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Master thesis

Tree regeneration dynamics in Norwegian forests

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Abstract

Tree regeneration is essential for res-establishing and extending our valuable early and existing woodland in the forest. Tree regeneration increases biodiversity, provide habitat, shelter and conserve genetic stock. Therefore, it has been considered as one of important biological process takes place in the forest. Tree regeneration can be affected by many factors including physical and biological impacts. The objectives were to quantify the regeneration pattern of Norway spruce (Picea abies) and Scots pine (Pinus sylvestris) in three inventory cycles of National Forest inventory data (NFI) in Norway. Norway spruce is the main dominant specie in Norway. The study aimed at site class impact on tree regeneration regimes of these species. Statistical analyses were performed in R studio software and some calculations were made by using equations. Regeneration rate was quantified relative to the dendrometric variables DBH, basal area, volume with bark and site index. The data also provided the chance to estimate the regeneration rate of these two species in all five regions across Norway. Eastern region of Norway favors the condition for regeneration compared to the rest of regions in Norway. Meanwhile, pine had lowest regeneration rate in Northern region of Norway. The Regeneration rate of spruce specie was significantly increased over the years with the mean value of 106.76 trees per hectare while found to be slightly different pattern in pine specie. Stand Basal area of pine was observed increased over the measurement periods with mean value of 3.29m^2 per hectare while spruce had 1.93m^2 per hectare. Pine specie showed more extent of regeneration rate 86.65 trees per hectare in medium site class. This way of analyzing may serve an example for quantifying regeneration and it requires furthered statistical analysis to check core factors responsible for success of regeneration.

Keywords: Tree regeneration, inventory cycle, site quality, stand density

Table of Contents

1. Introduction

Tree regeneration is an important phenomenon from ecological and economical perspective. Tree regeneration increases the biodiversity and contributes significant carbon pool in forest (Nilsson, Gemmel, Johansson, Karlsson, Welander, et al., 2002). Economic profitability and increased demand of domestic wood harvest spark various regeneration methods to accomplish the target. In Finland ,timber production was about 60 million m^3yr^{-1} in 2013 and then gradually increased to 107 million m^3 yr^{-1} in 2018 by adaptation of tree regeneration methods (Routa et al., 2019). Maintenance of native woodland by natural regeneration is low cost approach (Löf, Bergquist, Brunet, Karlsson, & Welander, 2010) and is favored option for conserving the genetic stock, habitat continuity and natural structures (Humphrey & Swaine, 1997). The overall regeneration pattern of tree species rely on the chain of events in terms of physical and biological impacts (Blanco, Welham, Kimmins, Seely, & Mailly, 2009). The success of tree regeneration is determined by the intensity of rainfall, forest remnant and site quality (K. H. J. F. E. Hanssen & Management, 2003). Successful tree regeneration leads to wood energy and Non-Timber Forest Products (NTFPs) which ultimately help the inhabitants to make better food security and household incomes (Doua-Bi et al., 2021). Tree regeneration of individuals that are more adapted to the extreme site conditions maintain more stability and functionality of the forest (Vacek, Nosková, Bílek, Vacek, & Schwarz, 2010). Tree regeneration rely on the interactions between the biotic and abiotic processes that vary with respect to space and time (Pettit, Burton, DeRose, Long, & Voelker, 2019).

Natural regeneration undergoes from many phases like formation of buds, flowering, germination of the seeds and survival of the seedlings (Juntunen & Neuvonen, 2006). Germination of the seeds is important phenomenon, but quality and quantity of seedbeds play vital role in survival of tree species (Blanco et al., 2009). Tree species response differently throughout the regeneration pattern and show abundance growth in their early stage if there is low competition for the resources (Klopčič, Simončič, & Bončina, 2015). After germination, there is more space develop for carbon allocation as the roots and leaves increase in their sizes (Blanco et al., 2009). In Norway, moose (Alces alces) forage on young Scots pine (Pinus sylvestris). There is high browsing pressure in dense stands due to forage availability (Saursaunet, Mathisen, & Skarpe, 2018). Fast growing plants becomes more damaged because of their attraction to the herbivores (Saursaunet et al., 2018). Potential of tree regeneration may be reduced after excessive land use by herbivores, weed invasion, repeated life cycles and soil depletion (Uriarte & Chazdon, 2016).

Seedlings undergo regeneration or planting response differently to open and closed forest canopy depending upon the nature of recruitment specie(Löf et al., 2010). Seedlings are more vulnerable during their first year of growth (Nilsson, Gemmel, Johansson, Karlsson, & Welander, 2002).Seedling mortality has been neglected in the past for timberline production The success in tree regeneration is not only depend on their reproduction rate, but survival rate of seedlings too (Juntunen & Neuvonen, 2006). Shelter trees can reduce the seedling growth competition, prevent frost damage(ice during snow fall which can penetrate the plant tissue cell) and ease nutrients availability on the site (Löf et al., 2010). In the past , seedling mortality has been neglected as the regulatory factor for timberline production and their dynamics (Juntunen & Neuvonen, 2006). Bare mineral soil and removal of ground vegetation results in favor of natural seedlings hence reduce the competition for water, nutrients and light (Nilsson, Gemmel, Johansson, Karlsson, & Welander, 2002). Adult trees with high density canopy have negative effect on the recruitment of English yew (Taxus baccata) due to autotoxicity and minimum light exposure (Devaney, Jansen, Whelan, & management, 2014).

On the other hand, the open areas or gaps underlying direct exposure to sunlight have been considered to be the important element for successful oak tree species (Humphrey & Swaine, 1997). It has been also observed that regeneration performance in Nothofagus forest, increased under gradually open canopy while greater canopy opening put the damage to the seedlings in absence of shelter tree functions which prevent from frost damage and wind storm strikes (Pastur et al., 2011). However many studies observed that substantial portion of change in seedling density cannot be linked with the light availability or the presence of suitable microsites (Szewczyk & Szwagrzyk, 2010).

Natural disturbances have vital role in determining the dynamics of forest and therefore it has been evidence from past decades that large scale disturbances like windstorm and bark beetle attack affected almost 1 million hectare of Norway Spruce (Picea abies) across the Europe (Tsvetanov et al., 2018). These multiscale disturbances can alter the dynamics and structure of forest canopy (Drobyshev, 2001). For example, severe storm disturbances happened in Europe 1990 and 1999, which damaged the forest cover dramatically by 120 and 180 million m3 of wood respectively

(Schelhaas, Nabuurs, & Schuck, 2003). Large scale disturbances can change the species regeneration success in community structure, like shifting of shade tolerant species to shade in-tolerant species (Drobyshev, 2001). Additionally, these disturbance regimes causes huge economic loses, like single severe storm event affecting the southern part of the Sweden in January 2005 was estimated £ - 2.4 billion (Knoke et al., 2021).

Norway Spruce regeneration success mainly depend on the forest floor cover type and show excessive growth on dead wood and less growth in thick ferns, whereas moisture and elevation favor's the condition of regeneration (Vacek et al., 2010). Norway spruce comprise of 45% timber volume and dominated in 40% of productive forest cover area in Norway (K. H. Hanssen, 2003) .Although, it is shade tolerant specie but for many boreal species shade provided by overstory trees results in better growth and survival (Blanco et al., 2009). Regeneration by planting and clear-cut practices were performed in Norway since 1950 to achieve spruce forest. Later, regeneration of Norway spruce by natural means was adopted and promoted through smaller clear cuts techniques (K. H. Hanssen, 2003). Despite their ecological and economical importance over other species, Norway spruce act as protective element in strengthen the soil and prevent from rockfall in mountainous areas (Tsvetanov et al., 2018). Norway spruce seedlings successfully recruit and show better growth under small gaps in canopy (Luguza et al., 2020).

In Sweden, canopy layer dramatically affect the regeneration of Scots pine specie where the basal area was over $4m^2$ ha^{-1} to $8m^2$ ha^{-1} (Luguza et al., 2020). Similarly, Seedlings of many birch (Betula) species also show more adaptation and survival in a shelterwood area than in clear-cuts (Nilsson, Gemmel, Johansson, Karlsson, & Welander, 2002). Previous studies also show that Norway spruce and Scots pine have high mortality rate in clear cuts area rather than in dense shelterwood areas (Nilsson, Gemmel, Johansson, Karlsson, & Welander, 2002). There are experiments which provide useful information about success of birch specie in a forest area (Karlsson, Albrektson, Forsgren, & Svensson, 1998). Regeneration by artificial means has become a problem due to financial cost and human involvement. Natural regeneration by means of seed dispersal is the reliable solution with minimum human disturbance. For example , birch species has capacity to produce 0.3 to 6.5 million seeds and dispersal distance is between 40 to 360m (Tiebel, 2021). Successful regeneration requires protection from foraging mammals and less ground vegetation competition (Karlsson et al., 1998).

Mostly researchers show that there are common factors that have effect on the tree regeneration patterns which can change the dynamics of forest area. These can be physical events or biological impacts which can be in favor for one specie and devastating for other species. Regeneration decreases with its age due to the competition for resources and hence causes mortality in some species (Klopčič et al., 2015). Competition among the tree species for light, water and nutrients determine the early or late successional growth (Nilsson, Gemmel, Johansson, Karlsson, & Welander, 2002). Almost every tree species has special characteristics of seedling survival, seed germination and “storage effect”. Like long living trees have this storage effect in order to maintain their share in forest stand even if they regenerate only once over many years of regeneration(Szewczyk & Szwagrzyk, 2010).

In this study, I try to emphasize on regeneration dynamics of two species Norway spruce and Scots pine in order to check their existing and future outcomes. The aim of this investigation here is to estimate (1) how regeneration varies across species types? (2) how it varies among Site class types? (3) is there any change of regeneration pattern with time?

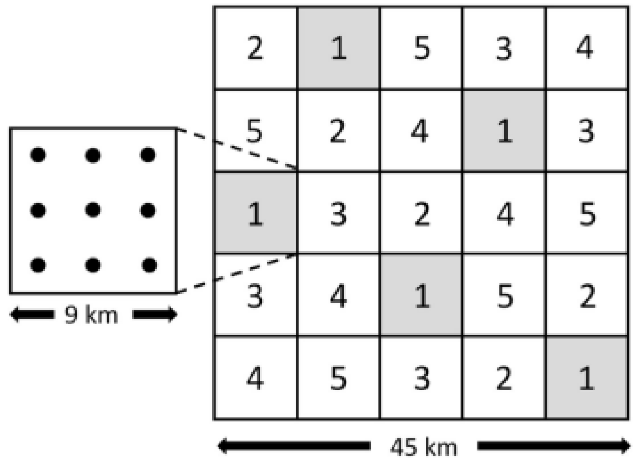
2. Material and Methods

2.1 Study Sites and Research Design

Norway has many lakes, valleys and fjords along with boreal mountain and boreal coniferous forests, of which most of the forest is semi natural. It has maritime climate with some polar and temperate oceanic areas (Yrjölä, 2002). Norway was the first country among Sweden and Finland which performed planning on national forest inventory in 1917 and field work in 1919. The main purpose of first inventory was to estimate the total volume or increment of timber which leads to sustainable management of timber resource (Breidenbach, Granhus, Hylen, Eriksen, & Astrup, 2020). Norway Spruce and Scot's pine constitutes the one third of forest area each and have commercial importance over the other tree species. Boreal deciduous forest such as Aspin and Birch account for last third of the forest area whereas many broadleaves deciduous tree species account for 1.3% of Norway productive area (Sætersdal, Gjerde, Heegaard, Schei, & Nilsen, 2016). Norway constitutes of 7.4 million ha of productive forestland including all counties except Finnmark which has never been included in national forest inventory (Yrjölä, 2002),which later on included in 2005 due to the requirement of greenhouse gas reporting (Breidenbach et al., 2020) . Approximately there are total 22,000 sample plots across Norway, of which around 12,000 are in the forests according to current Norwegian institute of bioeconomy research (NIBIO) data. We gathered the data of three inventory cycles (2004 to 2008 ,2009 to 2013,2014 to 2018) each consisting of 5 years.

2.1.1 Sample design

The Norwegian national forest inventory (NFFI) was designed to collect the information of forest, which is helpful in formulation of national and regional forest policy ,monitoring key biological parameters and forest planning (Breidenbach & Astrup, 2012). Latin square design was adopted to reduce the difficulty of topography. Design was consist of 5 × 5 = 25 blocks, each block contains 9 plot locations on the 3km ×3km grid with an area of 81km2 (Breidenbach et al., 2020). Permanent sample plots are located on 3×3 km grid except from high mountainous and northern part of the region. It takes 5 years to complete the measurement cycle because every year 20% of the sample plots are measured (Breidenbach & Astrup, 2012). Four strata design was applied, of which stratum 1 covers almost 46% of Norway's land area and 80% of its forest, Two strata in Finnmark and two outside of Finnmark which cover most of the Norway's area (Breidenbach et al., 2020).



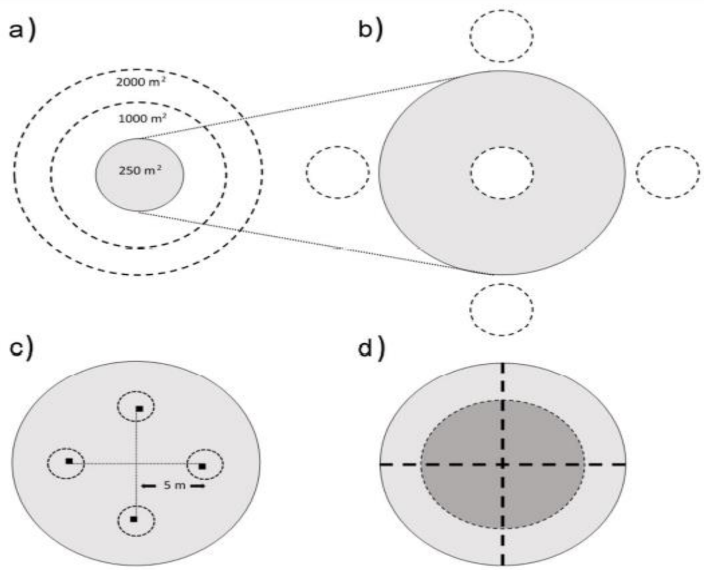
The Latin square design of the NFI. The numbers in the blocks indicate the panel of plots measured in 1 year. The blocks belonging to panel #1 are grey to visualize that blocks in one panel do not share borders. Nine sample plot locations on a 3 km x 3 km grid are located within each block

Figure 1: Latin square design

2.2 Data collection

2.2.1 Field measurement

Variables of interest in the forest were recorded by different sampling units. On tree level measurements, variables such as biomass, increment, growing stock volume were recorded on circular 250 m^2 plot of which smaller plot must have an area of 37.5m2 (15% of the total plot area) (Breidenbach et al., 2020). Landscape variables such as stand age, site index, forest type and soil type recorded on 0.1ha circular plots concentric with 250m^2 plot. Regeneration was recorded in young forest on five 16m^2 circular sample plots concentric with plot center. Site quality classification was done based on the $H_{1.3}40$ system ("height above breast height (1.3m) at 40 years of age") (Godal & Grønlund, 2014).



Design of the permanent plots. **a** Dendrometric variables for individual trees are measured on a plot sized 250 m², here indicated in grey, while landscape- and stand-level variables, and biodiversity habitats are recorded on larger plots of 0.1 and 0.2 ha, respectively. **b** Tree densities and tree heights in young stands are measured on five 16 m² subplots (dotted circles). **c** Four subplots are used to assess cover of bilberry and lingonberry (black squares), and for recording the number of trees with dbh < 5 cm and browsing intensity (dotted circles). **d** Patches of droppings from moose and red deer are counted on a 100 m² plot (dark grey), while downed deadwood is measured along perpendicular transects of length 18 m (thick dotted lines)

Figure 2: design of permanent plots

2.2.2 Dendrometric variables

Diameter at breast height, tree species and vitality status (dead or alive) were recorded of trees which have a dbh ≥ 5cm. A caliper device was used to measure the dbh. By using vertex III tree heights were measured of 10 trees approximately in each plot and height of remaining trees in the plot predicted by considering the volume function for height and dbh as input variables. The volume increment estimated by repeating the dbh measurements each year and the difference between the previous and current dbh in growing seasons (100 days of length between 4.00 to 6.00 in 5 year of inventory cycle). The maturity class system was developed based on the stand age, dominant tree species and site index. According to this system productive forest categorized into 5 classes starting from forest under regeneration class (age 0 yrs.) to a mature forest class (minimum age 40 - 120 years).

2.3 Statistical analysis

Most of the data is analyzed in R software (Team, 2013). Whereas, some of the calculations (basal area, stand density) are estimated by using equations in Microsoft Excel (Baier & Neuwirth, 2007).

Norwegian National Forest Inventory data is used for this study to perform analyses. Three measurement periods were taken 2004-2008, 2009-2013 and 2014-2018, of which each inventory consists of 5 years. The data consists of 9426 plots containing 775031 individual's trees in all three inventory cycles (2004-2008, 2009-2013, 2014-2018) collectively. There were total of 29 species present in the data, out of which spruce have been dominated in all measurement periods containing 44 percent of whole data. On the other hand, there were total of 4432 plots in which pine trees were present, having 17 percent portion of the whole data. As we were more concerned to estimate the overall regeneration of Norway spruce and Scots pine in each plot, condition of tree (i.e., alive, partially dead or completely dead) was neglected. Regeneration for Norway spruce and Scots pine was quantified by using variable DBH (< 60 cm) in each inventory cycle. Regeneration was also estimated in all five regions of Norway (Eastern, Southern, Central, Western and Northern part) by using commune number assigned to each plot. To assess the regeneration on site quality based on productivity level, I made three categories of site classes following (Godal & Grønlund, 2014) low class (6-8), medium class (11-14) and high class (>17).

General linear mixed model was used to interpret the significance of regeneration over the three measurement periods. Model was selected based on Akaike's Information Criterion (AIC) using the package AICcmodvag in R studio (Mazerolle & Mazerolle, 2017). Outliers in the data was checked in R studio by boxplot function before transforming the data for furthered analyses. The data was formatted by using omit values function in R studio to avoid from missing values present in the data. Pearson's chi-squared test was performed to check the statistically significant difference between the expected frequencies and the observed frequencies in the data. R packages used for organizing and visualization in charts ggplot2 (Villanueva & Chen, 2019), tidyverse (Wickham & Wickham, 2017).

3. Results

3.1 Overall descriptive statistics in each inventory cycle

There were 35310 trees were regenerated in each inventory cycle comprising of overall 5941 and 4432 plots of spruce and pine respectively. Stand density of spruce was estimated high in third measurement period (2014-2018) 669.76 per hectare, while regeneration per hectare was also on peak of 108.53 per hectare. Stand density was calculated by using formula

Stand density = number of trees in plot × tree factor

On the other hand, pine regeneration was little lower in second period (2009-2013) and was recorded 78.54 per hectare. Meanwhile, the average Spruce stand volume was recorded lower (139.72 m^3) than the pine stand volume (235.93m^3) as illustrated in the Table 1.

Table 1: Mean characteristics of spruce and pine species in each inventory cycle

Inventory cycles	Stand density (per hac) spruce	Stand density (per hac) pine	stand Basal area (m^2 per hac) Spruce	Stand basal area (m^2 per hac) Pine	Stand volume (m^3) spruce	Stand volume (m^3) pine	Regeneration (per hac) spruce	Regeneration (Per hac) pine
(2004 – 2008)	631.75	331.50	1.89	3.21	133.23	227.19	103.93	79.90
(2009 - 2013)	658.04	338.62	1.92	3.29	138.97	236.18	107.81	78.54
(2014 - 2018)	669.76	340.81	1.99	3.37	146.97	244.44	108.53	78.84
On Average	653.18	336.97	1.93	3.29	139.72	235.93	106.76	79.10

During the measurement period of 2004 to 2008 pine regeneration was recorded 79.90 per hectare, followed by stand volume (m^3) 227.19 on its lowest value comparing to the other measurement periods.

Basal area was calculated for each tree in a tree stand by using formula

Basal area $= \pi r^2$ (π = 3.114)

R = radius; whereas r = d/2

D = DBH (diameter at breast height) of tree

Stand basal area for spruce gradually increased over each inventory cycle 1.89 in 2004- 2008, 1.92 in 2009-2013 and 1.99m^2 per hectare in 2014-2018. Same pattern of stand basal area was observed for pine specie as 3.21,3.29 and 3.37 m^2 per hectare over each inventory cycle.

3.2 Regeneration across regions of Norway

A large proportion of sample plots for both species (spruce and pine) were present in Eastern Norway comprising of 3839 and 2604 plots of spruce and pine respectively. Number of regenerated trees were also recorded high in this region as shown in Fig (3). There were total of 20544 spruce trees were regenerated in all three measurement periods and recorded higher 3988 trees for pine specie as well in this region. Regeneration for spruce was estimated 112.59 per hectare, whereas 83.02 per hectare for pine specie.

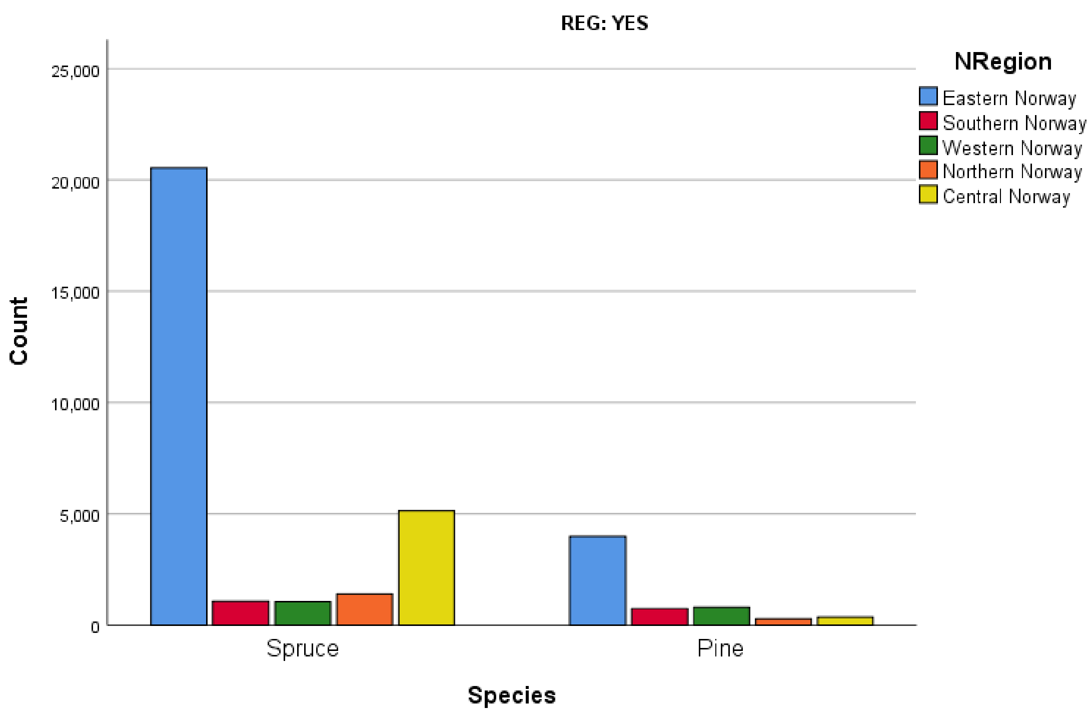


Fig 3: Region based regeneration of spruce and pine trees

Central part of the Norway contains total of 1087 and 424 plots for spruce and pine respectively.it is the second most spruce dominated region after Eastern part of Norway. There were 5137 trees were regenerated over all three inventory cycles having 95.98 regeneration per hectare, while pine regeneration was estimated low 62.66 per hectare. Furthermore, in southern part of Norway the number of plots for spruce specie was low but regenerated trees were counted 1072 compared to pine specie 738 trees. Moreover, the Same kind of pattern was observed in western part of Norway. Meanwhile, only 281 trees of pine specie were regenerated in Northern part of the Norway indicating the lowest regeneration rate as compared to other part of Norway. In contrast, 1393 trees of spruce specie were regenerated supporting the environment suitable for regeneration.

3.3 Regeneration across the site quality

The categories in H40 system include eight classes: 6, 8, 11, 14, 17, 20, 23, and 26. These site classes furthered categorized to three main site classes of low (6-8), medium (11-14) and high (>17) site class. Average Spruce stand density was found to be lower 416.40 per hectare in low class site quality, while higher 922.84 per hectare in high class site quality (table 2). On the other hand, density for pine stands was observed high 369.01 per hectare in medium class site quality following the high regeneration 86.65 per hectare in the same site class. There were total of 15465 spruce trees were regenerated in medium site class, utmost of its number in contrast to other site classes. Stand density of spruce in medium site class was estimated 641.27 per hectare. Stand volume for pine found to be one time greater 10.50 per hectare than the spruce stand volume 5.22 under medium site class. whereas the number of regenerated trees for spruce specie was higher (15464) in medium site class but regeneration rate was great in high site quality (fig 4).

Table 2: Mean characteristic values of spruce and pine specie following site classification in all measurement periods (2004-2008, 2009 – 2013, 2014 – 2018)

Site index	**Number of plots (spruce)**	**Number of plots (pine)**	**Spruce regeneration (per hac)**	**Pine regeneration (per hac)**	**Stand density (per hac) spruce**	**Stand density (per hac) pine**	**Stand volume (per hac) Spruce**	**Stand volume (Per hac) pine**
Low class (6-8)	1814	2015	80.65	71.45	416.40	303.96	4.92	9.36
Medium class (11-14)	2976	2027	112.94	86.65	641.27	369.01	5.22	10.50
High class (>17)	1570	637	118.63	75.00	922.84	315.14	7.92	11.56

In high site quality, stand volume (m^3) per hectare for spruce and pine specie found to be higher 7.92 and 11.56 respectively. As the number of plots present in medium site quality for spruce specie was greater than the high site quality, but the regeneration per hectare was recorded highest (118.63) in the high site class.

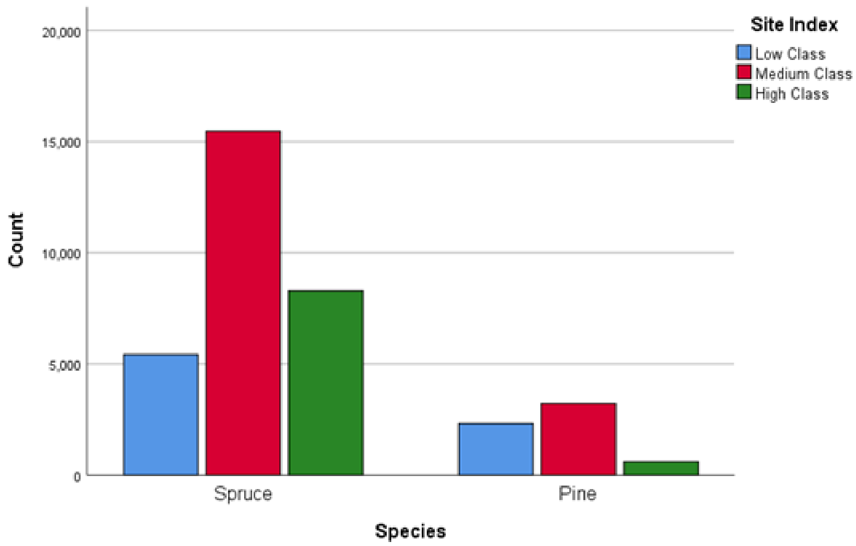


Fig 4: Regeneration of spruce and pine trees following the site classes (low, medium and high)

4.Discussion

In this study I try to interpret the tree regeneration of Norway spruce and Scots pine in three inventory cycles, also followed by regions across Norway. I also try to emphasize on the site class (low, medium and high) variations effects among the species and their trend of regeneration on these site classes. Tree regeneration is fundamental key to protection of local biodiversity, species interactions, stable native species composition, increase endurance to climate shocks due to various forest structure and availability of diverse timber production (Chazdon, 2017). The study was carried out to understand the complexity of tree regeneration trends affecting the local tree species structure and to provide essential key factors that can cause disturbances on present and future dynamics of Norwegian forests. In this study, tree regeneration was estimated with the data obtained from Norwegian Forest Inventory of three inventory cycles (each inventory of five years) 2004 to 2018.Potential variables were selected to forecast the tree regeneration pattern and forest stability functions, which can ultimately be helpful to understand the need of forest management applications. In this study, first objective was to check the temporal tree regeneration trends in Norwegian forests regardless of any disturbances occur to the forest land. Dendrometric variables like DBH(diameter at breast height) ,basal area ,stand density and volume were selected to assess the regeneration rate similar to the study of (Duchateau, Schneider, Tremblay, & Dupont-Leduc, 2020).

In some studies like (Nilsson, Gemmel, Johansson, Karlsson, Welander, et al., 2002) the scientists reveals that soil quality greatly influence the dynamics of regeneration in all stand types. But due to the scarcity of the data we could not include these factors into the consideration. The study results show overall increased tree regeneration trend in spruce specie with stand density of 669.76 per hectare in last inventory year, adding to the 108.53 regeneration per hectare. But pine specie had different scenarios in contrast to the spruce specie, with highest regeneration per hectare of 79.90 in first inventory year compared to the last two inventory cycles. Anyhow, stand basal area of pine specie was found to be greater in last two inventories (3.29, 3.37 m^2 per hectare respectively). Suggesting that there is an increment to the pine stand timber volume each year with strong competition within the specie and among the tree species present in the forest area. The overall regeneration rate was shown to be in increasing trend with the minor decline of regeneration pattern in pine specie in last two measurement periods (2009 to 2018). These results are in line with the previous studies (Chazdon, 2017) where natural regeneration was increased from 9% to 37% between 1950 and 1990.

Each region of Norway has different environmental conditions like raining pattern, temperature and humidity, which may be one of the main factors for success of tree regeneration. Eastern region of Norway comprises more than half of overall tree regeneration of spruce with 112.59 trees hectare and pine with 83.02 trees per hectare. Pine regeneration found to be lower in northern parts of the Norway with only 281 number of trees in total. This might be due to cold weather conditions of below -30^0 which makes difficult for pine specie to survive and grow in the same manner as other parts of Norway. Type of Topography is also another factor responsible for the growth and survival of any plant species(Chazdon, 2017).

Site index is an important indicator of regeneration success of spruce specie. Site quality system provides to the researchers a more diverse way of forest knowledge and for quantifying mortality and regeneration. Site index was highly corelate in determining the regeneration of spruce specie which also support by studies of (Sharma, 2019),which indicates that site quality is key factor in determining the survival of any specie. Due to the change in forest structure with the passage of time, the site index doesn’t follow the same pattern each year(Davidson, Gottschalk, & Johnson, 1999).Spruce specie found to be well established in a high site class rather than pine because regeneration was estimated 118.63 trees per hectare. While on the other hand pine specie regeneration was more reluctant to the high site class and instead had more regeneration success in medium site class.

Despite much uncertainty, regeneration pattern suggests that areas of regenerating forests will increase in the future. It will be needed to track and assess both qualitative and quantitative tree regeneration in more extensive manner. With the proper forest management and planning regenerated forest will provide new nexus for the people where their lives, livelihoods and cultures are interconnected with forest regeneration cycles.

5.Conclusion

The study illustrates that the tree regeneration pattern increased with the time unless there are some disturbances occur in the forest. These regeneration patterns can be positively or negatively affected by the type and severity of disturbances either physical events or biological impacts. various forest variables have their own degree of impact on determining the regeneration pattern. In each site class, regeneration rate was significantly different which supports the demand of more research under these site conditions. Spruce specie was abundantly present in every region of Norway with the high proportion as compared to the pine specie. Although Norway has done tremendously great when it comes to the forest sector. But this study indicates that, pine specie should be in consideration for making forest management plans in the future to enhance regeneration processes in the Norwegian forest.it is highly recommended to carry out the research with the focus on identifying the ecological or biological factors responsible for increasing regeneration pattern in Norwegian forests.

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