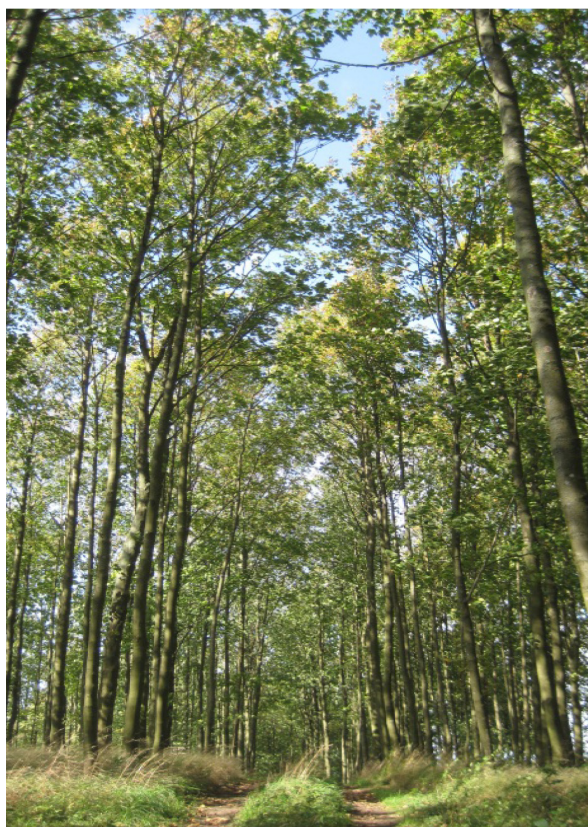




A literature study and survey of sycamore maple (*Acer pseudoplatanus* L.) in southern Sweden



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Supervisors: Emma Holmström

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Master Thesis no. 193

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Abstract

Sycamore maple (*Acer pseudoplatanus* L.) is a common broadleaved species throughout Europe, however often of minor interest to the forest sector. There is currently a lack of research on sycamore maple, and some of its characteristics have throughout history contributed to a negative reputation in both literature and the forest society. Since broadleaved species in general are of great importance to the forest sector in Europe and presumably of enhanced significance in the future, deepened research is needed and particularly Swedish.

With a desire to hopefully increase the interest for sycamore maple, was the objective of the study to examine the current status of the sycamore stands in southern Sweden. The study was carried out both as a survey with inventory field work and as a literature study. Parts of the latter mentioned is also presented in the introduction.

The study shows that the majority of the sycamore stands in Sweden are growing well, producing fairly high qualities and volumes. The survey gives a well detailed description of the current status of where, how and when the stands were established and by whom. In addition, most of the stand and site characteristics.

The lack of historical documentation on different management regimes and proveniences obstruct definite conclusions in the study, the recommendation is to fund more research on the topic in order to bring way for an increased diversity among the broadleaved species in southern Sweden.

Sammanfattning

Sykomorlön (*Acer pseudoplatanus* L.) är ett vanligt lövträd i Europa, dock ofta av obetydligt intresse för skogssektorn. Trädslagets karaktäristika har historiskt givit sykomorlönnen ett oförtjänt rykte, både inom litteratur och skogssektorn och således råder nu en forskningsbrist. Då lövträd generellt är av stor betydelse för skogssektorn i Europa och förmodligen av än större betydelse i framtiden så behövs mer fördjupad forskning, särskilt baserad på svenska förhållanden.

Med önskan om att förhoppningsvis öka det framtida intresset för arten var målet med studien att undersöka den aktuella statusen på sykomorlönbestånden i södra Sverige. Studien genomfördes både som en undersökande granskning och som litteratur studie, varav det sistnämnda också redogörs för i introduktionskapitlet.

Studien visar att majoriteten av sykomorlönbestånden i Sverige har en god tillväxt och genererar höga virkeskvaliteter och volymer. Undersökningen ger också en väl detaljerad beskrivning av var, hur och när sykomorlön bestånden är etablerade och av vem. Dessutom fastställer studien beståndens rådande karaktäristiska, baserat på en rad olika ståndortsbeskrivningar.

Bristen på historisk dokumentation av skötselmetoder och provenienser försvårar säkra slutsatser i den aktuella studien, således rekommenderas finansiering av mer forskning för att bredda väg för en ökad mångfald i lövbestånden i södra Sverige.

Abbreviations

SI	Site index
BA	Basal area
PCT	Pre commercial thinning
CAI	Current annual increment
FC	Future crop thinning
SLU	The Swedish university of agricultural sciences

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Introduction

Acer pseudoplatanus L., commonly named Sycamore maple, has since the last ice age become a widespread but minor broadleaved species in Europe (Weidema et al., 2010, Hein et al., 2009). The species is documented in Britain and Denmark since the 16th century and today naturalized in most parts of these countries. Sycamore is currently categorized as native in six European countries namely Denmark, Germany, Poland, Austria, Czech Republic and Belgium (Evans, 1984, Weidema et al., 2010).

The species natural distribution is a vexed issue (Illustrated in figure 1). As seen, the map does not include Denmark but adds several other European countries such as Italy and Spain. Since sycamore was first introduced into Danish forestry, during the late part of the 19th century, it has been a questioned species (Henriksen, 1988). The reason for the debate has mainly been based on its early abundance of seed and high capacity of natural regeneration. The fact that it is capable of afforesting new areas at the expense of other species, for instance *Fagus Sylvatica* ssp. is one cause of discussion (Henriksen, 1988). Nevertheless, sycamore easily regenerates in mixture with other broadleaved species, for instance beech and this is often the case in Denmark (Holmsgaard, 1981). Some of the Danish opponents to sycamore argument in advantage to beech since they claim that sycamore is not as well adapted to the natural conditions in Denmark and that its average production within a rotation period is scarcely as high as for beech (Henriksen, 1988). The species high capacity of natural regeneration is in focus among the majority of the former research and literature (Lindquist, 1953, Kjølby, 1953, Henriksen, 1988 and Lagerberg, 1962). Lindquist (1953) and Evans (1984) describe sycamore as a threat to other species and literature mention that it frequently has been fought against (Møller, 1965, Sabroe, 1958).

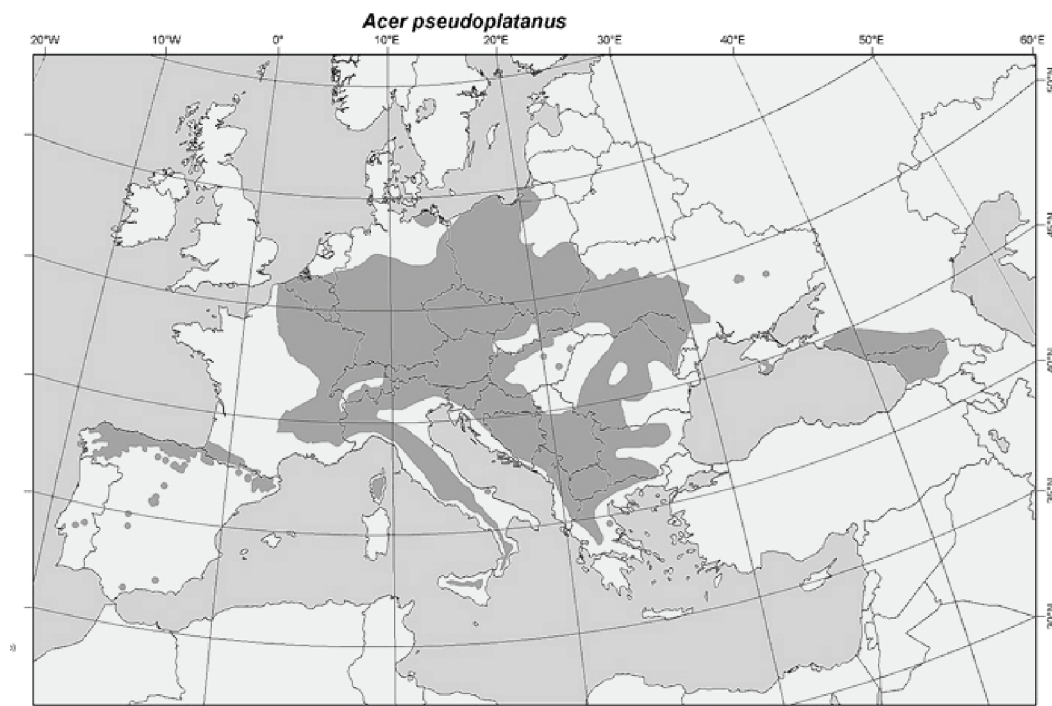


Figure 1. Distribution map of sycamore (*Acer pseudoplatanus*) compiled by EUFORGEN 2009. Retrieved from www.euforgen.org

Former Swedish literature assert that the spread of sycamore in Sweden since the beginning of the 20th was vast, enough to regard the species as fully acclimatized (Wahlgren, 1913). Today sycamore is locally dispersed in Sweden (Weidema et al., 2010). It occurs mainly as natural and as established productive forests within the larger estates in the south, but also as park trees further north (Author's personal comment). Still, recent Swedish literature draw negative attention to its easy natural regeneration by stating that the dense foliage and strongly built root system can oust other species if not controlled (Hallsby, 2007). Likewise, the *Swedish Forest Agency* currently categorize sycamore as invasive¹ in Sweden (Skogsstyrelsen, 2009).

Contrariwise, various research from Europe confirm that sycamore is as a broadleaved species with high potential in modern forestry (Hein et al., 2008, Thies et al., 2009). The species easy establishment and reasonable demands considering site characteristics are then highlighted as positive features (Evans, 1984). One of the main advantages mentioned is that it thrives on a wide range of soils which makes it capable of establishment both as monoculture and in mixture with other species (Evans, 1984, Møller, 1965). Moreover, the timber has a great range of possible utilization, from furniture and flooring to veneer and pulp (Holmsgaard, 1981 and Evans, 1984). Timber of desirable qualities is considered as some of the most valuable since it can yield high market prices (Whiteman et al. 1991, Soulères, 1997 and Evans 1984). Research also state that there is high potential for an expanding future market with timber prices comparable to beech (Møller, 1965). The prices are also expected to increase within the next two decades (Thies et al., 2009).

Historically the foremost literature concerning sycamore is Danish, German and British (Kjølby, 1958). Danish documents have been published since the 17th century and the species breakthrough occurred according to Kjølby (1958) in the years around 1890 when numerous Danish authors began to show interest in the species. Establishment of sycamore was first discussed in German forest literature around the middle of the 19th century. The first theses with aim to investigate the conditions for establishment were German, published during the middle of the 19th century (Kjølby, 1958). Sycamore is first described by British authors in the late 19th century and inventory plots have been established in England since the 1950's (Kjølby, 1953). These initial publications and investigations display a broad span of diverse information and experiences (Kjølby, 1953).

The more recent, probably more comprehensive with current forestry, literature and research is Danish, German, British and French. The foremost literature used in this study is *Ær (Acer pseudoplatanus L.)* by Kjølby et al. 1958, *A Review of growth and stand Dynamics of Acer pseudoplatanus L. in Europe: implications for silviculture* by Hein et al. 2009 and *Vore Skovtræarter og deres dyrkning* by Møller et al. from 1965. The first mentioned literature by Kjølby et al. is a pioneer work regarding sycamore in Europe; it is in this manner fundamental to many of the contemporary authors and researchers which often recite the work. The second is a contemporary research report with an aim to define the species potential in modern forestry while the last mentioned by Møller state explicable biological and silvicultural knowledge characterized by its time. Danish literature has in general been crucial to this study, mainly since there is numerous of published work easy to get hold of. A recommendation is also a compilation of contemporary broadleaved research in *Valuable Broadleaved Forests in Europe* by Spiecker et al. from 2009; this work includes ecological as well as economic and silvicultural research of sycamore and other important broadleaved species in Europe.

The Acer genus

Globally the *Aceraceae* family consists of over a hundred different species (Lindquist, 1953). In which all besides two, within the Chinese genus *Dipteronia*, belong to the genus *Acer* (Nationalencyklopedin, 2011). Some of the other species that the *Acer* genus carries are Elder (*Acer negundo*), Montpellier maple (*Acer monspessulanum*), Tatarian maple (*Acer tataricum ssp.*), Japanese maple (*Acer palmatum ssp.*), Bigleaf maple or Oregon maple (*Acer macrophyllum*), Field maple (*Acer campestre*), Red maple (*Acer rubrum*), Silver maple (*Acer saccharinum*) and Sugar maple (*Acer saccharum*) (Nationalencyklopedin, 2011). The *Acer* family is mainly

¹ Further explanation of invasive species:

<http://www.slu.se/sv/centrumbildningar-och-projekt/artdatabanken/arter/frammande-arter/invasiva-arter/>

spread within the north boreal zones of America, Europe and Asia. The species abundance is found in East Asia and China. One peculiar native *Acer* species found in Japan is the Hornbeam maple (*Acer carpinifolium*). This species completely differs from the typical characteristics of the genus and the leaves resemble much to Hornbeam (*Carpinus betulus*) (Lindquist, 1953).

Acer pseudoplatanus in Scandinavia

Former literature remark that three species of the *Acer* family occur in Scandinavia. Namely, Field maple (*Acer campestre*), Sycamore (*Acer pseudoplatanus*) and Norway maple (*Acer platanoides*) (Lindquist, 1958). The field maple mainly thrives on landscapes minor affected by human alteration and it seldom reaches the forest strata, thus rarely found in pure stands. The species lack competitiveness but might show positive respond to presuming climate change (Lindquist, 1953). Considering Denmark, it is mainly situated on the southern islands whereas in Sweden has been preserved and the occurrence limited to the southern parts of Scania (Lindquist, 1953). The Norway maple occurs within the broadleaved forests in Scania up to Dalälven and in particular edaphic areas in the western parts of northern Sweden. Sycamore, despite not a native Scandinavian species, has spread on fertile soils within parks and plantations during the last centuries. It has shown a higher vitality compared to the native Norway maple. During the 1950's it was the only maple species to be found in pure stands in Scandinavia (Lindquist, 1953). Since the *Swedish National Forest Inventory* register sycamore under 'Other deciduous species', which also includes several additional species, there is no precise amount of how much of the forested area it currently occupies in Sweden (Fridman, 2011).

Sycamore maple in Sweden

The cause for the announcement of sycamore as an invasive species in Sweden is based on its high natural self-sowing capacity. *The Swedish Forest Agency* claims that the species increasing presence has influenced the species abundance of plants and fungi negatively. The Agency stress that it may cause problems within areas attended for preservation of a more domestic flora of trees, for example the national park Söderåsen in Scania (Skogsstyrelsen, 2009). The few silvicultural guidelines for sycamore used in Sweden today are mainly Danish (Møller Madsen, 2011, Runge, 2011). Previous studies of the Swedish sycamore stands are more or less none existing. Hein et al. (2009) also state that there has been limited interest in research concerning the species within Europe due to the fact that it seldom grows in pure stands and is relatively scarce. The current lack of research concerning the species response to environmental, ecological and silvicultural influences makes this study useful (Hein et al., 2009). In order to comprehend the possibilities for an adequate silvicultural management, possible use and accordingly higher interest for this species in Sweden more research is needed, not least Swedish.

The future forestry

Many broadleaved species are considered as more stable to storms, adaptable to elevated temperatures and of crucial importance to forest living animal and insect species, not the least the endangered ones. With the current importance of enhanced biodiversity in addition to presuming climate effects broadleaves might play a more important role in the near future, especially if the forest policy supports their entry by creating subsidiaries. The dependence on conifer species to support the forest industry have been and still are fundamental to many of the great timber and pulp exporting countries in Europe. Introducing more broadleaved species will not affect this, at least not in Sweden since the areas suitable for broadleaves is minor compared to areas suitable for coniferous species (Author's own comment).

Hypothesis

In consideration of different site and stand characteristics is the intent of the study to establish a general overview of the current status of sycamore stands in southern Sweden.

- On what kind of sites, in which region, by whom and when were the sycamore stands in Sweden established?
- Does the location affect the status of the stands, does the northern and southern situated stands display different site and stand characteristics?
- Is difference in quality associated to different site characteristics such as subsoil water, vegetation cover, texture or location?

Materials and methods

Literature study

The secondary data was retrieved as literature from databases connected to the *Swedish University of Agricultural Sciences* (SLU), mainly *Lukas*, *Libris* and *SLU Library Journals*. The management personnel from the forest estates in southern Sweden also recommended some of the foremost Danish literature. The data retrieved by the author herself was assembled through personal communication by e-mail, telephone and meetings with forest owners and/or the forest personnel. The field inventory work also constitutes a great part of this data.

The inventory data was processed in Microsoft Excel and statistically evaluated in Minitab®. The functions retrieved from Kjølby's height development curves and the form quotient table was obtained from Klaus Wunsch at the Danish enterprise KW-PLAN ApS which administrates forest management plans for the estates in Hækkeberga and Skabersjö.

Informal interviews

The Danish forest managers Jesper Runge and Esben Møller Madsen in charge of the estates Skabersjö, Holmeja, Hækkeberga, Trolleholm, Maltesholm and Knutstorp, as well as several former estate managers and forest personnel of *the Swedish Forest Agency* and *Södra Skogsägarna* gave general opinions upon their experiences of sycamore maple.

Inventory work

The intention was to achieve to survey at least ten dominant height trees in each stand and to include as many stands as possible managed by different foresters to ensure diverse silvicultural management. An objective inventory with plots of 5.64 meter radius, equivalent to 100m² was carried out. Five plots were laid out in each stand and a starting point was chosen, not less than 10 meters from the stand border, situated to the nearest road. The following four plots were distributed in order to include as much of the stand area as possible. The site indexes were measured in two different ways. The spruce SI was determined according to site description factors and the Kjølby SI based on height development. The Kjølby SI range from 1 to 4, the first mentioned is the highest, compatible to G36, and the latter (4) the lowest. Kjølby SI is based on the measured height growth and the stand age and calculated with certain function parameters (See Data acquisition below).

Data acquisition

General information of the stands location, establishing year and size was given from each responsible administrator or forest owner. Concerning the stands situated in Hækkeberga, Skabersjö and Trolleholm

additional information regarding Kjølbj SI, year and harvest for the latest performed thinning and site influencing ditching were also given. A site description of each stands dominating vegetation (*Herba* ssp., *Poaceae* ssp., *Cyperaceae* ssp., *Carex* ssp., *Vaccinium myrtillus*, *Vaccinium* and *vitis-idaea*), subsoil water classification (missing, shorter, longer periods), soil texture (clay, silt and clay, sand) and ground moisture class (fresh, moist, dry) were gathered according to SLU:s field inventory guides (Hägglund et al., 2007). A contribution ratio (cover, gaps, missing) of the ground (foremost mosses), field (grass, herbs, sedges, ligneous plants) and tree cover (under storage of sycamore and/or other additional tree species) were also collected. Within each plot all trees with a minimum of 5 centimetres in breast height were included. Breast height diameters of the two thickest sycamore trees, referred to as diameter trees, were measured a second time along with the heights with the help from a digital hypsometer. If another species, included in the plot, was ten or above ten meters high they were noted. The qualities of the two diameter trees along with a third diameter tree, subjectively chosen, were determined according to quality class A to D. (See table 2).

Kjølbj growth functions

The Kjølbj SI was retrieved by using the Danish transformation of Kjølbj's (1958) height development curves. The height in the formula is defined as the highest possible height at a given age dependent of the three constants (k, a, b) and the age. The constants vary according to the different SI categories (1 to 4). In order to determine a precise index interpolation of intervening values was necessary.

Height = $H_{max} * \exp(-k * \exp(-a * t - b * \ln(t)))$
<p>H_{max} = function parameter, the maximal height k = constant a = constant, potential growth b = constant, potential growth t = age</p>

Figure 2. The mathematic growth function of sycamore retrieved from Kjølbj's height development curves (1958).

Volume functions

The volume per hectare was determined by using a Danish form quotient based on the height and the geometric mean diameter (D_{gv}) (See Appendix II). The value of the geometric mean diameter is based on all diameters in each plot in each stand, calculated according to figure 3. The height used in the form quotient is the mean of the two top height trees in each plot.

The Geometric mean diameter (D_{gv})
$D_{gv} = \sqrt{\sum d_i^3 / \sum d_i^2}$

Figure 3. The formula of the Geometric mean diameter (D_{gv}).

Quality determination

The quality determination is, as mentioned above, based on either two or three diameter trees in each invented plot, in total 10 to 15 stems per stand. The quality on each single diameter tree was determined according to table 2 below. As illustrated, class A represents the highest quality class and thus the strictest regulations concerning the type and amount of the defects. Class D represents the poorest quality not to be processed. For all diameter trees an ocular determination was carried out from left to right in the table depending on the amount of defects (See table 2). As seen, the amount of stem crookedness could thus directly determine if a top height tree belonged to class D if the stem crookedness in one joint exceeded 5 % and so on. When un-certainties regarding the amount of knots and epicormic branches on a particular stem length occurred, the hypsometer was used.

Table 2. Quality according to the determination of beech (Fagus spp.) quality. The quality was determined according to the amount of defects on the diameter trees. Class A constitutes the best quality and does not except any defects. Class B is the second best, and C the third. Class D is the poorest, representing those stems that exceed the limits for A-C. Stems in Class D will not be processed.

Defects	Class A	Class B	Class C	Class D
Stem crookedness (in one joint)	Max 5 %	Max 5 %	Max 5 %	Exceeds Class A-C
Fresh knots	Not allowed	Max 2 knots / two meter section The sum of the diameters is not allowed to exceed 20% of the stem diameter	Max 2 knots / two meter section. The sum of the knot diameters is not allowed to exceed 30% of the stem diameter	Exceeds Class A-C
Dry/rotten knots	Not allowed	Not allowed	1 knot max. 4 cm / meter	Exceeds Class A-C
Epicormic sprouting (>2cm=branch)	Not allowed	Small and shallow, max 2 knots / meter	Max 4 knots / meter	Exceeds Class A-D
Occluded knots (Chinese beard)	Not allowed	Max. 1 knot / two meter with angle < 60degrees. The height of the 'knots eye' must not exceed 10% of the diameter	Max. 1 knot / meter with an angle < 60degrees. The height of the 'knots eye' must not exceed 10% of the diameter	Exceeds Class A-D

Kjølby's height development curves

The volume growth is defined as the function of changes in diameter, height and the number of trees per hectare (Hein et al., 2009). Kjølby's (1958) height development curves (See figure 5) illustrate the volume productivity. The site class curves, numbered 1 to 4 derives from the original functions based on former Danish inventory data. As seen and mentioned in figure 5, SI 1 illustrates the highest SI and SI 4 thus the lowest. Kjølby SI 1 is 30 meters at age 100 and Kjølby SI 4 19 meters at age 100, thus a difference in height of almost 10 meters. Regarding Spruce SI there is only 2 meters of difference between G34 and G36. The Kjølby SI: s were calculated for all stands based on the top height trees mean heights and age (Further details in Appendix III).

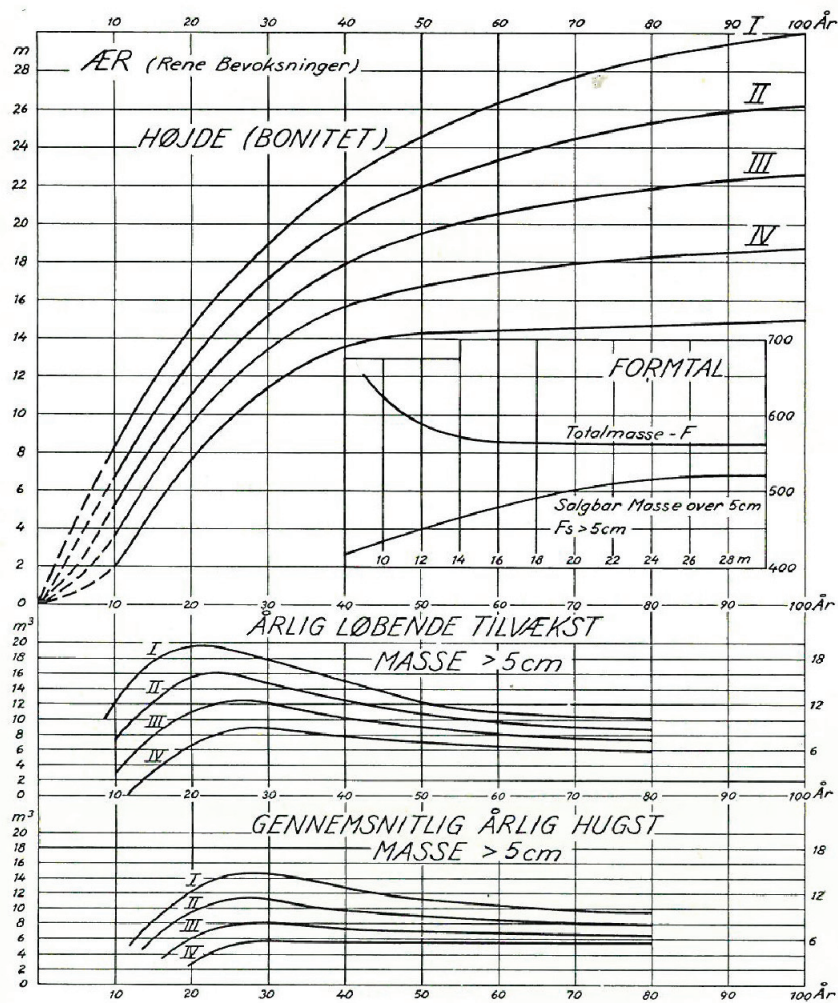


Fig. 10.

Bonitetsvis tilvækstoversigt for ær. Oversigten angives kun grafisk. Kurverne for højde, masse, grundflade og diameter gælder for standpunktet midt mellem hugsterne. Stamtalskurverne gælder for middeltallet mellem stamtallene før og efter hugst i samme hugstår. Alle

Figure 4. Kjølby's height development curves (Kjølby, 1958).

Results

Literature study

Sycamore maple *Acer pseudoplatanus* L. taxonomically belong to the family *Aceraceae* and genus *Acer*. The species was originally distributed within large parts of the middle, south and east European mountain regions i.e. the Alps, Pyrenees, Apennines and the Carpathians areas. In addition, parts of Balkan and northern Greece and Caucasus (Henriksen, 1988). The species optimal growth condition is presumed to be located in the Alps amidst 900 and 1300 meters above the ocean, with a mean annual precipitation of 1400 mm and mean annual temperature from minus three to plus fourteen degrees Celsius (Møller, 1965). Due to the species high capacity of self-sowing (naturally regenerate), it is hard to define its present natural occurrence (Møller, 1965).

Structure

The *Acer* species are anatomically shaped in three different ways. An individual tree can consist of either male or female flowers, contain both female and male or hermaphroditic flowers (Møller, 1965). Sycamore becomes sexually mature at the age of 15 to 20 years old (Barthélémy et al., 2009). The flowers are mainly pollinated by insects, for instance bumble bees, and some by wind. Alike the Norway maple the pollinated flowers develop winged seeds which in autumn spin away from the parent trees (Rusanen et al., 2003). Møller (1965) states that the germination capacity is around 80 percentages, one kilo of seed have been witnessed to produce 3000 seedlings.

One year old seedlings are characterized by an un-branched stem ornamented with two opposite entire leaves. Annual shoots are continually produced during the growth and increase in size during the first years when branches continuously develop (Barthélémy et al., 2009). The upper branches of the crown continuously turn upwards as the tree grows to form a spherical crown. After the tree flourish, a relay axis is formed and at a specific stage in the development the dominance of the relay axis disappears; thereby the top of the main stem forms a double leader (Barthélémy et al., 2009). This fork formation replicates during the succeeding flowerings, the crown of an old tree is thereby shaped by numerous small forks (Barthélémy et al., 2009).

Genetics

The genetic knowledge is considered as poor among several broadleaved species including sycamore (Rusanen et al., 2003). Considering sycamore, there is little research available regarding different proveniences (Jensen, 1984, Møller, 1965 and Henriksen, 1988). Kjølby (1958) state that the majority of the Danish sycamore are assumed to origin from Germany, since the first Danish imported sycamore seeds came from German Thüringen (Møller, 1965, Kjølby, 1958). The species ecological features such as the insect pollination, scattered occurrence and self-compatibility have most likely differentiated the species further compared to wind pollinated species with a more even distribution, for instance *Betula* and *Picea* ssp. (Rusanen et al. 2003). In a study of a hundred single tree progenies with origin from twenty Belgian stands Galoux et al. (1965) observed regional differences in seed size. Galoux (1969) also state that sycamore is an ecological specialised species as a decreased growth potential is connected to increased elevation and temperature from the origin sites. During the 1980's a provenience experiment including 45 different proveniences from seven European countries was collected and planted on ten field experimental sites in Germany. This research showed distinct ecotypic patterns of variation among the trees, some of the proveniences also displayed a virtuous growth development. The proveniences which displayed the greatest height and diameter growth originated from the county of Rosengarten and Bodenmais in Germany and Prachtice and Karlovice in the Czech Republic. The study showed a surplus 30 percentages of the mean height growth for the fastest growing proveniences and minus 15 for the slowest (Kleinschmit et al., 2009).

Sycamore can be bred by grafts, producing genotypes with specific desired characteristics by vegetative breeding is therefore possible (Kleinschmit et al., 2009). Kleinschmit et al. (2009) state that the lack of interest

in sycamore has negatively influenced the gene pool by former extinction, fragmentation, unregulated seed transfer etcetera. However, *Acer pseudoplatanus* is considered to still have a sufficient large population (Kleinschmit et al., 2009).

Soil preferences

Sycamore thrives on various soil textures but seems to prefer the more fertile soils where it is often found in pure stands or in mixture with other broadleaved species (Evans, 1984). Well drained soils with lime and chalk content and acid brown earths with a PH-value of 5.5 to 7.5 are considered as best suitable according to British research (Evans, 1984). Mature trees are considered as frost hardy and tolerant to salt-laden winds and industrial pollutions (Rusanen et al., 2003). Yet, Bryndum et al. (1988) show that too low temperatures in combination with sun can cause cambial late frost damages, appearing as canker wounds. Temperature and precipitation are limiting growth factors as too dry and infertile soils inhibit the growth (Henriksen, 1988 and Evans, 1984). However, when grown on suitable sites sycamore is considered as one of the fastest growing broadleaved species (Hein et al., 2009). The rotation period varies with region, according to Evans (1984) estimated from 50 years and 75 to 80 years according to Hein et al. (2008) and Møller (1965). It can live until an age of 400 to 500 years old (Grosser et al., 1985). Sycamores is regarded as a species in between light demanding and shade tolerant (Møller, 1965). The shade tolerance is considerably higher during the youth and if there is a good supply of water and nutrients (Møller, 1965, Kjølby, 1958). The light demand increases with age and in order to grow well it later demands plenty of light (Møller, 1965, Kjølby, 1958).

Stand preferences

Sycamore can grow under shade from surrounding trees and it often self-sows in mixture with other broadleaves or with broadleaves in mixture with coniferous species (Kjølby, 1958, Evans, 1984). The main species to be found in mixture with sycamore are beech and oak (*Quercus robur* L) (Hein et al., 2008). In addition, Norway maple, field maple, hornbeam (*Carpinus betulus* L.), ash (*Fraxinus excelsior* L.), cherry (*Prunus* ssp.) and various species of *Sorbus* and lime (*Tilia*) (Decocq et al., 2005). The ability to grow in mixture with other species is connected with two main characteristics. Initially, the species early and abundant seed dispersal which stimulates the natural regeneration capacity (Henriksen, 1988). Secondly, the rapid initial growth which attains an early dominance compared to other species (Henriksen, 1988, Evans, 1984, Kjølby, 1953). Danish studies from Skovsgaard et al. (2004) show that stems of 13 meters can yield a basal area of 40 cubic meters per hectare. The juvenile growth is according to Rusanen et al. (2003) faster than most other European tree species. The initial annual growth could exceed one meter on the most fertile soils (Rusanen et al., 2003). The species is competitive in the youth, Hein et al. (2008) state that the species is able to transfer former mixed stands into pure sycamore monocultures within a couple of rotation periods if not early and intensively thinned.

Sites

The chemical composition of the maple species leaves decrease pH-value of the soils. The site flora of sycamore is thus generally subordinated compared to the ground flora of noble broadleaved stands on similar soil. The acid composition also cause comparatively slow litter decomposition with an enfeebled nitrification, therefore it is less likely that the humus cover will deplete (Lindquist, 1953). Still, regarding broadleaved species both sycamore and Norway maple are considered to have a positive soil impact since their leaves are decomposed faster than those of oak and beech but slower than of ash, elm and alder (Møller, 1965). Holmsgaard (1981) and Jensen (1983) state that dense grass vegetation strongly inhibit the growth of sycamore. The growth loss is explained by Evans (1984) as moist and nitrogen insufficiency.

In certain literature, sycamore is described as a species with specific demands regarding soil type (Lagerberg, 1962, Holmsgaard, 1981). It is considered to grow well on deep, nutrient rich humus soil with clay content (Holmsgaard, 1981, Jensen, 1983, Kjølby, 1958). Furthermore, that it prefers well drained soils with good water supply during the entire growth season (Kjølby, 1958, Jensen, 1983, Møller, 1965). Nonetheless, the quantity

and quality of clay is more debated; some research claim that the clay can be fresh put preferably with a sand mixture (Kjølby, 1953). Møller (1965) states that stiff clay is tolerable, whereas Kjølby (1958) shows that seedlings on this type of soil have a delayed initial growth, bleach and yellow deformed leaves and often dry tops and branches. Kjølby (1953) also stress that the species does not endure any stagnant water and that a soil rich in lime is preferable. Furthermore, Jensen (1983) states that efficient supply of water might constitute a more limiting factor to the growth compared to nutrient supply. Yet, if sited with good water supply it can develop high BA proportions on the contrary to drought-inclined sites (Hein et al., 2008).

Natural regeneration

Considered as one of the most consistently seed producing tree species, the sycamore in Europe is mainly naturally regenerated (Thies et al., 2009). Bolton (1949) has observed up to 30 germinated seedlings per square foot in England and Rusanen et al. (2003) state that individual trees can produce up to 170 000 seeds. Bolton (1949) also claim that seedlings deriving from natural regeneration grow faster and produce stems with less and few apparent side branches compared to planted seedlings, due to more optimal light conditions shaped by the parent trees. Sycamore coppices rapidly after cutting, referred to as *Vorwuchs* in Danish forestry, a feature that could be profited when establishing new stands (Bryndum et al. 1988).

Regeneration by planting

Kjølby (1958) promotes low spacing, 1.25 times 1.25, in order to prevent ingrown grass vegetation and quality defects. Whereas later research asserts that wider spacing up to 2.0 times 2.0 meters can produce equally decent quality and economic outcome (Møller, 1965). Larger spacing is likewise considered to profit the fast initial growth and to promote a good natural stem shape, for example less amount of crooked stems (Holmsgaard, 1981). On the non-optimal sites, decreased spacing might be used in order to counterbalance the natural mortality and ensure stand closure (Jensen, 1984). Jensen also (1984) states that planting only should be carried out if the area is maximally 1.0 hectare, since larger stands loose the ability to catch side shade from surrounding stands. Sycamore is suitable for supplementary planting in beech stands when the stems have reached about 2 meters in height (Møller, 1965).

PCT

Considering younger naturally regenerated stands, current research considers positive selection as the most important PCT regime (Thies et al., 2009). The recommendation is to perform PCT when stems are 2 to 3 meters in height (Møller, 1965). Previous research by Jensen (1983, 1984) states that the accurate method is point cleaning, pre commercial thinning by cutting stems within a specific radius, often 0.5 to 1 meter, around the main stem (Karlsson et al., 2002). The naturally regenerated stand should undergo the first PCT at 2.5 to 3 meters of height, leaving about 4000 stems per hectare (Jensen, 1983). Within the next one, around three years later depending on SI and shape, the wolf trees and double tops should be removed resulting in 2500 stems per hectare (Jensen, 1983). The following cuttings ought to be carried out with two to three year intervals with an aim to detain a good height development by removing stems that suppress the main stems (Jensen, 1983). Considering planted stands, the recommendation is to carry out the first PCT slightly later, around ten years after regeneration (Jensen, 1984).

Thinning

There are numerous suggested management alternatives concerning thinning regime and grade. Prior research claim that the BA and CAI will drop and that the positive diameter growth does not substitute the decline if the species is heavily cut (Jensen, 1984). Current expertise in southern Sweden clarifies that sycamore stands, in general and from a historical point of view, have undergone too late and heavy thinnings consequently with a great loss in growth. In addition, that cleanings have been neglected as a result of negative focus on the costs (Møller Madsen, 2011). Møller Madsen (2011) argue that cleanings ought to be performed early in order to take advantage of the fast height development, to hasten stand closure and counter the ingrowth of grass

(*Deschampsia cespitosa* ssp.). The thinnings should be ended around the age of 30 years old, since later thinnings will not influence the growth, and too light and early will counter the growth (Møller Madsen., 2011).

A questionnaire replied by European experts, including head of forest managements, scientists and forest personnel, reveals that the majority recommend a combined negative selection and mixture control in the early stages, followed by a positive selection in the later stages of the stand development (Thies et al., 2009). The questionnaire also discloses that positive selection is the most common treatment in young stands (Thies et al., 2009). Regarding planted stands up to 20 years of age, the majority of the experts recommend cuttings of maximum 500 trees per hectare. If naturally regenerated and of the same age, 1000 to 4000 trees per hectare should be removed (Thies et al., 2009). Most of these experts also emphasize the use of FC. Explicitly, reducing the number of stems in order to promote certain stems of presuming high quality. In FC, the numbers of stems control the growth and determine the thinning intensity in combination with other significant criteria such as the length of branch free bole, crown development etcetera (Thies et al., 2009).

Some evaluations show that sycamore may be treated according to the guidelines for ash (Møller, 1965, Wahlgren 1914). Jensen (1984) recommends a light first thinning in planted stands, carried out at the age of 15 to 18 years old, by removal of approximately 20 to 35 percentages of all stems. These light thinnings should be performed up to the age of 30 to 40 years old in order to avoid loss in growth and flowering which could lead to inferior shape (Jensen, 1984). Others claim that the thinnings ought to be repeatedly carried out every third to fourth year (Jensen, 1984), certainly with no more than intervals of six years (Evans, 1984). Jensen (1984) asserts that it is necessary to perform regular thinnings to avoid epicormic branches and Savill et al. (2009) state that stronger cuttings tend to cease the growth if it is performed in order to catch up with the lack of earlier. On the contrary, some research even promotes heavy thinnings (Holmsgaard, 1981).

Anatomy

Sycamore produces potentially valuable timber characterized by a hard and even-textured grain. The colour is bright with a faint silken lustre covered by small red brown spots formed by the pith rays (Moltesen, 1988). The fibre content is regularly arranged within the wood (Moltesen, 1958). There is little scientific research regarding the content of cellulose, hemicellulose and lignin. The few results available indicate that the composition is approximately the same as of beech (Moltesen, 1988). The fuel capacity is considered as good, but the value per volume unit is estimated to fifteen percentages less compared to beech (Moltesen, 1988).

Defects

There are potential quality flaws that degrade the timber quality. Malmqvist et al (1991) classify dark coloured knots as one of the more serious defects while Jensen (1983) highlights the risks of epicormic branches aroused by too sudden exposure of light after PCT and thinnings. Epicormic branches are especially common among suppressed and co-dominant trees (Moltesen, 1958). Moltesen (1958) mention that frost cracks can appear due to late spring frosts when the annual rings are fragile by composition of parenchymal cells. These cracks can also develop dark coloured false heartwood (Moltesen, 1958). Malmqvist et al. (1991) also highlight stem curvatures related to provenance, top bud drop off and distinct phototropism.

The following five defects have been of most importance to the classification of the wood quality in this study.

Occluded knots

Occluded knots, often referred to as Chinese beard or mustache, occur as angular scars on the bark and often indicate severe quality damages of the wood inside the bark. The angle of the beard is in dependence on the angle of the knot, a narrow angle on the bark cause a narrow angle of the knot inside the bark, hence severe wood damage. As can be seen in the quality determination table it is especially crucial if the angle is below 60 degrees. When occluded knots form bumps without visible scars it is even harder to determine the status of the timber (Hein et al., 2007).

Knots

As mentioned, the dark coloured knot is one of the more serious quality defects (Malmqvist et al., 1991). The knots are composed of more solid wood, compared to fresh knots and the surrounding wood and they also reduce the stability when processing the timber (Møller 1965).

Stem crookedness

The stems can bend both in the basal area and higher up on the stems. Crookedness in the basal area is a phenomenon of gravitropism and occurs within the first years of growth as a cause of top bud drop off, related to frost damage, and a side branch substitutes as the leading shoot. The crookedness among sycamore stems also tend to get transferred as the lowest bud on a crooked stem often grow bigger and develop faster compared to the upper one. The impact of light on growth, phototropism, can also cause stem crookedness (Kjølby, 1958). In addition, browsing and cleaning likewise deteriorate the stem shape. Stem crookedness is considered as particularly common in naturally regenerated stands (Jensen, 1983). A slightly crooked stem is often accepted; however it must be even along the stem and in one joint (See Quality determination, table 2). The cost of processing crooked timber is also assumed to be greater.

Forking (double leader)

Forking, formation of a double leader, also occur when trees loose the top bud. It is especially common if a tree is suddenly exposed to increased light or has flourished in the early years (Kjølby, 1958). Forking reduce the quality since it tends to cause ingrown bark, which also lower the amount of merchantable timber. A fork could also weaken the wind-resilience (Drénou, 2000).

Epicormic branches

There are both physiological and environmental explanations to why sleeping buds develop into epicormic branches. Epicormic branches arise when stems are too quickly exposed to light, for instance after heavy thinnings in dense stands. When former inhibited stems are released they often have a poor crown development and unbalance between the amount of roots and crown size. The increased radiation from the sun chocks stems and buds convert into branches. If there is an unbalance between roots and crown stems also suffer from water deficit which promote epicormic shoots. This quality fault is in general not considered as a major problem, it easy to influence and branches can be removed before growing too big (Jensen, 1983). Yet, the amount and the size of the epicormic branches are of great importance to the quality determination used in this study (table 2).

Defects caused by animal and insects

Sycamore wood is quite often subject to wood defects caused by different species of fungi and insects (Moltesen, 1958). Logs in contact with the ground during the spring and summer months are especially exposed to wood decaying fungi (Moltesen, 1958.) Mould fungi can infect healthy and semi dry logs to cause discolorations which diminish the value of the sawn wood, fungi which cause blue stained wood also occur (Moltesen, 1958). One of the most frequent occurring diseases is *Nectaria cinnabarina*, the Coral spot fungus (Møller, 1965, Wulf et al., 2009, Kjølby, 1958). The fungi infect predisposed stems and branches after injuries or weakening caused by water deficit, severe frost etcetera. It is known to cause the greatest damage on *Acer* species (Wulf et al., 2009). The disease also cause widespread necrosis of bark and cambium, symptoms often appear during the early summer when shoots above fresh bark start to die (Wulf et al., 2009). The coral spot fungi is more common among planted stands compared to naturally regenerated, due to inappropriate seedlings and or sites (Wulf et al., 2009).

The Asian longhorned beetle *Anoplophora glabripennis* has caused severe damages to sycamore in North America during the 1990's (Wulf et al., 2009). The beetle deposits eggs into the bark and the larvae penetrate the wood, leaving the infected parts to die and the wood to rapidly decay. It has been observed in Europe but whether it has caused any outbreaks is yet unclear (Wulf et al., 2009). The honey fungus, *Armillaria mellea* Vahl., is known to affect both standing, dead and rotten non-dry wood. Several other more harmless fungi also

affect sycamore, one of the most common and conspicuous is *Rhytisma acerinum*, Tar spot disease. The tar spot disease discolours the foliage by centimetre large black tar like spots with yellow edges (Møller, 1965, Wulf et al., 2009). Wahlgren (1914) and Kjølby (1958) mention removal of wounded cankers, although without defining the source of occurrence. However, related literature mention that *Nectaria galligena* cause canker diseases which forms crater like wounds with surrounding elliptic ribs of annual wound wood on *Tilia* ssp. (Thies et al., 2009). Whether *Nectaria galligena* cause canker diseases on sycamore is not mentioned.

Game damages such as browsing and cleaning from deer species and gnaws on seedlings from rabbit and hare have been observed (Møller, 1965). In order to avoid growth loss and to develop stand closure Jensen (1984) recommend fencing.

Economic value

With both high economic value and great potential for reforestation of marginalized farmland sycamore is one of the most important broadleaved species in Central Europe (Kleinschmit et al., 2009). Besides, also one of the most progressively valuable broadleaved species in Europe (Thies et al., 2009). The current economic importance of sycamore to the timber and forests industries around Europe is low to moderate. Still, higher market prices for valuable timber produced in short rotations and important characteristics linked to deciduous species, such as biodiversity and recreation, might contribute to a an increase within the near future (Thies et al., 2009). Shorter rotations are explained by decreasing dimension size of merchantable timber, younger stands might thus generate increased economic value (Thies et al., 2009).

In Europe, 1.7 percentages of the total annual cuttings consist of sycamore. Research claim that the future area proportion of ash, sycamore and wild cherry in Europe will double, the future proportion of sycamore harvest could therefore increase remarkably (Thies et al., 2009). These three species currently cover 4.1 percentages of the European forests, with future estimations they are expected to reach up to 8.9 percentages and 12.1 percentages for German speaking countries alone (Thies et al., 2009).

Field of application

Sycamore is used for fabrication of more or less the same items as beech, especially objects which require homogeneity and stability, except those with higher demands in strength and elasticity (Moltesen, 1958). Historically, sycamore has been used among turners in England, manufacturing of the world's supply of wooden pearls in Czech Republic and clogs in Denmark (Moltesen, 1958). The wood lack smell and taste and can be used for several novelties such as household goods, toys, brushes and handles (Moltesen, 1958, Aaron, 1990, Rusanen et al., 2003). If the wood is of high quality and dimension, clean bole without damages or defects and of considerable large diameter, it can be used for veneer and manufacturing of furniture, boards, flooring and other decorations (Moltesen, 1958). However, thinner diameters of slightly lower qualities are also used for furniture (Moltesen, 1958). Moltesen (1958) state that the wood gets slick and stable after processing and thus the finest to be used for the sides and bottoms of drawers. The unique colouring also makes the veneer useable for diverse types of decorations (Moltesen, 1958).

Sycamore also develop an even more valuable wood texture called 'wavy-grained' or 'fiddle-back', this is especially coveted and highly prized among craft and cabinet manufacturers (Rusanen et al., 2003). The most excellent usage is for musical instruments, for instance pianos and violin necks (Moltesen, 1958, Aaron et al., 1990, Rusanen et al., 2003). It is also suitable for manufacturing of more massive furniture and as imitations of nobler broadleaved species, marquetry and semi chemical bond paper pulp (Moltesen, 1958). The wood is not suitable for outdoor usage without preservation treatment (Moltesen, 1958, Rusanen et al., 2003). Generally, the use of sycamore differs in Europe; some countries use sycamore for fire wood while others process sawn timber (Rusanen et al., 2003).

Market prices

Sycamore is currently not processed in Sweden, the logs from the estates in the south is transported to Danish sawmills (Møller Madsen, 2011). The classification of stem quality in this study is based on Danish pricelists and timber assessments. Sycamore quality classes range from A to D, class A defined as the best and D as the worst and not processed. A Danish pricelist, old but still representative, reveals that diameters above 60 centimetres of the best quality class A generate 3605 Danish crowns per m³. Compared to the same list, it is approximately 2000 crowns more than the same quality and dimension of beech (Skoven-Nyt, 1999). A detailed description of the prices is given in table 1.

Table 1. Danish pricelist of sycamore timber in different quality classes, A constitutes the best quality and D the lowest in which the timber does not get processed. Source: Skoven-Nyt 5/99.

Pricelist of Sycamore timber	Quality class			
(Danish crowns per m ³)				
Dimension, cm	A	B	C	D
≥60	3605	2480	900	X
50-59	3055	2190	830	X
40-49	2385	1775	660	X
35-39	1475	1010	540	X
30-34	795	665	540	X
25-29	745	630	540	X
20-24	X	X	X	X

Due to the fact that sycamore can produce valuable timber in short rotations by regular seed setting it has a great potential to even increase in economic importance and inspire further breeding (Rusanen et al., 2003). This is in line with the earlier presumptions of higher market within the next decades (Thies et al., 2009).

Ecological features

Sycamore has potentially high ecological values, which in mixture with other species and creation of structurally diverse stands can be enhanced (Hein et al., 2008). There is currently a lack of research concerning specific ecological features, but earlier research has shown that it supports a wide-ranging spectrum of epiphytes, herbivores and ground vegetation flora within its native geographical areas (Binggeli, 1993). As mentioned earlier, the litter also improve the formation of humus and the recycling of nutrients (Weber et al. 1993, Lindquist, 1953). Binggeli (1994) state that there are a number of epiphytic lichens and insect species connected to sycamore. During shorter periods, presuming during pollination, it is an essential source of food for invertebrates, for instance bees. Rodents and other vertebrates feed on sycamore, as well as migrating birds which feeds on insects underneath the bark of old trees. Birds are in general considered as highly connected to the species, provided that the stands consist of mosaic dispersed isolated trees and shrubs without a continuous canopy cover. However, a completely closed canopy can reduce the species richness and ground flora since it inhibits the amount of light (Binggeli, 1994).

Prospects for sycamore in Sweden

The current labelling of sycamore as foreign and invasive in Sweden can prevent the species from playing a greater part in the southern Swedish forestry, both because it is obligated to report the establishment of foreign species, also because its reputation as invasive might frighten forest owners and companies. However, the situation can be compared to the foreign conifer species *Pinus contorta* which was first introduced in a small scale in Sweden during the 1960's. Its introduction in Swedish forestry was triggered by a presuming timber decline and the introduction of a species with higher production capacity and shorter rotation periods aimed to

ensure an even timber supply (Skogsstyrelsen, 2009). *Pinus contorta* currently occupies nearly 500 000 hectares all around Sweden (Skogsstyrelsen, 2009). Perhaps it is not appropriate to compare a coniferous species to a broadleaved since the forestry in Sweden mainly constitutes of the first mentioned. However, since the so called 'sprucification' or transformation of land by regeneration of spruce on former deciduous areas is debated, it is not a completely unjustified statement (Björse et al., 1998). The *Swedish Forest Agency* also states that the interest in foreign species has increased particularly due to presuming climate changes (Skogsstyrelsen, 2009). The on-going climate change has and will affect the Swedish forests and some of the domestic species might be set aside in advantage to more adaptable introduced foreign species (Skogsstyrelsen, 2009). Research claim that the climate changes most probably have affected the climatic conditions in Sweden during the last century in several ways: The mean annual temperature has increased by 2 to 4 degrees and prolonged the vegetation period by one to two months. The mean annual precipitation has increased by 10 to 20 percentages, the summer rain is heavier, the deficit of water has on average decreased and there might be more likely that storms occur (Skogsstyrelsen, 2009). Furthermore is there also a higher risk for tree damages caused by several common species, for instance Root rot *Heterobasidion* ssp., pine weevil *Hylobius abietis* and bark beetle *Ips typographus* L, as well as new introduced insect species (Skogsstyrelsen, 2009). Even though foretelling climate changes is problematic, German research state that sycamore has a capacity to adapt to on-going changes if it results in elevated temperatures and reduced precipitation (Kölling et al., 2007). As response to climate changes, need and interest for more broadleaved and foreign species sycamore could gain a higher status among the Swedish forestry sector.

The survey and field inventory study

Study sites

The Swedish Forest Agency in Scania (Office of Höör) searched sycamore stands in their database, according to notifications of cuttings from year 2000 to 2010. The outcome was 5 stands, one located in the county of Kalmar (2.9 ha) and four in Scania, amounting to 7.4 hectares (Skogsstyrelsen, 2011). A visit to the office searching for additional ones gave no result. The forest company *Södra Skogsägarna* as well as the Swedish Forest Agency in Halland (Office of Ullared) were not aware of any sycamore stands in their regions. In addition, a few stands situated on Visingsö (island in Lake Vättern) were also found (Kraft, 2011). Bilde Jørgensen (2011) mentioned some experiment plots with sycamore in Denmark, for instance plots with thinning experiments situated in Midsjælland and Nordfalster, as well as plots with sycamore in mixture with broadleaved and coniferous species in Sjælland, Fyn and Midtjylland. None of these mentioned stands were included in the study. However, one inspector at *Södra Skogsägarna* knew about the one stand situated on Hallandåsen (S40).

Forty sycamore stands located within a south and a north region in southern Sweden was invented (See figure 6). The majority of the stands belong to some of the bigger south Swedish forest estates namely Skabersjö, Holmeja, Häckeberga, Trolleholm, Maltesholm and Knutstorp, managed by two different Danish foresters. The remaining part is also privately owned, managed by two different Swedish foresters and one private owner. Approximately 43 % of all stands (17 stands) were located in the north region and 57 % (23 stands) in the south. At the time of the inventory work all stands were classified as pure sycamore monocultures according to their forest management plans.

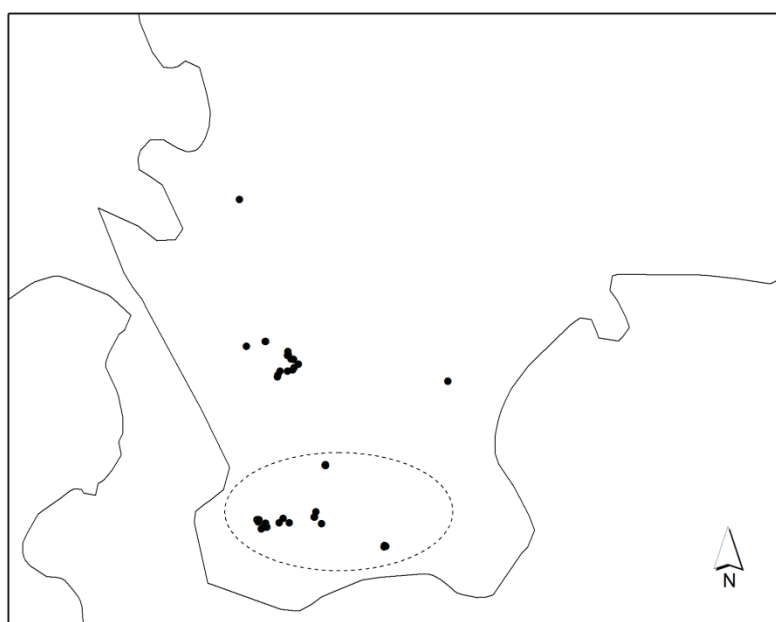


Figure 5. The geographical location of the invented stands. The stands are situated in nine differed areas and two regions, the north region contain 17 stands and the south (inside the circle) 23 stands.

There was only a limited selection of sycamore stands in Sweden, all situated in the south. The majority of the stands belonged to vast landowners with Danish management personnel, probably of similar manage according to Danish influences. The stands historical silvicultural management and proveniences were unfortunately too poor to be fully included in the study. The only true knowledge of the management was the time (year) and

the harvest (m^3sk) of the latest thinning. Concerning provenances, none of the stands included in the study had any specific confirmed. Neither was the time nor the harvest taken into account in the data analysis.

A simplified version of the general characteristics of each location is given in table 3. Fifty percentages of the stands were situated on the estates Skabersjö and Trolleholm. Håckeberga, Krageholm and Silvåkra each held four stands while Holmeja and Knutstorp held three. Maltesholm and Rössjöholm are represented by one stand each. The spruce site indexes varied from G34 to G36 and the mean ages in each area were quite evenly distributed around 40 to 50 years old. The mean size varied from 0.3 to 2.8 hectares, and the total areal of each location from 0.6 to 11.0 hectares. Krageholm is by far the single biggest location with 11.0 hectares divided in 4 stands. Table 3 shows that there were five different administrators, in which six locations were managed by two Danish foresters (Skabersjö, Holmeja, Håckeberga, Trolleholm, Maltesholm and Knutstorp). These two were altogether in charge of 15 respectively 16 of the invented stands. Two others shared a hold of eight stands (Locations Krageholm and Silvåkra) and a single private owner of one location (Rössjöholm).

The mentioned 31 stands in charge by the two Danish administrators differed considerably from the remaining nine. The stands were all in all well managed; from a silvicultural perspective they appeared to have undergone both PCT and frequent thinnings to a greater extent, perhaps also at a more suitable time compared to the others. The quality defects were not as apparent, instead less frequent on several stems rather than extreme on few. The sites seldom showed signs of “extreme” site characteristics, they were rarely too moist or too poor and the surrounding stands constituted of species with more comparable site demands, for example beech rather than spruce. However, there were more obvious signs of game within these stands mostly as grubs in the soil caused by wild boars, even though this is not taken in account in the analysis.

Table 3. General information on the invented stands divided by each location

Location	Geographic region	Administrator	Nr of stands	Site index (Spruce)	Mean age	Mean size (ha)	Total area (ha)
Skabersjö	South	2	8	G34, G36	48	1.0	8.1
Holmeja	South	2	3	G34, G36	47	0.9	2.6
Håckeberga	South	2	4	G36	53	1.4	5.5
Trolleholm	North	1	12	G35, G36	44	0.7	8.6
Maltesholm	North	1	1	G36	16	0.6	0.6
Knutstorp	North	1	3	G36	50	0.8	2.5
Krageholm	South	3	4	G36	42	2.8	11.0
Silvåkra	South	4	4	G36	44	0.3	1.2
Rössjöholm	North	5	1	G34	51	0.8	0.8

Area

Table 3 state that twenty-five of the stands had an area of less than 1.0 hectares, thirteen of the stands were in between 1.0 and 2.0 hectares. There were only two stands larger than 2 hectares, namely stand number 32 (3.3 ha) and stand number 34 (5.6 ha).

Age

The stands had an age distribution of 15 to 90 years old with a mean age of 46 years. The majority of the stands were in between 38 and 57 years old. The three outliers are stands of age 15, 16 and 90 years old (See table 3).

Top height

The top heights seen in table 4 were derived from the mean height of ten dominant height trees in each plot. The top heights varied from a minimum of 14 meters to a maximum of 21. The mean top height was 18.5 meters, the upper quartile (Q3) 19 and the lower quartile (Q1) 18 meters (Seen in table 5). Moreover, figure 6 states where the invented stands are distributed among Kjølby's growth curves. As seen, an age wise cluster occurs from age 35 to 55 years old. The majority of the invented stands are below Kjølby SI 2, the one stand below index 1 is one of the youngest stands (S16, age 15 years).

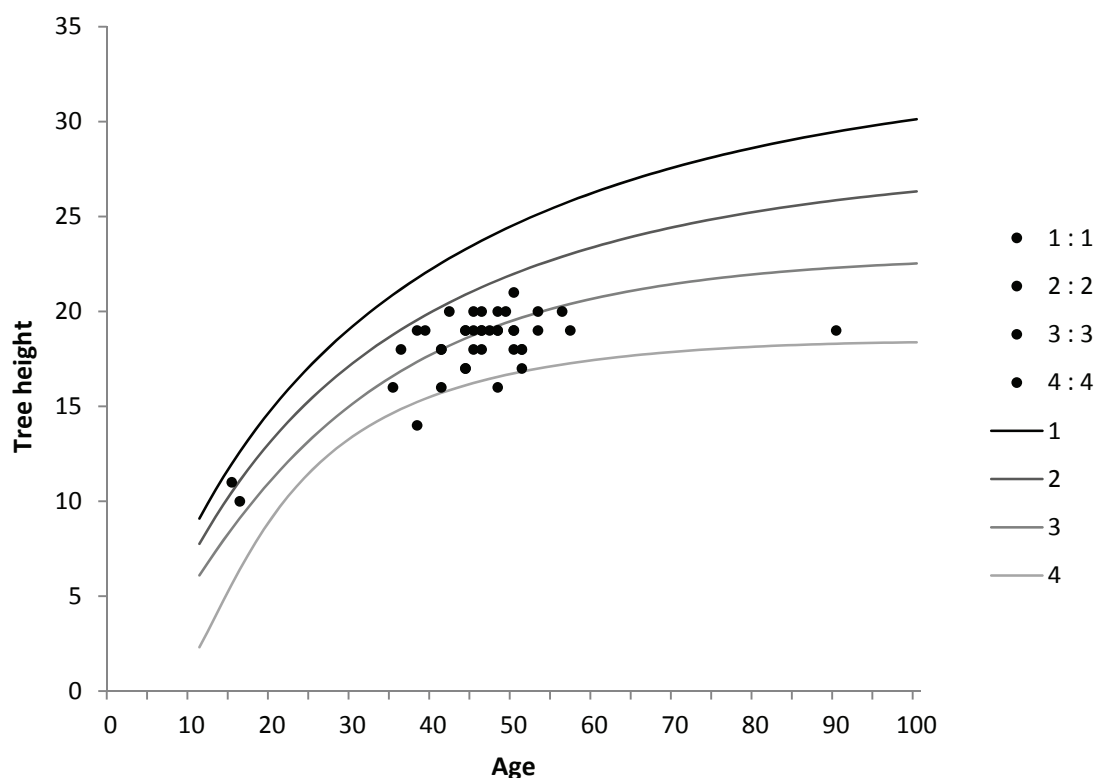


Figure 6. A comparison of Kjølby height growth curves and the invented stands.

Mean BA per hectare

The mean BA per hectare was calculated for all stands, based on the values of all five plots on each site. The minimum mean BA was 8 m² per hectare and the maximum 66 m²/ha. As seen in table 5, the mean BA was 33 m²/ha. The quartiles state that 75 % of the stands had a mean BA below 42 m²/ha but above 27 m²/ha.

Percentage sycamore

The sycamore percentage in table 4 and 5 are based on a comparison of the number of sycamore and the number of other species in each invented plot. The value was calculated by division of all sycamore stems in all plots (in each site) divided by all stems of all occurring species in all plots in each site. The sycamore percentages varied from 42 up to 100 %. The result state that 75 % of all stands were not pure sycamore monocultures and 25 % was (if regarded pure as 100 % sycamore), furthermore that one fourth of the stands had less than 71 % sycamore and three quarters more than 71%.

Sycamore volume

The sycamore volume given in m³sk per hectare was derived from the Geometric mean diameter (D_{gv}) and BA (m²/ha), as well as specific form quotients of sycamore, a more detailed description is given in Appendix II. The tables show that the sycamore volume varied from a minimum of 32 m³sk to a maximum of 407 m³sk per

hectare (See table 4 and 5). The mean value was 234 m³sk. The most frequent volume per stand was between 200 and 300 m³sk/ha (table 4).

Species mix

The species mix in table 4 states the occurrence of all other species beside sycamore in each stand. The species first stated in the column refers to the most frequent occurring. In total, 75 percentages of all stands held other species than sycamore. Represented in 89 % of all stands with other species occurring, beech was the most common other species. Oak and ash was the second most common with 25 % and birch and hazel third with 11 %. Half of the stands with dominating beech held beech in mixture with other species, oak and beech as the most frequent mixture.

Stems per hectare

The amount of stems per hectare is referring to the average number of stems (all occurring species) of 5 cm or above in all plots on each site. As can be seen in table 4 and 5, a maximum 1460 stems/ha and minimum 240 stems/ha. The mean value was 720, 25 % of all stands had more than 460 and 75 % less than 460 stems/ha. The percentage of stands in different diameter classes (x-axis referring to stems per hectare) given below in figure 7 show that most stands (25 % respectively 23 % of all) had in between 200 to 500 stems/ha.

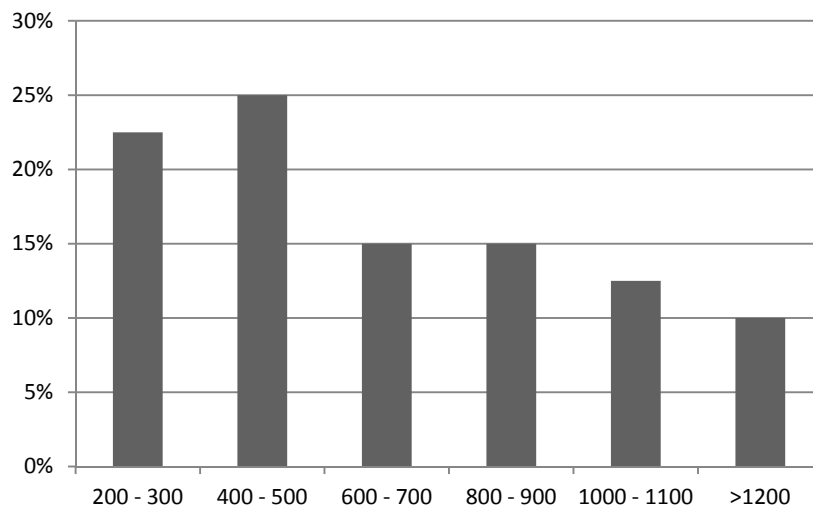


Figure 7. The percentage of stands in different diameter classes (x-axis stem class in amount of stems per hectare)

Table 4. The characteristics of all invented stands. The column geographic location refers to the location seen in Figure 1.

Site	Location	Geographic location	Area (ha)	Age	Top height	Mean BA (m ² ha)	Sycamore Percentage	Sycamore Volume (m ³ sk/ha)	Stems (per ha)	Species mix
S1	Skabersjö	South	0.7	51	18	27	91	225	460	beech
S2	Skabersjö	South	0.7	53	20	34	100	338	340	
S3	Skabersjö	South	0.9	46	18	42	100	352	1000	
S4	Skabersjö	South	0.9	46	20	34	87	280	460	beech
S5	Skabersjö	South	1.7	49	20	27	100	259	340	
S6	Skabersjö	South	1.5	44	17	27	100	219	760	
S7	Skabersjö	South	0.2	48	19	33	100	305	500	
S8	Skabersjö	South	0.5	47	19	35	100	309	580	
S9	Holmeja	South	0.6	36	18	40	98	341	1000	birch
S10	Holmeja	South	0.6	57	19	45	93	361	800	birch, hazel
S11	Holmeja	South	1.5	48	19	34	93	282	800	beech
S12	Häckeberga	South	2.1	90	19	28	82	210	340	beech, oak
S13	Häckeberga	South	1.2	35	16	66	83	407	940	birch, beech
S14	Häckeberga	South	0.3	38	19	30	89	240	760	beech
S15	Häckeberga	South	2.0	50	19	22	100	198	340	
S16	Trolleholm	North	0.6	15	11	16	82	68	1100	cherry
S17	Trolleholm	North	1.0	44	17	43	65	224	1140	ash, beech
S18	Trolleholm	North	0.4	45	19	34	42	126	960	beech
S19	Trolleholm	North	0.5	46	19	34	68	212	680	beech
S20	Trolleholm	North	0.3	41	16	56	68	295	1440	ash, beech
S21	Trolleholm	North	0.7	44	19	43	76	294	740	beech, oak
S22	Trolleholm	North	0.5	46	19	49	79	346	1400	Beech,hazel,ash
S23	Trolleholm	North	0.7	56	20	29	75	207	400	beech
S24	Trolleholm	North	1.0	39	19	27	74	178	540	beech
S25	Trolleholm	North	1.7	48	16	34	89	235	1240	beech
S26	Trolleholm	North	0.3	50	18	48	52	213	1040	beech, oak, ash
S27	Trolleholm	North	1.1	53	19	25	46	102	520	beech, oak
S28	Maltesholm	North	0.6	16	10	8	100	32	1460	
S29	Knutstorp	South	1.0	51	17	41	75	247	900	beech, oak, ash
S30	Knutstorp	South	0.4	50	21	43	67	279	480	beech
S31	Knutstorp	South	1.0	50	19	20	57	100	600	beech
S32	Krageholm	South	3.3	44	19	25	100	225	300	
S33	Krageholm	South	0.8	41	18	35	62	194	580	beech, ash
S34	Krageholm	South	5.6	42	20	26	80	202	300	beech
S35	Krageholm	South	1.3	41	18	32	81	223	620	beech, hazel
S36	Silvåkra	South	0.2	45	20	16	100	147	240	
S37	Silvåkra	South	0.2	45	18	27	89	200	540	ash, beech
S38	Silvåkra	South	0.3	48	20	27	100	256	260	
S39	Silvåkra	South	0.5	38	14	11	93	126	300	oak
S40	Rössjöholm	North	0.8	51	18	32	93	213	860	beech

Table 5. Statistics on different site characteristics, based on 37 of the invented stands.

	Age	Age class	Top height (m)	Mean BA (m ² /ha)	Percentage Sycamore	Sycamore volume (m ³ sk/ha)	Stems (per hectare)
Median	46	40	19	34	83	225	620
Mean	46	42	19	33	82	234	720
Min	35	30	14	8	42	32	240
Max	57	50	21	66	100	407	1460
Q3	50	50	19	42	100	295	980
Q1	43	40	18	27	71	199	460
Range	22	20	7	58	58	375	1220

Site characteristics

The distribution of Kjølby SI among all invented stands divided in the north and the south region is seen below in table 6. On average, both regions reached an index of 3.0 with a minimum of 1.4 and a maximum of 4.1. The stand with the highest Kjølby SI (1.4) is one of the youngest stands (S15, age 15 years), all other stands had an index above 2.0. The high Kjølby SI is therefore not to be regarded as representative to the majority of the stands. The table indicates that there is less difference in Kjølby SI among the southern stands; this is explained by the presence of the two youngest stands (S16 and S28, age 15 and 16 years).

Table 6. The Kjølby site indexes of all invented stands categorized in the north and south region.

Kjølby Site index	Total invented	Minimum value	Maximum value	Average
North	17	1.4	4.1	3.1
South	23	2.2	3.8	2.9
Total	40	1.2	4.1	3.0

The figure of top height versus age (seen in figure 8) comparing top height with age and Kjølby SI shows the range of the top heights very between 14 and 21 meters and the age of 35 to 60 years. The figure shows that the majority of the invented stands had Kjølby SI 3.

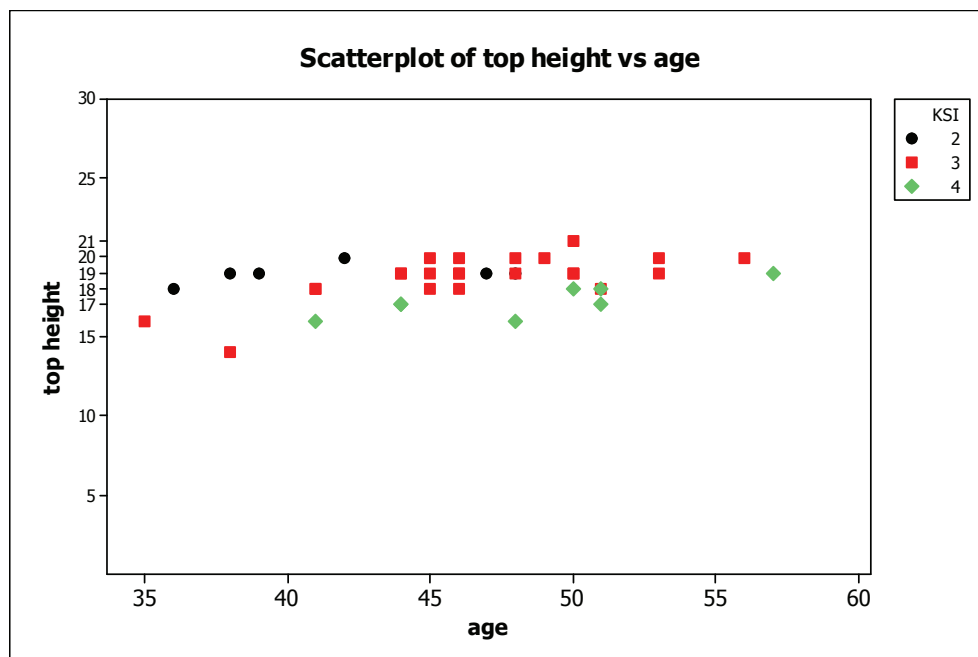


Figure 8. The distribution of the invented stands different Kjølbj and Spruce SI and the variation of age.

Site vegetation

An important factor that influences the spruce SI is the dominating site vegetation. Figure 9 shows the dominating site vegetation in all stands in each region. The north region showed higher amount of all types of dominating vegetation, except from the rich herb type which was dominating by a surplus of 12 % within the southern region. The higher amount of rich herbs in the southern region could be explained by a higher average of rich soils, but could also be connected to the contribution ratio below.

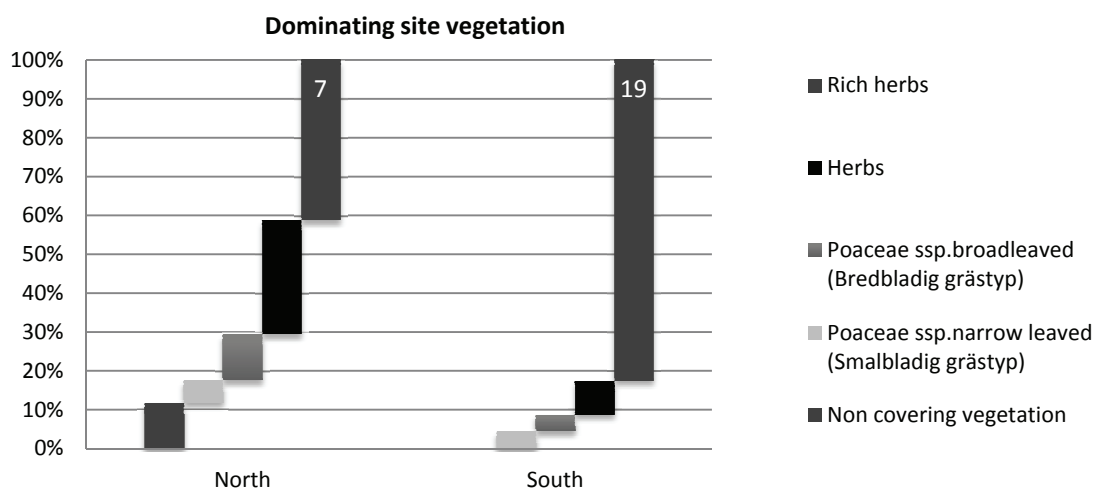


Figure 9. The dominating site vegetation in all stands divided by region.

Vegetation contribution ratio

The contribution ratio of the ground, field and tree layer of all inventoried stands in each region is shown in table 7. The table shows slight variations in cover rate among the south and the north region. The contribution ratio was more or less the same for the ground layer. However, the south region showed more gaps. The field layer was slightly denser in the southern region, but there were more gaps in the tree layer in the north. The table also shows that the northern region continuously had a understorey of tree layer while 57 % of the stands in the southern region lacked this layer entirely. The tree layer refers to the occurrence of a tree layer beneath the main layer of sycamore.

Table 7. The contribution ratio of all stands divided into ground, field and tree layer in the north and the south region.

	Ground			Field			Tree		
	Cover	Gaps	Missing	Cover	Gaps	Missing	Cover	Gaps	Missing
North	1	6	10	10	7		5	12	
South	1	11	11	18	4	1	2	8	13
Total	2	17	21	28	11	1	7	20	13

Qualities

Quality grades

The stands distribution of the four quality classes within the north and south region are seen as the percentage of the total in figure 10. The figure only shows the majority of the stands within 35 to 57 years old since the outliers of age 15, 16 and 90 years old have been left aside due to age incomparability.

The figure shows that the best quality class (A) occurred in roughly half of all stands (45 %), with a maximal single stand percentage of 21. Class A was evenly distributed among the north and south region, represented in nine stands in each region, with slightly higher average percentage in the north. Compared to A there were greater amounts of class B in all stands in both regions, the maximal single stand percentage was 80 %. Considering the average of all quality determined trees, there were higher amounts of class A and B in the south region compared to the north (64 % respectively 47 %).

Class C had a maximum single stand frequency of 79 % and the average percentage of the class was higher in the south compared to the north. The worst quality class D occurred in 31 stands, the highest single stand frequency was 40 %. The north region had a slightly higher frequency of class D, 14 out of 15 stands in the north had stems of class D compared to 17 out of 22 in the south. However, the south region held the highest maximum and the lowest minimum percentage.

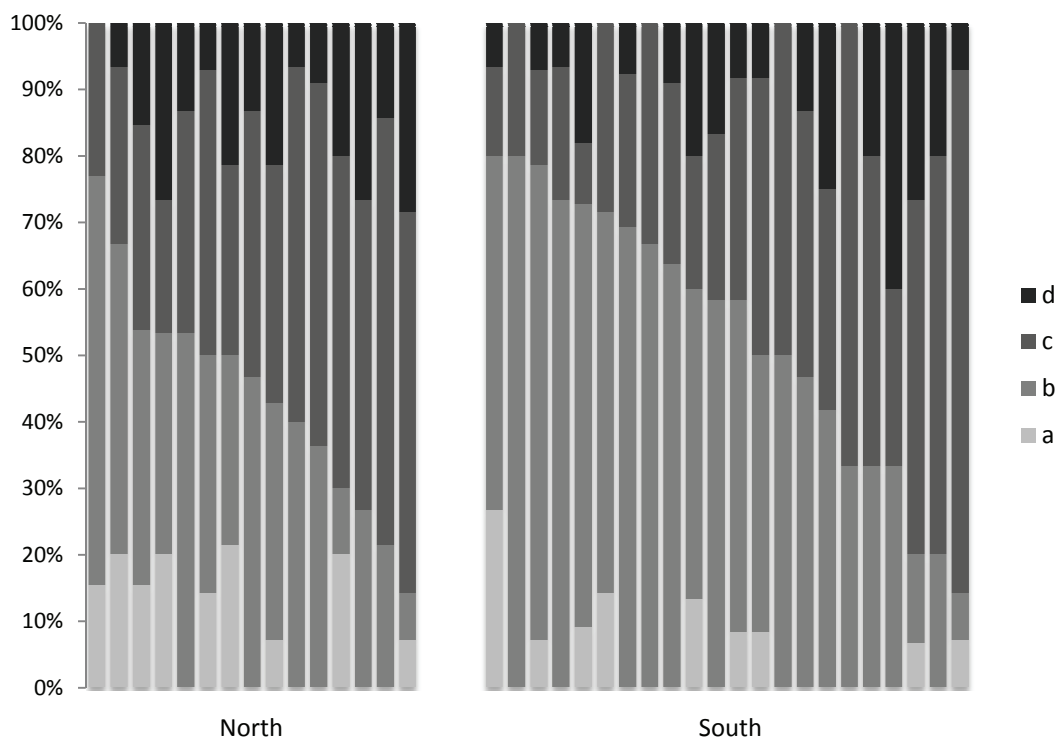


Figure 10. The distribution of quality classes of 37 of the 40 invented stands, divided into the northern and southern geographical location and the percentage of forks in each stand.

Timber quality defects

The timber quality defects refer to the amount of specific quality defects in which determined the quality class (A to D). The percentage data of the specific quality defects, figure 11 to 17, is based on the number of diameter trees with the specific quality defect divided by the total number of observed diameter trees (for 37 out of the 40 stands). The amount of each specific quality defect below is based on all stands since the comparison of the north and south region did not show any obvious differences.

Double leaders

Figure 11 shows the percentage of double leaders, forking, among the stands. The figure shows that forks occurred in 90 % of all stands, and that the stand percentage varied from a minimum of 7 % to a maximum of 21 %. Considering all stands, there was a quite even distribution among higher and lower percentages. 42 % of the stands with forks had below 10 % forking among the diameter trees whilst the remaining 58 % had 10 % or above.

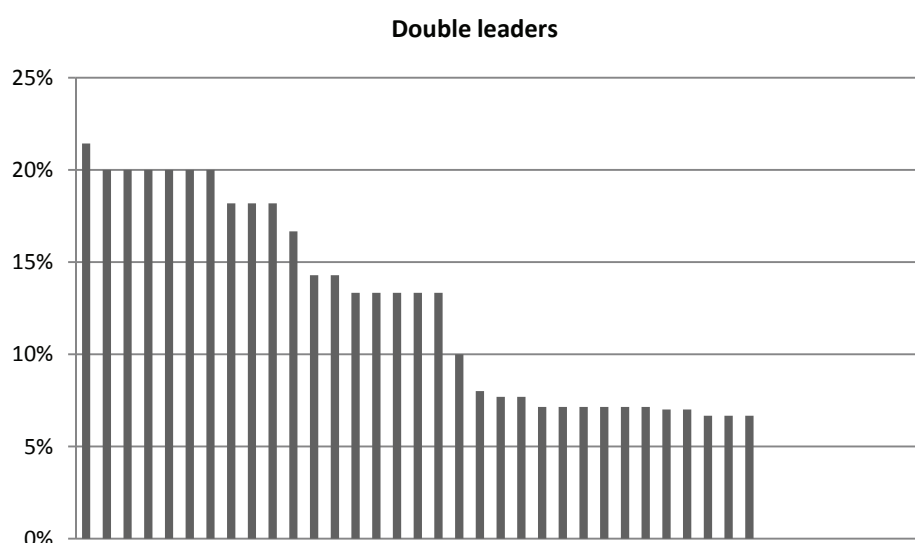


Figure 11. The percentage of double leaders referred to as forks among the diameter trees.

Occluded knots

The percentage of the quality defect in figure 12 is based on the number of observed diameter trees with occluded knots divided by the number of observed diameter trees in each stand, divided by the north and south region. The figure shows that occluded knots occurred in all 37 stands, the most frequent occurring percentage, represented by one fourth of all stands, were between 20 and 25 %. The figure does not indicate any difference among the north and the south region. However, the majority of the northern stands (three quarters) showed quality defects of 20 % or above compared to one third in the south.

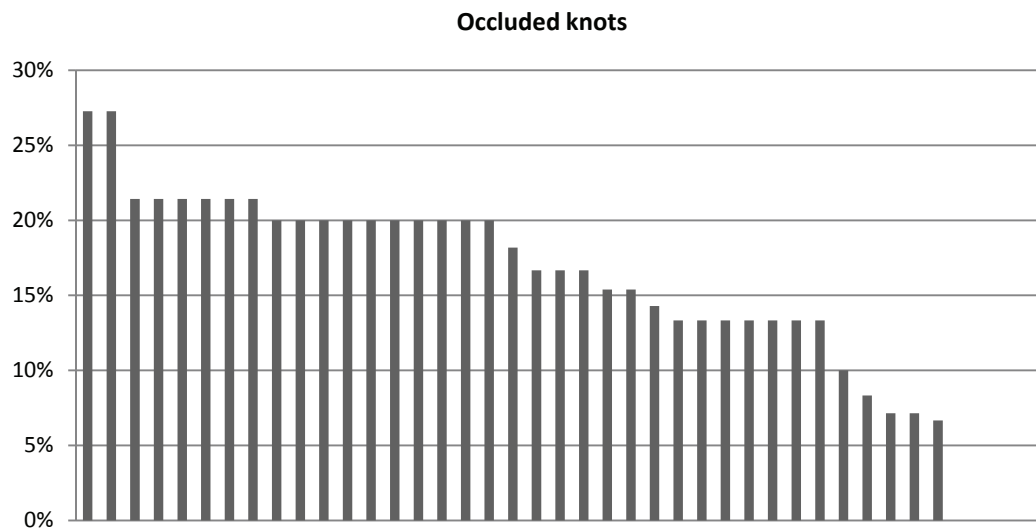


Figure 12. The percentage of the quality defect occluded knots among the diameter trees.

Knots

Figure 13 shows that all stands had a percentage distribution of both fresh and or dry knots among the observed diameter trees. The amount of both types of knots varied from a minimum of 7 to a maximum of 30 %. The fresh knots showed higher percentages in general compared to the dry and the occurrence of dry knots was always combined with fresh. Considering both types of knots within the stands the figure shows that the occurrence varied from 20 to approximately 55 % of all observed diameter trees in each stand. Both the north region and the south region had two stands with solitary fresh knots.

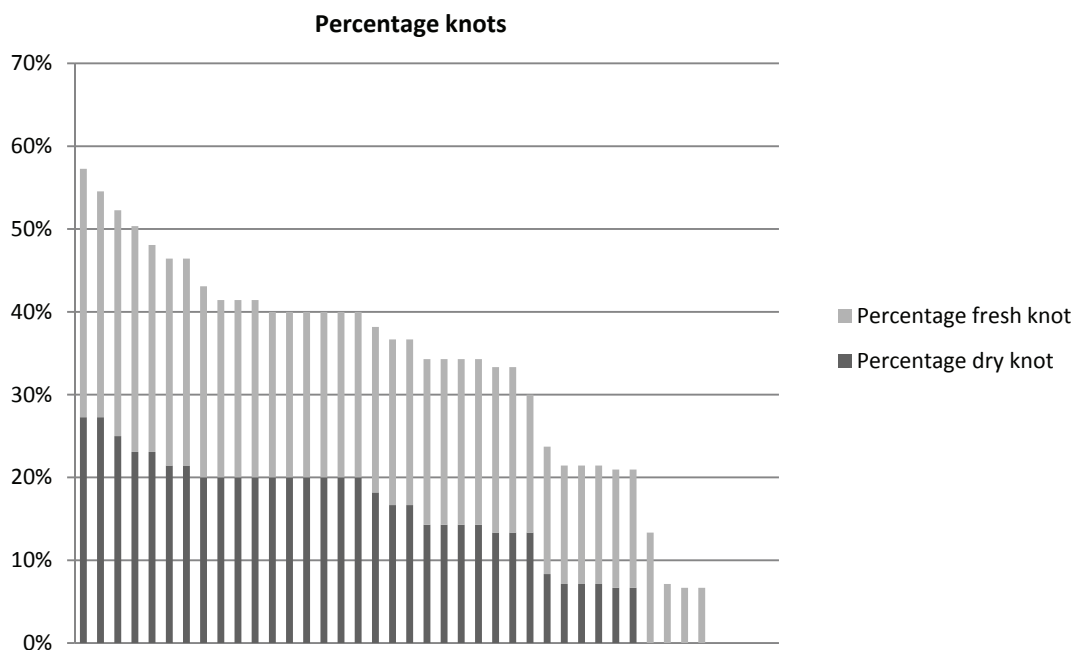


Figure 13. The percentage of fresh and dry knots among the diameter trees in the north and south region.

Epicormic branches

Figure 14 shows that about 95 % of all observed diameter trees had epicormic branches. The percentage of the quality defect had a minimum of 7 and a maximum of 25 %. It was generally a quite even percentage distribution of the quality defect, 37 % of all stands showed an occurrence of 20 % or above. The same amount of stands also showed an occurrence of 10 to 19 %, while the remaining 26 % of the stands showed 1 to 9 % of the defect.

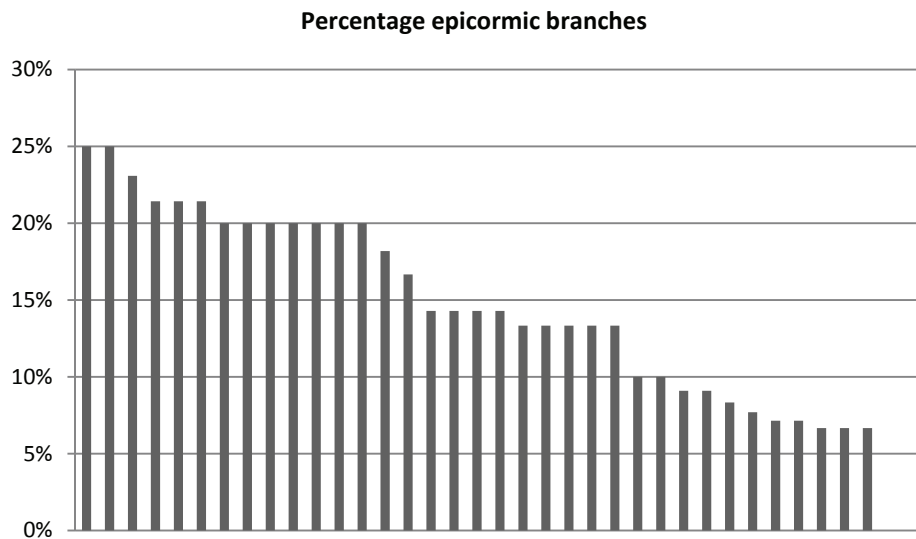


Figure 14. The percentage of epicormic branches among all diameter trees.

A comparison of the stands located in the north and south region (See figure 15) showed that the south region had higher percentages in general, 13 out of the 21 stands in the south had an occurrence above 15 % while the north showed 2 out of 14.

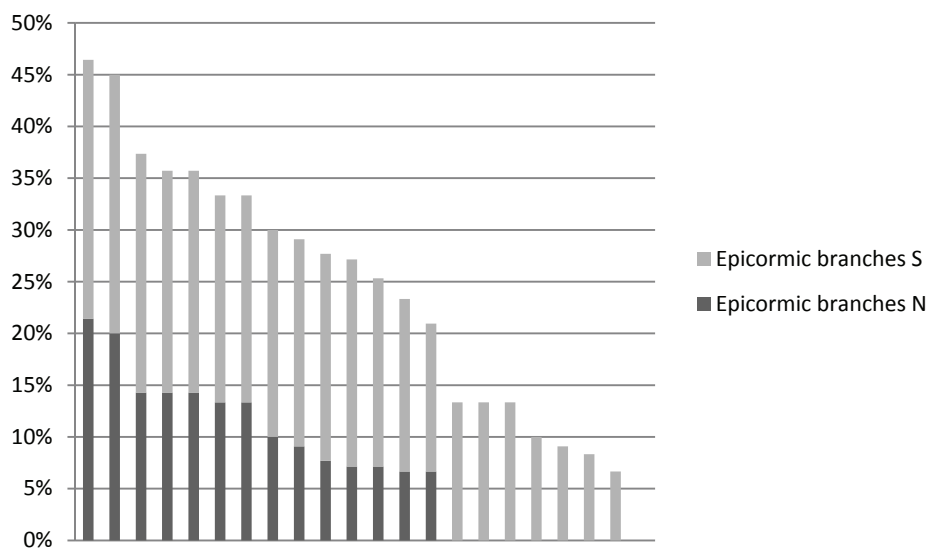


Figure 15. A comparison of the percentage of epicormic branches in the north and south region.

Knobs

Figure 16 shows the percentage of knobs among the stands in the north and south region, as can be seen 27 % of all stands in north region and 59 % of the southern had knobs. There was no clear difference in the percentage among the two regions, the figure only indicate that 46 % of the south region stands showed higher percentage values compared to the northern.

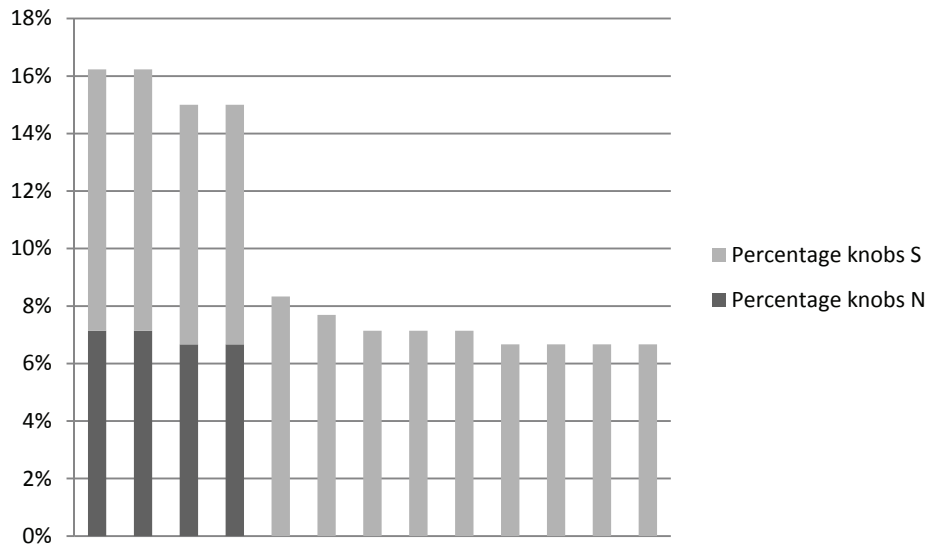


Figure 16. The percentage of the knobs divided by the north and south region.

Stem crookedness

The percentage of stem crookedness among the diameter trees are given in figure 17. The figure shows that crookedness was not especially common, but slightly more common among the stems in the north region compared to the south, two thirds were crooked in the north compared to one fourth in the south. This was the least common quality defect.

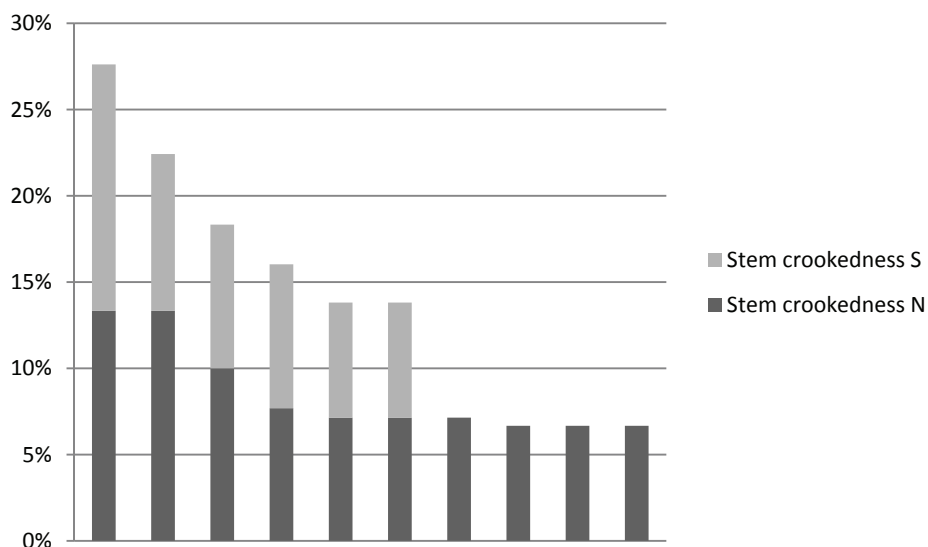


Figure 17. The percentage amount of stem crookedness among the north and south region.

Other quality defects

Four stands (two in the south and two in the north) showed other quality defects than the ones declared in the quality determination table. The quality defects in the two northern stands occurred as stems with triple leaders and wood injuries alike the earlier mentioned *Nectaria galligena* (For pictures, see Appendix VI). One of the southern stands also had the latter mentioned injury and the other one bark cracks. However, the defects only occurred on a couple of stems.

Soil texture

Table 8 shows the distribution of soil texture and subsoil water classes divided by the north and south region. As seen, the south region showed higher amounts of the finer soil textures clay and silt clay in both longer and shorter periods of subsoil water (20 compared to 9). The south region also had more stands with longer periods of subsoil water, 48 % of the stands compared with 12 % in the north. None of the stands in the south lacked subsoil water. The north region had a few more stands with short periods of subsoil water, the same region held the only stand with missing subsoil water and the highest amount of sand soil texture. The table also shows that the stands located in the north region were more often situated in slope areas, with shorter periods of subsoil water (83% of all stands) and soil texture SC or S. The southern stands had a quite even distribution between longer and shorter periods of subsoil water, 48 % respectively 52 % of all stands. Concerning soil texture in the south, 70 % were of SC. Moreover, table 8 indicates that sycamore is not established on sites that lack subsoil water.

Table 8. Soil texture and subsoil water classes within the north and south region.

Subsoil water				
Soil texture	longer	missing	shorter	Total
<i>North</i>	2	1	14	17
clay	1		1	2
sand			7	7
silt clay	1	1	6	8
<i>South</i>	11		12	23
clay	3		1	4
sand			3	3
silt clay	8		8	16
Total	13	1	26	40

The soil textures are also shown in the upper part of each box in figure 18. Clay referred to as C, Sand as S and mixture of sand and clay as SC. The figure shows that the majority, 75 percentages, of the invented sites had shorter periods of subsoil water and highest Spruce SI. As seen, the soil textures were foremost in the SC category, 19 out of the 31. The figure shows that sycamore is established on overall rich soil types independent of specific soil texture.

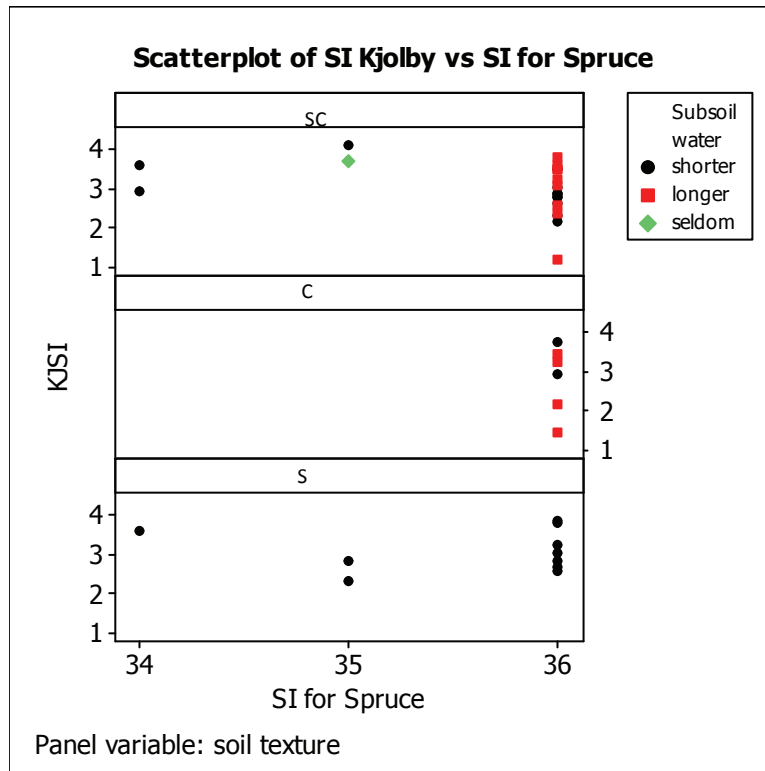


Figure 18. A comparison of the two different site index parameters Spruce SI and Kjølbby SI divided by three grades of subsoil water (longer, seldom, shorter) and soil texture (C, S, SC).

Density

A comparison of the amount of stems per hectare divided by age and region is seen below in figure 19. Sycamore density N shows that the stands in the north region had the highest and lowest amount of stems per hectare, minimum 300 stems/ha and maximum 1500 stems/ha. The figure also show that the northern stands of age 40 and 50 had overall higher densities compared to the southern of the same age. The stands in the south were to a higher extent clustered around the ages of 30 to 50 years old, with stem densities of 200 to 500 stems/ha.

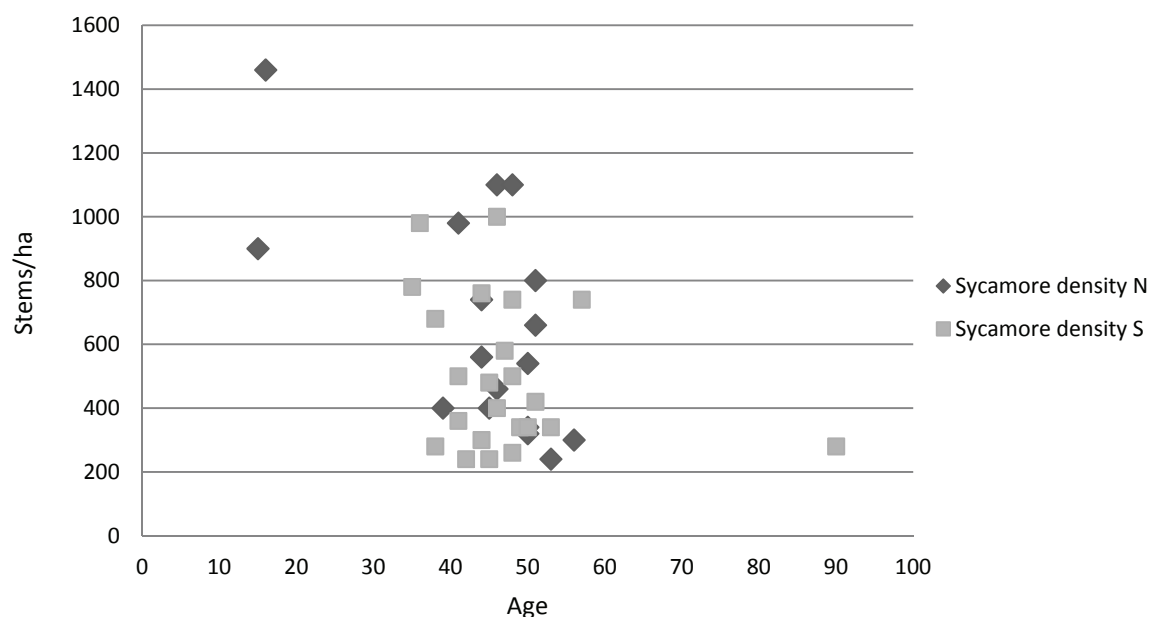


Figure 19. The sycamore stem density divided by age in the north and south region.

Contribution ratio

The contribution ratio of the ground, field and tree cover in all stands are presented in figure 20 to 22. An example of how the three levels of ratio (cover, gaps and missing) appear is given in Appendix V.

Figure 20 shows the contribution ratio of the ground flora in all stands divided by the two regions. The figure does not indicate any vast differences among the two regions. However, the north region lacked the ground cover 10 % more often compared to the south and the rate of covering layer was slightly higher. The south region had overall higher amount of gaps in the ground flora, while the amount of covering flora and missing was lower compared to the north.

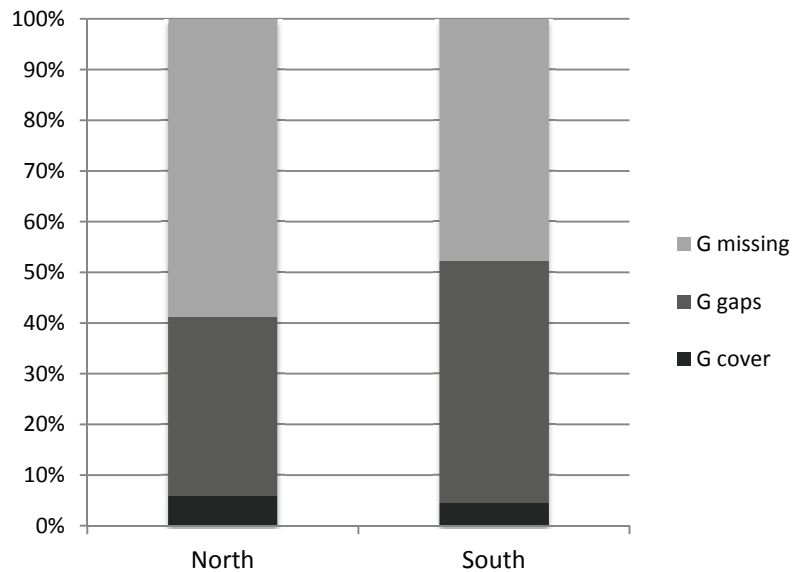


Figure 20. The contribution ratio of the ground layer divided by the north and south region.

Figure 21 shows the contribution ratio of the field layer in all stands divided by the two regions. The figure show some differences between the regions, the north region had overall higher amount of gaps (40 % compared to 15 %), the layer was more covered in the south (80 % compared to 60 %) and the northern stands never lacked the field layer.

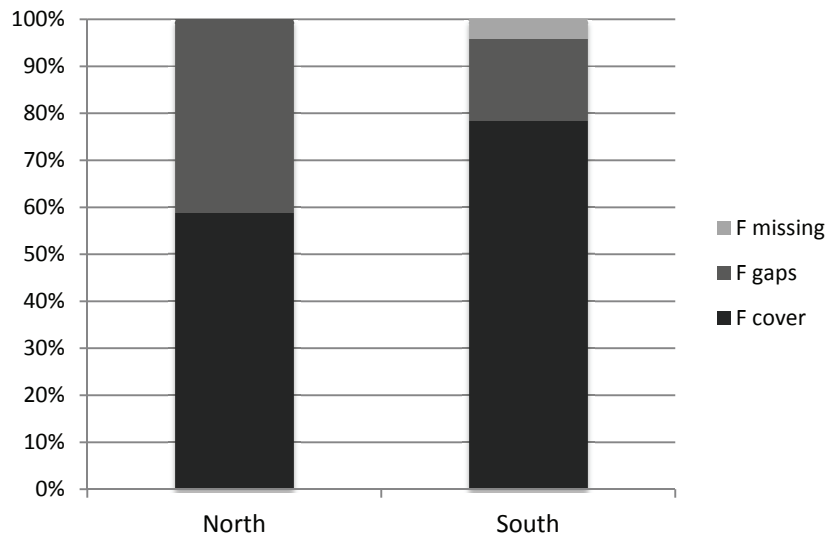


Figure 21. The contribution ratio of the field layer divided by the north and south region.

Figure 22 show the cover rate of the underlying tree layer. As seen, the stands in the north region had 20 % more covering tree layer 40 % more gaps. Additionally, 60 percentages of all stands in the south lacked an under storage.

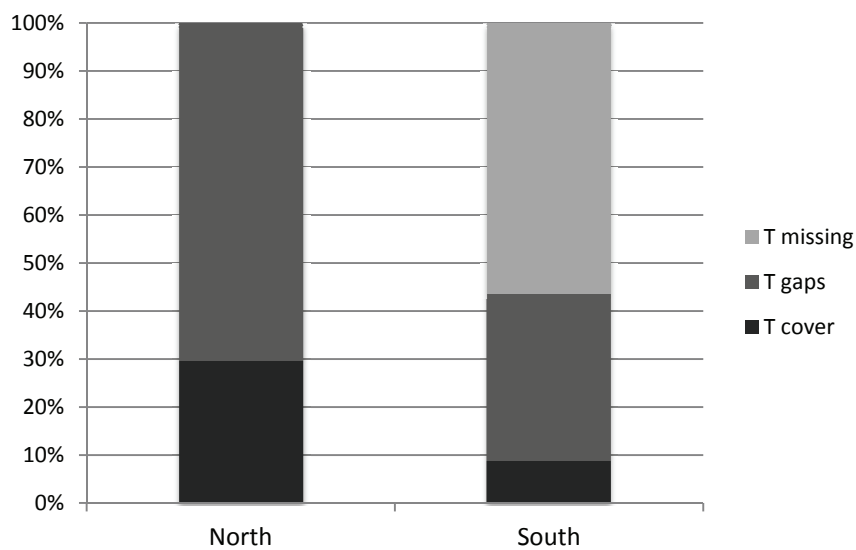


Figure 22. The contribution ratio of the tree field divided by the north and south region.

Discussion

The stands and the data acquisition

The study aimed to examine the current status of the sycamore stands in southern Sweden regarding both stand and site characteristics. The effort to find sycamore stands was a manner of research itself, several potential authorities such as the *Swedish Forest Agency* in Scania and Halland was contacted as well as forest companies, for example *Södra Skogsägarna*. The personnel had often a vague idea of where and if there occurred any sycamore stands within their regions. The recommendation was often to get in contact with former managers, employed in the forestry sector in the middle of the 20th century. The general lack of awareness of sycamore stands, and the minor results in the database of the *Swedish Forest Agency* in Scania is probably connected to the *Swedish forestry Act*. The law does incorporate Noble broadleaved species, administrating subsidies for regeneration of these species not including sycamore since it is, as already mentioned, a species of minor current interest regarded as neutralized but invasive. The interviews and search of stands also proved that the species often have a bad reputation among current foresters. When in contact with the older generation of forest personnel, working during 1950's, they stated a high interest for the species and explained that the rise of the *Forestry Act* including Noble broadleaved put a stop to the effort of regenerating sycamore maple in Sweden.

As mentioned in the introduction, the starting point when searching for the stands was to get as high distribution among different managers as possible, in order to reduce the amount of stands of possible similar silvicultural management. Unfortunately did the data of the stands historical management and their proveniences lack, a comparison concerning different silvicultural treatments would have been of great interest even to this study. It is, as often recited, always upon weighing the time in the field with the time for the data analyze and project writing. For the time given, five weeks of field work was concentrated upon determining some of the more standard inventory factors along with an estimation of the contribution ratio of other species and the quality of the top height diameter trees. A more detailed description of specific species frequency in the ground and field layer or investigations concerning their management was thus not prioritized. The size of the plots did not increase with increasing stand size or age; the aim was instead to include as many stands as possible and to scatter the plots as much as possible in order to get an objective justified description.

This study gives a survey of the current status of the sycamore stands in Sweden. The results indicate that there are not particularly big differences in height development, quality, soil texture, ground vegetation and so on among the Swedish stands. From the stands included in this study, it is not suitable to draw any statistical conclusions about the growth potential of sycamore in Sweden. However, the study does show that all stands included are sited on high fertile soils, according to Swedish standards, since the vegetation description results indicate Spruce SI G34 to G36.

The measured prognosis for height development according to Kjølby SI gave a result between 1.4 and 4.1, hence that the stand height at the age of 100 years would differ with 10 meters. Although, since the stands included in this study showed a cluster, was the difference in height merely 1 meter despite an age interval of 20 years. The results variation of Kjølby SI: s did not show any correlation to the stands being situated in the north of the south region, nor subsoil water, soil texture neither a combination of all. The contribution ratio of the tree, field and ground layer did not either prove the difference. The lack of correlation among the stands characteristics are likely connected to the structure of the study since a survey in difference to a test does not contribute independent and randomized treatments data. Data regarding proveniences lacked and the results could also be connected to differences in plant material and proveniences. The interpretation of the results also makes one speculate, is it likely that the height development decreases more dramatically than expected, are the stands stamping? The inventory work carried out in this study cannot prove this aroused hypothesis; however it is an interesting question.

The low spruce SI variation from G34 to G36 was expected since the species demand fertile soils, it is also likely that the stands ought to have been of the exact same index, that the minor variation itself is connected to measurement errors. Neither did the result indicate any correlation between high Kjølby SI and high spruce SI. The above stated result is in fact in line with Kjølby's (1958) statement that fertile sites with fine textures which ought to promote growth have not always done so, and that there is not enough research in order to determine what type of fine textures promotes and which does not. The comparison of the Kjølby SI among the north and south region indicated less difference among the southern stands and lower values (higher SI: s) in the region. This is explained by the occurrence of the two youngest stands, awareness of the impact of these stands is important while interpreting those results.

That there was higher amount of rich herb species in the dominating site vegetation in the south region could be connected to overall more fertile soils and higher degree of crown closure. That the same region shows more gaps in the ground layer and lack the tree layer could be explained by silvicultural management differences, the stands might have undergone treatments, such as PCT: s, to a higher extent compared to the northern. Also, more fertile soils lead to higher possible concurrence of other species which could explain higher efforts in removing the tree layer.

The quality classes (A to D) was overall quite alike in both regions, however showed the result a slightly higher amount of the greater classes A and B in the south region. The quality determination was carried out according to the quality determination table of beech timber, this is the one used in Sweden since the same quality defects occur in both species. The results are to be regarded as snapshot judgments since all stands of varying age were determined according to the same characterizations of current status. If and how the amounts of quality defects such as epicormic branches and occluded knots will differ and decrease with increasing age is not taken into account. Neither is the status of the wood inside the bark.

The percentage of the specific timber quality defects did not show any statistic proved variation among the two regions. Occluded knots were the most frequent occurring defect in both regions but the north region showed higher percentage. Epicormic branches were the next most frequent defect and the south region had overall higher percentages. The amount of double leaders was the third most frequent in both regions and did not show a percentage variation among the regions; neither did the amount of dry and fresh knots. As mentioned by Barthélémy et al. (2009) regarding forking, is there a natural explanation to why they occur. Therefore, it might not necessary be connected to silvicultural regimes, perhaps rather proveniences. The other quality fault, similar to *Nectaria galligena*, was not verified to occur on sycamore according to literature, therefore it is more likely that it could have been a cause of the cambial late frost damages as mentioned by Bryndum et al. (2009) in the introduction chapter.

Comparing both regions, the south region had higher amounts of finer soil textures, both in longer and shorter periods of subsoil water, as well as higher percentages of longer periods of subsoil water. The north had higher amounts of stands with short periods of subsoil water and more coarse soil textures. The northern stands were indeed situated in more slope areas compared to the southern. The gradient in the south varied both within and between the locations, hence the more even distribution of shorter and longer periods of subsoil water. The reason for the higher amount of silt and clay texture in the south could be richer soil types in general compared to the north. This could also be connected to the fact that the southern stands more often were located closer to agricultural influenced landscape, with farmland closer by. The north region showed overall higher densities compared to the southern, this is also in line with the ocular observation of presuming less amount of PCT: s in the north. The contribution ratio only showed slight variation among the regions. Concerning the ground flora they were minor, greater differences occurred in the field and tree layer. The explanation for the high covering rate in the field layer and less covering tree layer in the south region could be higher amount of silvicultural management.

The quartile results of the top heights showed no clear variations among the stands, since the upper and the lower quartile was 19 respectively 18 meters. That the mean BA showed a more wide variation and the quartiles differed with 15 m²/ha was in line with the general ocular observation of the stands. Higher BA could be connected to improved silvicultural management, siting as well as provenances. The percentage of sycamore indicated that 75 % of the stands were not pure sycamore monocultures. The nine stands (25 %) with less than 71 % sycamore could rather be considered as mixed in their management plans. The volume results showed that a variation of 100 m³sk/ha between highest and lowest, the majority of the stands held 200 m³sk/ha. The difference among the upper and lower quartile of the stem density was more surprising. One fourth of the stands had above 980 stems/ha and 75 % had less than 460 stems/ha. The explanation might, once again, be found in different management regimes, lack of PCT and thinnings.

Figure 23 also indicate differences in silvicultural management between the two Danish administrators. As seen, stands managed by M (red staples) show increased amount of stems in lower size classes, hence higher amount of under-storage, compared to stands managed by R (blue staples).

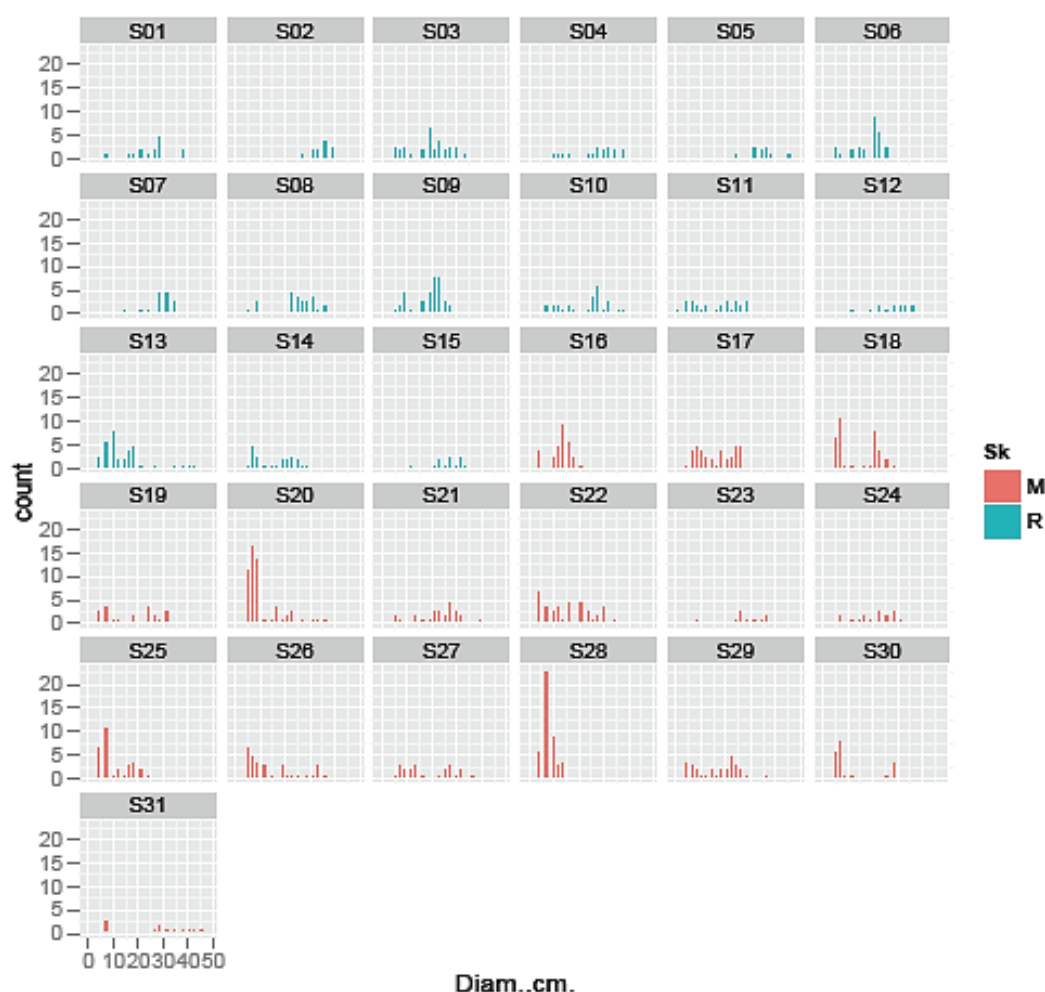


Figure 23. A comparison of the amount of stems (y-axis) in different size classes (x-axis) divided by the two Danish administrators (M and R).

The amount of gaps within the tree layer of the northern stands can also be connected to fewer PCT: s, if more stems have been left it is expected that this layer show more gaps compared to the south since the stems probably have undergone natural selection, i.e. more stems have died. When the under-storage of the field layer did occur as gaps within the south region, gaps were more often bigger compared to the north, which

also indicate that the stands must have undergone PCT: s to a higher extent compared to the north. The tree layer also indicated that the stands in the south region must have been managed in order to prevent concurrence from other species to a higher extent compared to the northern stands. It is possible that the southern administrators have allocated more resources towards silvicultural management regimes, but factors such as more sparse spacing and natural decease of plants could also explain the differences.

Conclusions

The study indicates that sycamore stands in Sweden are mainly situated in Scania, a few also in the western and northern parts of southern Sweden. The stands were most often situated on the biggest forest estates, primary managed by employed forest personnel or by the private owner (as in the case of Silvåkra). Most of the stands were in the age range of about 40 to 60 years old, hence established around 1950 or 1960.

The hypothesis of difference in quality related to different site characteristics (sub soil water, vegetation cover and so on) was not proved in the study since the differences among the two regions were minor and the quality defects often occurred to the same, high or low, extend un-dependent of specific siting.

Without the full description of the stands silvicultural management history and their proveniences it is hard, not to say impossible, to draw any certain conclusions connected to the both differences among the regions and site characteristics. However, the study also had an aim to survey the current status of the sycamore stands in southern Sweden, the literature study; the search for stands (including informal interviews) along with the massive inventory work including 40 stands, with an outcome of nearly 20 figures describing all stands and their characteristics was done with great success.

The study shows that the majority of the sycamore stands in the south of Sweden are growing well, producing fairly high qualities (possible even higher qualities if considering the change from current status to time of final felling) and volumes. Most of the ocular observations indicate that differences in silvicultural management could play a vital role in achieving high quality outcome since there were less apparent quality defects in the south where the stands are managed by Danish expertise. The use of a fairly old pricelist (from 1999) to compare sycamore timber value with beech is to be seen as a general comparison, not as current values. The time given for this study was also limited, thus no time given to search for additional pricelists.

Recommendations

A recommendation for future research of Swedish sycamore is first and foremost to track the history of the stands silvicultural management; by starting to follow younger stands today we could improve the knowledge of both environmental and physiological impacts on sycamore in a couple of decades. Moreover, is there probably also a need to further improve the knowledge of the regeneration phases and the species high natural regeneration in order to counter some of the current negative opinions regarding sycamore, as well among the forestry sector as among the authorities.

Furthermore, some negative opinions regarding sycamore, as well as questionable statements occur in former literature. For instance, sycamore not being able to regenerate in too big stands and that naturally regenerated stems grow faster and of better quality (Bolton, 1949 and Møller, 1965). More research on these topics, along with historical documentations and ecological features might enhance a higher awareness of the species positive characteristics for a future of more broadleaved species in the south Swedish forestry.

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Finally, I want to highlight the importance for enhanced research of broadleaved species in Sweden by stating that I am looking forward to see what the great researches from the *Southern Swedish Forest Research Centre* will publish on the topic in the future.

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Appendix I

An additional table of the forty invented stands, MASL refers to meters above sea level.

Site	Location	Coordinates (Sweref99)	Age	SI	Size (ha)	Stems/ha	MASL
S1	Skabersjö	6157266, 387835	51	G36	0.74	460	50
S2	Skabersjö	6158249, 385522	53	G36	0.70	340	59
S3	Skabersjö	6158196, 386110	46	G36	1.85	1000	59
S4	Skabersjö	6157630, 385865	46	G36	0.89	460	59
S5	Skabersjö	6155717, 386718	49	G36	1.68	340	53
S6	Skabersjö	6156287, 387408	44	G36	1.53	760	50
S7	Skabersjö	6156193, 387574	48	G34	0.22	500	50
S8	Skabersjö	6156186, 388192	47	G36	0.46	580	50
S9	Holmeja	6157393, 391532	36	G36	0.60	1000	55
S10	Holmeja	6158571, 392545	57	G34	0.55	800	40
S11	Holmeja	6157423, 394177	48	G36	1.46	800	60
S12	Häckeberga	6158927, 400893	90	G36	2.09	340	58
S13	Häckeberga	6158927, 400999	35	G36	1.21	940	58
S14	Häckeberga	6160366, 401300	38	G36	0.25	760	55
S15	Häckeberga	6157148, 402898	50	G36	1.95	340	65
S16	Trolleholm	6197058, 391150	15	G36	0.57	1100	91
S17	Trolleholm	6196610, 391069	44	G35	0.99	1140	91
S18	Trolleholm	6198123, 391717	45	G36	0.42	960	100
S19	Trolleholm	6198123, 393776	46	G35	0.53	680	100
S20	Trolleholm	6198452, 395181	41	G36	0.33	1440	100
S21	Trolleholm	6199981, 396640	44	G36	0.65	740	95
S22	Trolleholm	6201249, 395324	46	G36	0.46	1400	95
S23	Trolleholm	6201431, 394669	56	G36	0.66	400	100
S24	Trolleholm	6202284, 393692	39	G35	1.02	540	100
S25	Trolleholm	6202503, 393923	48	G35	1.65	1240	100
S26	Trolleholm	6203431, 393822	50	G36	0.25	1040	100
S27	Trolleholm	6199050, 395466	53	G36	1.06	520	100
S28	Maltesholm	6195350, 436755	16	G36	0.58	1460	95
S29	Knutstorp	6204829, 382694	51	G36	1.02	900	100
S30	Knutstorp	6206095, 387676	50	G36	0.41	480	125
S31	Knutstorp	6206063, 387900	50	G36	1.03	600	125
S32	Krageholm	6151296, 419748	44	G36	3.30	300	50
S33	Krageholm	6151164, 420017	41	G36	0.80	580	50
S34	Krageholm	6150867, 419708	42	G36	5.60	300	50
S35	Krageholm	6151005, 420134	41	G36	1.30	620	50
S36	Silvåkra	6172710, 403926	45	G36	0.20	240	35
S37	Silvåkra	6172772, 403884	45	G36	0.20	540	35
S38	Silvåkra	6172948, 403894	48	G36	0.30	260	35
S39	Silvåkra	6172845, 403856	38	G36	0.50	300	35
S40	Rössjöholm	6244159, 380855	51	G34	0.75	860	125

Appendix II

The form quotient table states one form quotient unit for each diameter tree pair in each plot. The volume per hectare was given by multiplication of the form quotient and the mean height of the diameter trees and the BA per hectare. The volume sum for each pair of top height diameter trees was summarized and divided by the number of plots (5). The latter has then been calculated with the percentage of sycamore stems in each plot in order to get the sycamore volume in cubic meters per hectare.

diam:	5	11	15	19	23	27	31	35	39	43	47	51	55	59
height_5,00	0,00	0,6390	0,6541	0,6698	0,6890	0,7113	0,7359	0,7621	0,7891	0,8164	0,8434	0,8697	0,8949	0,9187
height_6,00	0,00	0,5518	0,5701	0,5869	0,6061	0,6276	0,6510	0,6758	0,7012	0,7269	0,7524	0,7773	0,8012	0,8238
height_7,00	0,00	0,5057	0,5236	0,5393	0,5569	0,5766	0,5981	0,6207	0,6441	0,6677	0,6911	0,7140	0,7361	0,7570
height_8,00	0,00	0,4794	0,4960	0,5102	0,5261	0,5441	0,5637	0,5844	0,6059	0,6276	0,6492	0,6704	0,6908	0,7102
height_9,00	0,00	0,4639	0,4790	0,4916	0,5060	0,5223	0,5403	0,5594	0,5793	0,5994	0,6195	0,6392	0,6582	0,6762
height_10,00	0,00	0,4548	0,4683	0,4795	0,4924	0,5073	0,5239	0,5416	0,5600	0,5788	0,5976	0,6160	0,6338	0,6508
height_11,00	0,00	0,4496	0,4616	0,4714	0,4830	0,4967	0,5119	0,5284	0,5457	0,5633	0,5809	0,5982	0,6150	0,6310
height_12,00	0,00	0,4471	0,4576	0,4661	0,4765	0,4889	0,5031	0,5184	0,5346	0,5512	0,5678	0,5841	0,6000	0,6151
height_13,00	0,00	0,4463	0,4554	0,4627	0,4719	0,4833	0,4963	0,5107	0,5258	0,5414	0,5571	0,5726	0,5876	0,6019
height_14,00	0,00	0,4468	0,4545	0,4606	0,4687	0,4790	0,4911	0,5045	0,5187	0,5334	0,5483	0,5629	0,5772	0,5908
height_15,00	0,00	0,4481	0,4545	0,4595	0,4666	0,4759	0,4870	0,4995	0,5128	0,5267	0,5407	0,5546	0,5682	0,5811
height_16,00	0,00	0,4501	0,4552	0,4591	0,4652	0,4735	0,4838	0,4953	0,5079	0,5209	0,5342	0,5474	0,5602	0,5725
height_17,00	0,00	0,4524	0,4564	0,4593	0,4644	0,4718	0,4812	0,4919	0,5036	0,5159	0,5284	0,5409	0,5531	0,5648
height_18,00	0,00	0,4552	0,4580	0,4599	0,4641	0,4706	0,4791	0,4890	0,4999	0,5114	0,5232	0,5350	0,5466	0,5577
height_19,00	0,00	0,4581	0,4600	0,4609	0,4641	0,4698	0,4774	0,4865	0,4966	0,5074	0,5185	0,5297	0,5406	0,5511
height_20,00	0,00	0,4613	0,4622	0,4622	0,4645	0,4693	0,4761	0,4844	0,4937	0,5038	0,5142	0,5247	0,5350	0,5450
height_21,00	0,00	0,4646	0,4645	0,4637	0,4652	0,4691	0,4751	0,4826	0,4912	0,5005	0,5103	0,5201	0,5298	0,5392
height_22,00	0,00	0,4679	0,4671	0,4654	0,4661	0,4693	0,4744	0,4811	0,4890	0,4976	0,5067	0,5159	0,5250	0,5338
height_23,00	0,00	0,4713	0,4698	0,4674	0,4673	0,4696	0,4740	0,4799	0,4871	0,4950	0,5033	0,5119	0,5204	0,5287
height_24,00	0,00	0,4748	0,4726	0,4695	0,4686	0,4702	0,4738	0,4790	0,4854	0,4926	0,5003	0,5083	0,5162	0,5239
height_25,00	0,00	0,4782	0,4754	0,4717	0,4702	0,4710	0,4739	0,4784	0,4840	0,4905	0,4976	0,5049	0,5123	0,5195
height_26,00	0,00	0,4817	0,4783	0,4740	0,4719	0,4720	0,4742	0,4780	0,4829	0,4888	0,4952	0,5019	0,5086	0,5153
height_27,00	0,00	0,4852	0,4813	0,4765	0,4737	0,4732	0,4747	0,4778	0,4821	0,4873	0,4930	0,4991	0,5053	0,5114
height_28,00	0,00	0,4886	0,4843	0,4790	0,4757	0,4746	0,4755	0,4779	0,4815	0,4860	0,4912	0,4967	0,5023	0,5079
height_29,00	0,00	0,4921	0,4873	0,4815	0,4777	0,4761	0,4764	0,4782	0,4812	0,4851	0,4896	0,4946	0,4996	0,5047
height_30,00	0,00	0,4955	0,4902	0,4841	0,4799	0,4778	0,4775	0,4787	0,4811	0,4844	0,4884	0,4927	0,4973	0,5019
height_31,00	0,00	0,4988	0,4932	0,4867	0,4821	0,4795	0,4787	0,4794	0,4813	0,4840	0,4874	0,4912	0,4953	0,4994
height_32,00	0,00	0,5022	0,4962	0,4894	0,4844	0,4814	0,4801	0,4803	0,4816	0,4839	0,4867	0,4900	0,4936	0,4972
height_33,00	0,00	0,5055	0,4992	0,4920	0,4867	0,4833	0,4816	0,4813	0,4822	0,4839	0,4863	0,4891	0,4922	0,4954
height_34,00	0,00	0,5087	0,5021	0,4947	0,4890	0,4853	0,4832	0,4825	0,4829	0,4842	0,4861	0,4885	0,4911	0,4939

Appendix III

Mathematic functions of Kjølby SI

Height = Hmax * exp(-k * exp(- a * t - b * ln(t))					
Hmax is maximum height, k, a & b constants & t age					
Hmax	33		28		23
k	6,0095		6,9697		151,4455
a	0,01562		0,01871		– 0,01708
b	0,57035		0,61966		1,8333
Age	SI 1 Height	SI 2 Height	SI 3 Height	SI 4 Height	
5	3.59	2.69	2.04	0.00	
10	8.28	6.99	5.44	1.57	
15	11.96	10.48	8.54	5.61	
16	12.60	11.08	9.10	6.40	
20	14.88	13.24	11.17	9.14	
25	17.25	15.46	13.35	11.66	
30	19.22	17.27	15.14	13.41	
35	20.88	18.77	16.60	14.65	
36	21.18	19.04	16.86	14.85	
38	21.75	19.55	17.34	15.23	
39	22.02	19.79	17.57	15.40	
40	22.29	20.02	17.79	15.55	
41	22.55	20.25	18.00	15.71	
42	22.80	20.47	18.20	15.85	
44	23.27	20.88	18.58	16.11	
45	23.50	21.08	18.75	16.23	
46	23.73	21.27	18.92	16.34	
47	23.94	21.46	19.09	16.45	
48	24.15	21.64	19.24	16.55	
49	24.36	21.81	19.39	16.65	
50	24.56	21.98	19.54	16.74	
51	24.75	22.14	19.68	16.83	
53	25.12	22.45	19.94	16.99	
56	25.64	22.88	20.29	17.20	
57	25.81	23.02	20.40	17.27	
60	26.28	23.40	20.69	17.45	
70	27.61	24.46	21.46	17.88	
80	28.65	25.25	21.96	18.15	
90	29.47	25.86	22.30	18.30	
100	30.12	26.32	22.53	18.37	

Appendix IV

Mathematic functions of sycamore BA (Not used in this study)

Basal Area = $G_{max} * \exp(a*t + b*\ln(t)) / (\exp(k) + \exp(a*t + b*\ln(t)))$				
Gmax	54.4	50.9	46	42
g_k	11	11	11	11
g_a	-0.001	-0.001	-0.00105	-0.00053
g_b	3.00787	3	3.15365	3.1677
Age	BA	BA	BA	BA
5	0.11	0.11	0.12	0.11
10	0.90	0.83	1.06	1.00
15	2.92	2.68	3.57	3.40
20	6.43	5.89	7.90	7.53
25	11.26	10.33	13.53	12.87
30	16.87	15.49	19.52	18.47
35	22.61	20.81	25.01	23.55
40	27.96	25.79	29.61	27.73
50	36.55	33.85	36.03	33.46
60	42.33	39.33	39.75	36.71
70	46.06	42.87	41.90	38.57
80	48.47	45.18	43.20	39.68
90	50.06	46.70	44.01	40.37
100	51.14	47.74	44.54	40.81

Appendix V

Examples of how the three levels of contribution ratio (cover, gaps and missing) appear

- The ground flora mainly consisted of differed moss species. (Ground layer)



Figure I. An example of gaps in the ground layer.

- The field flora mainly consisted of grass, herbs, sedges and other ligneous plants. (Field layer)



Figure II. An example of covering field layer.

- The tree layer consisted of different tree species, other than sycamore. No bush species except hazel trees were found.



Figure III. Example of covering tree layer, beech as the other occurring species.

Appendix VI

Pictures on some of timber defects (Photographer, Jenny Sjöstedt)

- From upper left to right: Example of quality class D, bark cracks.
- Lower left to right: Double leaders (forking), canker wound.
- The small pictures to the right: Occluded knot (Chinese beard), epicormic branches.

