadelphus triquetrus*	Low herbs without shrubs: incl. *Pteridium aquilinum*, *Gymnocarpium dryopteris*, *Maianthemum bifolium*, *Trientalis eurpaea*, *Rubus saxatilis*, *Vaccinium myrtillus*, *Vaccinium vitis-idaea*, *Rubus idaeus*, *Hepatica nobilis*, *Potentilla erecta*, *Solidago spp.*, *Rubiaceae spp.*, *Vicia spp.*, *Veronica officinalis*, *Deschampsia flexuosa, Melica nutans*, *Calamagrostis epigeios*, *Festuca ovina*, *Carex spp.*
	B 3	Mesic mosses type: incl. *Hylocomium splendens*, *Dicranum scoparium*, *Pleurozium schreberi*, *Rhytidiadelphus squarrosus*, *Dicranum polysetum*	Low herbs without shrubs: incl. *Rubus saxatilis*, *Anemone nemorosa*, *Hepatica nobilis*, *Fragaria vesca*, *Solidago spp.*, *Filipendula ulmaria*, *Convallaria majalis*, *Geum rivale*, *Viola riviniana spp., Paris quadrifolia*, *Polygonatum odoratum*, *Rubiaceae spp.*, *Vicia spp.*, *Knautia arvensis*, *Succisa pratensis*, *Melica nutans*, *Calamagrostis arundinacea*, *Dactylis glomerata*
RG/GL	**FG 1**	Mesic mosses type: incl. *Hylocomium splendens*, *Pleurozium schreberi*, *Rhytidiadelphus triquetrus*, *Ptilium crista-castrensis*	Tall herbs without shrubs: incl. *Maianthemum bifolium*, *Rubus saxatilis*, *Geranium sylveticum*, *Anemone nemorosa*, *Hepatica nobilis*, *Melampyrum spp.*, *Paris quadrifolia*, *Rubiaceae spp.*, *Campanula spp.*, *Listera ovata*, *Epipactis helleborine*, *Platanthera spp.*, *Coeloglossum viride*, *Melica nutans*
	FG 2	Mesic mosses type: incl. *Hylocomium splendens*, *Dicranum scoparium*, *Dicranum undulatum*, *Pleurozium schreberi*	Narrow leafed grass: incl. *Maianthemum bifolium*, *Trientalis eurpaea*, *Rubus saxatilis*, *Oxalis acetosella*, *Vaccinium myrtillus*, *Melampyrum spp.*, *Deschampsia flexuosa*, *Milium effusum, Luzula pilosa*, *Carex digitata*
GL/CM	**FL1**	Mesic mosses type: incl. *Rhytidiadelphus triquetrus*, *Dicranum polysetum*	Tall herbs without shrubs: incl. *Trientalis eurpaea*, *Rubus saxatilis*, *Lactuca muralis*, *Geranium sylveticum*, *Hepatica nobilis*, *Filipendula ulmaria*, *Convallaria majalis*, *Geum rivale*, *Valeriana spp.*, *Polygonatum odoratum*, *Scrophula nodosa*, *Laserpitium latifolium*, *Urtica dioica*, *Ranunculus acris*, *Primula veris*, *Lysimachia thyrsiflora/L. vulgaris*, *Brachypodium sylvaticum*
	FL2	Mesic mosses type: incl.*Hylocomium splendens*, *Mnium hornum*	Low herbs without shrubs: incl. *Gymnocarpium dryopteris*, *Geranium sylveticum*, *Fragaria vesca, Filipendula ulmaria*, *Convallaria majalis*, *Geum rivale*, *Viola riviniana spp.*, *Melandrium rubrum*, *Urtica dioica*, *Rubiaceae spp.*, *Primula veris*, *Brachypodium sylvaticum*, *Deschampsia caespitosa*
RG	**R1**	Mesic mosses type: incl. *Dicranum scoparium*, *Pleurozium schreberi*	Narrow leafed grass: incl. *Solidago spp.*, *Convallaria majalis*, *Cornus suecica*, *Knautia arvensis*, *Filipendula vulgaris*, *Pimpinella saxifraga*, *Hieracium spp.*, *Campanula spp.*, *Deschampsia flexuosa*, *Melica nutans*, *Milium effusum*, *Anthoxanthum odoratum*, *Festuca ovina*, *Arrhenatherum pratense*
	R2	Mesic mosses type: incl. *Pleurozium schreberi*	Narrow leafed grass: incl. *Arnoseris spp.*, *Vaccinium vitis-idaea*, *Rubus idaeus*, *Convallaria majalis*, *Viola riviniana spp.*, *Hypericum spp.*, *Polygonatum odoratum*, *Rubiaceae spp.*, *Filipendula vulgaris*, *Achillea millefolium spp.*, *Deschampsia flexuosa*, *Melica nutans, Agrostis capillaris*, *Anthoxanthum odoratum*, *Festuca ovina*, *Arrhenatherum pratense*
AR/GL	**S1**		Non-classified: incl. *Arnoseris spp.*, *Filipendula ulmaria*, *Vicia spp.*, *Parnassia palustris*, *Potentilla anserina*, *Mentha spp.*, *Cenatrium littorale*, *Plantago maritima*, *Lysimachia thyrsiflora/L. vulgaris*, *Agrostis capillaris*, *Phragmites australis*, *Juncaceae spp.*, *Carex vaginata*
	S2		Non-classified: incl. *Arnoseris spp.*, *Valeriana spp.*, *Rubiaceae spp.*, *Mentha spp.*, *Cenatrium littorale*, *Triglochin maritima*, *Plantago maritima*, *Honkenya peploides*, *Lysimachia thyrsiflora/L. vulgaris*, *Deschampsia caespitosa*, *Agrostis spp.*, *Briza media*, *Phragmites australis*, *Bolboschoenus maritimus*, *Juncus articulatus*, *Carex spp.*
GL	**SS1**	Mesic mosses type: incl. *Hylocomium splendens*, *Dicranum scoparium*, *Pleurozium schreberi*, *Mnium hornum*, *Climacium dendroides*, *Polytrichum commune*	Low herbs without shrubs: incl. *Pteridium aquilinum*, *Gymnocarpium dryopteris*, *Maianthemum bifolium*, *Rubus saxatilis*, *Oxalis acetosella*, *Vaccinium myrtillus*, *Rubus idaeus*, *Filipendula ulmaria*, *Convallaria majalis*, *Viola riviniana spp.*, *Paris quadrifolia*, *Polygonatum odoratum*, *Galium boreale*, *Potentilla palustris*, *Lysimachia thyrsiflora/L. vulgaris*, *Epipactis helleborine*, *Deschampsia caespitosa*, *Carex spp.*
	SS2	Mesic mosses type: incl. *Hylocomium splendens*, *Dicranum scoparium*, *Pleurozium schreberi*, *Rhytidiadelphus squarrosus*, *Climacium dendroides*, *Polytrichum commune*	Low herbs without shrubs: incl. *Maianthemum bifolium*, *Rubus saxatilis*, *Oxalis acetosella*, *Lactuca muralis*, *Vaccinium myrtillus*, *Rubus idaeus*, *Anemone nemorosa*, *Fragaria vesca*, *Filipendula ulmaria*, *Geum rivale*, *Viola riviniana spp.*, *Paris quadrifolia, Equisetum spp.*, *Carex vaginata*
HI	**T1**	Wet mosses type (not *Sphagnum*): incl. *Mnium hornum*	Broad leafed grass: incl. *Myrica gale*, *Oxycoccus spp.* , *Peucedanum palustre*, *Pedicularis palustris spp.*, *Potentilla palustris*, *Phragmites australis*, *Carex lasiocarpa*
	T2	Wet mosses type (not *Sphagnum*): incl. *Amblystegium spp., Drepanocladus spp., etc.*	Broad leafed grass: incl. *Parnassia palustris*, *Myrica gale*, *Oxycoccus spp.*, *Potentilla palustris*, *Drosera rotundifolia*, *Phragmites australis*, *Carex lasiocarpa*
RG/GL-a	**A 1**	Mesic mosses type: incl. *Rhytidiadelphus squarrosus*, *Mnium hornum*	Broad leafed grass: incl. *Urtica dioica*, *Ranunculus acris*, *Rubiaceae spp.*, *Vicia spp.*, *Anthrisus sylvestris*, *Cirsium arvense*, *Veronica chamaedrys*, *Knautia arvensis*, *Achillea millefolium spp.*, *Dactylis glomerata*, *Alpecurus pratensis*, *Elymus repens*
	A 2		Broad leafed grass: incl. *Urtica dioica*, *Vicia spp.*, *Anthrisus sylvestris*, *Veronica chamaedrys*, *Knautia arvensis*, *Achillea millefolium spp.*, *Dactylis glomerata*, *Alpecurus pratensis*, *Elymus repens*

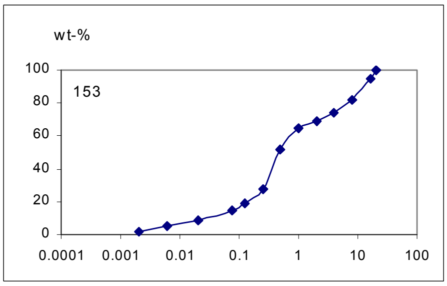
Grain-size distribution of the soil material < 20 mm in the plots of the Forsmark area, gravimetrical percentage

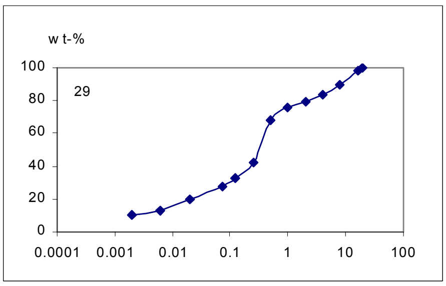
Pro-file	Depth, cm	Gravel, medium	Gravel, fine	Sand, coarse	Sand, medium	Sand, fine	Silt, coarse	Silt, medium	Silt, fine	Clay	Sample weight g
No		20-6 mm	6-2 mm	2-0.6 mm	0.6-0.2 mm	0.2-0.06 mm	0.06-0.02 mm	0.02-0.006 mm	0.006-0.002 mm	<0.002 mm	
		Grus		Sand		Mo		Mjäla		Ler	
		Grov-grus	Fingrus	Grov-sand	Mellan-sand	Grovmo	Finmo	Grov-mjäla	Fin-mjäla	Ler	
B	0-10	13	8.5	7	34.5	10.5	6.5	7	3	10	1250
2:	10 20	5	5	5.5	27	15	12	7.5	5.5	17.5	1228
9	55-65	6.5	10	9.5	16.5	21	17.5	10.5	5	3.5	1502
B	0-10	0	0	13.5	31.5	16	11.5	10.5	5.5	11.5	499
3:	10 20	10	6.5	16	26.5	14	10	7.5	3	6.5	922
1	55-65	7	6	8	17	15	10.5	15.5	8.5	12.5	1345
FG	0-10	6	7	8	18.5	17.5	11.5	11.5	7	13	1179
1:	10 20	5.5	5.5	7.5	13.5	16	14.5	13.5	10.5	13.5	1444
10	55-65	7	8.5	12	18	16	14.5	13	7	4	1457
FG	0-10	21	10	12	32.5	10.5	5	3.5	3.5	2	864
2:	10 20	17	11.5	11.5	26	15	7	5.5	2.5	4	1518
1	55-65	15	11	11.5	19	17	9	7.5	4.5	5.5	1572
FL	0-10	0	0	6	28.5	19	12.5	10	8	16	584
1:	10 20	18	8.5	8	20.5	12.5	7.5	8	5	12	953
6	55-65	0	0	2	10.5	17	18.5	15.5	14.5	22	1129
FL	0-10	0	0	5	22	24	14	12.5	7.5	15	543
2:	10 20	1.5	2	8	28.5	24	11	8.5	5.5	11	790
5	55-65	3	3	4	10	11	9.5	19	17.5	23	1443
R	0-10	1.5	5.5	40.5	35.5	7.5	3	2	2	2.5	515
1:	10 20	28.5	16	26	22	6	0.5	0.5	0.5	0	1330
9	55-65	0	0	40	57	2.5	0.5	0	0	0	1683
R	0-10	24	23	25	14	4.5	3	1.5	1	4	719
2:	10 20	50.5	32	12	3	2	0.5	0	0	0	1517
6	55-65	23.5	19.5	29	26	2	0	0	0	0	1647
S	0-10	0	0	17	80	3	0	0	0	0	1258
1:	10 20	0	0	16	81	3	0	0	0	0	1256
1	55-65	0	0	7	87	5.5	0.5	0	0	0	1535
S	0-10	7.5	6.5	11.5	39.5	8	4	4.5	5.5	13	1808
2:	10 20	8	6.5	8	13	12	8	8.5	11	25	1715
7	55-65	11	11	12	19.5	19	10.5	7.5	5.5	4	3161
SS	0-10	11	8.5	9	55	11.5	3	0.5	0.5	1	2132
1:	10 20	6.5	7	5.5	14.5	15.5	14	14	11	12	2138
11	55-65	5.5	5	7	12.5	14.5	15	14	13	13.5	2626
SS	0-10	1	1	11	14	5	2	4.5	9.5	52	857
2:	10 20										1027
23	55-65										998
A	0-10	9	6.5	6	43.5	8	2	3.5	4.5	17	1051
1:	10 20	9.5	5.5	5	43.5	10	5	2	2.5	17	1097
5	55-65	0	0	0	2	1.5	3.5	6	12	75	916
A	0-10	0	0	8.5	26.5	47.5	5	3	1.5	8	1148
2:	10 20	20	12	14	19	25.5	4	1	1	3.5	1392
13	55-65	0	0	2.5	2.5	5	3.5	5	21.5	60	994

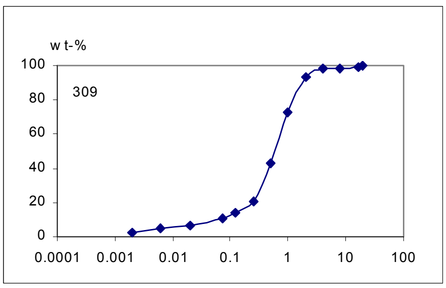
Textural composition of ten soil types in the Forsmark area. Left column from top to bottom: 33: sandy till, 263: coarse boulder clay, 153: gravelly out-washed sand, 309: out-washed sand, 29: weakly wave-washed till Right column from top to bottom: 125: clayey sandy till, 667: heavy clay, 663: coarse clay and sand mixed, 313: glacifluvial sand

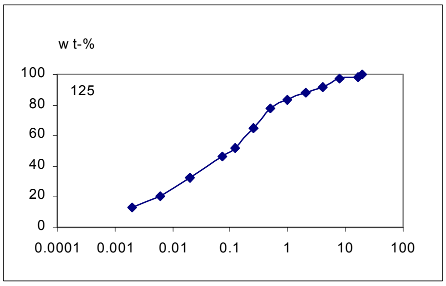


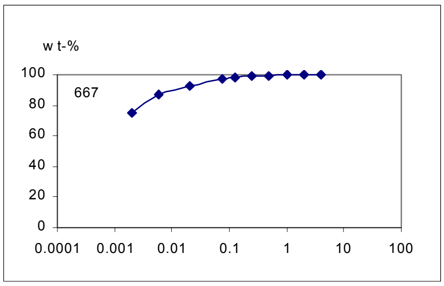


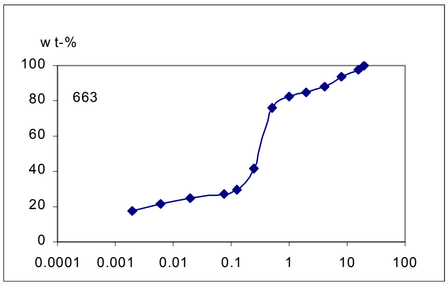


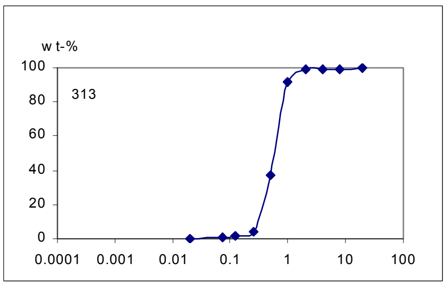












Relationship between analyses number, soil types and SKB identification codes

Sml, No	Depth, cm	Profile	Soil type	SKB Id-codes	Total sample weight, g
29	0-10	B 2:9	LPl	AFM001066	1250
31	10 20		LPl	AFM001066	1228
33	55-65		LPl	AFM001066	1502
55	0-10	B 3:1	LPl	AFM001067	499
57	10 20		LPl	AFM001067	922
59	55-65		LPl	AFM001067	1345
125	0-10	FG 1:10	RG/GL	AFM001068	1179
127	10 20		RG/GL	AFM001068	1444
129	55-65		RG/GL	AFM001068	1457
153	0-10	FG 2:1	RG/GL	AFM001069	864
155	10 20		RG/GL	AFM001069	1518
157	55-65		RG/GL	AFM001069	1572
217	0-10	FL 1:6	GL/CM	AFM001070	584
219	10 20		GL/CM	AFM001070	953
221	55-65		GL/CM	AFM001070	1129
259	0-10	FL 2:5	GL/CM	AFM001071	543
261	10 20		GL/CM	AFM001071	790
263	55-65		GL/CM	AFM001071	1443
309	0-10	R 1:9	RG	AFM001072	515
311	10 20		RG	AFM001072	1330
313	55-65		RG	AFM001072	1683
339	0-10	R 2:6	RG	AFM001073	719
341	10 20		RG	AFM001073	1517
343	55-65		RG	AFM001073	1647
369	0-10	S 1:1	AR/GL	AFM001074	1258
371	10 20		AR/GL	AFM001074	1256
373	55-65		AR/GL	AFM001074	1535
463	0-10	S 2:7	AR/GL	AFM001075	1808
465	10 20		AR/GL	AFM001075	1715
467	55-65		AR/GL	AFM001075	3161
511	0-10	SS 1:11	GL	AFM001076	2132
513	10 20		GL	AFM001076	2138
515	55-65		GL	AFM001076	2626
583	0-10	SS 2:23	GL	AFM001077	857
585	10 20		GL	AFM001077	1027
587	55-65		GL	AFM001077	998
663	0-10	A 1:5	RG/GL-a	AFM001080	1051
665	10 20		RG/GL-a	AFM001080	1097
667	55-65		RG/GL-a	AFM001080	916
723	0-10	A 2:13	RG/GL-a	AFM001081	1148
725	10 20		RG/GL-a	AFM001081	1392
727	55-65		RG/GL-a	AFM001081	994

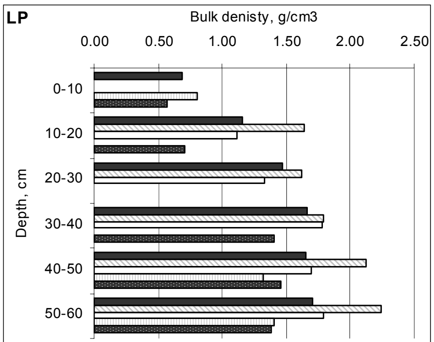
Interpretation of genetic characters of the regolith and lime content in material < 2.0 mm

Profile	Depth cm b s	Soil type	SKB Id-codes	Genetic characters	Lime characters based on Passon´s method (volumetric)
B 2:9	0-10	LPl	AFM001066	Outwash sand	Traces
	10 20	LPl	AFM001066	Coarse clay, mixed	Traces
	55-65	LPl	AFM001066	Sandy till	21.5 %
B 3:1	0-10	LPl	AFM001067	Clayey outwash sand	Free
	10 20	LPl	AFM001067	Clayey outwash sand	Traces
	55-65	LPl	AFM001067	Clayey sandy till	22 %
FG 1:10	0-10	RG/GL	AFM001068	Clayey sandy till	14.5 %
	10 20	RG/GL	AFM001068	Clayey sandy till	16.5 %
	55-65	RG/GL	AFM001068	Sandy till	22.5 %
FG 2:1	0-10	RG/GL	AFM001069	Gravelly outwash sand	Traces
	10 20	RG/GL	AFM001069	Gravelly outwash sand	4.0 %
	55-65	RG/GL	AFM001069	Clayey sandy till	24.0 %
FL 1:6	0-10	GL/CM	AFM001070	Coarse boulder clay	Free
	10 20	GL/CM	AFM001070	Glayey gravelly till	6.0 %
	55-65	GL/CM	AFM001070	Coarse boulder clay	19.5 %
FL 2:5	0-10	GL/CM	AFM001071	Coarse boulder clay	Free
	10 20	GL/CM	AFM001071	Clayey outwash sand	Traces
	55-65	GL/CM	AFM001071	Coarse boulder clay	22.0 %
R 1:9	0-10	RG	AFM001072	Outwash sand	Free
	10 20	RG	AFM001072	Outwash gravel	3.0 %
	55-65	RG	AFM001072	Glacifluvial sand	16.0 %
R 2:6	0-10	RG	AFM001073	Outwash gravel	Free
	10 20	RG	AFM001073	Outwash gravel	Free
	55-65	RG	AFM001073	Gravelly outwash sand	Free
S 1:1	0-10	AR/GL	AFM001074	Glacifluvial sand	Free
	10 20	AR/GL	AFM001074	Glacifluvial sand	Free
	55-65	AR/GL	AFM001074	Glacifluvial sand	Free
S 2:7	0-10	AR/GL	AFM001075	Clayey outwash sand	8.5 %
	10 20	AR/GL	AFM001075	Coarse boulder clay	16.0 %
	55-65	AR/GL	AFM001075	Sandy till	21.5 %
SS 1:11	0-10	GL	AFM001076	Gravelly outwash sand	Trace
	10 20	GL	AFM001076	Clayey silty till	20.0 %
	55-65	GL	AFM001076	Clayey silty till	21.5 %
SS 2:23	0-10	GL	AFM001077	Heavy clay	2.0 %
	10 20	GL	AFM001077	Heavy clay	3.5 %
	55-65	GL	AFM001077	Heavy clay	8.0 %
A 1:5	0-10	RG/GL-a	AFM001080	Coarse clay, sand mixed	Free
	10 20	RG/GL-a	AFM001080	Coarse clay, sand mixed	Free
	55-65	RG/GL-a	AFM001080	Very heavy clay	7.5 %
A 2:13	0-10	RG/GL-a	AFM001081	Clayey sandy fine sand	Free
	10 20	RG/GL-a	AFM001081	Mixed outwash material	Free
	55-65	RG/GL-a	AFM001081	Very heavy clay	4.0 %

Dry bulk density of the upper 0.6 m of the soil in the Forsmark area with two profiles in each plot. (Missing values means that sampling was not possible)

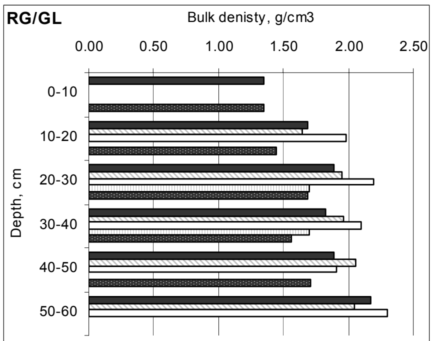
γ, g/cm^3						
Profiles	Depth from the soil surface, cm					
	0-10	10-20	20-30	30-40	40-50	50-60
B2:1		1.64	1.62	1.79	2.12	2.24
B2:5		1.12	1.33	1.79	1.70	1.79
B3:1	0.81				1.32	1.40
B3:2	0.57	0.71		1.40	1.46	1.39
FG1:1		1.64	1.95	1.97	2.05	2.04
FG1:13		1.99	2.19	2.10	1.91	2.30
FG2:1			1.70	1.69		
FG2:6	1.35	1.44	1.69	1.56	1.71	
FL1:6	0.73		1.76	1.93	2.07	2.05
FL1:15	0.58		1.51	1.88	1.88	1.86
FL2:1	1.01	1.03	1.52	1.41	1.20	
FL2:13	1.04	1.19	1.58	1.55	1.63	1.66
R1:1	0.42			1.65	1.46	1.36
R1:14	0.35					
R2:1	0.60	1.82	1.72			
R2.13	0.46		1.41	1.50	1.78	
S1:3	1.52	1.43	1.34	1.31	1.80	2.25
S1:7	1.52	1.69	1.64	1.77	1.86	
S2:1	1.28	1.78	1.81	2.10	2.03	
S2:8	1.30	1.48	1.31	1.89	1.90	2.03
SS1:1	1.34	1.52	1.97	1.97	1.99	1.76
SS1:11	1.55	1.99	1.95	1.99	1.98	1.99
SS2:10	2.25	1.37	1.15	1.49		
SS2:15	1.75	1.37	1.34	1.29	1.23	1.48
A1:1	1.11	1.21	1.31	1.42	1.55	1.51
A1:14	1.25	1.44	1.56	1.41	1.43	

Bulk density at LP, RG/GL, GL/CM, RG, AR/GL and GL sites. Average values black bar. (Missing values means that sampling was not possible)



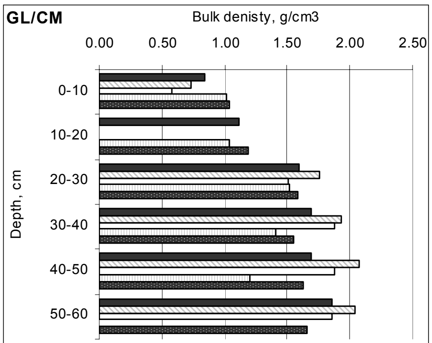
	50-60	40-50	30-40	20-30	10-20	0-10
B	1.71	1.65	1.66	1.47	1.16	0.69
B2:1	2.24	2.12	1.79	1.62	1.64	
B2:5	1.79	1.70	1.79	1.33	1.12	
B3:1	1.40	1.32				0.81
B3:2	1.39	1.46	1.40		0.71	0.57

B B2:1 B2:5 B3:1 B3:2



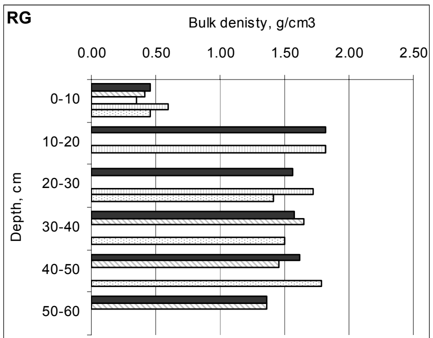
	50-60	40-50	30-40	20-30	10-20	0-10
FG	2.17	1.89	1.83	1.88	1.69	1.35
FG1:1	2.04	2.05	1.97	1.95	1.64	
FG1:13	2.30	1.91	2.10	2.19	1.99	
FG2:1			1.69	1.70		
FG2:6		1.71	1.56	1.69	1.44	1.35

FG FG1:1 FG1:13 FG2:1 FG2:6



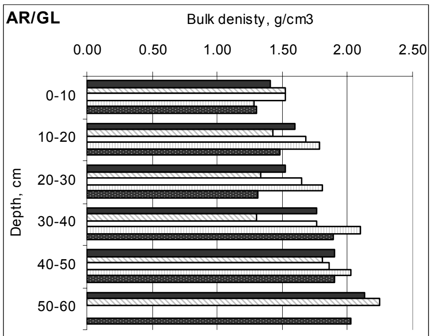
	50-60	40-50	30-40	20-30	10-20	0-10
FL	1.86	1.70	1.69	1.59	1.11	0.84
FL1:6	2.05	2.07	1.93	1.76		0.73
FL1:15	1.86	1.88	1.88	1.51		0.58
FL2:1		1.20	1.41	1.52	1.03	1.01
FL2:13	1.66	1.63	1.55	1.58	1.19	1.04

FL FL1:6 FL1:15 FL2:1 FL2:13



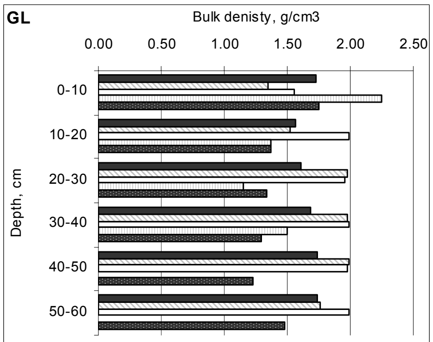
	50-60	40-50	30-40	20-30	10-20	0-10
R	1.36	1.62	1.57	1.57	1.82	0.46
R1:1	1.36	1.46	1.65			0.42
R1:14						0.35
R2:1				1.72	1.82	0.60
R2.13		1.78	1.50	1.41		0.46

R R1:1 R1:14 R2:1 R2.13



	50-60	40-50	30-40	20-30	10-20	0-10
S	2.14	1.90	1.77	1.53	1.60	1.40
S1:3	2.25	1.80	1.31	1.34	1.43	1.52
S1:7		1.86	1.77	1.64	1.69	1.52
S2:1		2.03	2.10	1.81	1.78	1.28
S2:8	2.03	1.90	1.89	1.31	1.48	1.30

S S1:3 S1:7 S2:1 S2:8



	50-60	40-50	30-40	20-30	10-20	0-10
SS	1.74	1.74	1.69	1.61	1.56	1.72
SS1:1	1.76	1.99	1.97	1.97	1.52	1.34
SS1:11	1.99	1.98	1.99	1.95	1.99	1.55
SS2:10			1.49	1.15	1.37	2.25
SS2:15	1.48	1.23	1.29	1.34	1.37	1.75

SS SS1:1 SS1:11 SS2:10 SS2:15

Frequencies (%) of pH (H_2O) in O, B and C-horizons in the Forsmark area and for forest soils in four regions of Sweden

Appendix VIa. O-horizon pH (H_2O).

Classified intervals	Survey area				
	Sweden	Sweden-IV	Uppsala County	Östhammar	Forsmark
3.5<x<=4.0	0.8	1.4			
4.0<x<=4.5	16.1	21.4	12.5	25.0	4.5
4.5<x<=5.0	50.4	46.4	31.3	8.3	8.1
5.0<x<=5.5	23.2	19.1	16.7	16.7	8.1
5.5<x<=6.0	5.7	7.9	16.7	16.7	9.0
6.0<x<=6.5	2.1	2.3	12.5	16.7	9.0
6.5<x<=7.0	0.8	0.9	6.3	16.7	22.5
7.0<x<=7.5	0.4	0.3	2.1		29.7
7.5<x<=8.0	0.1	0.1	0.0		7.2
8.0<x<=8.5	0.3	0.1	2.1		0.9
8.5<x<=9.0	0.1				0.9

Appendix VIb. B-horizon (0-10 cm) pH (H_2O).

Classified intervals	Survey area				
	Sweden	Sweden-IV	Uppsala County	Östhammar	Forsmark
3.5<x<=4.0	0.8	1.4			
4.0<x<=4.5	16.1	21.4	12.5	25.0	4.5
4.5<x<=5.0	50.4	46.4	31.3	8.3	8.1
5.0<x<=5.5	23.2	19.1	16.7	16.7	8.1
5.5<x<=6.0	5.7	7.9	16.7	16.7	9.0
6.0<x<=6.5	2.1	2.3	12.5	16.7	9.0
6.5<x<=7.0	0.8	0.9	6.3	16.7	22.5
7.0<x<=7.5	0.4	0.3	2.1		29.7
7.5<x<=8.0	0.1	0.1	0.0		7.2
8.0<x<=8.5	0.3	0.1	2.1		0.9
8.5<x<=9.0	0.1				0.9

Appendix VIc. B-horizon pH (H_2O), (10-20 cm).

Classified intervals	Survey area				
	Sweden	Sweden-IV	Uppsala County	Östhammar	Forsmark
3.5<x<=4.0	0.8	1.4			
4.0<x<=4.5	16.1	21.4	12.5	25.0	
4.5<x<=5.0	50.4	46.4	31.3	8.3	3.6
5.0<x<=5.5	23.2	19.1	16.7	16.7	10.9
5.5<x<=6.0	5.7	7.9	16.7	16.7	9.1
6.0<x<=6.5	2.1	2.3	12.5	16.7	7.3
6.5<x<=7.0	0.8	0.9	6.3	16.7	24.5
7.0<x<=7.5	0.4	0.3	2.1		29.1
7.5<x<=8.0	0.1	0.1	0.0		13.6
8.0<x<=8.5	0.3	0.1	2.1		1.8
8.5<x<=9.0	0.1				

Appendix VId. C-horizon pH (H_2O), (55-65 cm).

Classified intervals	Survey area				
	Sweden	Sweden-IV	Uppsala County	Östhammar	Forsmark
3.0<x<=3.5	0.1				
3.5<x<=4.0	0.0				
4.0<x<=4.5	0.7				
4.5<x<=5.0	29.2	38.4	3.0	14.3	
5.0<x<=5.5	43.3	32.7	18.2		5.4
5.5<x<=6.0	17.3	16.4	27.3	28.6	7.1
6.0<x<=6.5	5.4	8.5	15.2	28.6	10.7
6.5<x<=7.0	2.2	2.2	15.2		12.5
7.0<x<=7.5	0.9	0.6	6.1		12.5
7.5<x<=8.0	0.3	0.6	3.0	14.3	41.1
8.0<x<=8.5	0.2	0.6	9.1	14.3	7.1
8.5<x<=9.0	0.3	0.2	3.0		3.6
9.0<x<=9.5	0.1				

Profile pH_{H_2O} values in the Forsmark area B, FG, FL and R plots

Site	Horizon depth, cm	Used pH treatment	N	Average	Max	Min	Std.	Cv, %
B 2	H 0-30	pH H_2O	8	5.2	7.2	4.0	1.3	25.8
	M 0-10	pH H_2O	8	6.0	6.9	4.3	0.8	13.0
	M 10-20	pH H_2O	8	6.7	7.2	5.7	0.5	6.7
	M 55-65	pH H_2O	4	7.5	7.9	7.2	0.3	4.3
B 3	H 0-30	pH H_2O						
	M 0-10	pH H_2O	8	7.0	7.4	6.7	0.2	3.4
	M 10-20	pH H_2O	8	7.0	7.4	6.0	0.5	6.7
	M 55-65	pH H_2O	4	7.6	7.6	7.5	0.0	0.6
FG 1	H 0-30	pH H_2O	8	6.7	7.5	4.6	1.0	14.6
	M 0-10	pH H_2O	8	7.2	7.8	6.6	0.4	5.6
	M 10-20	pH H_2O	7	7.4	7.7	7.1	0.2	3.0
	M 55-65	pH H_2O	4	7.9	8.5	7.3	0.5	5.9
FG 2	H 0-30	pH H_2O	8	4.4	5.6	3.8	0.6	14.7
	M 0-10	pH H_2O	7	4.9	5.4	4.3	0.4	7.4
	M 10-20	pH H_2O	8	6.2	6.8	5.1	0.7	11.0
	M 55-65	pH H_2O	4	6.8	7.5	6.2	0.6	9.2
FL 1	H 0-30	pH H_2O						
	M 0-10	pH H_2O	8	6.9	7.4	6.1	0.4	6.4
	M 10-20	pH H_2O	8	7.2	7.6	6.5	0.3	4.2
	M 55-65	pH H_2O	4	7.5	7.9	6.5	0.6	8.7
FL 2	H 0-30	pH H_2O						
	M 0-10	pH H_2O	8	7.2	7.4	7.0	0.2	2.1
	M 10-20	pH H_2O	8	7.1	7.4	6.6	0.2	3.5
	M 55-65	pH H_2O	4	7.4	7.6	7.1	0.2	3.2
R 1	H 0-30	pH H_2O						
	M 0-10	pH H_2O	8	4.8	5.4	4.2	0.4	8.8
	M 10-20	pH H_2O	8	5.1	5.6	4.5	0.4	7.4
	M 55-65	pH H_2O	4	6.4	6.6	6.0	0.3	4.6
R 2	H 0-30	pH H_2O						
	M 0-10	pH H_2O	8	5.0	5.8	4.1	0.6	12.0
	M 10-20	pH H_2O	8	5.4	6.1	4.9	0.4	7.9
	M 55-65	pH H_2O	4	5.6	5.9	5.4	0.2	3.8

Appendix VIIb

Profile pH_{H_2O} values in the Forsmark area A, S, SS and T plots

Site	Horizon depth, cm	Used pH treatment	N	Average	Max	Min	Std.	Cv, %
S 1	H 0-30	pH H_2O	6	6.1	6.7	5.7	0.3	5.6
	M 0-10	pH H_2O	8	7.1	8.1	6.7	0.4	6.1
	M 10-20	pH H_2O	8	7.4	8.3	6.7	0.6	8.0
	M 55-65	pH H_2O	4	7.7	8.2	7.5	0.3	4.3
S 2	H 0-30	pH H_2O	7	7.1	7.7	6.4	0.4	6.2
	M 0-10	pH H_2O	8	7.2	8.0	6.3	0.6	7.9
	M 10-20	pH H_2O	8	7.6	8.3	7.1	0.4	5.6
	M 55-65	pH H_2O	4	7.7	8.4	6.7	0.7	9.2
SS 1	H 0-30	pH H_2O	7	6.7	7.3	6.1	0.4	6.6
	M 0-10	pH H_2O	8	7.1	8.1	6.7	0.4	6.1
	M 10-20	pH H_2O	8	7.4	8.3	6.7	0.6	8.0
	M 55-65	pH H_2O	4	7.7	8.2	7.5	0.3	4.3
SS 2	H 0-30	pH H_2O	8	7.2	7.8	6.8	0.3	4.9
	M 0-10	pH H_2O	8	7.0	7.5	5.9	0.5	6.8
	M 10-20	pH H_2O	8	7.3	7.7	7.0	0.2	3.2
	M 55-65	pH H_2O	4	7.7	7.9	7.6	0.1	1.9
T 1	H 0-30	pH H_2O	8	5.8	6.1	5.4	0.3	4.6
	H 40-60	pH H_2O	6	6.1	6.4	5.8	0.2	4.0
T 2	H 0-30	pH H_2O	8	6.1	6.3	5.8	0.1	2.4
	H 40-60	pH H_2O	8	6.1	6.4	5.9	0.2	2.6
A 1	H 0-30	pH H_2O						
	M 0-10	pH H_2O	8	7.1	7.9	6.3	0.5	6.6
	M 10-20	pH H_2O	8	6.5	7.2	5.4	0.6	9.3
	M 55-65	pH H_2O	4	7.4	8.0	6.8	0.6	8.5
A 2	H 0-30	pH H_2O						
	M 0-10	pH H_2O	8	5.9	6.4	5.8	0.2	3.3
	M 10-20	pH H_2O	8	6.0	6.3	5.8	0.2	2.7
	M 55-65	pH H_2O	4	6.3	6.7	6.0	0.3	4.8

Profile pH ($CaCl_2$) values in the Forsmark area B, FG, FL and R plots

Site	Horizon depth, cm	Used pH treatment	N	Average	Max	Min	Std.	Cv, %
1	2	3	4	5	6	7	8	9
B 2	H 0-30	pH $CaCl_2$	8	4.4	6.4	3.2	1.4	30.7
	M 0-10	pH $CaCl_2$	8	5.6	6.4	3.6	0.9	16.5
	M 10-20	pH $CaCl_2$	8	6.3	6.6	5.1	0.5	8.0
	M 55-65	pH $CaCl_2$	4	6.6	6.8	6.4	0.2	2.5
B 3	H 0-30	pH $CaCl_2$						
	M 0-10	pH $CaCl_2$	8	6.5	6.8	5.8	0.3	4.8
	M 10-20	pH $CaCl_2$	8	6.6	7.1	5.5	0.6	8.8
	M 55-65	pH $CaCl_2$	4	6.9	7.3	6.7	0.3	4.5
FG 1	H 0-30	pH $CaCl_2$	8	6.1	6.8	3.8	1.0	16.7
	M 0-10	pH $CaCl_2$	8	6.8	7.2	6.3	0.3	4.3
	M 10-20	pH $CaCl_2$	7	6.9	7.1	6.7	0.1	2.0
	M 55-65	pH $CaCl_2$	4	7.0	7.3	6.7	0.2	3.3
FG 2	H 0-30	pH $CaCl_2$	8	3.6	4.6	3.0	0.6	15.9
	M 0-10	pH $CaCl_2$	7	4.1	4.6	3.6	0.4	8.6
	M 10-20	pH $CaCl_2$	8	5.8	6.4	4.3	0.9	15.3
	M 55-65	pH $CaCl_2$	4	6.3	6.9	5.7	0.5	7.5
FL 1	H 0-30	pH $CaCl_2$						
	M 0-10	pH $CaCl_2$	8	6.5	6.9	5.8	0.4	5.7
	M 10-20	pH $CaCl_2$	8	6.7	6.9	6.2	0.3	3.8
	M 55-65	pH $CaCl_2$	4	6.7	6.9	6.0	0.4	6.1
FL 2	H 0-30	pH $CaCl_2$						
	M 0-10	pH $CaCl_2$	8	6.7	6.9	6.5	0.1	1.8
	M 10-20	pH $CaCl_2$	8	6.8	7.0	6.4	0.2	3.0
	M 55-65	pH $CaCl_2$	4	7.0	7.0	6.9	0.1	1.0
R 1	H 0-30	pH $CaCl_2$						
	M 0-10	pH $CaCl_2$	8	4.1	4.8	3.4	0.5	12.3
	M 10-20	pH $CaCl_2$	8	4.3	4.8	3.8	0.3	7.8
	M 55-65	pH $CaCl_2$	4	6.0	6.4	5.4	0.4	7.3
R 2	H 0-30	pH $CaCl_2$						
	M 0-10	pH $CaCl_2$	8	4.4	5.2	3.4	0.6	14.6
	M 10-20	pH $CaCl_2$	8	4.6	5.6	4.0	0.6	12.2
	M 55-65	pH $CaCl_2$	4	4.9	5.2	4.7	0.2	4.5

Profile pH ($CaCl_2$) values in the Forsmark area A, S, SS and T plots

Site	Horizon depth, cm	Used pH treatment	N	Average	Max	Min	Std.	Cv, %
S 1	H 0-30	pH $CaCl_2$	6	5.5	6.3	5.0	0.4	8.0
	M 0-10	pH $CaCl_2$	8	6.3	7.1	5.6	0.5	8.1
	M 10-20	pH $CaCl_2$	8	6.0	7.1	4.5	0.8	14.0
	M 55-65	pH $CaCl_2$	4	5.7	7.1	4.5	1.3	23.0
S 2	H 0-30	pH $CaCl_2$	7	6.5	7.3	5.8	0.5	8.1
	M 0-10	pH $CaCl_2$	8	6.7	7.3	5.6	0.6	8.5
	M 10-20	pH $CaCl_2$	8	7.0	7.2	6.5	0.3	3.7
	M 55-65	pH $CaCl_2$	4	6.7	7.4	5.6	0.8	11.8
SS 1	H 0-30	pH $CaCl_2$	7	6.1	6.6	5.3	0.5	7.7
	M 0-10	pH $CaCl_2$	8	6.6	7.0	6.1	0.3	5.0
	M 10-20	pH $CaCl_2$	8	6.8	7.1	6.4	0.3	3.7
	M 55-65	pH $CaCl_2$	4	6.8	7.0	6.6	0.2	3.1
SS 2	H 0-30	pH $CaCl_2$	8	6.7	7.0	6.4	0.2	2.4
	M 0-10	pH $CaCl_2$	8	6.6	6.9	5.5	0.5	7.0
	M 10-20	pH $CaCl_2$	8	6.8	7.0	6.5	0.2	2.4
	M 55-65	pH $CaCl_2$	4	7.0	7.3	6.9	0.2	2.8
T 1	H 0-30	pH $CaCl_2$	8	5.3	5.9	4.9	0.3	6.5
	H 40-60	pH $CaCl_2$	6	5.7	6.1	5.3	0.3	4.9
T 2	H 0-30	pH $CaCl_2$	8	5.7	5.7	5.5	0.1	1.4
	H 40-60	pH $CaCl_2$	8	5.7	6.1	5.5	0.2	3.3
A 1	H 0-30	pH $CaCl_2$						
	M 0-10	pH $CaCl_2$	8	6.2	6.9	5.5	0.4	6.8
	M 10-20	pH $CaCl_2$	8	6.1	6.9	5.3	0.7	11.5
	M 55-65	pH $CaCl_2$	4	6.8	7.1	6.6	0.3	4.9
A 2	H 0-30	pH $CaCl_2$						
	M 0-10	pH $CaCl_2$	8	5.3	5.8	5.1	0.2	4.6
	M 10-20	pH $CaCl_2$	8	5.1	5.4	4.8	0.2	3.8
	M 55-65	pH $CaCl_2$	4	5.7	6.6	5.4	0.6	9.9

Appendix IXa–d

Frequencies of carbon concentrations in O-, B- and C-horizons for the Forsmark area and for forest soils in four regions of Sweden.

Appendix IXa. O-horizon carbon concentration frequencies (%).

Classified intervals	Survey area				
	Sweden	Sweden-IV	Uppsala County	Östhammar	Forsmark
0<x<=10	13.8	32.2	39.0	17.5	11.6
10<x<=20	7.9	8.3	14.3	22.5	26.1
20<x<=30	9.7	8.4	6.5	5.0	20.3
30<x<=40	21.2	16.9	18.2	27.5	14.5
40<x<=50	42.4	30.4	19.5	22.5	27.5
50<x<=60	5.0	3.9	2.6	5.0	

Appendix IXb. Upper B-horizon carbon concentration frequencies (%).

Classified intervals	Survey area				
	Sweden	Sweden-IV	Uppsala County	Östhammar	Forsmark
0<x<=2	54.3	59.5	59.5	45.5	35.5
2<x<=4	31.7	28.1	35.7	54.5	16.4
4<x<=6	9.1	8.5	4.8		9.1
6<x<=8	3.6	2.7			13.6
8<x<=10	0.7	0.2			10.9
10<x<=12	0.4	0.9			4.5
12<x<=14					3.6
14<x<=16					4.5
16<x<=18	0.1	0.2			0.9
>18	0.1				0.9

Appendix IXc. B-horizon, 10-20 cm, carbon concentration frequencies (%).

Classified intervals	Survey area				
	Sweden	Sweden-IV	Uppsala County	Östhammar	Forsmark
0<x<=2	54.3	59.5	59.5	45.5	47.7
2<x<=4	31.7	28.1	35.7	54.5	38.7
4<x<=6	9.1	8.5	4.8		10.8
6<x<=8	3.6	2.7			0.9
8<x<=10	0.7	0.2			1.8
10<x<=12	0.4	0.9			
12<x<=14					
14<x<=16					
16<x<=18	0.1	0.2			
>18	0.1				

Appendix IXd. C-horizon carbon concentration frequencies (%).

Classified intervals	Survey area				
	Sweden	Sweden-IV	Uppsala County	Östhammar	Forsmark
0<x<=2	95.5	97.3	92.9	85.7	58.9
2<x<=4	2.6	1.1	3.6		41.1
4<x<=6	1.1	1.1			
6<x<=8	0.4	0.4	3.6	14.3	
8<x<=10	0.2				
10<x<=12					
12<x<=14					
14<x<=16					
16<x<=18	0.2				
>18	0.0				

Appendix Xa

Profile carbon values (%) in the Forsmark area B, FG, Fl and R plots

Site	Horizon depth, cm	N	Average	Max	Min	Std.	Cv, %
1	2	4	5	6	7	8	9
B 2	H 0-30	8	30.2	34.7	18.1	6.0	19.9
	M 0-10	8	2.0	3.5	0.3	1.2	61.4
	M 10-20	8	1.7	2.1	1.2	0.4	23.5
	M 55-65	4	2.1	2.5	1.7	0.4	18.6
B 3	H 0-30						
	M 0-10	8	9.1	14.3	5.6	3.1	34.0
	M 10-20	8	4.7	9.2	0.7	2.9	60.7
	M 55-65	4	2.5	3.1	2.1	0.4	16.6
FG 1	H 0-30	8	10.9	31.4	6.4	8.4	77.1
	M 0-10	8	3.1	5.0	0.5	1.6	53.0
	M 10-20	7	2.3	2.7	1.6	0.4	19.2
	M 55-65	4	2.3	2.4	2.2	0.1	3.2
FG 2	H 0-30	8	37.1	49.1	21.6	9.2	24.8
	M 0-10	7	2.9	8.0	1.4	2.3	80.3
	M 10-20	8	1.5	2.2	0.9	0.5	30.2
	M 55-65	4	2.0	2.2	1.7	0.2	12.1
FL 1	H 0-30						
	M 0-10	8	9.1	14.8	4.9	2.9	32.2
	M 10-20	8	4.1	5.6	1.6	1.3	32.6
	M 55-65	4	2.2	2.4	2.2	0.1	4.1
FL 2	H 0-30						
	M 0-10	7	6.5	8.0	4.8	1.2	17.9
	M 10-20	8	3.5	4.8	1.9	1.1	31.9
	M 55-65	3	1.7	1.7	1.7	0.0	1.8
R 1	H 0-30						
	M 0-10	8	9.3	15.2	3.7	3.4	36.6
	M 10-20	8	1.8	3.4	0.9	0.8	45.2
	M 55-65	4	1.4	2.3	0.7	0.7	52.9
R 2	H 0-30						
	M 0-10	8	14.2	24.0	6.2	5.1	35.8
	M 10-20	8	2.3	4.0	0.6	1.0	44.8
	M 55-65	4	0.4	0.5	0.3	0.1	24.8

Profile carbon values (%) in the Forsmark area A, S, SS and T plots

Site	Horizon depth, cm	N	Average	Max	Min	Std.	Cv, %
1	2	4	5	6	7	8	9
S 1	H 0-30	6	18.4	27.1	12.6	5.4	29.0
	M 0-10	8	0.2	0.2	0.1	0.0	18.0
	M 10-20	8	0.2	0.7	0.1	0.2	113.4
	M 55-65	4	1.0	2.0	0.1	1.0	104.5
S 2	H 0-30	8	18.6	28.4	1.7	8.1	43.3
	M 0-10	7	0.8	1.7	0.3	0.6	71.0
	M 10-20	8	1.5	2.2	0.8	0.5	34.5
	M 55-65	4	1.7	2.0	1.1	0.4	24.5
SS 1	H 0-30	7	19.9	35.6	9.3	8.6	42.9
	M 0-10	8	0.7	1.7	0.2	0.7	95.2
	M 10-20	8	1.3	2.4	0.2	0.9	68.1
	M 55-65	4	1.9	2.3	1.5	0.3	16.6
SS 2	H 0-30	8	17.3	23.2	9.7	5.1	29.2
	M 0-10	8	1.6	5.8	0.2	2.2	139.6
	M 10-20	8	1.4	4.2	0.1	1.4	96.9
	M 55-65	4	1.4	2.1	0.9	0.5	38.7
T 1	H 0-30	8	46.4	46.9	45.3	0.6	1.2
	H 40-60	6	46.0	46.4	45.5	0.3	0.8
T 2	H 0-30	8	46.1	47.2	45.4	0.5	1.2
	H 40-60	8	46.7	49.4	45.1	1.3	2.9
A 1	H 0-30						
	M 0-10	8	3.0	4.0	2.3	0.7	22.0
	M 10-20	8	2.5	3.5	1.8	0.6	23.4
	M 55-65	4	1.8	2.5	1.2	0.6	33.0
A 2	H 0-30						
	M 0-10	8	8.1	11.3	5.7	2.0	24.7
	M 10-20	8	3.4	4.8	2.1	1.0	30.8
	M 55-65	4	1.2	2.6	0.4	0.9	75.0

Nitrogen concentration frequencies (%) in the O-, B- and C-horizons in the Forsmark area and for forest soils in four regions of Sweden

Appendix XIa. O-horizon nitrogen concentration frequencies (%).

Classified intervals	Survey area				
	Sweden	Sweden-IV	Uppsala County	Östhammar	Forsmark
0<x<=1	35.7	33.3	48.1	60.0	23.2
1<x<=2	58.6	50.2	39.6	37.5	69.6
2<x<=3	5.6	3.0	3.2		7.2
3<x<=4	0.1	0.1	0.6		
>4		13.4	8.4	2.5	

Appendix XIb. Upper B-horizon (0-10 cm) nitrogen concentration frequencies (%).

Classified intervals	Survey area				
	Sweden	Sweden-IV	Uppsala County	Östhammar	Forsmark
0<x<=1	99.7	85.9	85.7	90.9	30.0
1<x<=2	0.3	4.9	4.8	9.1	13.6
2<x<=3		4.6	7.1		8.2
3<x<=4		2.9	2.4		10.9
>4		1.7			37.3

Appendix XIc. B-horizon (10-20 cm) nitrogen concentration frequencies (%).

Classified intervals	Survey area				
	Sweden	Sweden-IV	Uppsala County	Östhammar	Forsmark
0<x<=1	99.7	85.9	85.7	90.9	100.0
1<x<=2	0.3	4.9	4.8	9.1	
2<x<=3		4.6	7.1		
3<x<=4		2.9	2.4		
>4		1.7			

Appendix XId. C-horizon (55-65 cm) nitrogen concentration frequencies (%).

Classified intervals	Survey area				
	Sweden	Sweden-IV	Uppsala County	Östhammar	Forsmark
0<x<=1	99.5	97.6	100.0	100.0	100.0
1<x<=2	0.5	2.0			
2<x<=3		0.4			
3<x<=4					
>4					

Profile nitrogen values (%) in the Forsmark area A, S, SS and T plots

Site	Horizon depth, cm	N	Average	Max	Min	Std.	Cv, %
B 2	H 0-30	8	1.12	1.33	0.83	0.16	14.3
	M 0-10	8	0.12	0.17	0.04	0.05	43.0
	M 10-20	8	0.07	0.13	0.03	0.04	51.2
	M 55-65	4	0.03	0.03	0.02	0.01	22.1
B 3	H 0-30						
	M 0-10	8	0.55	0.98	0.33	0.23	41.5
	M 10-20	8	0.30	0.61	0.09	0.18	59.8
	M 55-65	4	0.03	0.04	0.03	0.00	12.0
FG 1	H 0-30	8	0.48	1.11	0.31	0.26	55.1
	M 0-10	8	0.15	0.23	0.06	0.07	43.4
	M 10-20	7	0.06	0.11	0.03	0.03	46.8
	M 55-65	4	0.02	0.03	0.02	0.01	29.7
FG 2	H 0-30	8	1.45	1.78	1.02	0.30	20.7
	M 0-10	7	0.16	0.40	0.11	0.11	64.2
	M 10-20	8	0.09	0.14	0.07	0.02	24.0
	M 55-65	4	0.02	0.03	0.02	0.00	21.1
FL 1	H 0-30						
	M 0-10	8	0.69	1.04	0.40	0.20	28.4
	M 10-20	8	0.32	0.46	0.15	0.12	36.5
	M 55-65	4	0.04	0.04	0.04	0.00	7.6
FL 2	H 0-30						
	M 0-10	7	0.53	0.70	0.40	0.10	18.9
	M 10-20	8	0.28	0.40	0.11	0.09	34.1
	M 55-65	3	0.04	0.04	0.03	0.00	3.5
R 1	H 0-30						
	M 0-10	8	0.50	0.82	0.22	0.18	36.3
	M 10-20	8	0.11	0.17	0.06	0.04	34.6
	M 55-65	4	0.04	0.07	0.03	0.02	44.5
R 2	H 0-30						
	M 0-10	8	0.77	1.17	0.40	0.24	31.2
	M 10-20	8	0.14	0.26	0.05	0.06	42.6
	M 55-65	4	0.04	0.05	0.04	0.00	7.3

Appendix XIIb

Profile nitrogen values (%) in the Forsmark area A, S, SS and T plots

Site	Horizon depth, cm	N	Average	Max	Min	Std.	Cv, %
S 1	H 0-30	6	1.24	1.88	0.86	0.37	30.2
	M 0-10	8	0.04	0.04	0.03	0.01	15.6
	M 10-20	8	0.03	0.04	0.03	0.00	10.6
	M 55-65	4	0.02	0.04	0.01	0.01	39.4
S 2	H 0-30	8	1.34	1.86	0.02	0.60	44.7
	M 0-10	7	0.06	0.08	0.05	0.01	25.7
	M 10-20	8	0.04	0.10	0.02	0.03	61.6
	M 55-65	4	0.03	0.04	0.02	0.01	40.1
SS 1	H 0-30	7	1.27	2.39	0.49	0.59	46.0
	M 0-10	8	0.05	0.14	0.03	0.04	71.4
	M 10-20	8	0.03	0.05	0.03	0.01	18.9
	M 55-65	4	0.03	0.03	0.03	0.00	9.2
SS 2	H 0-30	8	1.04	1.59	0.57	0.33	31.9
	M 0-10	8	0.15	0.48	0.03	0.18	121.4
	M 10-20	8	0.11	0.32	0.02	0.10	94.5
	M 55-65	4	0.06	0.09	0.02	0.04	70.2
T 1	H 0-30	8	1.78	1.94	1.58	0.13	7.5
	H 40-60	6	1.94	2.19	1.58	0.23	12.0
T 2	H 0-30	8	2.01	2.20	1.78	0.13	6.6
	H 40-60	8	2.11	2.95	1.57	0.51	24.1
A 1	H 0-30						
	M 0-10	8	0.31	0.40	0.24	0.07	21.4
	M 10-20	8	0.26	0.36	0.20	0.06	23.1
	M 55-65	4	0.07	0.09	0.03	0.03	37.8
A 2	H 0-30						
	M 0-10	8	0.68	0.93	0.45	0.17	25.4
	M 10-20	8	0.30	0.44	0.18	0.09	30.2
	M 55-65	4	0.07	0.10	0.04	0.02	36.3