Restoration of mixed forest: Effects of fencing, site preparation and distance to existing mixed forest on planted European beech and natural tree regeneration

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Abstract

During restoration of mixed forest from mono-specific spruce forest there is a great need for knowledge of the extent to which proximity to other mixed forest affects regeneration results and diversity of tree and shrub layers. There is also lack of knowledge of what fencing means for the regeneration of individual species, as well as how mechanical site preparation (MSP) influences both planted and naturally regenerated plants. Mixed forests of pine (*Pinus sylvestris*), beech (*Fagus sylvatica*) and other deciduous species are valuable for nature conservation and recreation in Southern Sweden and other parts of Northern Europe. The purpose of this work was to assess the effects of inverted soil scarification, fencing and proximity to mixed forest in planted beech and natural regeneration of Scots pine as well as other tree species. The hypothesis of the work was that beech and pine growth benefits from site preparation and fencing as well as that natural regeneration of pine also benefits from site preparation and the proximity of existing seed trees in older mixed forest. Data collection took place in a field experiment established in 2011 in Sveaskogs ecopark Raslången in northern Scania (Skåne). During winter in 2017 an inventory of planted beech trees in the experiment was made concerning height and potential damages. In the same way all natural regeneration of Scots pine and other tree species were measured.

Planted beech's height was found to be positively affected by site preparation, saplings were on average about twenty centimeters taller, as well as natural regeneration of both Scots pine, where the regeneration was doubled comparing to non-preparated sites, and goat willow (*Salix caprea*) where regeneration turned out to be over six times more frequent. Fencing was shown to be a crucial aspect especially for Scots pine regeneration as the species experienced a high level of browsing in unfenced plots. The distance to the nearest mixed forest turned out not to have notable influence on the magnitude of natural regeneration, which was dominated by birch (*Betula* spp., 53% of all naturally regenerated trees). Birch, as well as goat willow and pine are pioneer species which find it easy to establish on most of the sites. Birch however is more universal and can grow as good on not-prepared site as on the prepared.

In the coming years, an early thinning in birch and goat willow seems to be necessary due to its ability to overgrow species that develop on the same site. The recommendation for the experiment should be promoting pine development, as a light demanding species it requires space to grow. The condition of the fence should be taken care of as well because it favors the development of both beech and pine, two main species of the future mixed forest.

Key words: European beech, Fencing, Mechanical site preparation, Mixed forest restoration, Scots pine, Raslången ecopark.

Streszczenie

Podczas przekształcania monokultur świerkowych w lasy mieszane, brak jest dostatecznej wiedzy na temat, jak odległość od innych lasów mieszanych wpływa na różnorodność gatunkową drzew i krzewów. Większa znajomość tematu jest również potrzebna z zakresu znaczenia grodzeń młodych drzewostanów dla odnowienia poszczególnych gatunków, jak również znaczenia mechanicznego przygotowania gleby dla sadzonek oraz naturalnego odnowienia. Lasy mieszane z sosną, bukiem oraz innymi gatunkami liściastymi są cenne z punktu widzenia ochrony przyrody jak i rekreacji nie tylko
w południowej Szwecji, ale również wielu obszarach Europy północnej. Celem tej pracy było określenie efektów jakie miały przygotowanie gleby, grodzenie oraz odległość do najbliższych drzewostanów mieszanych na posadzonego buka zwyczajnego (*Fagus sylvatica*) oraz naturalne odnowienie sosny zwyczajnej (*Pinus sylvestris*). Postawiona została następująca hipoteza: *przygotowanie gleby oraz grodzenie pozystywnie oddziałuje zarówno na przyrost buka oraz przyrost i urodzaj odnowienia sosny. Na odnowienie sosny pozytywny wpływ ma również bliski dystans do znadującego się na terenie eksperymentu starodrzewiu mieszanego z udziałem starych sosen.* Dane do niniejszej pracy zebrane zostały na powierzchni doświadczalnej założonej w 2011 roku w ekoparku Raslången, należącego do Szwedzkich Lasów Państwowych *Sveaskog*. Powierzchnia ta znajduje się w północnej Skanii. W roku 2017 w zimie przeprowadzona została inwentaryzacja nasadzeń bukowych z uwzględnieniem wysokości oraz potencjalnych szkód wyrządzonych przez zwierzynę. Te same czynności wykonane były w przypadku sosny oraz innych gatunków pochodzących z naturalnego odnowienia.

Wysokość buka okazała się leżeć w pozytywnej korelacji z wczśniejszym procesem przygotowania gleby. Buk posadzony na przygotowanej glebie był średnio o dwadzieścia centymetrów wyższy od buka posadzonego na glebie pozrębowej bez wcześniejszej skaryfikacji. Również sosna wykazała pozytywny wpływ tego procesu dając dwukrotnie większe odnowienie niż przy glebie bez przygotowania. Z innych gatunków odnawianych naturalnie, wierzba iwa (*Salix caprea*) wystąpiła o sześć razy częściej na terenie z przgotowaną glebą. Biorąc pod uwagę trzeci czynnik – grodzenie, wykazało ono wysoki poziom zgryzania przez dziką zwierzynę na działkach bez ogrodzenia. Odległość od lasu mieszanego nie dała żadnych różnic w ilości naturalnego odnowienia, które zdominowane było przez brzozę (*Betula spp.*) stanowiącą 52,9% naturalnie odrodzonych drzew w eksperymencie. Brzoza jak i wierzba oraz sosna są gatunkami pionierskimi, którym łatwo jest kolonizować większość siedlisk. Brzoza jednakże jest bardziej uniwersalna i jest w stanie rosnąć dobrze zarówno na terenie przygotowanym jak i nie. W eksperymencie nie odnotowano żadnego zgryzania na brzozie.

W kolejnych latach czyszczenia z ukierunkowaniem na wycinkę brzozy oraz wierzby wydają się być koniecznością, jako że gatunki te łatwo wygrywają konkurencję z innymi gatunkami rosnącymi na tym samym siedlisku. Powinno się promować odnowienie sosny, a jako gatunek światłożądny, wymaga on przestrzeni do rozwoju. Stan techniczny ogrodzenia powinien być sprawdzany regularnie, zwłaszcza, że wpływa on pozytywnie na rozwój sosny i buka - dwóch głównych gatunków przyszłego lasu mieszanego.

Słowa klucze: Buk zwyczajny, ekopark Raslången, Grodzenie, Mechaniczne przygotowanie gleby, Przekształcanie lasów mieszanych, Sosna zwyczajna.

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Introduction

The subject of converting mono-culture forests into mixed-forests has become a hot topic nowadays. Not only is it under a big discussion in Sweden but also in central Europe (Knoke et al., 2008). Current reluctance to promote Norway spruce (*Picea abies*) plantations is motivated by several factors. On one hand Norways spruce is claimed to be planted and promoted over its natural range, outcompeting broadleaved species formely growing on a given terrain (Teuffel et al., 2004). On the other hand, even-aged spruce plantations even if perceived by private forests owners more economically profitable (Knoke et al. 2008) are at a high risk of being attacked by a bark beetle, *Ips typhographus* (Löf et al. 2010) and are at a high risk of being infected by root rot (Vollbrecht & Agestam, 1995). In addition to that, spruce monocultures are well known to be prone to stormfelling that was shown on a large scale in 2005 during the Gudrun storm in Småland, Sweden (Valinger & Fridman, 2011). Taking social aspects into consideration, mixed forests are shown to constitute a relevant balance between interests of forest owners and non-forest owners (Schraml & Volz, 2004).

Managing a forest is not an easy task when it comes to choosing the species which future stands will consist of. Walking away from spruce plantations and switching into more nature-conservation forestry with a big percent of deciduous trees might be challenging for many forest owners (Knoke et al., 2008). On one hand, we should observe the market and adjust our silviculture to industry requirements, both when it comes to tree species selection and timber characteristics (like the share of a heartwood for example) (Nylinder, 2016). In reality it sounds extremely difficult as the market can change rapidly and the regular rotation of several dozen years is simply too long time for an accurate planning of future needs. On the other hand we can look at the example from Skåne and a local beech forest owner who, as many owners of this kind of ecosystem in southern Sweden, is struggeling now with selling beech timber (Lindberg, 2017). The problem lies both in the strong interest almost solely directed toward highest quality logs, and in the low quantity needs for this sort of timber. Due to that fact forest owners are made either sell their beech logs for pulp and textile industry for low price (Lindberg, 2017) or wait until changes in the market, exposing beech trees into the risk of occurring heartwood in older trees (Savill, 2013). Another aspect of the difficulty in selling beech timber is a scarcity of sawmills in Sweden that would process that species. There is only one, Skättilljunga Sågverk AB, processing 5000 m^3 per year (Lindberg, 2017). When considering exporting sawn timber of beech abroad, the reality seems to be even darker. Countries like Ukraine or Romania get their beech logs of the highest quality from Carpathian mountains with a very cheap labor, which makes their timber immensly cheaper than the timber from Sweden (Lindberg, 2017).

For Sweden, the Swedish Meteorological and Hydrological Institute (SMHI) expects an average annual temperature to increase by two to six Celsius degrees (Josefsson, 2017). As this trend may indicate a prospective changes in forest structure, a trend for strong winds is not so clear (Swedish Commission on Climate and Vulnerability , 2007) as many can expect. Tracing the history of severe storms there is no evidence of increasing repeatability or increasing violence of the storms. Well-known and very destructive storm "Gudrun" that occurred in January 2005 (SMHI, 2011) was the first storm with such pounding to the forestry with 70 million cubic meters of timber blown down (Valinger & Fridman, 2011). As it was found, the damages were in majority inflicted toward mature, pure spruce stands (Valinger & Fridman, 2011). The same study in relation with others prove right to the statement 'the bigger the proportion of Norway spruce the bigger the risk for damages from wind (Albrecht et al., 2012).

Swedish landscapes tends to suffer from the lack of valuable broadleaved forests (excluding birch it is still only about 6% of broadleaved trees in Swedish forests) (Sveriges oficiella statistik, 2017). However it has not always been like that. The popularity and vast spread of spruce domination in southern Sweden began as early as several hundred years ago, when the anthropogenic disturbances harshly influenced previously *Fagus*-dominated landscapes beginning to more or less extend the era of *Picea* (Lindbladh et al., 2008). It is worth mentioning here that, admittedly the sprucification effects indeed began that early, however current increase in spruce share results from the changes in agriculture and silviculture that occured as late as in the beginning of the twentieth century. Both effects of slash and burn farming as well as selective cutting approach in forestry favoured the speading of spruce, which finds it easier to develop under such conditions as opposed to other species (Lindbladh et al., 2014).

The interest in cultivation of valuable hardwood species has been increased since 1970s as a result of a growing demand on furnitures, wooden floors and the production of high quality paper. In addition to that a prognosis about climate changes as well as forest damages speak for that a higher share of noble tree species has a positive effect on the structure of a forest by strengthening and stabilizing it (Löf et al., 1999). The main limiting factor as far as changing the coniferous landscape is concerned, is a great tradition and experience in silviculture of spruce-monocultures that has been focused more toward converting deciduous forest into conifers rather than in the opposite direction (Löf et al., 1999). Moreover, changes in climate in the next decades and centuries will inevitably force forest oweners to shift their current habits and their point of view on Swedish forestry towards adjusting silviculture to more extreme storms, strong downpours and long periods of droughts which are known to affect the general resilience of forests (Löf et al., 2007). In addition to that, spruce plantation requires from a forest owner to take actions of preventing root rot and bark beetles (*Ips typohgraphus* L.) (Bergquist et al., 2009). Other reasons why to consider a greater share of natural broadleaved forests is the fact that these ecosystems ameliorate the quality of water as well as enhance the biology diversity. On the other hand, the potential high browsing pressure on pine and on broadleaved species discourages foresters in Southern Sweden to experiment with these species as it requires very often fencing the area, which implies extra expenses (Bergquist et al., 2009).

Starting the restoration of mixed forest after spruce monocultures does not have to mean clearcutting. The example from Germany and Poland shows that edge and gap cutting can be a great substitutes to the common clearcut system since it diminishes a risk from insect gradation, root rot and frost (Löf et al., 1999). Even though planting of a desirable species of future mixed forest is inevitable in this example, as the seeds falling from the mother trees of species like beech, ash (*Fraxinus excelsior*) and oak (*Quercus robur* and *Quercus petraea*) are often not sufficient, a natural regeneration of other species present in existing forest is more abundant as we handle smaller area and the old stand surrounds it from all directions.

Taking into consideration the restoration of valuable mixed forests, there is a strong need to know how the distance to the nearest mixed-forest influences prospective natural regeneration of tree species. In addition to that, one should get to know how soil scarification and fencing can affect the growth of both planted, and naturally regenerated species as well as their quantitative abundance. In order to address these questions, as soon as Raslången ecopark in northern Skåne had been established in 2011, a field experiment was started.

In the present study I aimed to test the following hypotheses considering the effect of fencing, site preparation and the distance from the plot to mixed forest:

1. The abundance of tree species in the natural regeneration increases with the proximity to mixed-species stands
2. The browsing pressure on the tree regeneration is reduced by the fencing
3. Mechanical site preparation has a positive effect on both the abundance and the height of the tree regeneration

Materials and methods

Raslången ecopark

Of the 36 ecoparks that belong to Sveaskog state forest company, it is Raslangen ecopark that is the southernmost and is located on the edge of two counties – Skåne and Blekinge (*Figure 1*). The name of the park derives from "Raslången" lake, which lies in the center of the area, dividing the land area of ecopark into three parts.

Raslången ecopark was founded in 2011 and is managed to restore, preserve and develop high ecological values of the area (Östh, 2009). More than half of the productive sites are set aside for conservation purposes which are the priority in the park as opposed to economical values. There is an abundance of broadleaved forests in Raslången ecopark, what becomes a valuable character of this area (Sveaskog, 2011).

The entire park consists of 1200 ha. Currently, about 15 % of the forests in the park are classified as containing a high nature value and about 50 % is under restoration process so that in the future more than half of the area of the park can consist of such ecosystems (Sveaskog, 2011).

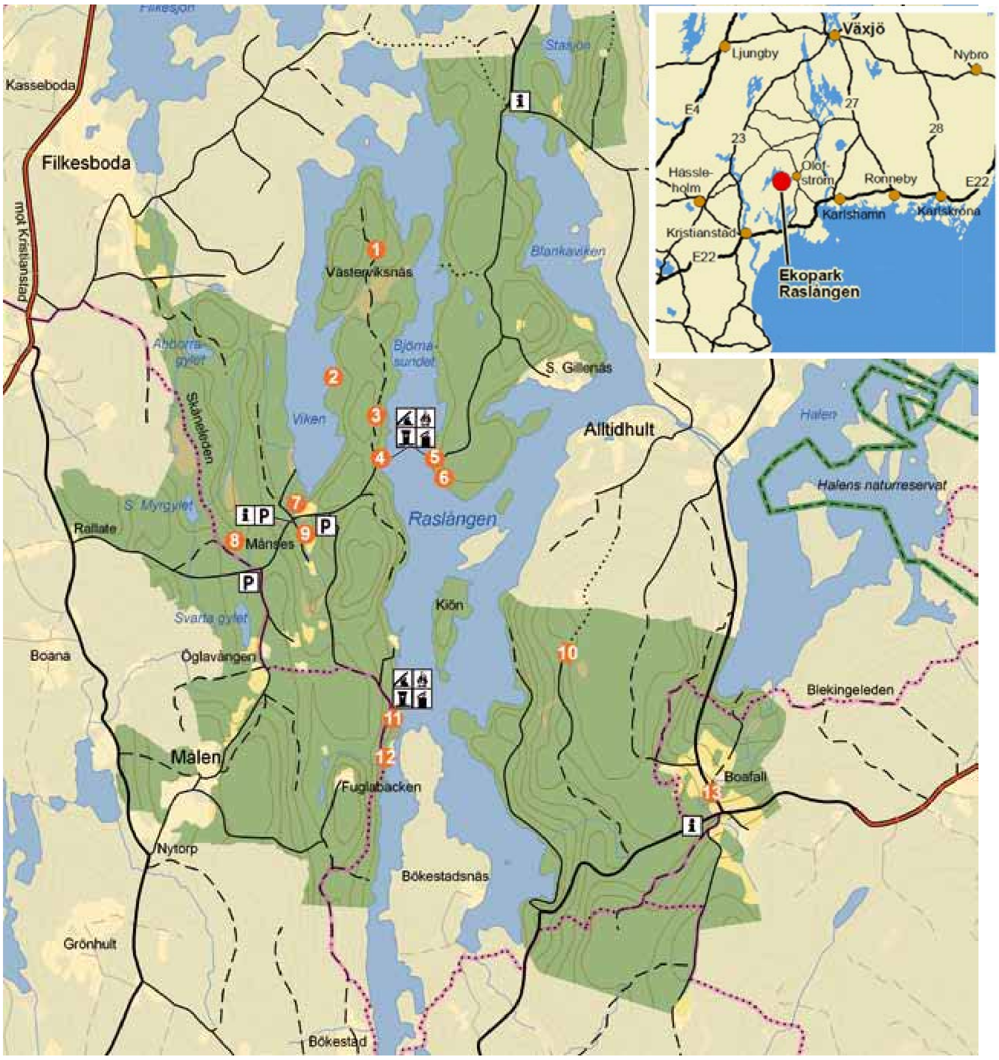

Figure 1. Map of Raslången Ecopark and location in southern Sweden (Sveaskog, 2011).

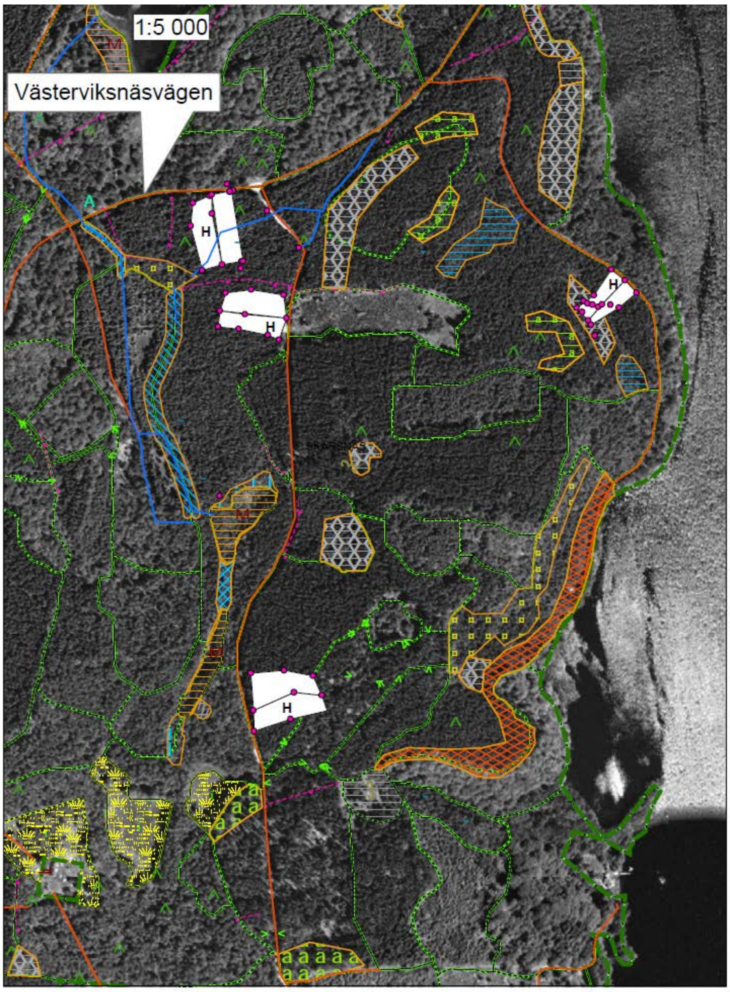

Figure 2. Map of the research area showing the four experimental blocks. H indicates the fenced part of the blocks.

The field experiment

The major point of reference while deciding upon the location of the experiment was to find areas which are close both to already existing mixed forest on one side and coniferous forest on the other (Figure 2). The distance from the edge of broadleaved forest to the edge of the experiment on the other side was about 100m. The experiment is divided into four blocks scattered around the ecopark (Figure 2). Each block is more or less rectangular and consists of two major parts: fenced and unfenced (Figure 2, 3, Photo 1). Both of these parts are further divided into smaller plots: with and without soil scarification (site preparation). A plot was on average about 100m^2 where the smallest one was 50m^2 and the biggest one 214m^2. The scarification strip was carried out in the middle of two parts, therefore the plots with site preparation are situated always close to the fence. These small plots are located both close to mixed forest and at a distance from it. That gives us a number of four plots per part and eight per block. When multiplying it by the number of blocks – four – in the end we have 32 plots where I collected data. After inverted soil scarification was performed, beech seedlings were planted in the plots in 2011 (Sandell Festin, 2013). The entire setup of the experiment is shown in *Figure 3.*

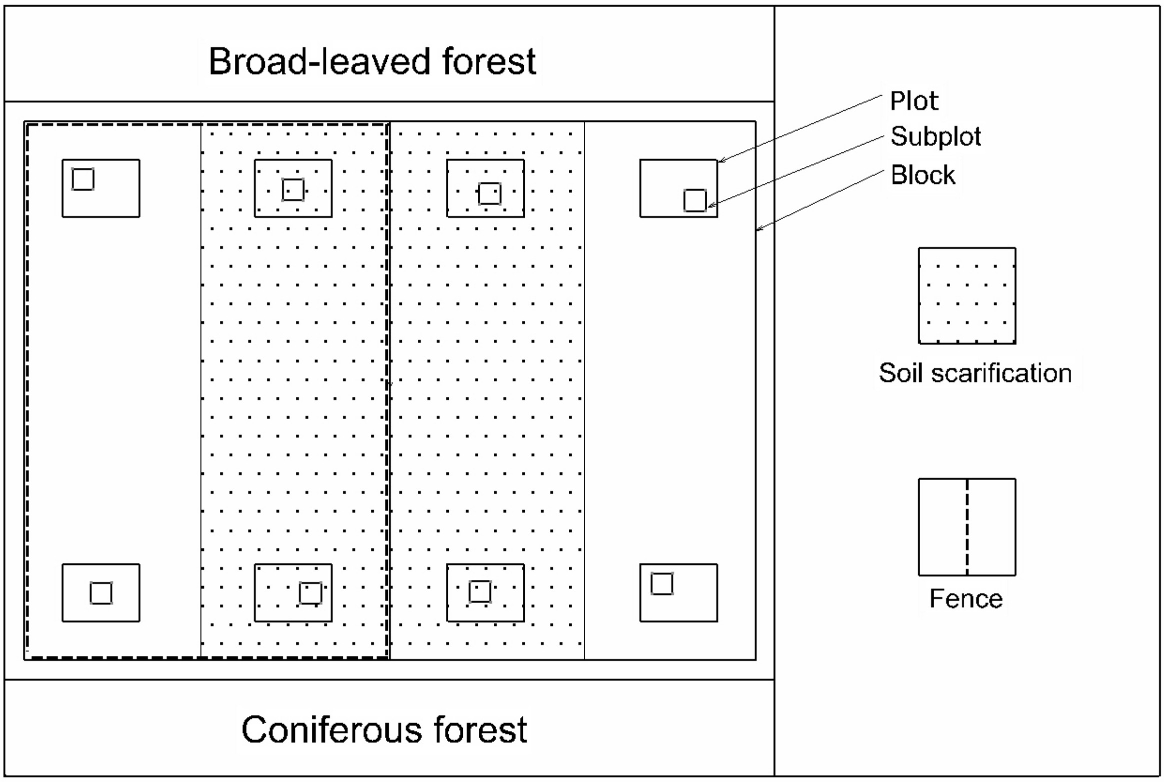

Figure 3. The setup of a single experimental block at Raslången ecopark.

Data collection

The data collection was carried out at the end of January 2017 and took two weeks. The following variables were measured:

- The height of planted beech trees
- The height and the amount of natural regeneration of pine and oak within the plots of planted beech
- The height and the amount of natural regeneration of other species within a square subplot of 4x4m within each plot

Height measurement was carried out with the use of a folding ruler to the nearest cm (Photo 2 and 4).

While measuring the height of the first species, which in this case was always beech, I was using the data from a previous data collection in November 2013 (Löf and Brunet, unpublished data) in order to know the number of planted trees on the given plot. Since the establishment of the experiment in 2011, every tree had been marked with a plastic stick in order to indicate which trees are included in the survey. Every now and then a beech tree was lacking a stick and was part of a tree row with sticks. In this case I placed a new stick. In the case of a presence of a stick but a lack of a tree, I marked the tree as a dead one. In addition to the stick-marking method, once a tree was measured, I tied a red or yellow ribbon around the tree in a way that allowed to identify the already measured trees from a distance (Photo 3). Red ribbon was used for trees on the plots with site preparation, and yellow ribbon for lack of site preparation. After the measuring of all planted beech had been performed, I measured pine and oak regeneration. In this case plastic sticks were placed next to every single tree together with ribbons. The data was noted on the previously prepared sheets for each plot. Wherever signs of browsing were recorded, mostly they were in shape of multiple stems, I marked “x” next to the height number of a given tree.

In addition, natural regeneration was also measured in birch, spruce, hornbeam (*Carpinus betulus*), goat willow, grey willow (*Salix cinerea*) and hazel (*Corylus avellana*), however only in 4x4m subplots on each plot. Upon standing on a plot I chose a central part for carrying out the measurements. In this case ribbons were tied only on the four corners of a 4x4m subplots. The following code was used when collecting the data:

Block	**Fence**	**Distance**	**Site preparation**
1	0	0	0
1	1	1	1

a plot without site preperation

a fenced plot

a plot in close to a mixed forest

Photo 1. General view of an experimental block where Jörg Brunet is standing outside the fence.

Photo 2. The way of measuring tree height.

Photo 3. Labeling the trees.

Photo 4. Measuring the height of the trees.

Statistical analysis

The mixed model for the analysis of variance (ANOVA) was used to test differences in regeneration performance (number and height of planted beech trees and naturally regenerated trees, browsing damage) in relation to proximity to mixed species stands, fencing and inverting site preparation following the 2016 growing season (SAS Institute Inc., Cary, NC, USA).

The experiment was analysed using a randomized block design even though inverting site preparation plots were not completely randomized. For most variables the criss-cross design was used, but for browsing damage the split-plot design was used (excluding the fenced plots) and for browsing preferences the standard block design was used (excluding fenced plots and merging plots near mixed and Norway spruce forests). An alpha level of less than 0.05 was considered significant. Some tree species were incorporated in the total number of naturally regenerated trees, but were excluded from species-specific analyses since they were not occuring in all blocks (e.g. hornbeam, hazel, oak and spruce).

Results

Distance to mixed forest

According to the statistical analysis there was no evidence that the proximity to the mixed forest would affect height, browsing frequency or abundance of natural regeneration. None of the species showed propability value P<0,05 (*Table 1, 2, 3*).

Table 1. The effect of three different treatments on the height of the species. An alpha level (p-value) less than 0,05 was marked in bold as indicating a statistically significant effect.

Species / Effect	*Fagus sylvatica*	*Betula spp.*	*Pinus sylvestris*	*Salix caprea*	*Picea abies*	All individuals
		P-value				
Proximity	0,507	0,584	0,757	-	-	0,428
Fencing	0,237	0,109	**0,022**	-	-	0,056
Soil scarification	**0,019**	0,548	0,127	0,222	0,554	0,779

Table 2. The effect of three different treatments on the frequency of browsing. An alpha level (p-value) less than 0,05 was marked in bold as indicating a statistically significant effect.

Species / Effect	*Betula spp.*	*Pinus sylvestris*	*Fagus sylvatica*	*Salix caprea*	All individuals
		P-value			
Proximity	0,934	0,102	0,219	-	0,603
Fencing	0,759	0,050	**0,028**	-	**0,031**
Soil scarification	0,177	0,094	**0,001**	0,554	**0,010**

Table 3. The effect of three different treatments on the number of naturally regenerated trees. An alpha level (p-value) less than 0,05 was marked in bold as indicating a statistically significant effect.

Species / Effect	*Betula spp.*	*Pinus sylvestris*	*Salix caprea*	All individuals
	P-value			
Proximity	0,883	0,454	0,407	0,876
Fencing	0,848	0,148	0,281	0,961
Soil scarification	0,624	**0,036**	**0,007**	0,507

Fencing

When considering fencing, statistical analysis didn't show any effect on the height of planted beech trees (Table 1). Significant effect of the treatment could be noticed on height of pine as well as on total mean height of all tree species (Table 1, *Figure 4*). In addition to the effect on height there was a clear evidence of affecting the browsing pressure by fencing the area (*Table 2, 4*). All browsed species benefited from fencing while at the same time keeping damages from game to a minimum (*Figure 5*).

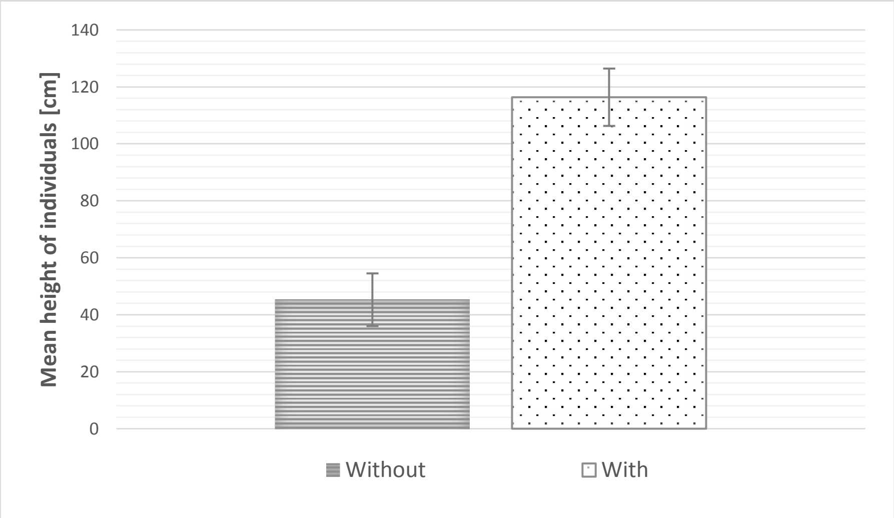

Figure 4. The effect of fencing on height (cm +/- SE) of Pinus sylvestris.

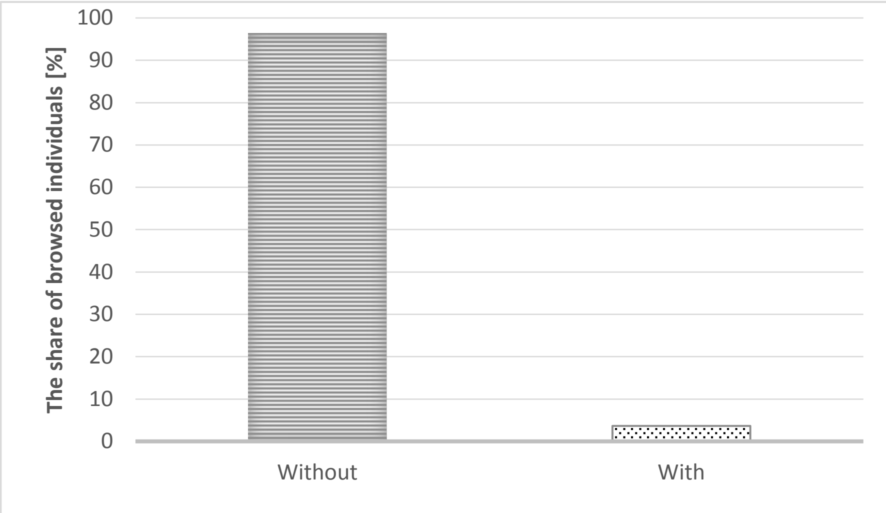

Figure 5. The effect of fencing on the share of browsed trees.

Table 4. The number and the percentage of browsed individuals of the respective tree species.

Species	No. of browsed trees on unfenced plots	No. of browsed trees on fenced plots	No. of all marked individuals outside the fence	No. of all marked individuals within the fence	% browsed trees outside the fence	% browsed trees within the fence
Beech	16	2	255	270	6,3	0,7
Pine	107	3	209	377	51,2	0,8
Oak	3	0	6	5	50	0
Birch	0	0	144	133	0	0
Goat willow	5	0	18	33	27,8	0
Spruce	0	0	62	30	0	0
Hazel	0	0	0	4	0	0
Hornbeam	1	0	1	2	100	0
Grey willow	0	0	0	1	0	0

Site preparation

Inverted soil preparation is related to a lower number of browsed individuals (*Figure 6*).

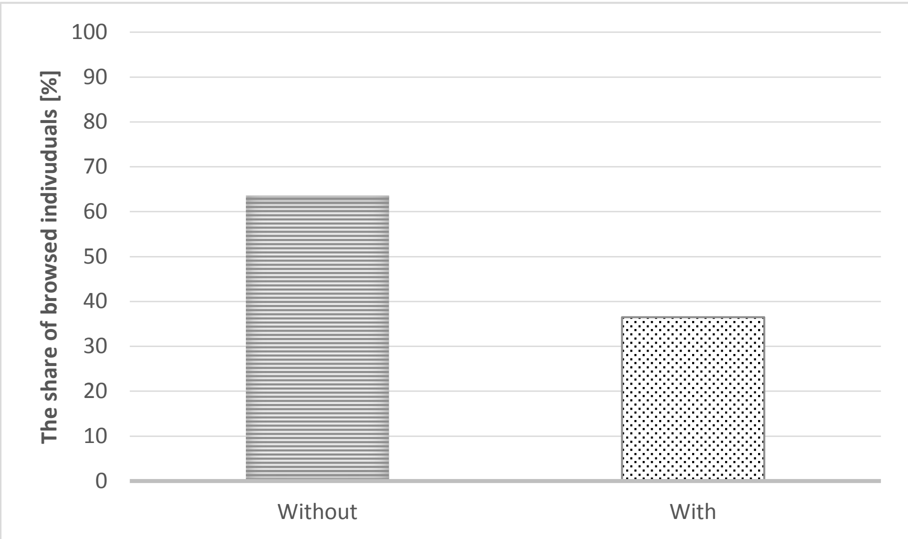

Figure 6. The effect of soil scarification on the share of browsed individuals of all species.

This result is dependent to some extent on European beech, which is the only species that presents a significant influence of soil preparation on its browsed individuals (Table 2). In order to exclude the prospective effect of fencing while assessing the importance of soil preparation in browsing pressure, one more analysis was performed including only plots outside the fence.

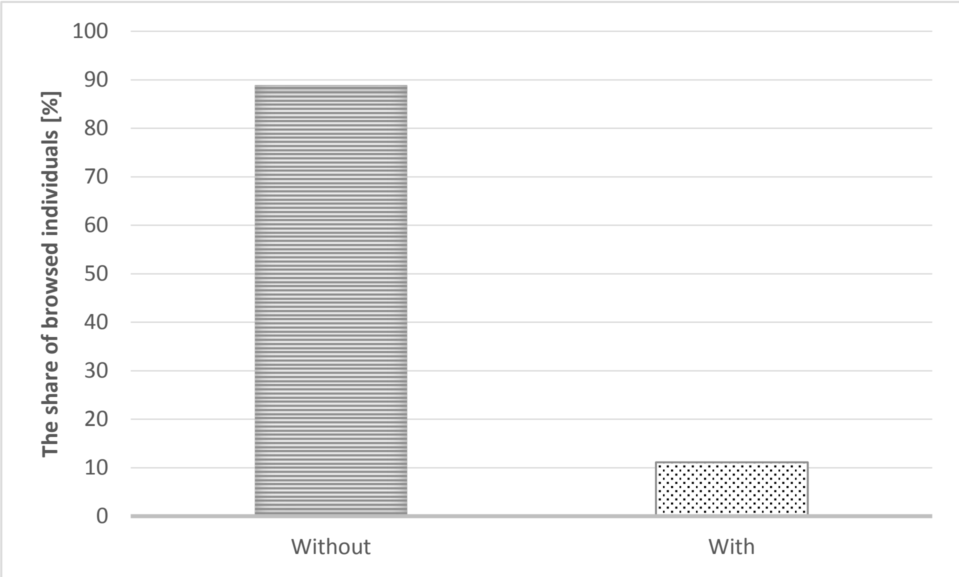

Figure 7. The share of browsed Fagus sylvatica individuals in plots with and without soil preparation.

As shown (*Figure 7*), fencing does not affect the obtained result of significance of soil scarification on browsing pressure. Taking into account height of the trees and the effect of soil scarification, beech was the only species with noticeable effect of site preparation treatment (Table 1, *Figure 8*). European beech on average was almost 20 cm higher than individuals growing on not prepared ground.

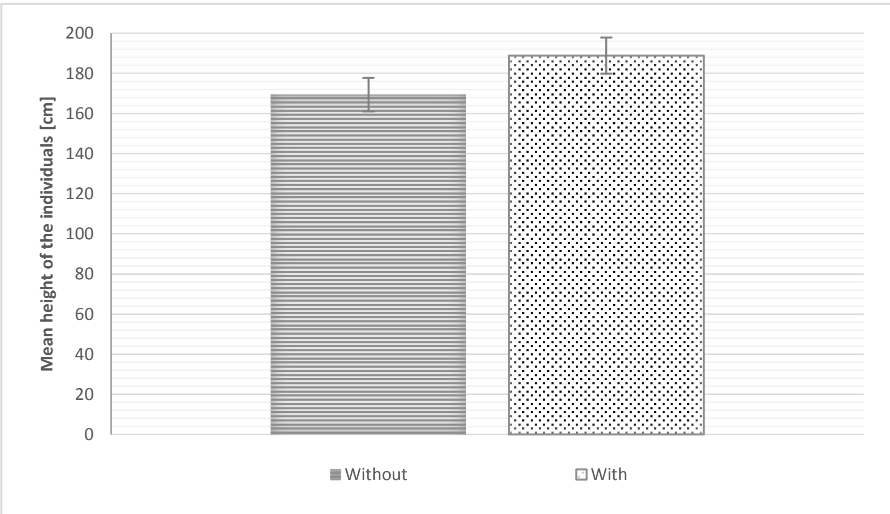

Figure 8. The effect of soil preparation on height of Fagus sylvatica.

Natural regeneration was dominated by birch, which made up more than half of all recorded trees, followed by Scots pine, Norway spruce and goat willow, while regeneration of other species was very low (*Figure 9*). Of eight naturally regenerated species (*Figure 9*), two showed statistically significant effects of site preparation on their abundance – Scots pine, and goat willow (Table 3). In the case of pine, the difference in the number of individuals is almost doubled on the terrain with soil scarification (*Figure 10*). When considering goat willow, the evidence is even more clear. On average the number of goat willow individuals are six times larger on the plots with soil scarification (*Figure 11*).

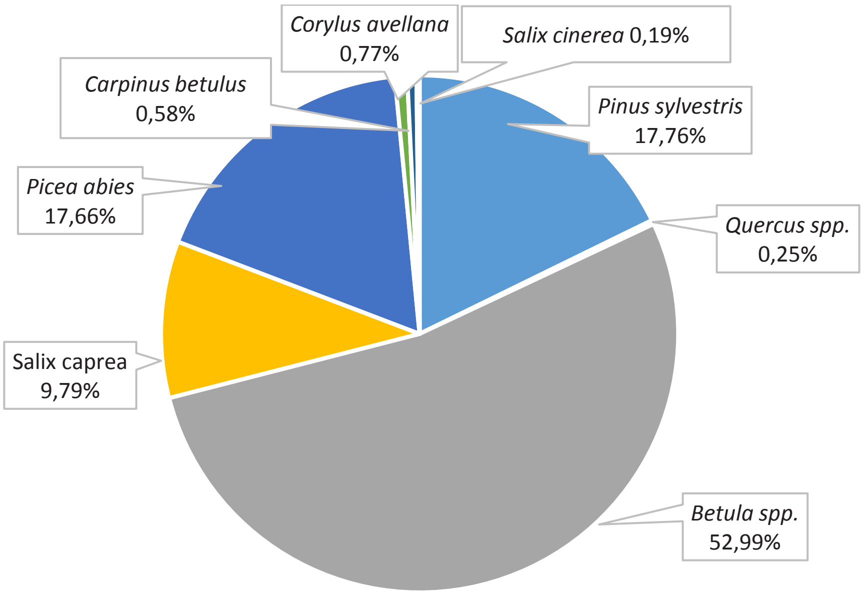

Figure 9. The percentage share of all naturally regenerated tree species in all experimental blocks.

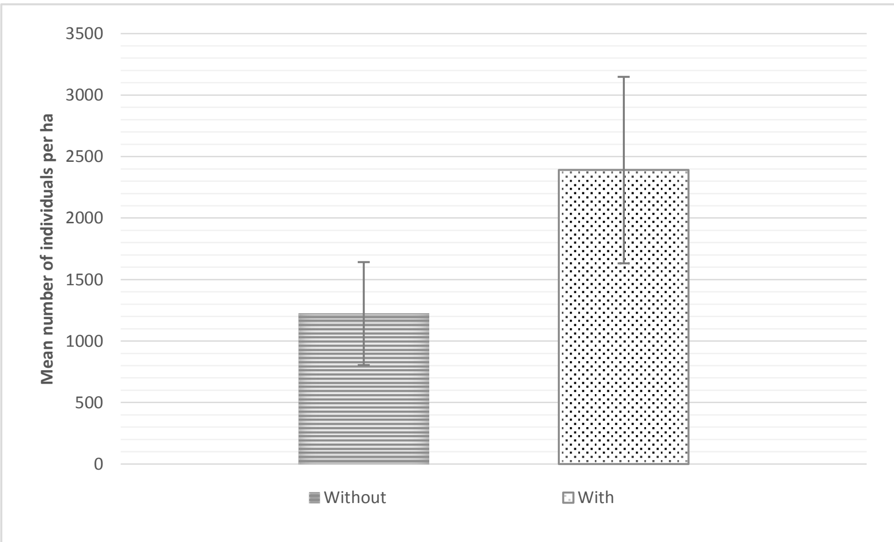

Figure 10. The effect of soil preparation on the number of Pinus sylvestris regeneration. The graph represents the overall mean number of pine trees with and without soil preparation.

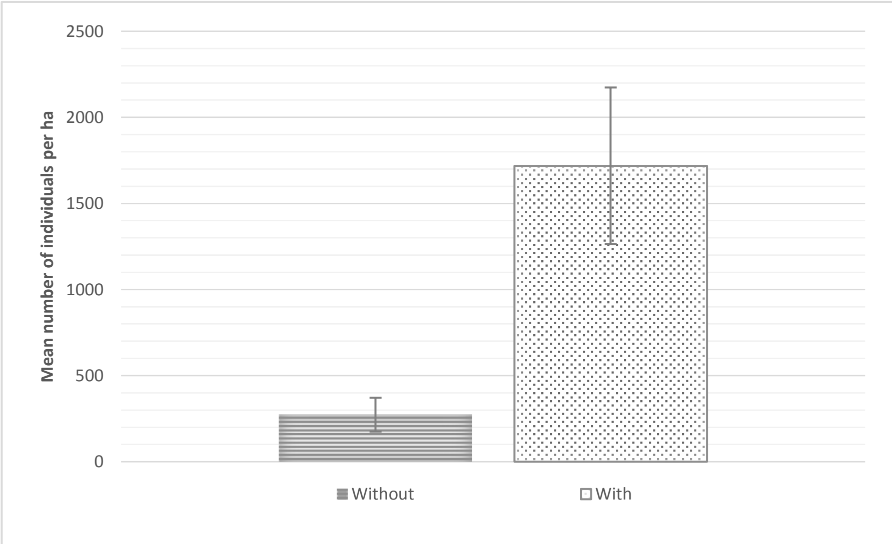

Figure 11. The effect of soil preparation on Salix caprea. The graph represents the overall mean number of goat willow trees with and without soil preparation.

Discussion

Hypothesis I – distance to mixed forest

According to the statistical analysis, the proximity of one part of each block to the existing mixed forest, that is the distance of about 100m, does not affect the number of naturally regenerated tree species. The most abundant species in the experiment were birch, goat willow and pine. These species are known to produce a lot of small seeds easily dispersed by wind, especially the first two whose seed production per mature tree is the highest among European species, and their seed weight is the lowest (Götmark et al., 2005). That fact and the sufficient number of mature trees in the broadleaved forests, adjacent to the experiment (with a large proportion of tall mature pine trees (Jónsson, 2016)) explains the large number of natural regeneration of these species regardless of in which plot we are standing. Few oak saplings were found on the experimental plots. First and foremost it can be caused by low acorn production after the experiment was started in 2011. The comparison to other, more prolifically regenerated species might also make the oak regeneration to seem very low. Other reason of oak's rarity can be dispersal limitations, which are common also in other parts of Southern Sweden where a plethora of lakes, forests and mires hampers the dispersal of heavy seeds (Götmark et al., 2005). In addition to that, species like oak or beech are known to have large short-lived seeds which are not preferred by dispersal vectors because of lack of the fleshy pulp, but are dispersed by forest birds and rodents as a hoarding behavior (Finegan, 1984). According to the same author, many forest vertebrates as well as the jay (*Garrulus glandarius*) which are the main vector for oak acorns that constitute an important component of their diet, are likely not to enter clearings or open fields. That might be the reason for the scarce oak regeneration. However the prevailing expansion of naturally regenerated birch, pine and goat willow might in the future favour the colonization of the same site by other, long-lived trees, such as oak and beech (Tansley, 1949). In this case pioneers make the site more appealing to prospective vectors (Finegan, 1984).

Hypothesis II – fencing and browsing

As far as the growing interest to increase the share of Scots pine is concerned, the issue of browsing is under great discussion and is a hot topic right now. The results clearly show that fencing has a great importance in keeping the saplings away from the damage caused by the game (*Photo 5*), as the browsing pressure in this area as well as in Southern Sweden in general is at high level.

The reason for that is partly the high share of Norway spruce in the landscape. According to (Wallgren, 2016) Norway spruce is not a favorite species to browse on. In this situation whenever Scots pine appears it becomes a delicacy for browsers when having these two species to choose from. Due to that fact it is crucial to spread the risk of browsing on a larger amount of trees as a higher density of pine trees (of height up to 4 m) results in less damages on those trees by elk browsing (Wallgren, 2016). According to the same study, between 4000 and 10000 stems per hectar are needed in order to get a safe quantity of unbrowsed trees to secure the future goal of producing a relevant number of high quality timber trees. When comparing, on the other hand, Scots pine with noble, deciduous tree species, red deer and moose do not hesitate and choose broadleaved species. That is why establishing a mixed forests on the old spruce stand is so difficult, without fencing which is another very important issue. As (Löf et al., 2007) see it, fencing a given area is not the remedy for the game browsing. In addition to high setup costs, it requires a constant care since wild boar is known to be capable of rooting under the fence making the fenced area available for other wild animals. In the experiment luckily there have been no damages to the fence which remained functional since establishment. *Table 4* shows that only few individuals were affected by browsing within the fence, most likely by rodents. Taking beech into consideration however, it does not belong to the species attractive for the game in terms of the taste. That is why it does not demand fencing, at least not at moderate game densities (Löf et al., 2007).

Photo 5. Fencing effect on browsing of pine. There is hardly any visible pine regeneration outside the fence.

The results from the experiment agree with the report about the browsing pressure for southern Sweden published by the Swedish Forest Agency (Cederholm et. al, 2017). In the report it states that the browsing pressure from deer is too high and has been on a stable high level. Furthermore it is roe deer that is responsible to a great extent for browsing damages on the natural regeneration of pine. In the prognosis for the year 2017 the authors emphasize that such an amount of deer in the forests contribute unfortunately to steering the share of species in the stands. However the future does not have to be darkly colored as long as we try to follow simple rules. As (Cederholm et. al, 2017) and (Jonasson & Jonasson, 2016) say, planting right tree species on the right site and soil can contribute largely to increasing both vitality and resistance of a tree. Following the same rule we increase the share of mixed forests which in comparison with spruce plantation, during the rotation period, have a sufficient proportion of potential food in the ground cover. The reason for that is simply a higher light availability which in case of spruce forests is diminished almost to zero during half of the rotation period (Cederholm et. al, 2017).

In Sweden the problem of browsing on the regeneration is attributed generally to two species: roe deer (*Capreolus capreolus*) and moose (*Alces alces*) (Bergquist et al., 2001). (Bergquist & Örlander, 1996) states that it is mostly roe deer who is responsible for damages on small coniferous trees, and it is more intense in southern Sweden than in the north. In the experiment browsing pressure took place to a large extent on pine. As the browsed saplings were most of the time not higher than fifty centimeters, it is assumed that the damages were not caused by moose. The statement that all the damages found on the regeneration are attributed only to roe deer cannot be proved either, as only stem form (multiple stems) was taken into consideration to determine whether a plant is browsed or not. No faecal pellets were being looked for. According to a hypothesis proposed by (Bergquist et al., 2001) soil scarification can bring a counter-productive effect to our regeneration by browsing to a larger extent. The main argument to this hypothesis is the fact that plants having no competition with surrounded vegetation, that would be taken away, are more nutritious, grow faster thus alluring deer. Another argument for soil scarification influencing the increasing browsing is the issue of removing potential vegetation t.ex. bilberry (*Vaccinum myrtillus* L.) that constitute a significant source of food for roe deer. Both the results of this work and the experiment of (Bergquist & Örlander, 1996) show however, that it is not so obvious. There is no statistical proof for defending the aforementioned hypothesis. Conversely, my study, especially in the beech example and partly on the pine example, shows that less trees were browsed on inverted soil scarification patches (Figure 6 and 7). As (Price, 1991) says, a species growing faster due to soil scarification may at the same time reach a height and size that would make a tree less accessible for a browser. This statement seems to be relevant in case of beech in the experiment. Both height of beech was shown to be positively and significantly affected by soil scarification and the number of browsed individuals as well. Unfortunately the small scale of this experiment as well as insufficient natural regeneration of some other species like oak for example cannot provide a reasonable explanation to this result and further research of this aspect would be required, taking into consideration not only the stem form, but also needle colour, vegetation cover, grass and sedges cover as well as data about faecal pellet of cervids, all used in the experiment by (Bergquist & Örlander, 1996).

Hypothesis III – site preparation

Taking pine and goat willow into consideration, some other studies confirmed the results from this experiment about the positive influence of site preparation on the abundance of these species, e.g. (Hille & Ouden, 2004). Out of three stages of establishment, that is germination, elongation and root establishment in the mineral soil (Nilsson et al., 2002) the last one is said to be the most crucial since it lets a seedling reach a sufficient and stable water supply what in the earliest stage of seedling growth is critical (Hille & Ouden, 2004). The faster the roots will penetrate the soil through the ectorganic soil layer, therefore reaching mineral soil, the bigger chances of survival for a young tree. It was showed both in (Hille & Ouden, 2004) experiment and in my study that the success of pine regeneration is strictly associated with soil scarification which doubles the chances for seedling survival. Another species that showed a remarkable difference between soil scarification treatment and lack of such treatment was goat willow. Possibly, a higher soil moisture present at inverted soil patches that in consort with outstanding ability of willow to disperse seeds, resulted in extremely high regeneration and survivability (Aoyama et al., 2008). In addition, the small seeds of goat willow may need exposed mineral soil for successful establishment.

When planting trees with the aim of producing high quality timber it is said that soil preparation is a must. Not only prevents it from the strong competition with weeds in the beginning but also assures that a plant can be placed directly into the mineral soil (Löf et al., 2007). That took place in the experiment where inverted soil scarification was done, yielding up mineral soil. As shown in my study, after 6 years since the experiment had been started, beech trees are more than twenty centimeters higher on the plots with soil scarification.

Conclusions

The presented results as well as the aforementioned aspects on each variable in the experiment (distance to the mixed forest, fencing and soil scarification) give us a certain scope as far as forest management is concerned. To begin with fencing, it seems that this particular treatment is a must when we aim at natural regeneration. Browsing pressure is on a high level in the area of the park and in order to promote Scots pine as a significant tree species in the experiment, we should stick to the results that indicate a great help from fencing the plots. On the other hand, average number of pine regeneration in Raslången ecopark is too small to meet the safety level of four to ten thousand seedlings per ha, what is said to be sufficient to avoid fencing. As for planted beech, the browsing damages are insignificant, pointing out non-necessity of fencing. In case of the experiment, the expectation of producing high quality beech trees should not be a priority since the number of trees to choose from in the beginning is too small. The goal should be producing enough of future mother trees that will be able to start a natural regeneration in the future, which is a well-studied and proven-method of regenerating European beech (including continuous cover forestry and shelterwood system). What is important to state is an issue of leaving browsed species in the area, not removing them. Deer tend to come back to the same place and browse on the same tree thus getting rid of a damaged tree we hazard new trees to be browsed (Wallgren, 2016).

Soil scarification should be implemented both when we look at the height increment of planted beech which benefits from this treatment as well as natural regeneration of pine. Positive influence of soil scarification on the regeneration of goat willow is not a desirable result in this case. The species itself is often treated as unwanted, triggering extra expenses during tending operations. In the experiment there was no clear evidence of the influence of proximity to the broadleaved forest on the natural regeneration. Owing to that fact we can see that a distance of about one hundred meters from a source of light seeds species does not trigger an uneven regeneration. Unfortunately, in case of acorns, oak regeneration was too weak to draw any reasonable conclusion. That indicates however, that in order to promote a presence of oak species in the area, implementing such a valuable broadleaf tree into an ecosystem, additional planting, most likely fenced, would be necessary to give this species chance to develop on a clear-cut area.

Last but not least the abundant regeneration of birch as well as goat willow has to be managed in the coming future. They have a strong tendency to overgrow other species. Postponing the first tending would lead to extra expenses of this operation, as the price is strictly related to the height of the trees.

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References

Albrecht, A., Hanewinkel, M., Bauhus, J., & Kohnle, U. (2012). How does silviculture affect storm damage in forests of south-western Germany? Results from empirical modeling based on long-term observations. *European Journal of Forest Research*, *131*(1), 229-247

Aoyama, K., Yoshida, T., & Kamitani, T. (2009). An alternative of soil scarification treatment for forest restoration: effects of soil replacement. *Journal of Forest Research*, *14*(1), 58.

Bergquist, J., & Örlander, G. (1996). Browsing deterrent and phytotoxic effects of roe deer repellents on Pinus sylvestris and Picea abies seedlings. *Scandinavian Journal of Forest Research*, *11*(1-4), 145-152.

Bergquist, J., Kullberg, Y., & Örlander, G. (2001). Effects of shelterwood and soil scarification on deer browsing on planted Norway spruce Picea abies L.(Karst) seedlings. *Forestry*, *74*(4), 359-367.

Bergquist, J., Löf, M., & Örlander, G. (2009). Effects of roe deer browsing and site preparation on performance of planted broadleaved and conifer seedlings when using temporary fences. *Scandinavian Journal of Forest Research*, *24*(4), 308-317.

Cederholm, A., Hermansson S., Kollander H., Lundahl B., Strid I., Persson I, … Kalén C. (2017). *Skogsskador i Region Syd 2016 – Skogsskaderapport.* Skogsstyrelsen.

Finegan, B. (1984). Forest succession. *Nature*, *312*(5990), 109-114.

Götmark, F., Fridman, J., Kempe, G., & Norden, B. (2005). Broadleaved tree species in conifer-dominated forestry: regeneration and limitation of saplings in southern Sweden. *Forest Ecology and Management*, *214*(1), 142-157.

Hille, M., & Den Ouden, J. (2004). Improved recruitment and early growth of Scots pine (*Pinus sylvestris* L.) seedlings after fire and soil scarification. *European Journal of Forest Research*, *123*(3), 213-218.

Jonasson, P., & Jonasson, B. (2016, September 23). *Styrka mot storm* [Audio podcast]. Retrived from http://www.skogspodden.se/blandskog/avsnitt-10-styrka-mot-storm/

Josefsson, W. (2017, May 24). *Klimatindikator - temperatur*. Retrieved from https://www.smhi.se/klimat/klimatet-da-och-nu/klimatindikatorer/klimatindikator-temperatur-1.2430

Jónsson, J. Á. (2016). Natural regeneration on clear cuts in Southern Sweden. How fencing, soil treatment and distance from broad-leaved forest affect tree regeneration and ground vegetation*.* Master thesis no. 249. Southern Swedish Forest Research Centre. SLU.

Knoke, T., Ammer, C., Stimm, B., & Mosandl, R. (2008). Admixing broadleaved to coniferous tree species: a review on yield, ecological stability and economics. *European Journal of Forest Research*, *127*(2), 89-101.

Lindberg, T. (2017, May 29). *Är bokens saga slut*? [Audio podcast]. Retrieved from http://www.sverigesradio.se/sida/avsnitt/897123?programid=412

Lindbladh, M., Niklasson, M., Karlsson, M., Björkman, L., & Churski, M. (2008). Close anthropogenic control of *Fagus sylvatica* establishment and expansion in a Swedish protected landscape–implications for forest history and conservation. *Journal of Biogeography*, *35*(4), 682-697.

Lindbladh, M., Axelsson, A. L., Hultberg, T., Brunet, J., & Felton, A. (2014). From broadleaves to spruce–the borealization of southern Sweden. *Scandinavian Journal of Forest Research*, *29*(7), 686-696.

Löf, M., Karlsson M., & Welander T. (1999). *Från gran till ädellövskog - långsiktig strategi nödvändig för föryngring*. Fakta skog nr 13. Uppsala, SLU.

Löf M., Bergquist J. & Welander T. (2007). *Plantering av ädellövskog - erfarenheter av anpassad skogsskötsel efter stormfälld gran*. Fakta skog. Uppsala, SLU.

Löf, M., Bergquist, J., Brunet, J., Karlsson, M., & Welander, N. T. (2010). Conversion of Norway spruce stands to broadleaved woodland–regeneration systems, fencing and performance of planted seedlings. *Ecological Bulletins*, *53*, 165-173.

Nilsson, U., Gemmel, P., Johansson, U., Karlsson, M., & Welander, T. (2002). Natural regeneration of Norway spruce, Scots pine and birch under Norway spruce shelterwoods of varying densities on a mesic-dry site in southern Sweden. *Forest Ecology and Management*, *161*(1), 133-145.

Nylinder, M. (2016, July 8). Interview for skogspodden.se. Retrieved from http://www.skogspodden.se/sadd/avsnitt-5-intervju-med-mats-nylinder/

Price, P. W. (1991). The plant vigor hypothesis and herbivore attack. *Oikos*, 62(2), 244-251.

Sandell Festin, E. (2013). Omvandling av granskog till ädellöv i södra Sverige–fallstudier från Söderåsens nationalpark och Raslångens ekopark. Examensarbete nr 216. Institutionen för sydsvensk skogsvetenskap. SLU.

Savill, P. (2013). *The Silviculture of Trees Used in British Forestry, 2nd Edition.* SABI.

Schraml, U., & Volz, K. R. (2004). Conversion of coniferous forests in social and political perspectives. Findings from selected countries with special respect to Germany. *Norway spruce conversion–options and consequences. EFI Research Report*, *18*, 97-119.

SMHI. (2011). Gudrun - Januaristormen 2005. Retrieved July & aug., 2017, from https://www.smhi.se/kunskapsbanken/meteorologi/gudrun-januaristormen-2005-1.5300

Swedish Commission on Climate and Vulnerability. (2007). *Sweden facing climate change - threats and opportunities.* Stockholm: Swedish Government Official Reports SOU 2007:60.

Sveaskog. (2011, September). *Ecopark Raslången* [Brochure]. Stockholm: Sveaskog.

Sveriges Officiella Statistik. (2017). *Skogsdata 2017. Aktuella uppgifter om de svenska skogarna från Riksskogstaxeringen.* Umeå: Institutionen för skoglig resurshushållning, SLU.

Tansley, A. (1949). *The British Islands and their vegetation, second edition.* Cambridge: Cambridge University Press.

Teuffel, K. V., Heinrich, B., & Baumgarten, M. (2004). Present distribution of secondary Norway spruce in Europe. *Norway spruce conversion—options and consequences. EFI Research Report*, *18*, 63-96.

Valinger, E., & Fridman, J. (2011). Factors affecting the probability of windthrow at stand level as a result of Gudrun winter storm in southern Sweden. *Forest Ecology and Management*, *262*(3), 398-403.

Vollbrecht, G., & Agestam, E. (1995). Modelling incidence of root rot in Picea abies plantations in southern Sweden. Scandinavian Journal of Forest Research, 10(1-4), 74-81.

Wallgren, M. (2016, Maj 27). Interview for skogspodden.se. Retrieved from http://skogspodden.se/blandskog/avsnitt-2-viltanpassad-rojning/

Östh, S. (2009). *2000 years of forest dynamics in the Ecopark Raslången, South Sweden – basis for ecological management*. Examensarbete 2009:8. Institutionen för skogens ekologi och skötsel. SLU.

Appendix – statistical analysis

ANALYSER I SAS FÖR RASLÅNGEN (21 april 2017 -)

Number of plants 2017

```
proc print data=pinenumber;
run;
proc mixed data=pinenumber;
class Broadleaf Fence Siteprep Block;
model Pine=Broadleaf Fence Siteprep Broadleaf*Fence Broadleaf*Siteprep
Fence*Siteprep Broadleaf*Fence*Siteprep;
random Block Broadleaf*Block Fence*Block Broadleaf*Fence*Block;
run;
quit;
```

Pinenumber

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	0.74	0.4536
Fence	1	3	3.75	0.1481
Siteprep	1	12	5.57	0.0361
Broadleaf*Fence	1	3	1.42	0.3184
Broadleaf*Siteprep	1	12	0.39	0.5460
Fence*Siteprep	1	12	1.42	0.2560
Broadl*Fence*Sitepre	1	12	0.00	0.9586

Totalnumber

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	0.03	0.8763
Fence	1	3	0.00	0.9614
Siteprep	1	12	0.47	0.5070
Broadleaf*Fence	1	3	2.82	0.1918
Broadleaf*Siteprep	1	12	2.28	0.1572
Fence*Siteprep	1	12	0.85	0.3736
Broadl*Fence*Sitepre	1	12	0.52	0.4828

Birchnumber

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	0.03	0.8831
Fence	1	3	0.04	0.8479
Siteprep	1	12	0.25	0.6236
Broadleaf*Fence	1	3	1.18	0.3567
Broadleaf*Siteprep	1	12	1.34	0.2692
Fence*Siteprep	1	12	0.02	0.8824
Broadl*Fence*Sitepre	1	12	0.04	0.8437

Salixnumber

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	0.92	0.4074
Fence	1	3	1.72	0.2813
Siteprep	1	12	10.45	0.0072
Broadleaf*Fence	1	3	2.21	0.2341
Broadleaf*Siteprep	1	12	1.29	0.2782
Fence*Siteprep	1	12	0.62	0.4469
Broadl*Fence*Sitepre	1	12	1.72	0.2145

Oak and spruce N.S.

Height of plants 2017

Beechheight

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	0.57	0.5066
Fence	1	3	2.17	0.2371
Siteprep	1	12	7.38	0.0187
Broadleaf*Fence	1	3	0.79	0.4405
Broadleaf*Siteprep	1	12	0.01	0.9052
Fence*Siteprep	1	12	0.07	0.7959
Broadl*Fence*Sitepre	1	12	0.18	0.6820

Pineheight

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	2	0.13	0.7570
Fence	1	2	44.71	0.0216
Siteprep	1	9	2.82	0.1274
Broadleaf*Fence	1	2	0.91	0.4416
Broadleaf*Siteprep	1	9	1.50	0.2516
Fence*Siteprep	1	9	0.11	0.7451
Broadl*Fence*Sitepre	1	9	0.19	0.6770

Birchheight

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	0.37	0.5837
Fence	1	3	5.10	0.1090
Siteprep	1	9	0.39	0.5475
Broadleaf*Fence	1	3	0.75	0.4496
Broadleaf*Siteprep	1	9	0.53	0.4845
Fence*Siteprep	1	9	3.29	0.1032
Broadl*Fence*Sitepre	1	9	0.98	0.3474

Goat willow height

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	0	0.05	.
Fence	1	0	6.06	.
Siteprep	1	1	7.56	0.2221
Broadleaf*Fence	1	0	0.02	.
Broadleaf*Siteprep	1	1	3.29	0.3209
Fence*Siteprep	1	1	0.01	0.9550
Broadl*Fence*Sitepre	1	1	0.21	0.7262

Spruceheight

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	0	3.35	.
Fence	1	0	3.34	.
Siteprep	1	1	0.71	0.5535
Broadleaf*Fence	0	.	.	.
Broadleaf*Siteprep	1	1	1.03	0.4956
Fence*Siteprep	1	1	4.77	0.2733
Broadl*Fence*Sitepre	0	.	.	.

Totalmeanheight

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	0.84	0.4279
Fence	1	3	9.28	0.0556
Siteprep	1	12	0.08	0.7792
Broadleaf*Fence	1	3	0.17	0.7043
Broadleaf*Siteprep	1	12	0.36	0.5606
Fence*Siteprep	1	12	1.71	0.2159
Broadl*Fence*Sitepre	1	12	0.50	0.4928

Vegetation cover 2011-13

```
proc print data=vegcover11;
run;
proc mixed data=vegcover11;
class Broadleaf Fence Siteprep Block;
model veg11=Broadleaf Fence Siteprep Broadleaf*Fence Broadleaf*Siteprep
Fence*Siteprep Broadleaf*Fence*Siteprep;
random Block Broadleaf*Block Fence*Block Broadleaf*Fence*Block;
run;
quit;
```

2011

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	0.00	0.9952
Fence	1	3	0.03	0.8670
Siteprep	1	12	11.22	0.0058
Broadleaf*Fence	1	3	0.26	0.6449
Broadleaf*Siteprep	1	12	0.32	0.5842
Fence*Siteprep	1	12	0.61	0.4517
Broadl*Fence*Sitepre	1	12	0.00	0.9631

2012

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	0.08	0.7971
Fence	1	3	0.05	0.8448
Siteprep	1	12	13.28	0.0034
Broadleaf*Fence	1	3	0.14	0.7332
Broadleaf*Siteprep	1	12	0.03	0.8605
Fence*Siteprep	1	12	0.19	0.6675
Broadl*Fence*Sitepre	1	12	0.12	0.7346

2013

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	1.91	0.2613
Fence	1	3	0.05	0.8344
Siteprep	1	12	6.57	0.0249

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf*Fence	1	3	2.70	0.1987
Broadleaf*Siteprep	1	12	0.83	0.3797
Fence*Siteprep	1	12	0.06	0.8145
Broadl*Fence*Sitepre	1	12	2.27	0.1581

Beechsurvival in 2016 and 2011

2016

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	2.60	0.2053
Fence	1	3	0.01	0.9248
Siteprep	1	12	11.74	0.0050
Broadleaf*Fence	1	3	3.58	0.1548
Broadleaf*Siteprep	1	12	0.53	0.4793
Fence*Siteprep	1	12	0.30	0.5930
Broadl*Fence*Sitepre	1	12	6.94	0.0218

2011

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	3.55	0.1559
Fence	1	3	0.20	0.6854
Siteprep	1	12	12.67	0.0039
Broadleaf*Fence	1	3	6.29	0.0871
Broadleaf*Siteprep	1	12	0.00	0.9721
Fence*Siteprep	1	12	0.01	0.9131
Broadl*Fence*Sitepre	1	12	5.30	0.0400

Browsing 2017

Total

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	0.33	0.6034
Fence	1	3	14.86	0.0308
Siteprep	1	12	9.39	0.0098
Broadleaf*Fence	1	3	0.00	0.9702
Broadleaf*Siteprep	1	12	0.30	0.5918
Fence*Siteprep	1	12	6.43	0.0261
Broadl*Fence*Sitepre	1	12	1.62	0.2269

PINE

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	2	8.35	0.1018
Fence	1	2	18.54	0.0499
Siteprep	1	9	3.50	0.0942
Broadleaf*Fence	1	2	5.40	0.1457
Broadleaf*Siteprep	1	9	0.02	0.8946
Fence*Siteprep	1	9	0.25	0.6285
Broadl*Fence*Sitepre	1	9	1.21	0.2992

BIRCH

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	0.01	0.9339
Fence	1	3	0.11	0.7587
Siteprep	1	9	2.15	0.1766
Broadleaf*Fence	1	3	0.01	0.9353
Broadleaf*Siteprep	1	9	2.77	0.1301
Fence*Siteprep	1	9	0.86	0.3777
Broadl*Fence*Sitepre	1	9	2.27	0.1663

GOAT WILLOW

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	0	1.01	.
Fence	1	0	6.53	.
Siteprep	1	1	0.71	0.5535
Broadleaf*Fence	1	0	1.49	.
Broadleaf*Siteprep	1	1	10.04	0.1946
Fence*Siteprep	1	1	4.04	0.2939
Broadl*Fence*Sitepre	1	1	6.27	0.2419

BEECH

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	2.41	0.2187
Fence	1	3	16.19	0.0276
Siteprep	1	12	17.25	0.0013
Broadleaf*Fence	1	3	6.89	0.0787
Broadleaf*Siteprep	1	12	3.40	0.0900
Fence*Siteprep	1	12	16.31	0.0016
Broadl*Fence*Sitepre	1	12	4.19	0.0632

Totalbrowsenofence (SPLIT-PLOT DESIGN)

```
proc print data=totalbrowsenofence;
run;
proc mixed data=totalbrowsenofence;
class Broadleaf Siteprep Block;
model totalp=Broadleaf Siteprep Broadleaf*Siteprep;
random Block Broadleaf*Block;
run;
quit;
```

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	0.08	0.7924
Siteprep	1	6	9.52	0.0215
Broadleaf*Siteprep	1	6	1.01	0.3535

Pinebrowsenofence

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	2	9.02	0.0953
Siteprep	1	4	1.88	0.2418
Broadleaf*Siteprep	1	4	0.26	0.6342

Beechbrowsenofence

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	4.70	0.1186
Siteprep	1	6	18.09	0.0054
Broadleaf*Siteprep	1	6	4.08	0.0898

Birchbrowsenofence

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	3	0.00	0.9813
Siteprep	1	4	0.25	0.6449
Broadleaf*Siteprep	1	4	4.31	0.1066

Goatwillowbrowsenofence

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	0	0.64	.
Siteprep	1	0	0.99	.
Broadleaf*Siteprep	1	0	1.30	.

Oakbrowsenofence

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	0	2.39	.
Siteprep	1	0	3.38	.
Broadleaf*Siteprep	0	.	.	.

Sprucebrowsenofence

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Broadleaf	1	1	38.64	0.1015
Siteprep	1	0	1.485E9	.
Broadleaf*Siteprep	1	0	2.821E9	.

Speciesbrowsenofence (ORDINARY BLOCK DESIGN WITH ONE TREATRMENT)
Beech =1
Birch=2
Pine=3

```
proc print data=speciesbrowsenofence;
run;
proc glm data=speciesbrowsenofence;
class block species;
model specp = block species;
means species / tukey lines;
run;
```

The GLM Procedure

Dependent Variable: specp specp

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	6.85589309	1.37117862	13.45	<.0001
Error	37	3.77198308	0.10194549		
Corrected Total	42	10.62787617			

R-Square	Coeff Var	Root MSE	specp Mean
0.645086	47.02486	0.319289	0.678979

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	0.53664948	0.17888316	1.75	0.1728
Species	2	6.24485428	3.12242714	30.63	<.0001

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	Species
A	1.2613	13	3
B	0.4326	16	1
B			
B	0.4198	14	2