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*Full Length Research Paper*

# Density and growth performance of Scots pine (*Pinus sylvestris* L.) understory saplings in logged forests of Tujiin Nars National Park in the Western Khentii Mountains, Case study from Northern Mongolia

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**The paper presents the analysis of seven naturally regenerated stands in native Scots pine forests located in the Western Khentii of Northern Mongolia. The findings show natural regeneration of Scots pine in logged areas directly after felling with different intensities. The natural regeneration in the study areas were characterized by continuous age distribution, high understory density and growth variation among stands. Mean density of regenerated saplings in logged pine forests were varied among stands, while densities were lower in heavily logged areas (3700 individuals ha$^{-1}$) and higher in the forests logged with low intensity (21306 ind. ha$^{-1}$). The results indicate that the intensity of logging, abundance of parent trees and their sheltering effects are important determinants of differentiation for success of natural regeneration and growth performance of regenerated trees. Sapling growth rate was greater under light shelter and lower under dense cover. Furthermore, a regression model for understory sapling growth in the region was developed. The regeneration density clearly indicates the high potential for reproduction of Scots pine within 15 years, as saplings in the logged areas attained a mean height of 249.7 ± 67.3 cm by the age of 10.45 ± 1.32.**

**Keywords:** natural regeneration, logging, stand density, growth rate.

## INTRODUCTION

In the conifer forests of Northern Mongolia, the demand for multi-use of natural resources and the high cost of reforestation causes Mongolian foresters to focus on natural regeneration. A number of studies in forest research journals have explored the main factors affecting natural regeneration of Scots pine (*Pinus sylvestris* L.), including population structure, density and growth performance (Harri Makinen and Antti Isomaki, 2004; Jonson, 1995; Ruha and Varmola, 1997; Santiago et al.,2001; Spracklen et al., 2013). Forest utilization and climatic range are the most important factors which influence forest type, soil structure, species composition and the natural regeneration process (Mirschel et al., 2001; Spacklen et al., 2013; Stokes and Kerr, 2013). Although a number of studies have focused on the management of native Scots pine (Dieguez-Aranda et al., 2006; Mark Palahi and Timo Pukkala, 2003; Sonohat et al., 2004), there has been little research on the density and growth

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performance of naturally regenerated Scots pine saplings in the understory. Scots pine is a light-demanding tree species that is tolerant to poor soils and drought (Picon-Cochard et al., 2006; Sanchez-Gomez et al., 2006). Its natural regeneration is dependent on climatic factors, which affect the quantity and quality of seed crop, germination and early development of saplings (Agestam et al., 2003). However, the natural regeneration of Scots pine consists of many phases, such as formation of regenerative buds, flowering, maturation, germination, early survival of seedlings and yearly climatic conditions (Vesa Juntunen and Seppo Neuvonen, 2006).

Mongolia is situated in the transition zone between the Great Siberian taiga forests and the Eurasian steppe, with 17.6 million ha of forest area. Closed forests occupy only 8.03% of the total land area in Mongolia (MNGD, 2013) and distribution and quality of forest resources vary greatly throughout the country (Tsogtbaatar, 2004). The country's growth in population has led to an ever-increasing demand for forest products, which has a negative effect on the forest resources. Therefore, forestry has been playing an important role in the Mongolian economy and has a great potential today as a source of sustainable livelihoods for people living in forested areas (World Bank, 2002). Although the Scots pine has a large distribution area, adapting to many kinds of habitat (Richardson, 2000), its distribution in Mongolia is very limited, occupying only 5 percent of total forest land (MNGD, 2013). In addition, Scots pine provides important protection for the water and soil resources as well as ecosystem balance. It is also one of the most commercially important native tree species in the country (Udval and Batkhuu, 2013). A forest management study in the region resulted in discussions about the important elements of Scots pine silviculture in the Western Khentii mountain range where there is little forest management but an increasing national interest in in-situ natural resources conservation (JICA and MNE, 1996). The objective of this study was (1) to evaluate the understory density of Scots pine in logged stands and (2) to analyze growth performance of saplings.

## METHODS AND MATERIALS

### Site description

The study was carried out in native Scots pine forests of Tujiin Nars National park in Selenge province, Mongolia, near the northern border with Russia. The area is located between 50°05' and 50°12'N, 106°14' and 106°31'E, and covers approximately 45,000 ha (Figure. 1). The study region is within the Western Khentii mountain range and considered a forest-steppe transitional zone (Muhlenberg et al., 2012) called sub-taiga forests (Tsedendash, 1995). The forest is characterized by serious ecological changes caused by uncontrolled utilization over the past two decades (JICA, 1998; MNGD, 2013). Tujiin Nars is between 650 and 900 meters above sea level and experiences a harsh continental climate, which is characterized by sunny days, extended dry and cool periods, short growing seasons, low precipitation and large annual, seasonal, monthly and diurnal fluctuations in air temperature (Gerelbaatar, 2011). The mean annual precipitation in the study area is 276 mm, and the annual temperature is 1.0°C while the mean monthly temperature ranges from -22°C to 19.0°C. A maximum temperature of 36.4°C has been recorded in June, and a minimum temperature of -40.1°C in January (Regzedmaa, 2008).

The soil in the study area is mainly Haplic Arenosols (also called Derno-Forest soils in Mongolia), which are derived from sandy sediments (JICA, 1998). The sand stratum, which provides the parent materials, is extremely thick, forms in the higher terraces up to 870 m in elevation and is widely observed in the study region. The sand is fine and extremely homogeneous. The 0 horizon of Haplic Arenosols is 2-6 cm thick and the mineral horizons are scarcely differentiated. In soil profiles a brownish black or dark brown A horizon of a few cm (15-23 cm)(sandy loam) in thickness and a yellowish brown C horizon were observed. The current soil type is characterized by extremely good water retaining capacity and poor floor vegetation. Soil texture was similar in all the sampled stands and the pH mean was 5.9.

Native Scots pine forests thrive on drained soils, many of which are pure forests with a high potential of reproduction after logging. The vegetal communities are mainly dominated by *Pinus sylvestris, Rhododendron dahuricum, Cotoneaster melanocarpa, Vaccinum vitis-idaea, Rosa dahurica, Carex pediformis, Iris ruthenica, Lathyrus humilis, Aster alpinus, Artemisia tanacetifolia, Artemisia sericea, Bromus Pumpellianus, Buplerum scorsonerifolium, Stipa baicalensis,* and *Elymus dahurica*, all of which are known for their tolerance to drought and extremely low temperatures.

### Measurements and data collection

The field survey was conducted during August and September 2012. The sampling was focused on selection of stands logged with different intensity in the past and representative of natural regeneration in the region. The sampling involved 6 logged stands (US, TK, BD, SD, TN, KS) and a control plot (GN)(Table 1). In each stand we established 4 square sample plots with a size of 10 x 10 m (100 $m^2$), separated by 50 m from each other. The total height and annual height increment of all saplings in each sample plot were measured using measuring tape and stem diameter was measured at ground level by using calipers with an accuracy of 0.01cm. The age of the individual saplings was estimated by calculating the

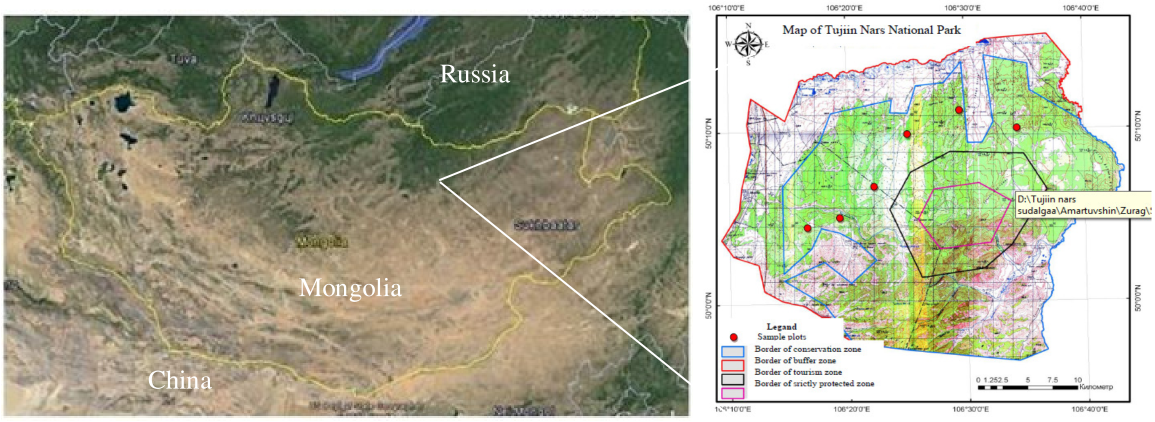


**Figure 1.** Location of study area.

**Table 1.** Location and characteristics of permanent sample plots used for this study

| Sample plots | Name of sites | Alt. (M) | Long. (E) | Lat. (N) | Standdensity (tree $ha^{-1}$) | Understory density (tree $ha^{-1}$) | Loggingintensity (%) | Year of logging |
|---|---|---|---|---|---|---|---|---|
| I | Ustai Shaamar (US) | 700 | 106°16'42.4" | 50°05'18.3" | 87 | 6170 | 79.2 | 2001 |
| II | Temeen khuzuu (TK) | 764 | 106°19'30.7" | 50°07'09.1" | 156 | 10112 | 60.5 | 2003 |
| III | Bayanbulag dehj (BD) | 744 | 106°26'29.5" | 50°11'13.3" | 51 | 9790 | 86.5 | 2002 |
| IV | Shaamariin denj (SD) | 680 | 106°14'22.1" | 50°05'43.8" | 28 | 3682 | 92.1 | 2000 |
| V | Taliin nuruu (TN) | 840 | 106°16'44.3" | 50°05'30.3" | 360 | 21306 | 13.2 | 2003 |
| VI | Khuurai Shaamar (KS) | 685 | 106°16'48.3" | 50°05'27.8" | 105 | 5611 | 74.0 | 2000 |
| VII | Gun nuur (GN) | 670 | 106°13'52.0" | 50°37'58.1" | 425 | 2700 | - | - |

number of nodes and by ring counting on samples. The tree age and radial growth of saplings were measured on collected samples in the laboratory of dendrochronology. The logging intensity was calculated by comparing the number of stumps at the time of measurement and the total number of trees in the stand before harvesting and expressed as a percentage. In order to evaluate the logging effect on natural regeneration in Scots pine, a control area was selected in a mature stand where logging never occurred. The crown diameter of each tree was calculated as the average value of diameter measured in north-south, east-west directions. The soil survey was conducted to examine morphological features of the soil profiles. The soil profiles were described in accordance with the FAO Guidelines and the measurement values using a portable pH meter. Stem analysis for the determination of the age, radial growth, annual increment and basal area of stems were implemented on 140 model samples following Anuchin (1971).

### *Data analyses*

The analyses of variance (ANOVA) were used to determine differences of variables among each sample plot and between stands. The descriptive statistical estimates of the variables generally refer to mean, maximum and minimum value, standard deviation, standard error and variance of each variables. A total of 1258 saplings aged from 5 to 13 years and with a height ranging from 28 to 370 cm was used to compute statistical analyses. To estimate the year of logging we collected 10 samples (5 from parent tree, 5 from stumps) from each plot with an increment borer. The logging year for each stand was determined by

**Table 2.** Stand characteristics of understory Scots pine

| Stand | Mean age (years) | Height (cm) | Diameter (cm) | Basal area ($m^2$ $ha^{-1}$) | Volume ($m^3$ $ha^{-1}$) |
|---|---|---|---|---|---|
| I | 8.0 ± 1.23 | 140.4 ± 32.1 | 2.63 ± 0.80 | 14.15 | 7.66 |
| II | 6.27 ± 2.01 | 93.8± 37.3 | 1.97 ± 0.94 | 3.84 | 1.21 |
| III | 9.53 ± 1.74 | 222.5 ± 87.9 | 3.83 ± 1.8 | 13.77 | 10.52 |
| IV | 10.45 ± 1.32 | 221.9 ± 51.2 | 5.16 ± 1.22 | 8.17 | 7.21 |
| V | 6.38 ± 2.03 | 36.1 ± 17.5 | 0.87 ± 0.63 | 1.31 | 0.18 |
| VI | 8.44 ± 1.04 | 249.7 ± 67.3 | 4.01 ± 1.69 | 16.67 | 14.78 |
| VII | 12.2 ± 3.62 | 52.5 ± 19.2 | 1.12 ± 0.22 | 0.617 | 0.15 |

*data expressed as mean values ± standard deviation

**Table 3.** Statistical analyses of variables among stands

| **Variables** | ***F*** | ***P -value*** |
|---|---|---|
| Understory density | 12.63 | 0.004** |
| Age | 16.99 | 0.001** |
| Height | 18.23 | 0.001** |
| Diameter | 1.39 | 0.259 |
| Basel area | 2.75 | 0.122 |
| Crown diameter | 16.58 | 0.002*** |

* Different at p<0.05;

comparing stump age and live parent tree age based on counting of tree rings on cores sampled with the increment borer. The estimation of annual radial growth was calculated based on tree ring width and the annual height was estimated as the mean of annual height increment measured in the field. To explore the differentiation of sapling height all saplings were divided into 8 height classes (>50 cm, 50-100 cm, etc). The relationship between sapling height and diameter in the study region was calculated and examined through a linear equation. We also used statistical analyses of variance among crown parameters in the stands.

## RESULTS

The stand characteristics of the understory Scots Pine are presented in Table 2.

### *Understory density and age structure*

In relation to the establishment of sample plots in Scots pine stands with different understory densities and ages, the results of this study are varied among sample plots and significant differences were observed between stands. Results show that understory density varied among stands (*df =1, F=12.63, P=0.004*), with the lowest understory density observed in GN (2700 saplings $ha^{-1}$) and highest in TN (21306 saplings $ha^{-1}$)(Table 1). Therefore, the dendrochronological data indicates that the logging occurred between 2000 and 2003 with logging intensity of 13.2%, 60.5%, 74%, 79.2%, 86.5% and 92.1% in TN, TK, KS, US, BD and SD, respectively. (Table 1).

Table 3 shows there is high variation in age among stands (*df =1, F=16.99, P=0.001*), although the majority of sapling were between 7 and 12 years of age. The mean age of each stand is as follows: 8.0 ± 1.23 in US, 6.27 ± 2.01 in TK,9.53 ± 1.74 in BD, 10.45 ± 1.32 in SD, 6.38 ± 2.03 in TN, 8.44 ± 1.04 in KS and 12.2 ± 3.62 in GN (Table 2).

### *Growth performance of saplings*

The findings show that there is a significant difference in Scots pine sapling height (*F= 18.23, P=0.001)* and diameter (radial) growth (*F=1.39, P=259*)(Table 3) among stands, while the mean height for US is 140.4 ± 32.1 cm, TK is 93.8 ± 37.3 cm, BD is 222.5 ± 87.9 cm, SD is 221.9 ± 51.2 cm, TN is 36.1 ± 17.5 cm, KS is 249.7 ± 67.3 and GN is 52.5 ± 19.2 cm (Table 2). Meanwhile, the greatest height growth rate observed was in KS (249.7 ± 67.3 cm)(5611 ind. $ha^{-1}$) and relatively slower rate in TN (36.1 ± 17.5 cm)(21306 ind. $ha^{-1}$). Figure 2 illustrates the frequency distribution of saplings by height classes. The frequency

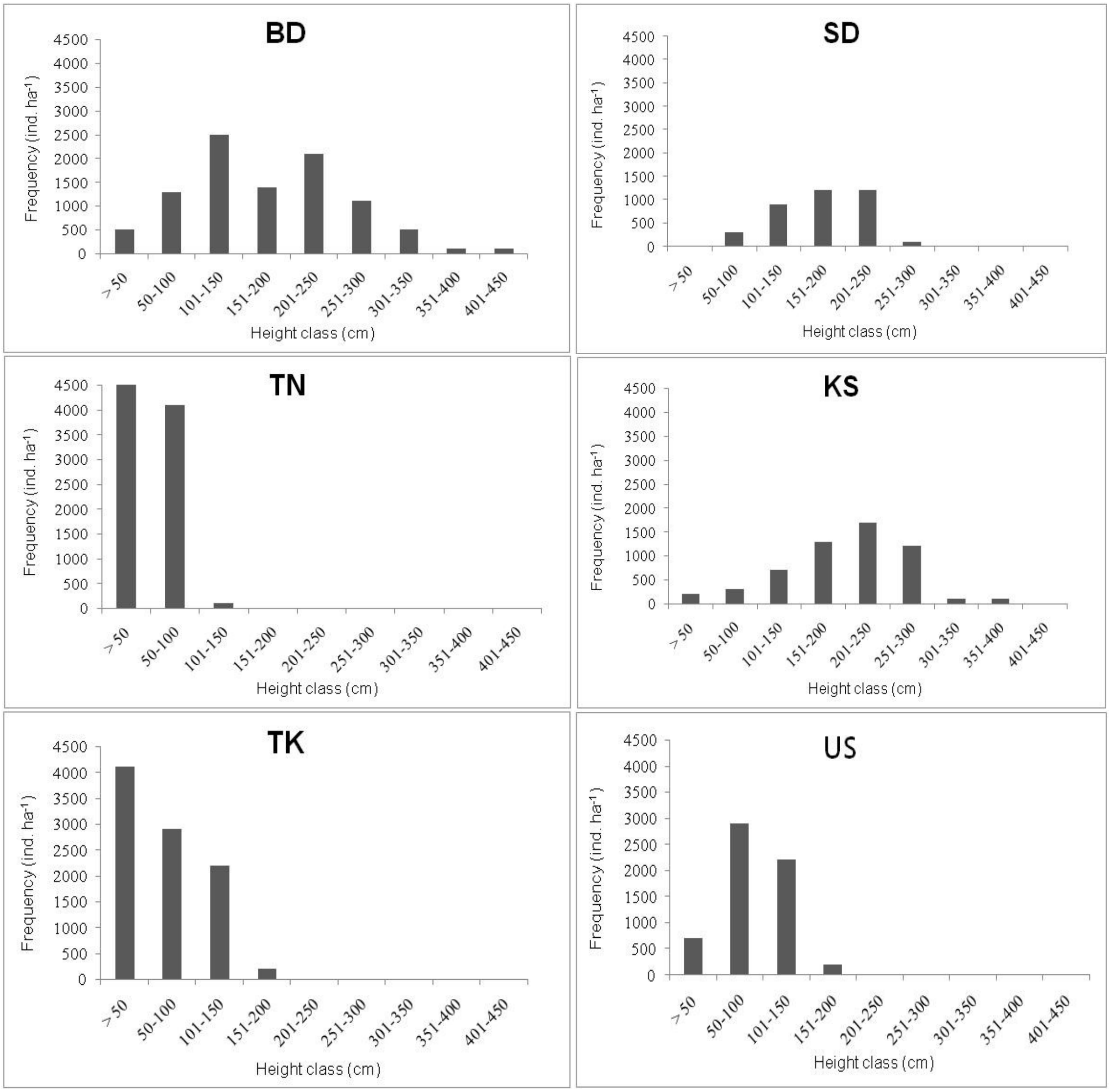


**Figure 2.** Frequency distribution of sapling height in plots

distribution map indicates there is an irregularity of frequency by height classes, which was caused by high differentiation in height growth. From the frequency distribution map we were able to observe a normal distribution by height classes in US, BD, SD, KS stands (Figure. 2). Nevertheless, the mean diameter ranged between 0.87 ± 0.63 cm (TN) and 5.16 ± 1.22 cm (SD). Figure 3 indicates that both the height and radial growth performance have a similar growth trend, which is characterized by a regular increase of annual growth. We found that the height and radial growth rates of saplings were very low during the first years after germination. However, after 5 years, the Scots pine seedlings and saplings achieved a higher growth rate in open conditions. In connection with large differences between stands in understory density and growth rate, the mean basal area also differed (*F=2.75, P=0,122*) between 1.31 $m^2$ $ha^{-1}$ (TN) and 16.67 $m^2$ $ha^{-1}$ (KS) and the mean volume varied (*F=16.58, P=0.002*) from 0.18 $m^3$ $ha^{-1}$ (TN) to 14.78 $m^3$ $ha^{-1}$ (KS) (Table 2).

The figures (Figure. 3) of height and radial growth performance demonstrate that the growth rate of understory saplings in Scots pine steadily increases with age. The fastest radial growth was observed in SD (3682 ind. $ha^{-1}$) and in other stands radial growth kept at the same level. At the same time, height growth obtained

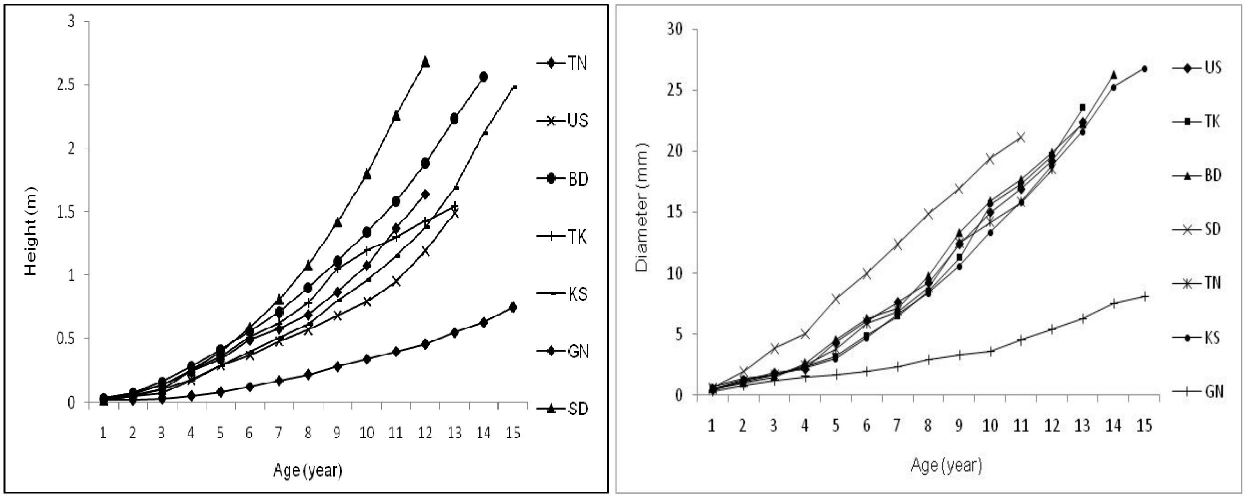


**Figure 3.** Height and radial growth of saplings

similar tendency as in radial growth, while the fastest height growth was observed in KS with understory density 5611 individuals $ha^{-1}$ and slowest in TN with density 21306 individuals $ha^{-1}$. Therefore, the differences in height growth rate between stands regularly grow depending on understory density.

## DISCUSSION AND CONCLUSION

of natural regeneration in Scots pine is that it has an ability to germinate easily in poorly drained forests. The seedling and sapling density of Scots pine is dependent on canopy cover, soil moisture and less in closed stands with ground vegetation (Noémie Gaudio et al., 2011). Orlander and Karlsson (2000) highlighted the main advantages of naturally regenerated forests are better plant establishment and high seedling densities. In this study, we identified the high variation of understory density can be explained by the intensity of logging and sufficiency of parent trees. The highest density was observed in TN, where we calculated 21306 individuals $ha^{-1}$ and a logging intensity of 13.2% and the lowest in the control stand GN with 2700 individuals $ha^{-1}$ and no previous logging activity (Table 1). Furthermore, we concluded that there is a high potential for natural regeneration in Scots pine forests after moderate logging (we suggest less than 80%). The higher sapling densities were observed in stands with logging intensities of 60.5%, 86.5%, and 79.2% in TK, BD and US, respectively (Table 1). All logged stands were observed with greater sapling densities than the control stand GN. We did not find a strong relationship between the understory density and the number of parent trees. Cameron and Ives (1997) found a

Natural regeneration is an important process for the replacement of existing tree stands (David Scott et al., 2000). Scientists have reported that the success of natural regeneration is dependent on a number of factors including a sufficient number of parent trees with proper fruiting capacity, suitable status of seedbed, favorable stand microclimate and climate conditions (Noémie Gaudio et al., 2011; Heithecker and Halpern, 2006). We found that in the study region natural regeneration of Scots pine has occurred in the past 15 years. One of the specific qualities weak correlation between sapling density and canopy openness. Initial densities of saplings were very high in Scots pine stands and much higher than the ground vegetation. The response in terms of the height of saplings clearly indicates the reproduction capacity of the site over the last 15 years, as pines in the logged areas attain a mean height of 249.7 ± 67.3 cm (KS) by the age of 10.45 ± 1.32 (SD) (Table 2). Ruha and Varmola (1997) asserted that the height positions are primarily established during the first 5-10 years and might be determined even by the height growth of the first years. In the case presented here, the stability of height positions is favored by the homogeneity and high density of the saplings. Light is assumed as the most limiting factor, which influences the pine sapling growth in temperate forests, and the height dimension of pine saplings controls the potential of growth and annual increment in the stand (Canham et al., 1994; Schmidt, 2005; Serdar Carus, 2004.). Our predicting model of growth of naturally regenerated saplings of Scots pine in logged forests of West Khentii found a correlation between stem height and diameter growth. We developed the following linear equation, where coefficient of determination is $R^2$=0.856 (Figure. 4).

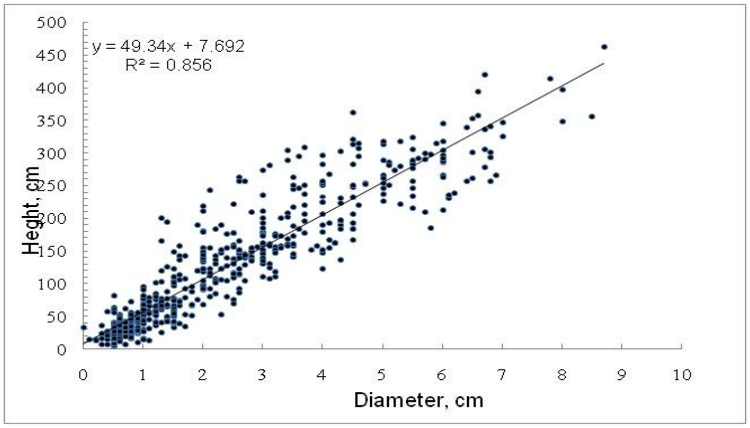


**Figure 4.** Correlation between sapling height and diameter in stands

**Table 4.** Statistical characteristics of crown diameter of saplings in Scots pine stands.

| Variables | Sample plots | | | | | | |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII |
| Mean | 58.23 | 44.38 | 73.35 | 114.4 | 14.24 | 102.37 | 25.61 |
| Maximum | 95.2 | 107.1 | 190.0 | 165,9 | 60.7 | 191.7 | 48.7 |
| Minimum | 20.4 | 21.2 | 10.6 | 53,1 | 2.3 | 25.6 | 13.8 |
| Median | 60.5 | 45.3 | 70.5 | 120.3 | 11.7 | 100.4 | 22.8 |
| Standard deviation | 19.82 | 21.28 | 35.76 | 28.38 | 9.34 | 41.71 | 18.45 |
| Standard error | 2.56 | 2.11 | 3.61 | 4.66 | 0.64 | 5,57 | 2.87 |
| Variation | 392.6 | 453.17 | 1279 | 805.9 | 87.41 | 1739 | 820.7 |

$y = 0.493x+0.076$ (Eq. 1)

Scots pine, as a light-demanding tree species, tends to grow best in an open or light canopy (Henman, 1961). Our findings demonstrated that canopy openness leads to a height and radial growth increase of saplings in logged stands. In general, we conclude that the success of natural regeneration in our study area was rather good and the logging positively affected the regeneration density and sapling growth. The data related to sapling density in logged forests suggest that the natural regeneration capacity in Scots pine forests is highly dependent on logging intensity and sufficiency of parent trees in logged forests. Meanwhile, the findings show that low intensity logging stands had greater regeneration density than in high intensity ones. Hyppönen *et al.* (2005) also found a good relationship between pine sapling height and age. They reported that the height reached by pine seedlings in their scarce forest stands in Finland was 2.5 m at 15 years old, whereas in our study, the height reached by pine saplings at 10.45 ± 1.32 years was 221.9 ± 51.2 cm (SD) (Table 2). Differentiation between individuals increases with time, which is caused by limitation of growing space, shortcomings of solar radiation and intensive crown closure for individuals in stands (Coomes and Grubb, 2000; Canham et al., 1994). Our crown measurements in the understory indicate significant differences (*F=16.58, P=0.002*) in crown diameters, not only within a stand, but also between stands (Table 4). The mean crown diameters were found as follows: US was 58.23 ± 19.82 cm (max 95.2 cm and min 20.4 cm), TK 44.38 ± 21.28 cm (max 107.1 cm and min 21.2 cm), BD 73.35 ± 35.76 cm (max 190.0 cm and min 10.6 cm), SD 114.4 ± 28.38 cm (max 165.9 cm and min 53.1 cm), TN 14.24 ± 9.34 cm (max 60.7 cm and min 2.3 cm), KS 102.37 ± 41.71 cm (max 191.7 cm and min 25.6 cm) and GN 25.61 ± 18.45 cm (max 48.7 cm and min 13.8 cm)(Table 3). Sven Wagner et al. (2011) recommended cutting treatments are predominantly designed to create growing space for natural regeneration. Consequently, there exists a great need for proper thinning aimed at reducing competition for growing space and creating optimum growing conditions in stands. Site qualities including soil fertility and climatic conditions are also important factors which influence sapling growth and annual increment, which has already been demonstrated in other studies (Kneeshaw *et al*., 2006; Balandier *et al*., 2007). Our findings confirm the high adaptation and survival of seedlings and saplings of Scots pine in semi-arid climatic conditions and well-drained sandy soils in Northern Mongolia.

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