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Natural regeneration of Sycamore maple in southern Sweden and Lithuania

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Abstract

Sycamore maple (*Acer pseudoplatanus*) is a widespread but minor species in many central European countries. In Sweden and Lithuania it is non-native tree species, but natural distribution range is less than 100 km away in neighbouring countries. However here sycamore is able to regenerate and disperse to local forest stands. The aim of the study was to investigate sycamore regeneration in different forest stands and clearcuts adjacent to sycamore seed source stands. The study was conducted in southern Sweden and southwestern Lithuania. 30 sycamore source 48 adjacent stands of spruce, beech, oak, pine and clearcuts were selected for the survey. Results revealed that dominant tree species of adjacent stand and distance from a sycamore seed source were the most sycamore regeneration density influencing factors. The most suitable conditions for naturally regenerated sycamore were in oak stands. Sycamore regeneration was more abundant in the sample plots closer to the source stand and had a tendency to be influenced by prevailing winds. Seedlings in the height group lower than 0,5 m accounted for 98 % of all regeneration. Other investigated stands parameters: basal area, age, height, stand size, groundcover type did not have an influence on regeneration density.

Key words: Sycamore, source, adjacent stand, dispersal, natural regeneration, density, seedlings, saplings.

Contents

1 Introduction

Sycamore maple (*Acer pseudoplatanus* L., Sapindaceae) is a large deciduous tree species reaching up to more than 35 m height, and 1 m in diameter. It is a widespread but minor species in many European countries. On suitable sites it is able to grow fast and produce valuable timber. It is, therefore, a species with growing economic interest (Hein et al. 2009).

Climate change is triggering species distribution shifts in many parts of the world, including Europe (Thuiller et al. 2005; Kelly et al.2008). Studies based on phenological tree observation already show an increase of vegetation period in Northern Europe (Chmielewski and Rötzer, 2001; Menzel et al. 2006). Climate simulation models predict further increase of temperature and precipitation in Sweden and Lithuania (SMHI, 2014; LHMT, 2013). Moreover tree species distribution is predicted to change. Northern Europe should become more suitable for European hardwood tree species (Hanewinkel et al. 2013). Sycamore may be one of the species to benefit from these changes in Northern Europe and extend its distribution range northwards. (Theurillat and Guisan, 2001; Broadmeadow et al. 2005). There are already evidence that sycamore demonstrates capacity for invasiveness in Sweden and Lithuania (Straigyte and Baliuckas, 2015; Felton et al. 2013). Furthermore, species invasive properties should cause the increase of natural regeneration and gradual change in tree species composition (Straigyte and Baliuckas, 2015).

The purpose of this survey is the attempt to answer whether sycamore is able to regenerate and compete in native tree species stands in Sweden and Lithuania. Assuming that sycamore is able to regenerate, there would be a competition with native tree species and furthermore an increase of sycamore in the area. Sycamore dispersal trends were estimated by evaluating amount of regeneration in different types of stands. This is done by collecting various types of data from the stands adjacent to sycamore seed source stands. In addition, the paper will also provide more insight what conditions are favoured by sycamore regeneration and what are limiting factors for its dispersal. Finally, in the literature study, we will look at the possibilities and drawbacks of the current sycamore dispersal trends as well as ecological impact.

2 Background

Sweden and Lithuania share similar situation when it comes to sycamore maple. In both countries sycamore is non-native tree species, but natural distribution range is less than 100 km away in neighbouring countries (Figure 2). Denmark is the closest country with natural sycamore distribution to Sweden. Kaliningrad Region (Russia) and Poland are the closest countries with natural sycamore distribution to Lithuania. However there is no land path between Sweden and Denmark for trees to migrate naturally while there is such a possibility in Lithuania. Nevertheless in both countries sycamore was introduced by people (Straigyte and Baliuckas, 2015; Felton et al. 2013). In the surveyed stands area in southern Sweden sycamore was introduced by Danish foresters while in Lithuania more intensively sycamore was planted in Southwest by German foresters.

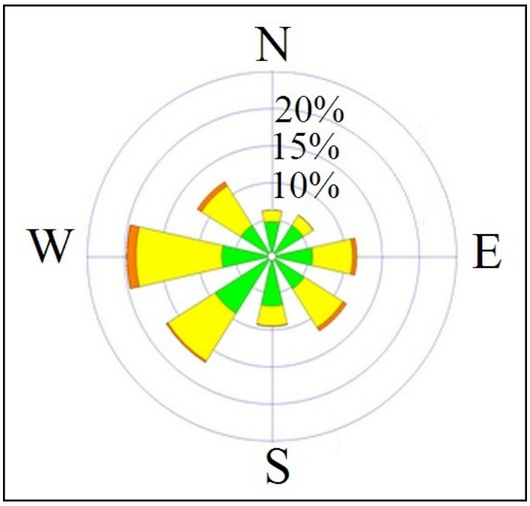
2.1. Climate

According to FAO (2000) ecological zones in Europe classification southern Sweden is classified as temperate oceanic forest zone and Lithuania is classified as temperate continental forest zone. However there are only minor differences when comparing climatological data (Table 1).

Table 1. Climatic conditions in surveyed areas in Sweden and Lithuania (SMHI, 2015; LHMT, 2015).

	South Sweden	Southwest Lithuania
Mean annual air temperature	7-7,5 ^{o}C	7-7,5 ^{o}C
Mean January air temperature	-1 - -0,5 ^{o}C	-3 - -2,5 ^{o}C
Mean July air temperature	16 – 16,5 ^{o}C	17 – 17,5 ^{o}C
Mean annual amount of precipitation	600-700 mm	750-800 mm
Mean annual wind speed	5 m/s	3,5-4 m/s
Length of vegetation period	214 days	208 days

Dominant wind directions in Sweden and Lithuania are presented in (Figure 1).



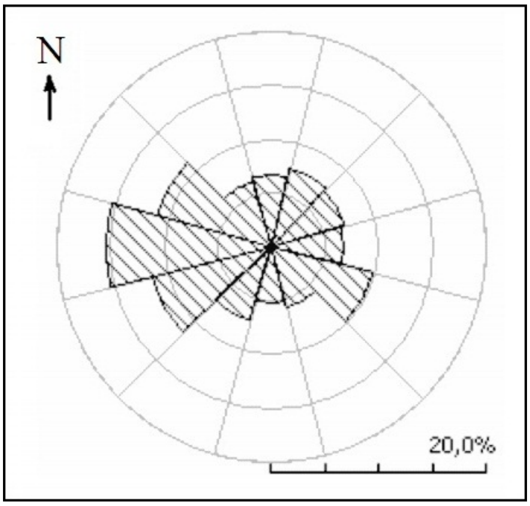


Figure 1. Wind rose plot for Malmö, Sweden (on the left) (SMHI, 2015) and Klaipėda, Lithuania (on the right) (Marčiukaitis et al., 2009).

2.2. Invasiveness definition

Definition of invasive tree species on forest sector is still debated. In every specific case it has to be reviewed in the context of forest management and ecological impact (FAO, 2005). The definition of invasive species of plants varies according to author. Van Wilgen (2001) defines invasive tree species as: “Species that are able to survive, reproduce and spread, unaided, and sometimes at alarming rates, across the landscape”. Richardson et al. (2000) defines invasive plant species as: “Naturalized plants that produce reproductive offspring, often in very large numbers, at considerable distances from parent plants (approximate scales: > 100 m; < 50 years for taxa spreading by seeds and other propagules; > 6 m/3 years for taxa spreading by roots, rhizomes, stolons, or creeping stems), and thus have the potential to spread over a considerable area”. Le Roux (1981) defines it as: “An invader plant is any indigenous or exotic plant species having a detrimental effect on the growth of commercial tree species, giving rise to particular management problems or growing where it is not wanted”. IUCN (1999) provides general definition of invasive species: “An alien species which becomes established in natural or semi-natural ecosystems or habitats, is an agent of change, and threatens native biological diversity”. EU Regulation 1143/2014 (2014) defines invasive alien species as: “alien species whose introduction or spread has been found to threaten or adversely impact upon biodiversity and related ecosystem services”. USDA (1999) definition of invasive species is: “an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health”.

Some examples of invasive tree and shrub species in Northern Europe: Black elder (*Sambucus nigra*) is native to Central European countries and is now naturalized further in the north (Kabuce and Priede, 2006). Box-elder (*Acer negundo*) and dwarf serviceberry (*Amelanchier spicata*) are native to North America and now are naturalized in East and North European countries (Mędrzycki, 2011; Kabuce and Priede, 2006). Japanese rose (*Rosa rugose*) is native to Eastern Asia and now is naturalized in 16 European countries (Weidema, 2006).

2.3. Sycamore invasiveness in different countries

Sycamore has strong invasive properties duo to vide ecological amplitude. It invades semi-natural woodlands with disturbances (Leslie, 2005; Rusanen and Myking 2003). Some form of disturbance on woodland edges creates better conditions for regeneration than gaps formed by natural tree falls. However even in most suitable localities it seldom achieves total dominance over other species (Leslie, 2005) According to Falkengren-Grerup and Tyler (1991) the appearance of sycamore saplings in European beech (*Fagus sylvatica*) stands increased during 1980's in southern Sweden while native Norway maple (*Acer platanoides*) decline. The Author explains that early sycamore establishment may be beneficial in the management regimes of the Scanian beech forest. Moreover, rich fruiting can also play an important role for increased regeneration.

Frequency and establishment of sycamore varies between countries in Europe. In central European countries: Germany, France, Austria, Check Republic, Belgium, Poland and Denmark, the species is considered to be native (Figure 1), (Weidema and Buchwald, 2010). In United Kingdom sycamore is considered as invasive and non-native but is a very common tree species in forest (Morecroft et al., 2008). In Lithuania and Ireland there are many sites in the countries with abundant seedlings and it is considered to be invasive. In Sweden, Norway, Latvia and European part of Russia sycamore is locally common with abundant seedlings in the sites and it is also considered to be invasive. In Estonia, Finland and Iceland there is no natural sycamore regeneration. (Weidema and Buchwald, 2010). However Svenning and Skov (2004) states that after ice-age refugee to southern Europe, sycamore is still expanding to its potential distribution range in the North.

2.4. Seed dispersal

Sycamore produces meteoranemochorous seeds i.e. dispersed by wind (Kolzowski, 1972). Mean sycamore diaspore mass is 89 mg. It is 34% less than average diaspore mass of Norway maple (134 mg). However the rate of decent of sycamore seeds is 1.04 m/sec. which is 16 % faster than Norway maple (0.87 m/sec). Nevertheless lateral dispersal capacity of sycamore in a light breeze conditions is 16 % greater than Norway maple (Matlack, 1987). Length of seed dissemination period improves short-distance dispersal success of maple seeds (Karlsson, 2001) Hydrochory i.e. dispersal by water and can be an effective secondary dispersal agent for *Acer* species (Middleton, 2000; Säumel and Kowarik, 2010; Vogt et al. 2004), as well as chamaechory i.e. dispersal by wind when rolling on the surface of the snow (Greene and Johnson,1997; Vittoz and

Engler, 2007). Von der Lippe and Kowarik (2007) suggest that trafic-derived seed dispersal can be important means for plant invasion.

2.5. Light requirements for seedlings and saplings

According to Petriţan et al. (2007) sycamore is classified as mid-tolerant to shading as well as ash (*Fraxinus excelsior*). However, a young sycamore seedling can have similar light requirements as beech (Collet, 2008) which is classified as shade-tolerant (Petriţan et al. 2007). Smaller saplings are more shade tolerant than taller ones (Petriţan et al. 2007; Kneeshaw et al.2006). These qualities allow sycamore to regenerate and persist under shade conditions (Collet, 2008). For significant lead shoot growth sycamore requires more than 20 % from above canopy light (Petriţan et al. 2007). Under shade conditions sycamore has higher mortality rate than beech and in a long run if conditions do not change sycamore regeneration can be strongly reduced or completely eliminated. Nonetheless beech is not able to surpass sycamore in height. However under intensive light conditions sycamore overtops beech (Petriţan et al. 2007; Klopčič, 2015). Length growth, total leaf area and average leaf size of sycamore (as well as ash and beech) increases with increasing light availability (Petriţan et al. 2007, 2009).

2.6. Regeneration strategy

Sycamore is a gap specialist (Petriţan et al. 2007, 2009). Sycamore seedlings establishes under closed canopy conditions but do not show sufficient growth until canopy gap occur (Diaci, 2002). Ability to establish and survive under shady conditions gives sycamore advantage when compared to other tree species, like for example hornbeam (*Carpinus betulus*) that start germinating after amount of light increases (Collet, 2008). For maintaining dominant position to adjacent saplings in low light conditions gap specialists favour lateral growth (Runkle and Yetter 1987). Furthermore in these conditions shade specialists firstly reduces diameter growth and only secondly length growth (Kimmins, 1997). When light is scarce sycamore forms more expressed ‘umbrella’ like crown than ash or beech by concentrating most of the leaves and branches in the top. However in bright conditions proportion of leaves in lower crown layers increases. (Petriţan et al. 2009). Investing much of tree resources to height growth without receiving enough light can lead to starvation and death (Messier et al. 2000).

2.7. Ecological impact

Brunet (2007) compares conditions of sycamore and English oak (*Quercus robur*) stands for herbaceous plants. Results of this study do not show significant difference in vegetation patterns between the two species in southern Sweden. However there is a tendency that sycamore plantations have more shade tolerant forest species than oak. This is explained duo to denser canopy structure. Sycamore litter stimulates humus formation and nutrient cycles in the soil (Heitz and Hasenauer, 2000). Sycamore bark conditions are similar to that of Scots elm (*Ulmus glabra*). Accordingly it has a high bark pH and supports a relatively large number of lichen species (Leslie, 2005). More than twenty different species of insects - bees, flies and beetles visit sycamore flowers for nectar (Elton, 2012). However sycamore supports relatively small number of phytophagous insects species (Kennedy and Southwood, 1984). Numerous aphids feed on sycamore leaves and buds phloem sap. Moreover aphids are food source for other species of insects, such as ladybirds, hoverfly larvae and lacewings, as well as birds. (Dixon, 1971; Leslie, 2005).

2.8. Browsing and fraying

Browsing has a significant impact on sycamore regeneration. It reduces height increment and limits the possibility of sycamore forming part of the future stand. In the same territory browsing is more intensive on sycamore than on beech or Norway spruce (*Picea abies*). Browsing intensity is resulted by the size of ungulates population involving two species of deer: roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*) (Ammer, 1996). Seedlings, buds and young shoots are eaten by rabbits (Savill, 2013). Another tree damaging factor for saplings is fraying. It is done by roe and red deer when removing velvet from antlers or marking territory (Gill, 1992; Motta, 1996). Roe deer fray springy, branchless, sapling-sized stems while red deer choose slightly larger, from 50 to 250 cm height trees. (Gill, 1992) Fraying can severely damage tree or even be lethal (Gill, 1992; Motta, 1996).

2.9. Climatic requirements

Sycamore is more resistant to late spring frosts than most of broadleaved trees (Savill, 2013; Rusanen and Myking 2003). However small trees are seldom damaged by late spring frosts (Spiecker and Hein, 2009). It is tolerant to strong wind and can recover after salt spray. These qualities make sycamore suitable for coastal regions. Moreover this species can tolerate smoke and industrial pollution (Savill, 2013; Rusanen and Myking 2003). Sycamore growth in high altitudes is better than for other important deciduous trees (Savill, 2013). South facing side of a tree can develop sun scald during cold winters. In young ages sycamore is susceptible to high bark temperatures duo to superficial periderm. This problem decreases with maturity when bark becomes thicker (Spiecker and Hein, 2009).

2.10. Soil requirements

Sycamore is tolerant to a wide range of soils. Species do not grow in too wet or too dry locations. Most suitable are deep, moist and fertile, with good drainage and reasonably high pH soils (Savill, 2013; Rusanen and Myking, 2003). Sites with rapid decay of organic matter experience the best growth and regeneration of sycamore (Savill, 2013). Increased nitrogen content has a positive influence on sycamore growth (Jensen, 2008).

2.11. Pests and diseases

Sycamore seedlings are damaged by few different pests and diseases. Leaves are eaten and seedlings are killed by slugs (*Deroceras sp.*) and lepidoptera larvae (Pigot and Leather, 2008). Moreover seedlings are killed by small mammals: wood mouse (*Apodemus sylvatica*) and the common rat (*Rattus norvegicus*) (Paterson et al. 1996). Coral spot (*Nectria cinnabarina*) causes external necrosis of bark and cambium. This parasitic fungus act when host tree experiences severe frost, wounding or especially water deficit. Because of root biomass loss and wounding, incorrect planting procedures, low water retention capacity of the soil and drought periods, coral spot disease mostly affects freshly planted seedlings. Naturally regenerated maples are less susceptible to this disease (Spiecker and Hein, 2009). Seedling development is reduced when leaves are affected by sycamore aphid, (*Drepanosiphum platanoidis*) (Dixon, 1971; Savill, 2013).

Older trees are damaged by several pests and diseases: Tar spot fungus (*Rhytisma acerinum)* is common on leaves but only cause minor damage to the tree (Savill, 2013; Spiecker and Hein, 2009). Formerly it was thought that tar spot disease avoids polluted areas but the results of Leith and Fowler, (1988) study shows that there is no correlation between tar spot disease frequency and air pollution with SO_2. Parenchyma galls are common on sycamore leaves (Spiecker and Hein, 2009; Skrzypczyńska, 2004). In Western Europe the most common is window gall midge (*Dasineura vitrine*) (Spiecker and Hein, 2009) In Poland and Central Europe (*Artacris cephaloneus*), (*Drisina glutinosa*) and (*Harrisomyia vitrine*) are the most abundant species on sycamore (Skrzypczyńska, 2004; Skuhravá and Skuhravý, 1986). Sycamore aphid, (*Drepanosiphum platanoidis*) can also significantly reduce growths of mature trees. Not infested trees produce 280 % more stem wood than heavily aphid infested trees (Dixon, 1971). Bark is damaged by fungus (*Cryptostroma corticale*) which causes ‘sooty bark disease’. It causes death of inner bark and cambium followed by die-back and shedding. Disease can be located only in small portions of the trunk or single branches. In this case tree can survive. But if the cambium is completely encircled disease can be lethal. Fungus enter the tree through wounds and broken ends of branches (Gregory and Waller,1951; Savill, 2013; Spiecker and Hein, 2009). Fungus favours young sycamore trees and grows best in high temperatures when tree experience water shortage (Dickenson and Wheeler,1981). Asian longhorned beetle (*Anoplophora glabripennis)* is a beetle introduced from Asia. The first record in Europe was in August 2001 in Austria. Beetle deposits its eggs in bark and larvae feed on sapwood. Infested tree parts soon dye and wood decays. Control measures have been applied and spreading of beetle is limited (Krehan, 2002; Spiecker and Hein, 2009)

2.12. Competitiveness

Under low light conditions sycamore shows strong competitive abilities (Stancioiu and O’Hara, 2006). Growth success and competitiveness with neighbours after canopy opening is determined by pre-release seedling size. This is the main influencing factor for long-term seedling dominance. After canopy opening sycamore, Norway maple, field maple (*Acer. Campestre*) and beech experience similar diameter increment.

However height increment is greatest for sycamore and Norway maple. Even though Norway and field maples have similar increment, sycamore and beech species will grow faster, which makes them able to over compete. Gap creation and increment growth in the first years does not significantly increase death rate of seedlings (Caquet et al. 2010). Herbaceous vegetation show rapid growth immediately after canopy opening and if not controlled may have strong negative effect on seedling growth and survival (Balandier et al. 2006; Savill, 2013). In the closed stand conditions ground cover does not have a significant influence on regeneration success. However groundcover consisting grasses have a tendency to be less favourable than nitrate flora (Jensen, 2009).

2.13. Distribution

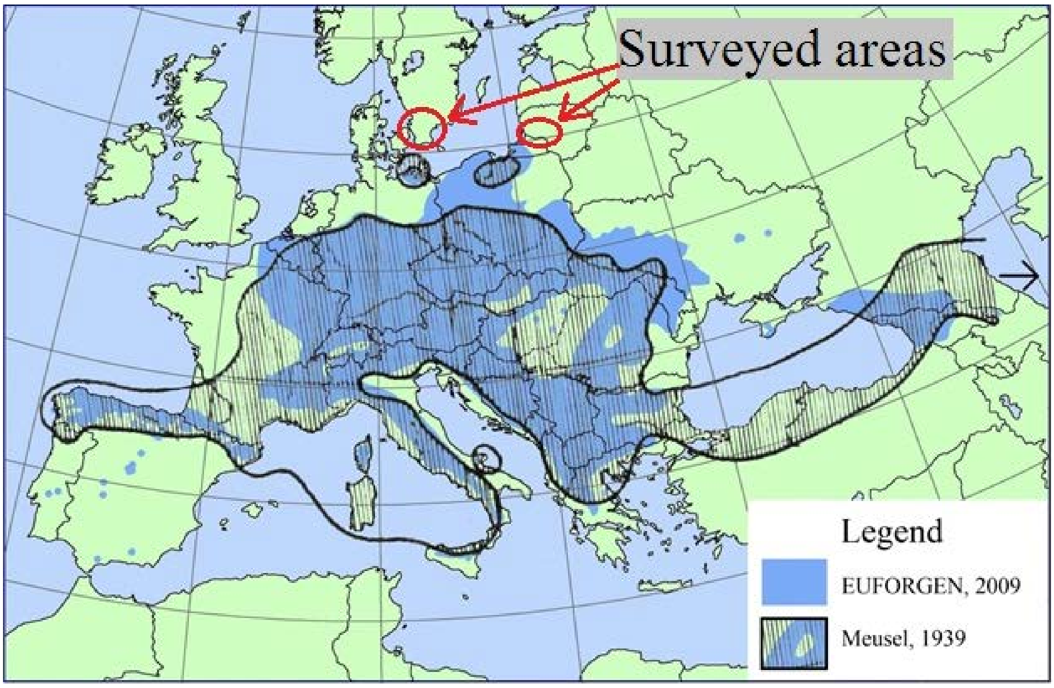


Figure 2. Distribution map of sycamore (*Acer pseudoplatanus)* and location of surveyed areas. Continuous darker colour represents distribution map compiled by EUFORGEN, 2009. Line fill with bold boundary represents distribution map complied by Meusel, 1939.

3. Aim of the study

The intention with this study is to investigate sycamore dispersal trends and how different stand parameters influence natural sycamore regeneration density.

- Different stand parameters have a small influence on sycamore regeneration inside sycamore source stand.

- Distance from the source stand and dominant tree species in adjacent stand has a strong influence on sycamore regeneration and its ability to compete with regeneration of other tree species.

- Adjacent stand orientation to the cardinal direction, as well as lower canopy layer and shrub layer density has some influence on sycamore regeneration density.

- Average basal area, age, height, stand size, groundcover type have no or little influence on regeneration.

4. Material and methods

4.1. Sites

30 sycamore stands were selected for this survey. 23 stands were located in southern Sweden (Figure 3). Of these stands ten were in Trolleholm, six in Skabersjö, three in Häckeberga, two in Holmeja, one stand in Knutstorp and one in Silvåkra. Seven stands were located in Lithuania (Figure 3). Five of them in Jurbarkas district, one in Pagėgiai and one in Šilutė district.

Information about 22 of the stands in Sweden was obtained from Sjöstedt (2012) master thesis and one stand in Skabersjö was discovered and measured independently. Location of five sycamore stands in Lithuania was obtained from Straigyte and Baliuckas (2015) article. Two stands in Jurbarkas and Pagėgiai districts were discovered independently.

48 stands which were adjacent to sycamore source stands were measured. 15 spruce stands, 13 beech stands, eight Scots pine (*Pinus sylvestris*) stands, six oak stands and six clearcuts.

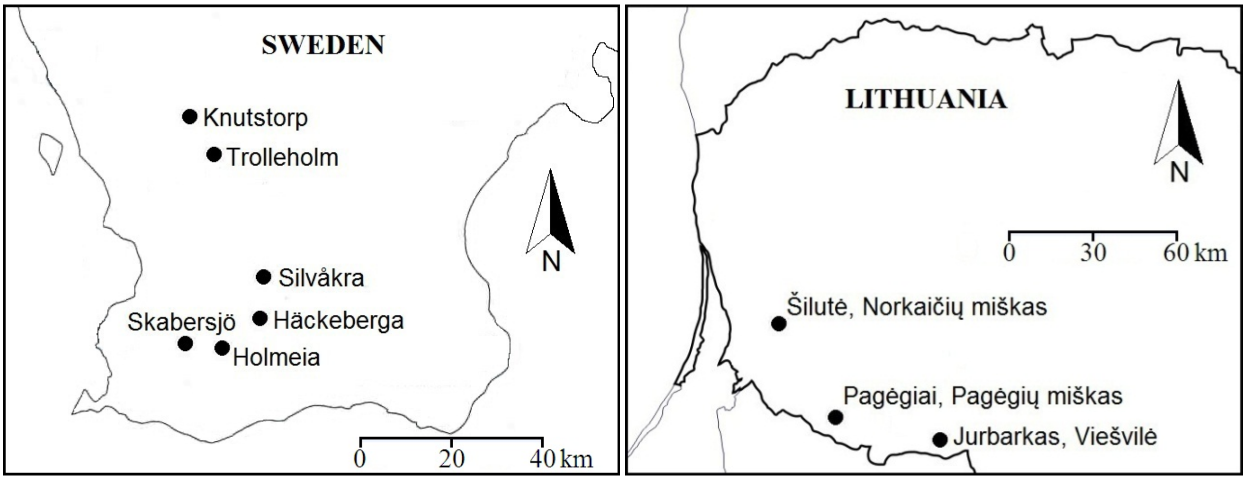


Figure 3. Geographical location of surveyed stands in Sweden (on the left) and surveyed stands in Lithuania (on the right).

4.2. Canopy layers characterization

Upper canopy layer consists of dominant trees in the stand. Lower canopy layer consists of younger or suppressed individuals of the dominant trees, together with smaller trees of other species. These trees are at least 5 m smaller than dominant trees, but overall height should be more than 5 m. Shrub layer consists of large shrubs and small tree species which do not exceed 5m height. Ground layer consists of herbaceous plants and small shrubs.

4.3. Source stands selection

Sycamore propagation in forest conditions starts at around 30 years of age (Rusanen and Myking, 2003) In order to have a sufficient amount of regeneration stands older than 40 years were selected for this survey. Moreover small (<50 cm) sycamore seedling is able to survive more than 15 years under dense canopy conditions (Hättenschwiler and Körner, 2000). Selected stands contained at least 30% mature sycamore trees in upper canopy layer. If two sycamore stands were adjacent, the area of sycamore source stand was considered to be the sum of the both stands. In that case other characteristics of the source stand were considered to be of the one which was closer to the sample plot. Finally 30 sycamore stands were included in the survey.

4.5. Adjacent stands selection

All forest stands adjacent to sycamore stand were examined for this survey. Adjacent stand was rejected if:

- contained mature sycamore trees.
- was located between sycamore stands.
- had inseparable border with sycamore stand.
- had smaller parameters than 40 m width and 120 m length and because of that there was not possible to make at least four sample plots.
- was dominated by other tree species than spruce, beech, oak and pine.

Other land use categories than forest, were disregarded duo to the lack of the sites and unsuitable conditions for sycamore regeneration. Surveyed stands were classified by dominating tree species: spruce, beech, pine and oak. Stand was considered to be dominated by a certain tree species if it consisted of at least 50% of all trees in the upper canopy layer. Young beech stands were selected from 15 years of age. Clear cut sites were selected regardless of the species composition in the former stand or of the newly planted. Before the felling five stands contained spruce and one European larch (*Larix decidua*). All clear cut sites were scarified. Five scarified by harrowing and one by applying herbicides. When data was collected from the clearcut with planted sycamore trees only naturally regenerated trees were counted. Clear cut site was considered to be until average tree height reached 3 m. Stands with applied beech shelterwood system were rejected due to difficult data collection conditions. In total 102 adjacent stands were rejected from the survey, on average 3,5 adjacent stands per source stand. Finally 48 adjacent stands were selected for the survey.

4.6. Sample plots scheme

Sample plots were located in source stands and in adjacent stands. In each sycamore source stand 4 to 10 plots were selected. These plots were called base plots. The centre of the base plots were located 5,64 m inside the source stand from the boundary to adjacent stand. Sample plots inside adjacent stands were located 50 and 100 m away from base plot which was located on the boundary to that stand. Practically it was done by inputting border of the source stand and adding two buffer zones around it with GIS software (Figure 6). Inside each adjacent stand 4 to 10 plots were selected with equal amount of plots in each distance group. Amount of sample plots per stand varied in regard to stand area. Distance between sample plots in the same distance group could not be less than 20 m. Distance between sample plot in the adjacent stand and the edge of that stand could not be less than 10 m (Figure 4). Distance between sample plots was measured and sample plots were located by the tablet computer with GPS function. In total 391 sample plots were made. 248 sample plots in adjacent stands, on average 5,2 sample plots per stand, and remaining 143 plots in sycamore source stands, on average 4,9 sample plots per source stand.

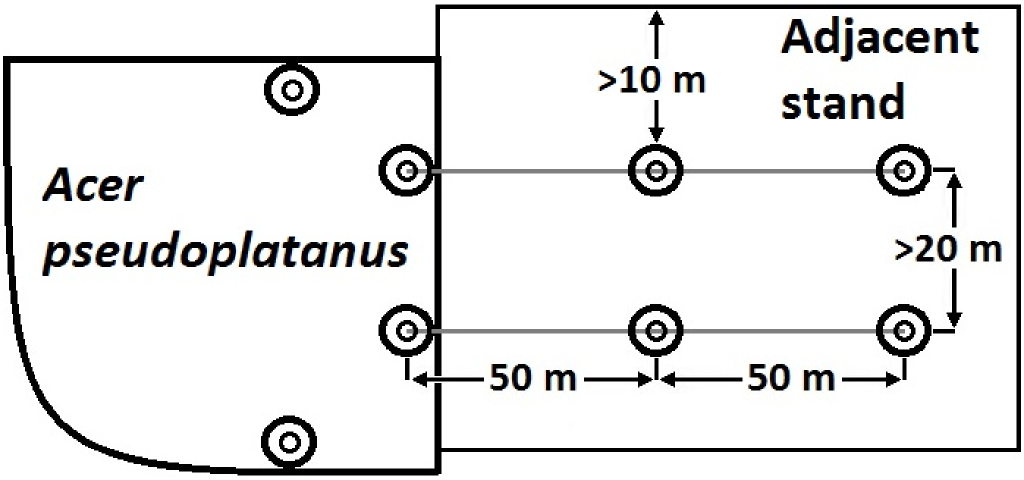


Figure 4. Sample plots distribution. Irregular shape figure represent sycamore source stand, regular shape figure represents adjacent stand. Sample plots (drawn in circles) were located by the boundary inside the sycamore source stand and repeated after 50 and 100 m inside adjacent stand.

Concentric circle plots of two different sizes were used in this research. At each sampling point, a small inner 1,78 m radius circle and a big outer 5,64 m radius circle were established (Figure 5). In the small circle, all seedlings (<0,5 - 1,5 m height) and saplings (≥ 1,5 m height) were counted, independently of their height. In the remaining 90 m^2 of the full circle (a 3,38-m-wide strip around the inner circle), only the saplings were counted and seedlings were disregarded. All selected regeneration was divided by species and grouped into seven height groups. Seedlings: (1) < 0.5 m; (2) 0.5-1; (3) 1-1.5 m and saplings: (4) 1.5-2 m; (5) 2-2,5 m (6) 2,5-3 m (7) > 3 m.

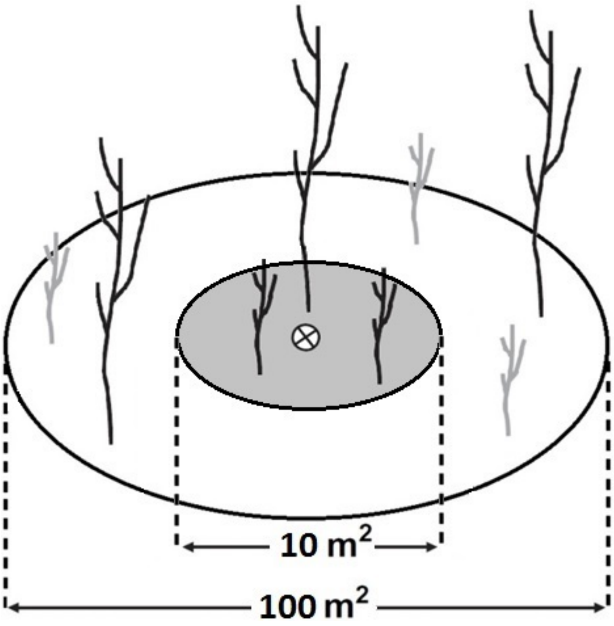


Figure 5. Sample plots strategy in the inventory circles: in the exterior circle (100 m^2), saplings (height ≥ 1.5 m, black color) are counted and seedlings (height < 1.5 m, grey color) are disregarded. In the internal circle (10 m^2), all seedlings and saplings are counted, independently of their height (drawn in black).

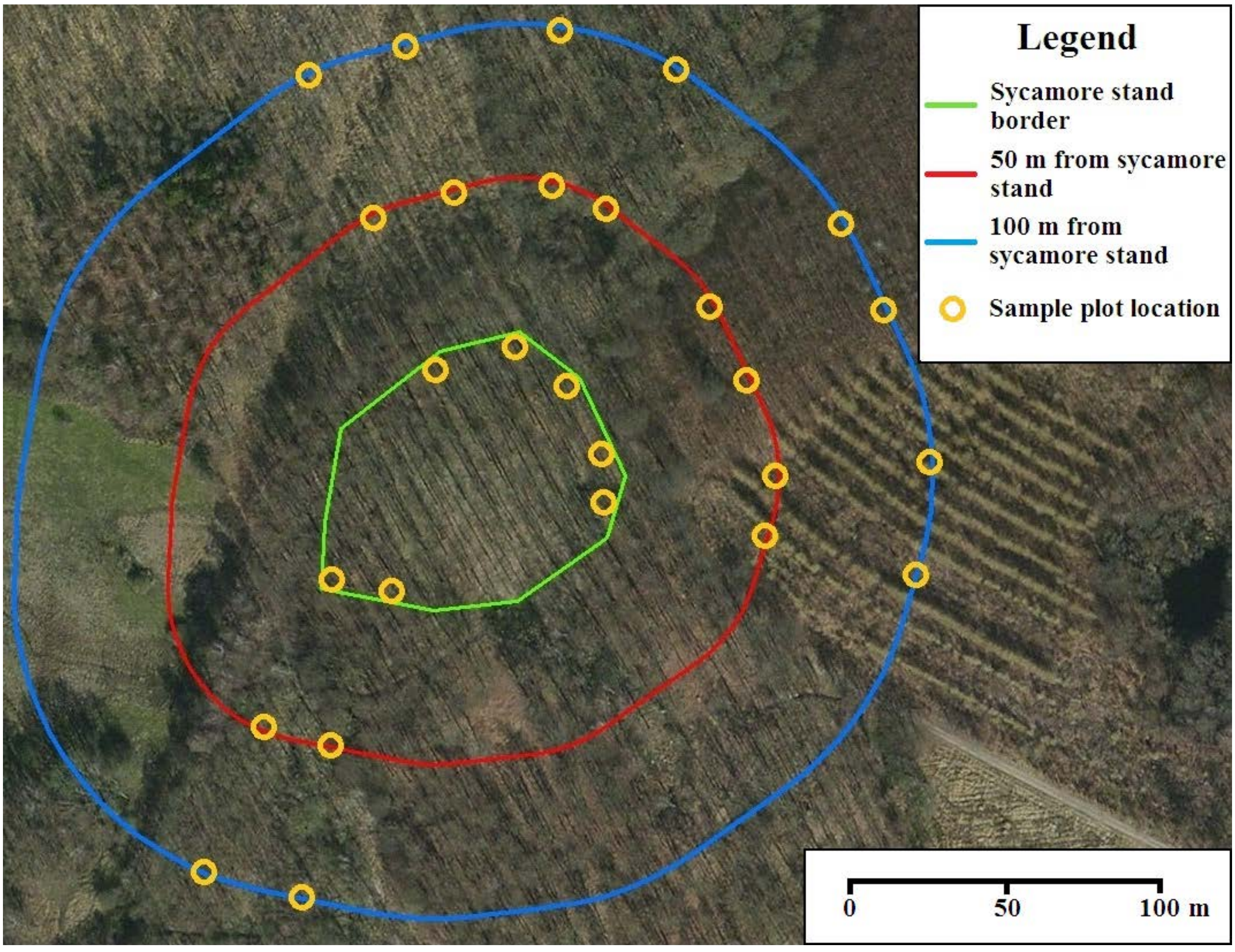


Figure 6. Example of practical sample plots distribution from the forest in Skabersjö.

4.7. Data collection

In each sample plot following information were collected: Firstly, different tree species composition in upper canopy layer in percent. Secondly, amount of sycamore regeneration distributed by height groups: (1) < 0.5 m; (2) 0.5-1; (3) 1-1.5 m; (4) 1.5-2 m; (5) 2-2,5 m (6) 2,5-3 m (7) > 3-5 m or DBH <8 cm. As well as amount of competing tree regeneration distributed by species and height groups in the same height groups as above. Light conditions in understorey were evaluated by measuring basal area. Basal area was measured with relascope in at least 5 places per stand. Another important factor for estimating light conditions was amount of lower canopy layer and shrub layer trees and shrubs in 100 m^2 plot. Description of forest ground cover was done by evaluating amount of Grass (*Poacaea and Cyperaceae* families plants), Herbs (all herbaceous plants except *Poacaea and Cyperaceae* families), Tree leaves litter, Needles litter, Moss, Open soil, Ferns, Raspberry and Blueberry by the 10% classes. Height of the stand was evaluated by measuring at least four trees with average height. Age of the stand was assessed by counting tree rings of the stumps from the most recent thinning or evaluating visually. Site class was determined by Lithuanian classification. Cardinal direction of the adjacent stand was identified.

Fieldwork in Sweden was carried out during May and June 2015. Fieldwork in Lithuania was done in July and August 2015.

4.8. Data analysis

Data collected from 4 - 10 sample plots per stand was used to determine standwise characteristics. However when comparing sycamore regeneration 50 m and 100 m from a source stands regeneration density was assessed separately for these two groups in each stand. Student’s t-test was used to determine whether regeneration distribution was significant between 50 m and 100 m groups from a source stands. Data analysis and some graphs were produced using R statistics programme (R Core Team, 2012). Other graphs were produced using Microsoft Office.

5. Results

5.1. Primary results

In total 78 stands were surveyed with sample plots whereof 30 were sycamore and 48 adjacent stands dominated by other tree species. In total data was collected from 391 sample plots on average 5 sample plots per stand. 143 base plots were measured in sycamore source stands and 248 sample plots in adjacent stands. 25 adjacent stands were excluded from the survey duo to admixture of mature sycamore.

The sycamore source stands were all, except for two, in the age range of 40 – 60 years with a high variability in basal area (13 to 58 (m^2/ha)) (Figure 7). The variability in basal area was due to different management approaches and gaps in some stands. Sycamore monocultures accounted for 20 %, mixtures with sycamore dominance accounted for 60 % and mixtures with sycamore accounted for 20 % of all stands.

5.1.1. Sites variability

Norway spruce and beech were the most common species in the adjacent stands in Sweden, while in Lithuania it was pine. There was no pine stands adjacent to sycamore source stand in southern Sweden. Moreover, there was much less sycamore source stands in Lithuania than in Sweden. Sizes of sycamore source stands had a significant difference between countries. Average sycamore source stand size in Sweden was 1 ha while in Lithuania it was only 0,2 ha. The stands with Norway spruce was younger (35 - 50 years) than the pine stands in Lithuania (50 – 140 years) (Figure 7). The adjacent beech and oak stands varied in age from 20 to 130 and had in general a lower basal area than the Norway spruce stands. Six adjacent stands were clearcuts, from which two were afforested with pure spruce, one by spruce and silver fir (*Abies alba*) mixture, one by larch, one by grand fir (*Abies grandis*) and one by sycamore. All sites were scarified.

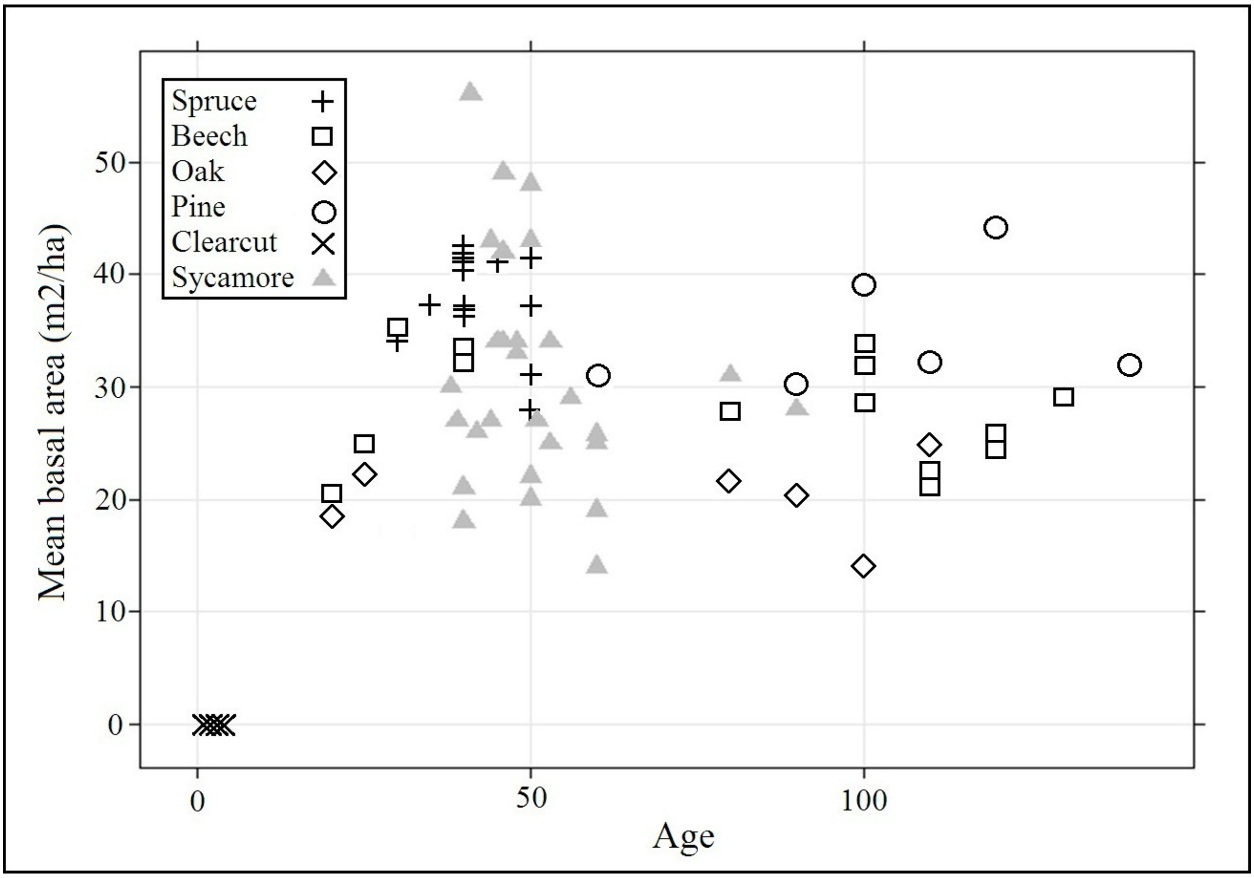


Figure 7. Mean basal area dependence on age in surveyed stands. Dominant species listed in the legend. The sycamore stands are the source stands and all other are adjacent stands.

5.2. Sycamore within sycamore stands

The measured variables in the sycamore source stands did not seem any strong influence on regeneration density. There was no clear correlation observed with an increase of mean basal area and sycamore trees share in the stand, increase of stand age (Figure 8). As well as other variables: lower canopy layer and shrub layer composition, stand height, size, ground vegetation had even less correlation with regeneration density.

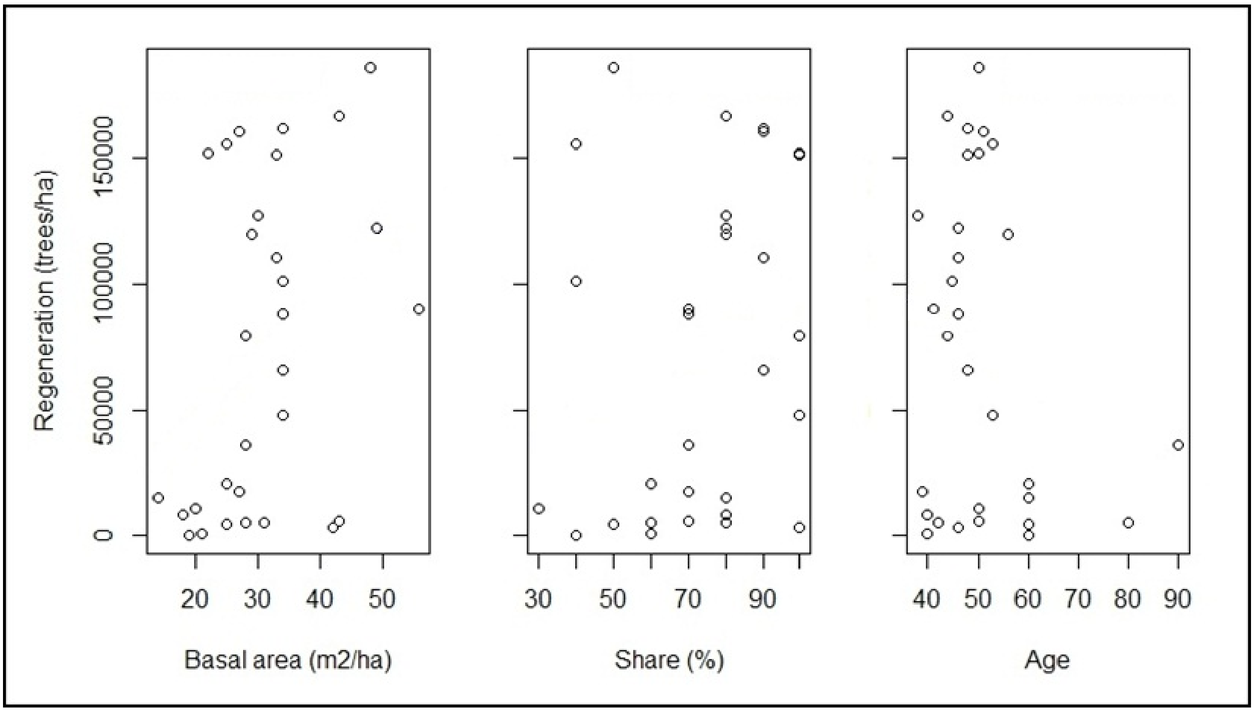


Figure 8. Relation between sycamore stand basal area, percentage sycamore trees and stand age with regeneration density.

Age of the sycamore stand have some influence on the distribution of regeneration. Seedlings distribution with regard to the age of the stand is more scattered while in saplings group it tend to have a slight increase with the age (Figure 9).

Figure 9. Sycamore stand age influence on regeneration density of seedlings and saplings.

The density of sycamore regeneration in sycamore stands was highest in sample plots where leaves litter was the dominant groundcover type (Figure 10). Herbs groundcover type was the least suitable for sycamore regeneration.

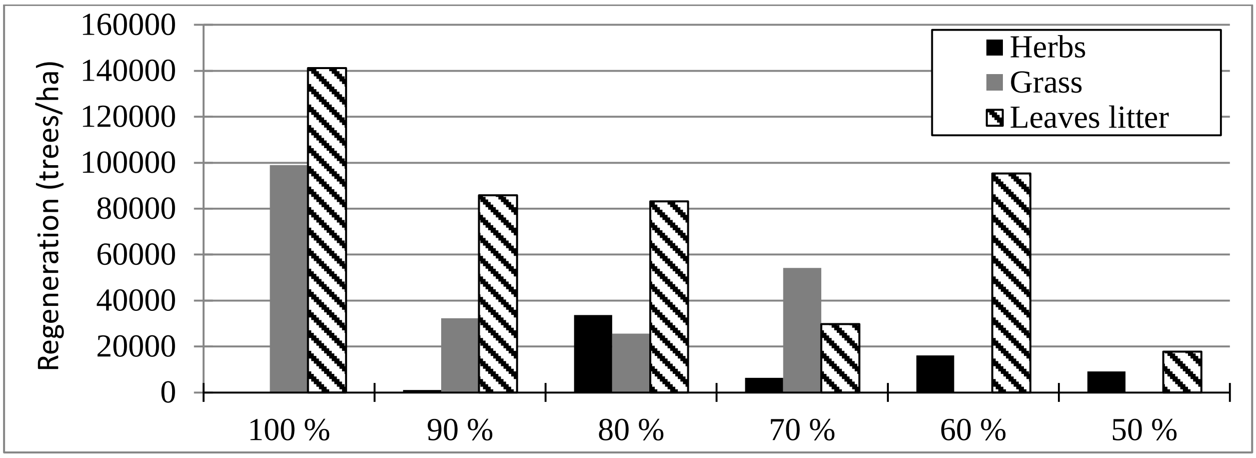


Figure 10. Relation between percentage of groundcover type and average density of sycamore regeneration per sample plots in sycamore stands. N: herbs - 78; grass - 18; leaves litter – 37

5.3. Sycamore regeneration in adjacent stands

5.3.1. Regeneration frequency

Sycamore regeneration was found in every type of investigated stand. However there were also sample plots or stands with no regeneration. Most of the adjacent stands with no sycamore regeneration were dominated by beech and spruce. Sycamore regeneration was present more often in the sample plots which were closer to the source stand. However saplings density in sample plots in the pine stands and oak stands showed opposite results. Sycamore seedlings were present in more sample plots than saplings. This trend applies to all types of stands and distances from the seed source except of sample plots in pine stands 50 meters from the source stand (Table 2). Sycamore seedlings were present in 90% of the base plots, whereas saplings were present in 35% of the base plots. Sample size (N) – 143 plots.

Table 2. Percentage of sample plots with present sycamore regeneration. N_1 – Number of stands; N_2- number of sample plots.

Stand			50 meters				100 meters	
	N_1	N_2	seedlings	saplings	N	N_2	seedlings	saplings
Spruce	15	37	75 %	10 %	15	37	34 %	3 %
Beech	14	28	69 %	3 %	13	28	60 %	0 %
Oak	6	16	85 %	24 %	6	16	63 %	33 %
Pine	8	24	16 %	19 %	8	24	45 %	26 %
Clearcut	6	19	72 %	20 %	6	19	37 %	4 %

On clearcuts the regeneration density was significantly higher (p-value 0,02) at 50 meters distance from the source stands compared to plots at 100 m distance. However, there was no difference in distance from source in adjacent stands with canopy cover, regardless of dominant species.

In oak, pine, spruce up to 50 meters and clearcuts sycamore saplings were more abundant than saplings of other species. However in beech stands and spruce stands 100 m from the source stand sycamore saplings density did not exceed other tree species saplings density. Nevertheless sycamore seedlings were much more abundant than the saplings of any tree species in all sites (Table 3).Sycamore seedlings with the height lower than 0,5 m accounted for 98 % of all species regeneration.

Table 3. Mean density of sycamore and other tree species, 50 and 100 meters distance from sycamore source stand.

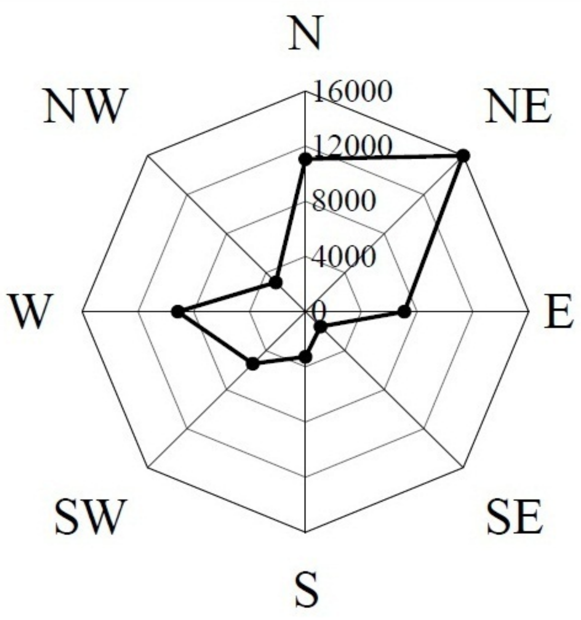
Site	No. of stands	Seedlings (trees/ha)		Saplings (trees/ha)		Other trees saplings (trees/ha)	
		50 m	100 m	50 m	100 m	50m	100m
Spruce	15	15868	2878	84	14	46	70
Beech	13	16864	5071	9	0	153	305
Oak	6	16431	11594	431	406	389	151
Pine	8	942	1142	442	183	182	73
Clearcut	6	5547	1974	126	26	17	8

Regeneration of 12 other tree species was present in adjacent stands. List of the species by frequency: beech (69 %), spruce(8%), hornbeam (6%), silver birch (*Betula pendula*) (4%), elm (4%), ash (2%), Norway maple (2%), grey alder (*Alnus incana*) (2%), oak (2%), small-leaved lime (*Tilia cordata*) (1%), red oak (*Quercus rubra*) (1%) and silver fir (0,3%).

Regeneration density varied greatly between sample plots in the same stand, average density between stands and stand types. Greatest seedling density variation was in spruce and beech stands. Highest identified seedling density per ha in spruce stand was 320000; beech – 234000; oak – 93000; pine 39000; clearcut – 21000. Highest identified sapling density per hectare in pine stand was - 3900; spruce - 2400; oak - 2100; clearcut – 800; beech - 200.

5.3.2. Adjacent stand orientation influence

Adjacent stand orientation to cardinal direction seems to influence on the seedling density (Figure 11). Sample plots oriented northeast and north directions from the source stand had the highest average regeneration density. Lowest regeneration density was observed in the stands oriented northwest and southeast directions from the source stand.



Direction	N of plots
N	38
NE	36
E	46
SE	36
S	18
SW	14
W	42
NW	18

Figure 11. Average sycamore regeneration density per stand (trees/ha) according to adjacent stand orientation to the cardinal direction.

5.3.3.Other stands characteristics influence

However lower canopy layer and shrub layer seemed to have a negative effect on sycamore regeneration. Sycamore regeneration was the most abundant in the stands with no or very little trees in lower canopy layer and shrub layer. Most common lower canopy layer species in Sweden was beech and sycamore and in Lithuania - spruce. Most common shrub layer species in Sweden was common hazel (*Corylus avellana*) and in Lithuania – serviceberry and hazel. Sycamore regeneration density did not show to have a relationship with basal area nor the age of the adjacent stand (Figure 12). Other investigated stand parameters: upper canopy layer tree height and source stand size, did not have influence on sycamore regeneration.

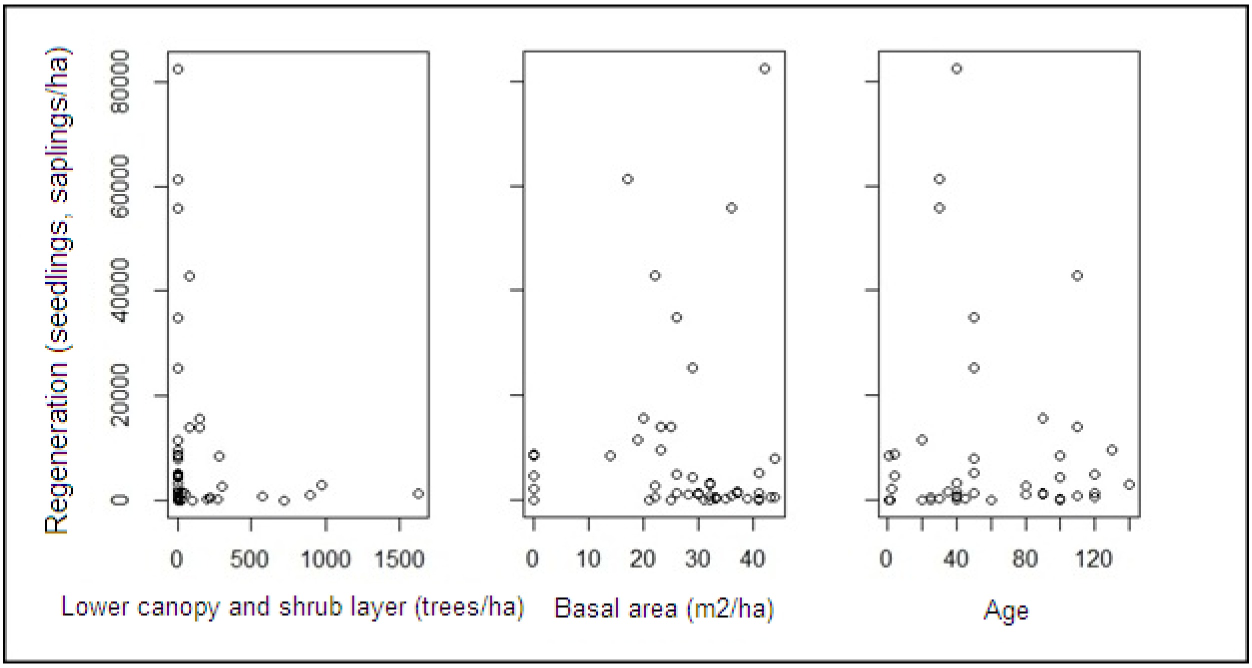


Figure 12. Relation between adjacent stand basal area, age, lower canopy and shrub layer density with sycamore regeneration density.

Sycamore seedlings density did not show to have a clear relationship with a ground cover (Figure 13). However there were more seedlings in the sample plots where ground cover was a mixture of a two or more groundcover types. Exception was with leaves litter type which was most abundant in beech stands. Saplings density was highest in sample plots dominated by herbs and grass (Figure 14).

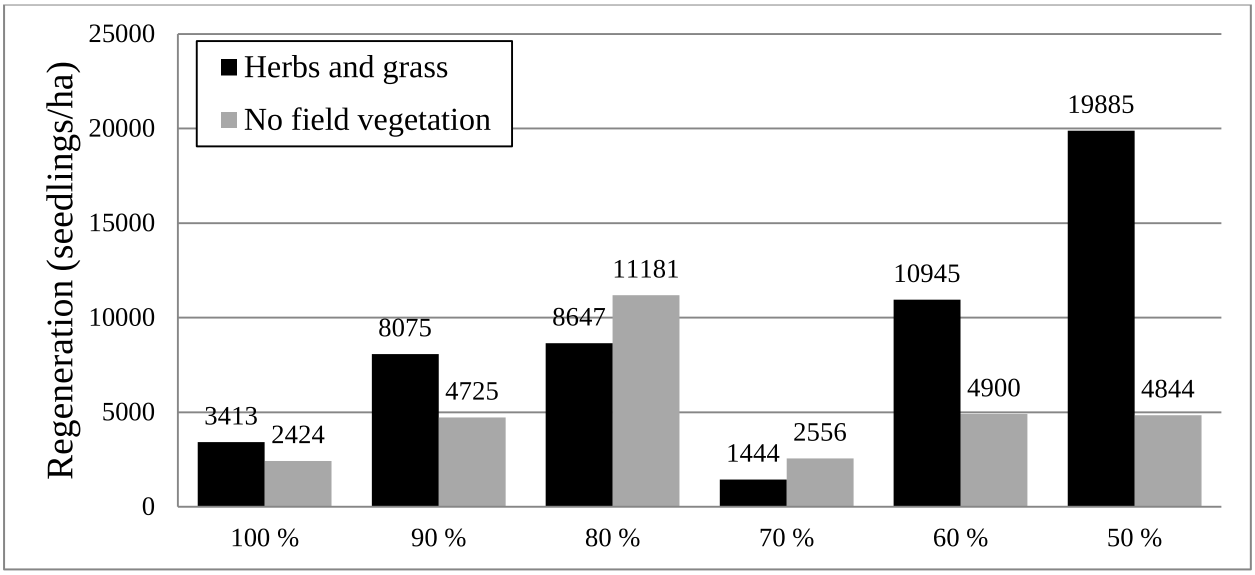


Figure 13. Relation between percentage of ground covered by different groundcover types and average sycamore seedlings density per sample plots in adjacent stands. N: “Herbs and grass” – 104. “No field vegetation” consists of: leaves litter; soil; moss and needles litter, N – 133.

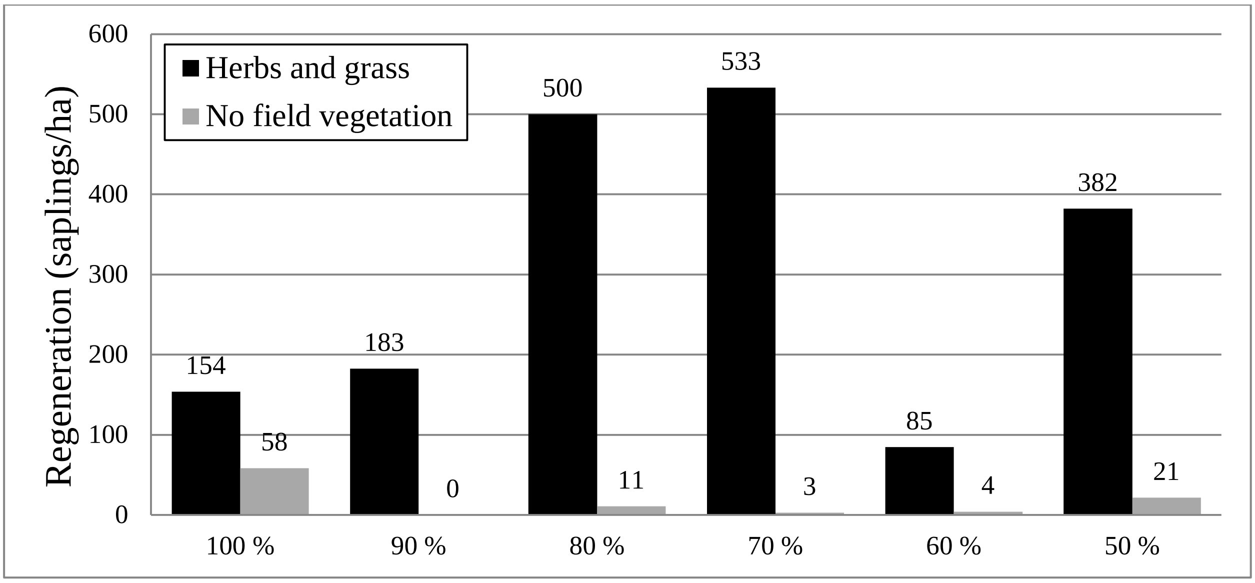


Figure 14. Relation between percentage of ground covered by different groundcover types and average sycamore Saplings density per sample plots in adjacent stands. N: “Herbs and grass” – 104. “No field vegetation” consists of: leaves litter; soil; moss and needles litter, N – 133.

There was no relation between average regeneration density in sycamore source stands and in adjacent stands (Figure 15).

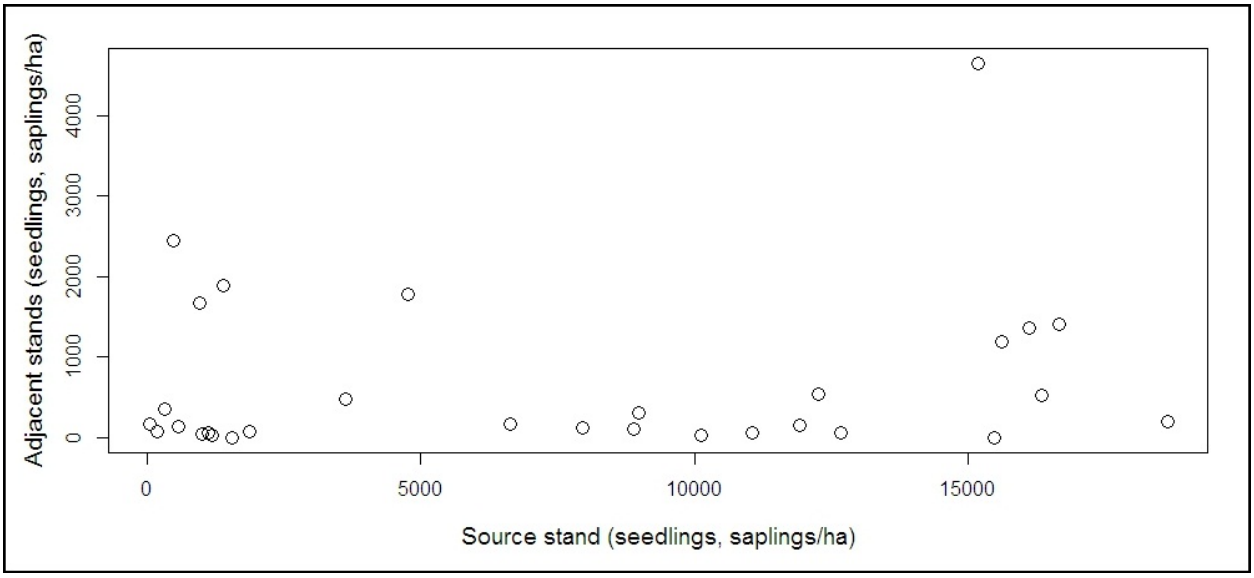


Figure 15. Relation between mean sycamore regeneration density in sycamore source stand and mean sycamore regeneration density of adjacent stands.

6. Discussion

6.1. Sites variability

The great variability of adjacent stands parameters resulted in difficulties with withdrawal of some results from the variables. Surveyed tree species of spruce, beech, oak and pine varies greatly of the conditions they create within the stand. Spruce and beech creates the shadiest environment while oak and pine allows more light on forest floor. Oak, beech and pine rotation is much longer than spruce so there was a high difference between adjacent stands age. Because of the variance of dominant tree species, age and managers approach basal area was also hardly comparable. Surveyed stands in Lithuania had specific conditions not only because of pine dominance, but also due to less fertile soils.

6.2. Sycamore within sycamore stands

Sycamore stand variables investigated in this survey did not show strong influence on regeneration density within sycamore stands. This result can be explained by the biology of the tree. Sycamore shade tolerance in a young age (Collet, 2008) and regeneration strategy to establish under shady conditions (Diaci, 2002) enables sycamore to regenerate in closed canopy conditions regardless lower canopy layer and shrub layer influence. Average stand basal area and stand age had a low influence on regeneration it is possible that light availability is more important factor for regeneration. However there was a tendency that highest sycamore regeneration was in the stands where sycamore leaves litter groundcover type was dominant. This result could be associated with fast sycamore leaves litter decomposition which releases nutrients back into the soil and provides new generation of trees with sufficient amount of microelements (Millard and Proe 1991). Moreover herbs groundcover type showed negative influence on sycamore regeneration density. Herbs may use up the nutrients and water which negatively affect sycamore regeneration abilities. However results from adjacent stands show that herbs groundcover type does not have the same negative effect as in sycamore stands. Moreover grass groundcover had a reasonably high regeneration density.

6.3. Sycamore regeneration in adjacent stands

6.3.1. Regeneration frequency

Ability to regenerate was observed in all surveyed stand types. However in this survey it seemed as sycamore saplings varied in their ability to compete with beech due to the stand type. In beech and some spruce stands, the sycamore saplings were less abundant than beech saplings but in pine, oak, some spruce stands and clearcuts the density of sycamore saplings was higher than saplings of beech and other tree species. The findings are consistent with other studies, where beech has been stated to be more successful in shady conditions due to its higher shade-tolerance than sycamore (Petriţan et al. 2007). However other factors may influence regeneration density as well. Ungulates can play an important role in forming a regeneration structure. Research conducted by Ammer, (1996) states that sycamore was more preferred by ungulates than beech and under shady conditions it needed more time to recover than beech.

European studies have stated some of the sycamore dispersal tendencies which were analysed in this thesis. Species ability to germinate in low light conditions and form dense undergrowth was analysed by identifying regeneration density under different stand types. Results from (Table 3) show that average seedling density in adjacent beech and Norway spruce stands was around 16000 seedlings/ha. These results that sycamore demonstrates very good dispersal abilities within the Norway spruce plantations go along with other studies from European countries (Hérault et al. 2004; Diaci, 2002). However density was declining fast with an increased distance from a source stand. Moreover, there were some sample plots with absence of sycamore regeneration. Furthermore, sycamore saplings were the scarcest in the stands of spruce and beech (Table 2). Light availability may be one of the most limiting factors for sycamore regeneration. Upper canopy layer composition in this case is the most reliable indicator. Beech and spruce dominated stands creates shady conditions inside the stands while in oak and pine dominated stands more light reaches forest floor. Sycamore regeneration have better conditions to establish and develop where is more light available. However with increased amount of light more competing vegetation appears which may reduce the success of sycamore establishment.

Hypothesis statement that amount of sycamore regeneration should decrease with distance from a source stand was correct for most of the surveyed conditions, except of sample plots in pine stands. Unexpected result was that in the pine stands amount of regeneration is higher 100 m than 50 m from the source stand .There may be a few reasons for these differences. One reason for this could be connected with soil fertility. Generally sycamore is more fertile soils demanding species than pine. In Lithuania most of the surveyed sycamore stands are formed after natural regeneration. So in order for sycamore not to be over competed by pine, it had to grow on more fertile site. In that case with increasing distance from sycamore stand soil fertility should decrease leading to lower density of the competing vegetation. This should increase chance of successful sycamore establishment.

While the average density was quite low in both spruce and beech stands some sample plots had extraordinary high regeneration density. In most cases this high density occurred only in single sample plots per stand. This shows that not only whole stand conditions have influence, but also variance within a stand. There may be a few occasional stand elements which locally increase conditions for regeneration. Gaps in the upper canopy layer are the typical incentive for sycamore growth. Another reason may be terrain, when depressions create better conditions for regeneration duo to higher water availability. While sample clots cover only small area of the stand most of the occasional areas with extraordinary amount of regeneration were not investigated.

Sycamore was able to regenerate in great numbers even though soil was not scarified. This ability may be the result of sycamore growing on suitable sites which were selected by forest managers when planting sycamore. Another reason for successful regeneration could be because of scarce ground cover of competing vegetation in the forest stands.

6.3.2. Adjacent stand orientation influence

Results showed that adjacent stand orientation to the cardinal direction has an influence on sycamore natural regeneration (Figure 11). The result can be associated with sycamore wind dispersed seeds, which are adapted to cover longer distances to the direction of wind (Matlack, 1987). Results compared with wind statistics in southern Sweden and west Lithuania (Figure 1) show that regeneration density could be affected by dominant wind directions. However sycamore seeds disperse during winter when dominating wind direction can be different than rest of the year. Wind direction influence on regeneration in adjacent stands can be attributed as an external factor. Moreover it can have an influence on the results regardless of adjacent stand characteristics. This should have a negative influence on the accuracy of the data analysis.

6.3.3. Other stands characteristics influence

Lower canopy layer and shrub layer have some negative influence on abundance of sycamore regeneration. This could be also associated with decreased light availability for sycamore. Moreover upper canopy layer has the highest influence on light availability. However there is no connection when comparing stands basal area and regeneration density. This result shows that light conditions cannot be evaluated by the basal area. More influencing factor in this case is the dominant tree species compsition in the upper canopy layer.

When analysing sycamore regeneration density relationship with a ground cover in all stands there is no clear tendency. However it is different in different stand types. Spruce together with beech had a great amount of sycamore regeneration in some plots. Leaves litter groundcover type accounted for beech stands and density was also high. However in spruce stands where conditions were not suitable for herbs and grass to grow and needles litter was most abundant ground cover type neither sycamore had good conditions to regenerate. High saplings density on the sample plots dominated by herbs and grass was more influenced the dominant tree species than the groundcover itself. Most of the sample plots dominated by herbs and grass were located in oak and pine stands where saplings density was the highest. Which indicate that both saplings and field vegetation managed to survive in oak and pine stands but not from competition of Norway spruce and beech.

Results did not show that there is a correlation between regeneration density in sycamore source stands and adjacent stands. This result indicates that lack of regeneration in adjacent stands cannot be connected with seed production abilities of the source stand. However, any eventual correlation with seed production ability in the source stands was not possible to detect within the scope of this study.

There is a chance that sycamore regeneration in some stands was decreased by the forest managers. However management operations of shrub removal would not happen often and only saplings could be removed. Seedlings are too small to be weeded. Because seedlings lower than 50 cm account for 98 % of all sycamore regeneration shrub layer removal would not have a major influence on the results. Furthermore during the fieldwork there were no stands observed with stumps of cut of seedlings.

6.3.4. Differences in sycamore regeneration between Sweden and Lithuania

Sycamore seedlings regeneration in adjacent stands was denser in Sweden than in Lithuania. However sycamore saplings density did not show to have difference between countries. Seedlings regeneration differences may be the result of less fertile sites dominated by pine in Lithuania while in southern Sweden soil is more fertile and dominated by spruce, beech and oak. Another reason for seedlings regeneration difference may be the climatic conditions. Southern Sweden's oceanic climate with longer vegetation period and higher winter temperatures could be more beneficial for sycamore than continental climate conditions in Lithuania. High density of ungulates in Sweden may decrease the possible density of saplings while in Lithuania even in possibly worse climate and soil conditions but with fewer browsers sycamore has more chances reaching sapling height.

6.4. Practical implication

Practical conclusion that can be drawn from this thesis is that if there are mature sycamore trees in the area natural regeneration will occur in the adjacent stands. Depending on the stand parameters it can be more or less intensive. Already known stands parameters as light conditions, lower canopy layer and shrub layer density that affect the natural regeneration can be promoted or controlled for. If sycamore is considered to be a danger for forest ecosystem it can be controlled. Control intensity should be adjusted with regard to the dominant species in the adjacent stands. Control intensity will be lower in spruce, beech and young oak stands while in old oak and pine stand it should be more intensive. If sycamore is considered to be a valuable tree species, natural sycamore regeneration could be promoted by reducing stand density in spruce stands. In oak and pine stand there is no need of active management for regeneration to appear. However soil scarification could increase regeneration density by reducing competing herbaceous vegetation. In order to promote sycamore in beech stands traditional shelterwood system should be applied and sycamore should be retained during PCT. There are already signs in southern Sweden that sycamore is a desirable tree species in forest stands for some managers. Sycamore is retained after PCT in naturally regenerated beech stands and other mixtures. In these areas sycamore should persist and continue to disperse at least for one more generation even with ought additional planting. Different situation is in Lithuania. According to Lithuanian forest law sycamore is not allowed to be planted in forest stands. At the moment there is an ongoing discussion weather sycamore is an invasive and if existing population should be removed from forest stands. However there is a great amount of sycamore planted as ornamental trees which is increasing regeneration in suitable locations.

My recommendations for further research on this topic: Best Sycamore regeneration is in the stand gaps. Research focused on the stand gaps in the areas close to the sycamore source stands could provide with the information how gaps influence sycamore dispersal. However, in my opinion, focus more on older naturally regenerated sycamore trees would be also informative. Natural regeneration can show dispersal tendencies, but naturally regenerated trees which have reached flowering stage could show the ways of dispersal success. Also investigation of sycamore dispersal corridors, such as regeneration by the forest roads or the chances of naturally regenerated sycamore reaching maturity under different management systems.

References

Ammer, C. (1996). Impact of ungulates on structure and dynamics of natural regeneration of mixed mountain forests in the Bavarian Alps. *Forest Ecology and Management*, *88*(1), 43-53.

Balandier, P., Collet, C., Miller, J. H., Reynolds, P. E., & Zedaker, S. M. (2006). Designing forest vegetation management strategies based on the mechanisms and dynamics of crop tree competition by neighbouring vegetation. *Forestry*, *79*(1), 3-27.

Broadmeadow, M. S. J., Ray, D., & Samuel, C. J. A. (2005). Climate change and the future for broadleaved tree species in Britain. *Forestry*, *78*(2), 145-161.

Brunet, J. (2007). Plant colonization in heterogeneous landscapes: an 80-year perspective on restoration of broadleaved forest vegetation. *Journal of Applied Ecology*, *44*(3), 563-572.

Caquet, B., Montpied, P., Dreyer, E., Epron, D., & Collet, C. (2010). Response to canopy opening does not act as a filter to Fagus sylvatica and Acer sp. advance regeneration in a mixed temperate forest. *Annals of Forest Science, 67*(1), 105.

Chmielewski, F. M., & Rötzer, T. (2001). Response of tree phenology to climate change across Europe. *Agricultural and Forest Meteorology*, *108*(2), 101-112.

Collet, C., Piboule, A., Leroy, O., & Frochot, H. (2008). Advance Fagus sylvatica and Acer pseudoplatanus seedlings dominate tree regeneration in a mixed broadleaved former coppice-with-standards forest. *Forestry*, *81*(2), 135-150.

Diaci, J. (2002). Regeneration dynamics in a Norway spruce plantation on a silver fir-beech forest site in the Slovenian Alps. *Forest Ecology and Management*, *161*(1), 27-38.

Dickenson, S., & Wheeler, B. E. J. (1981). Effects of temperature, and water stress in sycamore, on growth of Cryptostroma corticale. *Transactions of the British Mycological Society*, *76*(2), 181-185.

Dixon, A. F. G. (1971). The role of aphids in wood formation. I. The effect of the sycamore aphid, Dreopanosiphum platanoides (Schr.)(Aphididae), on the growth of sycamore, Acer pseudoplatanus (L.). *Journal of Applied Ecology*, 165-179.

Elton, C. S. (2012). *The pattern of animal communities*. Springer Science & Business Media. 201-207.

EUFORGEN distribution maps. Retrieved 2015-03-04, from European forest genetic resources programme: <http://www.euforgen.org/distribution-maps/>, [04 March 2015]

EU REGULATION (EEC) No 1143/2014 OF THE EUROPEAN PARLIAMENT AND COUNCIL of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species, 2014 O.J. L 317/35.

Falkengren-Grerup, U., & Tyler, G. (1991). Dynamic floristic changes of Swedish beech forest in relation to soil acidity and stand management. *Vegetatio*, *95*(2), 149-158.

FAO (2000). Food and Agriculture Organization of the United Nations, 2000. Global Forest Resources Assessment 2000, Chapter 27. Europe: ecological zones. Available from: <http://www.fao.org/docrep/004/y1997e/y1997e0w.htm> [24 November 2015].

FAO (2005). Food and Agriculture Organization of the United Nations, 2005. Alien Invasive Species: Impacts on Forests and Forestry. Available from: <http://www.fao.org/docrep/008/j6854e/j6854e00.htm [24 November 2015].

Felton, A., Boberg, J., Björkman, C., & Widenfalk, O. (2013). Identifying and managing the ecological risks of using introduced tree species in Sweden's production forestry. *Forest Ecology and Management*, *307*, 165-177.

Gill, R. M. A. (1992). A review of damage by mammals in north temperate forests: 1. Deer. *Forestry*, *65*(2), 145-169.

Greene, D. F., & Johnson, E. A. (1997). Secondary dispersal of tree seeds on snow. *Journal of Ecology*, 329-340.

Gregory, P. H., & Waller, S. (1951). Cryptostroma corticale and sooty bark disease of sycamore (Acer pseudoplatanus). *Transactions of the British Mycological Society*, *34*(4), 579-IN10.

Hanewinkel, M., Cullmann, D. A., Schelhaas, M. J., Nabuurs, G. J., & Zimmermann, N. E. (2013). Climate change may cause severe loss in the economic value of European forest land. *Nature Climate Change*, *3*(3), 203-207.

Hättenschwiler, S. T., & Körner, C. (2000). Tree seedling responses to in situ CO2-enrichment differ among species and depend on understorey light availability. *Global Change Biology*, *6*(2), 213-226.

Hein, S., Collet, C., Ammer, C., Le Goff, N., Skovsgaard, J. P., & Savill, P. (2009). A review of growth and stand dynamics of Acer pseudoplatanus L. in Europe: implications for silviculture. *Forestry*, *82*(4), 361-385.

Heitz, R., & Hasenauer, H. (2000). Reconversion of Norway spruce (Picea abies (L.) Karst.) stands into mixed forests: effects on soil properties and nutrient fluxes. In: *Forest ecosystem restoration: ecological and economical impacts of restoration processes in secondary coniferous forests. Proceedings of the International Conference, Vienna, Austria, 10-12 April, 2000*. (pp. 119-125). Institute of Forest Growth Research.

Hérault, B., Thoen, D., & Honnay, O. (2004). Assessing the potential of natural woody species regeneration for the conversion of Norway spruce plantations on alluvial soils. *Annals of forest science*, *61*(7), 711-719.

IUCN [International Union for the Conservation of Nature]. 1999. IUCN guidelines for the prevention of biodiversity loss due to biological invasion. *Species*, 31/32: 28-42.

Jensen, J. K., Rasmussen, L. H., Raulund-Rasmussen, K., & Borggaard, O. K. (2008). Influence of soil properties on the growth of sycamore (Acer pseudoplatanus L.) in Denmark. *European Journal of Forest Research*, *127*(4), 263-274.

Kabuce, N. and Priede, N. (2006): NOBANIS – Invasive Alien Species Fact Sheet – Sambucus nigra. – From: Online Database of the European Network on Invasive Alien Species - NOBANIS <www.nobanis.org>, [26 November 2015]

Karlsson, M. (2001). *Natural regeneration of broadleaved tree species in Southern Sweden* (Vol. 196).

Kelly, A. E., & Goulden, M. L. (2008). Rapid shifts in plant distribution with recent climate change. Proceedings of the National Academy of Sciences,105(33), 11823-11826.

Kimmins, J.P. (1997) Forest ecology—a foundation for sustainable management. Prentice Hall, Upper Saddle River, p 596S

Kennedy, C. E. J., & Southwood, T. R. E. (1984). The number of species of insects associated with British trees: a re-analysis. *The Journal of Animal Ecology*, 455-478.

Klopčič, M., Simončič, T., & Bončina, A. (2015). Comparison of regeneration and recruitment of shade-tolerant and light-demanding tree species in mixed uneven-aged forests: experiences from the Dinaric region. *Forestry*, cpv021.

Kneeshaw, D. D., Kobe, R. K., Coates, K. D., & Messier, C. (2006). Sapling size influences shade tolerance ranking among southern boreal tree species. *Journal of ecology*, *94*(2), 471-480.

Kolzowski, T. T (1972). Seed Biology: Importance, Development, and Germination. Academic press inc., 161.

Krehan, H. (2002, January). Asian longhorned beetle in Austria: critical comments on phytosanitary measures and regulations. In *US Department of Agriculture Interagency Research Forum On Gypsy Moth and Other Invasive Species, General Technical Report NE-300. SLC Fosbroke and KW Gottschalk (eds.), USDA, Forest Service, Northeastern Research Station. Newtown Square, PA* (pp. 5-6).

Leith, I. D., & Fowler, D. (1988). Urban distribution of Rhytisma acerinum (Pers.) Fries (tar spot) on sycamore. *New phytologist*, *108*(2), 175-181.

Le Roux, P. J. 1981. Plant invader species in pine plantations in South Africa. *Proc. of the 4th National WEEDS Conference of South Africa*. Pretoria, South Africa, 27-29 January 1981. (Editors Van de Venter, H. A. and Mason, M.), A. A. BALKEMA, Cape Town, pp. 155-168.

Leslie, A. (2005). The ecology and biodiversity value of sycamore with particular reference to Great Britain. *Scottish Forestry*, *59*(3), 23.

LHMT, Lithuanian Hydrometeorological Service under the Ministry of Environment, 2015. Available from: http://www.meteo.lt/en/web/guest/klimato-kaita, [13 November 2015].

LHMT, Lithuanian Hydrometeorological Service under the Ministry of Environment, Climate change, 2013. Available from: <http://www.meteo.lt/en/web/guest/klimato-kaita> [11 November 2015].

Matlack, G. R. (1987). Diaspore size, shape, and fall behavior in wind-dispersed plant species. *American Journal of Botany*, 1150-1160.

Marčiukaitis, M., Erlickytė-Marčiukaitienė, R., & Tumosa, A. (2009). Vėjo greičio kitimo dėsningumų Lietuvos pajūrio regione tyrimas. *Energetika*, *55*(1), 27-34.

Mędrzycki, P. (2011): NOBANIS – Invasive Alien Species Fact Sheet – Acer negundo. – From: Online Database of the European Network on Invasive Alien Species – NOBANIS <www.nobanis.org>, [27 November 2015]

Menzel, A., Sparks, T. H., Estrella, N., Koch, E., Aasa, A., Ahas, R., ... & Zust, A. N. A. (2006). European phenological response to climate change matches the warming pattern. *Global change biology*, *12*(10), 1969-1976.

Messier, C., & Nikinmmaa, E. (2000). Effects of light availability and sapling size on the growth, biomass allocation, and crown morphology of understory sugar maple, yellow birch, and beech. *Ecoscience*, 345-356.

Meusel, H. (1939). Verbreitungskarten mitteleuropäischer Leitpflanzen. 3. Reihe, Herzynia 2, Halle.

Middleton, B. (2000). Hydrochory, seed banks, and regeneration dynamics along the landscape boundaries of a forested wetland. *Plant Ecology*, *146*(2), 167-181.

Millard, P., & Proe, M. F. (1991). Leaf demography and the seasonal internal cycling of nitrogen in sycamore (Acer pseudoplatanus L.) seedlings in relation to nitrogen supply. *New Phytologist*, *117*(4), 587-596.

Morecroft, M. D., Stokes, V. J., Taylor, M. E., & Morison, J. I. (2008). Effects of climate and management history on the distribution and growth of sycamore (Acer pseudoplatanus L.) in a southern British woodland in comparison to native competitors. *Forestry*, *81*(1), 59-74.

Motta, R. (1996). Impact of wild ungulates on forest regeneration and tree composition of mountain forests in the Western Italian Alps. *Forest Ecology and Management*, *88*(1), 93-98.

Paterson, J. P., Binggeli, P., & Rushton, B. S. (1996, October). Slug-and small mammal-induced seedling mortality in sycamore Acer pseudoplatanus L. In*Biology and Environment: Proceedings of the Royal Irish Academy* (pp. 49-53). Royal Irish Academy.

Petriţan, A. M., Von Lüpke, B., & Petriţan, I. C. (2007). Effects of shade on growth and mortality of maple (Acer pseudoplatanus), ash (Fraxinus excelsior) and beech (Fagus sylvatica) saplings. *Forestry*, *80*(4), 397-412.

Petriţan, A. M., Von Lüpke, B., & Petriţan, I. C. (2009). Influence of light availability on growth, leaf morphology and plant architecture of beech (Fagus sylvatica L.), maple (Acer pseudoplatanus L.) and ash (Fraxinus excelsior L.) saplings. *European Journal of Forest Research*, *128*(1), 61-74.

Pigot, A. L., & Leather, S. R. (2008). Invertebrate predators drive distance-dependent patterns of seedling mortality in a temperate tree Acer pseudoplatanus. *Oikos*, *117*(4), 521-530.

Richardson, D. M., Pyšek, P., Rejmánek, M., Barbour, M. G., Panetta, F. D., & West, C. J. (2000). Naturalization and invasion of alien plants: concepts and definitions. *Diversity and distributions*, *6*(2), 93-107.

R Core Team (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL *<http://www.R-project.org/>*

Runkle, J. R., & Yetter, T. C. (1987). Treefalls revisited: gap dynamics in the southern Appalachians. *Ecology*, 417-424.

Rusanen, M., & Myking, T. (2003). *EUFORGEN technical guidelines for genetic conservation and use for sycamore (Acer pseudoplatanus)*. Bioversity International.

Savill, P. S. (2013). *The silviculture of trees used in British forestry*. CABI.

Säumel, I., & Kowarik, I. (2010). Urban rivers as dispersal corridors for primarily wind-dispersed invasive tree species. *Landscape and Urban Planning*, *94*(3), 244-249.

Skrzypczyńska, M. (2004). Studies on the population frequency of insects and mites causing galls on the leaves of the sycamore maple Acer pseudoplatanus L. in southern Poland. *Journal of Pest Science*, *77*(1), 49-51.

Skuhravá, M., & Skuhravý, V. (1986). Outbreak of two gall midges, Harrisomyia n. gen. vitrina (Kieffer) and Drisina glutinosa Giard (Cecidomyiidae, Diptera) on maple, Acer pseudoplatanus L. in Czechoslovakia, with descriptions of the two genera and species. *Journal of Applied Entomology*, *101*(1-5), 256-274.

SMHI, Swedish Meterological and Hydrological Institute, 2015. Awailable from: <http://www.smhi.se/ > [13 November 2015].

SMHI, Swedish Meterological and Hydrological Institute, Climate scenarios, 2014. Awailable from: <http://www.smhi.se/en/climate/climate-scenarios> [11 November 2015].

Spiecker, H., & Hein, S. (Eds.). (2009). *Valuable broadleaved forests in Europe* (Vol. 22). Brill.

Stancioiu, P. T., & O'Hara, K. L. (2006). Regeneration growth in different light environments of mixed species, multiaged, mountainous forests of Romania. *European Journal of Forest Research*, *125*(2), 151-162.

Straigyte, L., & Baliuckas, V. (2015). Spread intensity and invasiveness of sycamore maple (Acer pseudoplatanus L.) in Lithuanian forests. *iForest-Biogeosciences and Forestry*, 710.

Svenning, J.-C. & Skov, F. (2004). Limited filling of the potential range in European tree species. - Ecology Letters 7: 565-573.

Theurillat, J. P., & Guisan, A. (2001). Potential impact of climate change on vegetation in the European Alps: a review. *Climatic change*, *50*(1-2), 77-109.

Thuiller, W., Lavorel, S., Araújo, M. B., Sykes, M. T., & Prentice, I. C. (2005). Climate change threats to plant diversity in Europe. *Proceedings of the National Academy of Sciences of the united States of America*, *102*(23), 8245-8250.

USDA. 1999. United States Department of Agriculture. 1999. Executive Order 13112. Awailable from: < http://www.invasivespeciesinfo.gov/laws/execorder.shtml> [24 November 2015].

van Wilgen, B.W., Richardson, D.M., Le Maitre, D.C., Marais, C., & Magadlela, D. 2001. The economic consequences of alien plant invasions: examples of impacts and approaches to sustainable management in South Africa. *Environment, Development and Sustainability*, 3: 145-168.

Vittoz, P., & Engler, R. (2007). Seed dispersal distances: a typology based on dispersal modes and plant traits. *Botanica Helvetica*, *117*(2), 109-124.

Vogt, K., Rasran, L., & Jensen, K. (2004). Water-borne seed transport and seed deposition during flooding in a small river-valley in Northern Germany. *Flora-Morphology, Distribution, Functional Ecology of Plants*, *199*(5), 377-388.

Von der Lippe, M., & Kowarik, I. (2007). Long-Distance Dispersal of Plants by Vehicles as a Driver of Plant Invasions. *Conservation Biology*, *21*(4), 986-996.

Weidema, I. (2006): NOBANIS – Invasive Alien Species Fact Sheet –Rosa rugosa. – From: Online Database of the European Network on Invasive Alien Species – NOBANIS www.nobanis.org, [26 November 2015]

Weidema, I. & Buchwald, E. (2010): NOBANIS – Invasive Alien Species Fact Sheet – Acer pseudoplatanus. – From: Online Database of the European Network on Invasive Alien Species – NOBANIS <www.nobanis.org>, [26 November 2015]

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