Silvicultural Efficiency of the Thinning Efficiency of *Pinus sylvestris* L. Plantation in the Dry Subzone of Northern Kazakhstan Steppes

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Abstract

Aim of study: Thinning efficiency after 18 years of cutting at the Scots pine (*Pinus sylvestris* L.) plantations, in the subzone of the dry grass steppe, were examined.

Area of study: On 45-year-old Scots pine plantations on the territory of the state enterprise "ZhasylAimak" in Nur-Sultan city in the Northern Kazakhstan.

Material and methods: The plantations were established by high density planting (13,300 seedlings/ha) of 2-year old seedlings. The planting was carried out on forest-suitable soils. To assess the silvicultural efficiency of the thinning in the plantation, the coefficient of growth tension or a complex estimated figure (CEF) was used.

Main results: The research confirm that Scots pine plantations can be established in the subzone of dry fescue feather-grass steppe (*Festuca valesiaca-Stipetum capillatae* Sillinger 1930). The maximum silvicultural effect of thinning was achieved with three steps. In the 1st step of the thinning of the forest, 10-15 years old trees are cut down. Trees with over-developed crown are also cut down. The 2nd step is made in 25-30 years with thinning intensity of 25% by stock. The 3rd step is made in 40-50 years in a uniform way.

Highlights: In the harsh climatic conditions of Northern Kazakhstan steppe, deciduous trees and shrubs begin to age and die much earlier than the long-lived Scots pine.

Keywords: *Pinus sylvestris*, Plantation, Thinning, Forest productivity, Steppe

Kuzey Kazakistan Steplerinin Kuru Altzonlarındaki Sarıçam Plantasyonlarında Aralamanın Etkinliği

Öz

Çalışmanın amacı: Step vejetasyonun kuru-alt bölgesindeki Sarıçam (*Pinus sylvestris* L.) plantasyonlarında aralamanın 18 yıl sonraki etkinliği incelenmiştir.

Çalışma alanı: Kuzey Kazakistan'ın Nur-Sultan şehrindeki "Zhasyl Aimak" devlet işletmesi arazisinin 45 yaşındaki sarıçam plantasyonları.

Materyal ve yöntem: Plantasyon, yüksek yoğunlukta dikilen (13300 fidan/ha) 2 yaşlı fidanlar ile tesis edildi. Dikim, uygun orman toprakları üzerinde gerçekleştirildi. Aralamanın, plantasyondaki silvikültürel etkinliğini değerlendirmek için büyüme gerilim katsayısı veya karmaşık tahmini rakam kullanılmıştır (CEF)

Temel sonuçlar: Araştırma sonuçları, Kuzey Kazakistan'ın kuru çayır bozkırlarının alt bölgesinde sarıçam plantasyonlarının oluşturulabileceğini teyid etmektedir. Aralamanın maksimum silvikültürel etkisi üç aşamada elde edilmiştir. Aralamanın 1. aşaması; aşırı tepe gelişimli ağaçlar ile 10-15 yıllık kuru-ölü ağaçların kesilmesidir. Aralamanın 2. adımı, 25-30 yaşlarında servetin %25'nin çıkarılmasıdır. 3. aşama ise 40-50 yaşlarında uniform bir şekilde yapılır.

Önemli vurgular: Kuzey Kazakistan'ın sert iklim koşullarında; yaprak döken ağaçlar ve çalılar uzun ömürlü sarıçamdan çok daha erken yaşlanmaya ve ölmeye başlarlar.

Anahtar kelimeler: Sarıçam, Plantasyon, Aralama, Orman verimliliği, Step

Introduction

Afforestations on xeric soil conditions are very difficult to establish and properly grow due to harsh climatic conditions (Kabanov et al., 2018). The seedlings have to fight against moisture deficiency and high competition with natural steppe vegetation. The specifics of the terrain and soil-forming rocks form a wide variety of soil types in the research area. The main limiting factors affecting the growth and development of plants are the capacity of the fresh soil horizon accessible to roots and the depth of saline soil layers. Soils are subject to salinization in large areas. All soils in the region are divided into four groups: suitable for forest plant growth (9 types of soil), limited suitable for forest plant growth (12 types of soil), conditionally suitable for forest plant growth (5 types of soil) and absolutely unsuitable for forest plant growth (4 types of soil). This region is characterized by a mosaic of soils (Kabanova et al., 2017). Soil mosaic is a frequent change of different types of soil on the same territory, the soil conditions of which may differ dramatically in the possibility of plant growth. In the research area, there is a dominance of soils with a high degree of salinity. The latter makes it necessary to observe a number of features in the establishment of forest stands. In particular, they are established primarily in areas with forest-suitable soils, and to combat both grassy vegetation and minimize agrotechnical treatment. The plantations are established with a high planting density, which ensures rapid closure of the crowns of the trees. However, the high planting density causes the need for temporary felling of maintenance to clean up potential waste, reduce fire risk and moisture transpiration by trees (Lagergrena et al., 2008; Kazuhiko et al., 2013; Ruano et al., 2013; Gavinet et al., 2015; Boczon et al., 2016). Timofeev & Georgievski (1957) denote that for various purposes, improvement thinning can be used as a main silvicultural method of cultivation of healthy and highly productive forests. Unfortunately, data on the modes of thinning cuttings in the plantations of the steppe zone in the scientific literature is highly insufficient, and in Scots pine plantations of the subzone of the dry fescue feather-grass steppe of Northern Kazakhstan they are simply absent. This point determined the direction of the research.

Taking into account the great value and increase in demand for Scots pine wood, the importance of the further cultivation of this species become more visible in local forests. The recent forest inventory data indicates a significant change of distribution of Scots pine plantations, more than that of commercial less valued species aspen and birch in Kazakhstan. Furthermore, nowadays in economic environment it becomes more urgent to find ways of optimizing silvicultural and economic indicators of improvement felling for Kazakhstan (Ebel et al., 2019). The aim of this research is to develop a regime of thinning in Scots pine (*Pinus sylvestris* L.) plantation subzone dry fescue feather-grass steppe of Northern Kazakhstan.

Material and Methods

The Scots pine plantations were established by high density planting of 2-year-old bare root seedlings (13,300 seedlings·ha^{-1}) to effectively create a forest environment. The planting was carried out on forest-suitable soils in the subzone of dry fescue feather-grass steppe. The vegetation of the site is represented by halophytic steppe community dominated by fescue (*Festuca valesiaca* Schleich. ex Gaudin) and feather-grass (*Stipa capillata* L.), i.e., *Festuca valesiaca-Stipetum capillatae* Sillinger 1930. Site conditions are characterized by harsh climatic conditions. Trees lack moisture in the soil and experience competition from steppe vegetation at the young stage. The soils in dry subzone of fescue feather-grass steppes experience prolonged periods of dry conditions, resulting in low moisture availability, negatively impacting the growth of many plants.

We have researched two pine plantations sites. The first is represented by permanent inventory plots №15-18, and the second is represented by permanent inventory plots №5 and №7. Both sites are similar in forest plantation development and care technology. The sites differ only by the age of the stands. In the first site -the artificial pine stands, the age is 43 years, and in the second site it is 44 years. The research was carried out by the method of permanent inventory plots (PIP)

using generally accepted and widely tested methods (Paivinen & Yli-Kojola, 1989). The original planting scheme was used. Scots pine was planted in 9-12 rows. After the pine tree, 3 rows of elm (*Ulmus pumila* L.) were planted. After the elm, 1 row of honeysuckle (*Lonicera tatarica* L.) was planted. This design of forest plantations allows to evenly place the winter precipitation. The supply of winter moisture allowed to reduce the fire risk and ensure good survival of plants.

The research was carried out 18 years after the experimental thinning on 45-year-old Scots pine plantations. The pine plantations were planted on the territory of the state enterprise "Zhasyl Aimak" in Nur-Sultan city (Figure 1). The investigation area is located in the subzone of the dry fescue feather-grass steppe in the Northern Kazakhstan.

Figure 1. Geographical location of the study area

The research was carried out in the arid conditions of the dry feather grass-fescue steppe of Northern Kazakhstan. The climate of Northern Kazakhstan is sharply continental and dry. The air temperature varies sharply from - 37.2 °C in winter to 44 °C in summer. The area is characterized by insufficient precipitation of 302 mm per year. It should be particularly noted that the evaporation rate during the growing season is 700 mm. In these harsh natural and climatic conditions, afforestations provide conditions for the formation of new types of landscapes and increases biological diversity. The research on the effectiveness of afforestation has been carried out on a regular basis since 2011.

Previously, the soil was plowed completely. Trees were planted by hand in a row. On the first site (permanent inventory plot №15-18) pine planting was carried out according to the following scheme: 9 rows of pine were alternated with strips of 3 rows of elm (*Ulmus pumila* L.), limited by rows of honeysuckle (*Lonicera tatarica* L.). At permanent inventory plot №17 strips of pine were presented in 12 rows. At permanent inventory plot №16, the pines were planted in 13 rows and separated by deciduous strips similar to those planted at permanent inventory plot №15 and 18 (Figure 2). The broadleaf strip consisted of 2 rows of honeysuckle and 3 rows of elm.

On the second site (permanent inventory plot №5 and 7) pine was planted in 9 rows. The broadleaf strip consisted of 5 rows of elm.
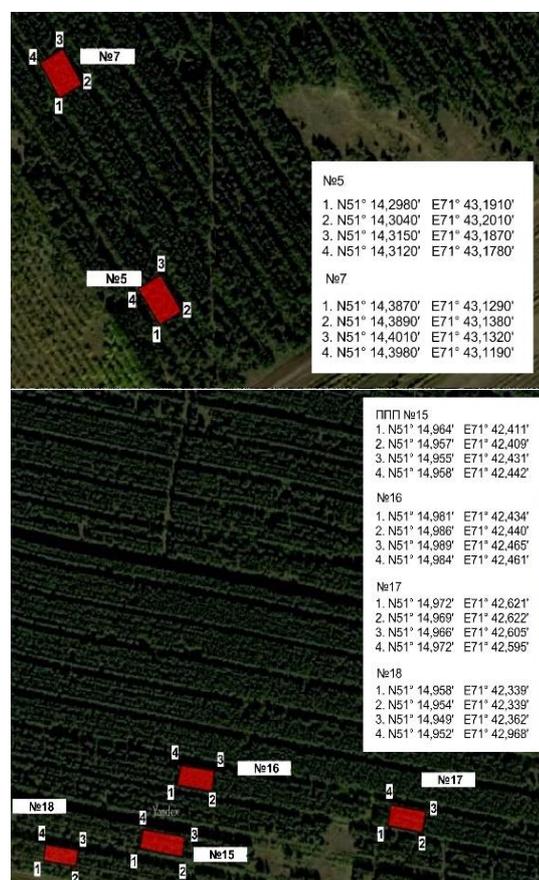
Figure 2. The permanent inventory plots

The width of the rows in both sections was 1.5 m. The distance between the seedlings in the row was 0.5 m. The experimental data were obtained on inventory plots in pine stands after thinning. Experimental thinning was carried out to research the forestry efficiency of nurturing for the pine plantations. Strips of broadleaf species in pine

plantations contributed to a more uniform distribution of winter precipitation over the area. Deciduous plantations perform the task of fire barriers. In other words; the use of deciduous strips provides fire resistance of pine monocultures. In addition, the fall of foliage contributed to the improvement of soil fertility.

To assess the silvicultural efficiency of cleaning cuts in the pine plantation, we used the coefficient of tension of growth or a complex estimated figure (CEF), which characterizes the state of the stand (Dancheva & Zalesov, 2016).

Complex estimated figure is defined by ratio indicator of the average tree height of the stand to its basal area at a height of 1.3 m. In addition to the inventory component, the complex estimated figure indicator has also hydro-physical component that shows the value of tree stem volume served by moisture per unit area of its cross-sectional area (cm/cm^2).

Complex estimated figure of the special stand is calculated as follows:

$$CEF = \frac{H \bullet 100}{G_{1,3}} = \frac{H \bullet 100}{\pi \bullet d_m^2 / 4}$$

CEF: complex estimated figure (growing tension coefficient), cm·cm^{-2};
H: the average forest stand height, m;
d_m: the average forest stand diameter at breast height (1.3 m), cm;
G: the area that is occupied by the cross-section of tree trunk of the average tree at the height of 1,3 m, cm^2;
π: mathematical constant equal to 3.14.

Complex estimated figures in the same forest conditions depends primarily on the stand density and age. The higher the numerical value of the complex estimated figure, the lower resistance of the forest stand.

Results and Discussion

The results had shown that the pine plantation can be cultivated on the soils in the subzone of dry fescue feather-grass steppe of Northern Kazakhstan (Table 1).

Table 1. Main forest inventory indicators of Scots pine stands

| PIP | Species composition | Average | | | Stand density, individuals per 1 ha | Basal area, m^2·ha^{-1} | Stand density index | Wood stock, m^3·ha^{-1} | Site index |
		Age, years	Height, m	Diameter at breast height (1.3 m), cm					
15		43	14.3	15.1	3000	53.54	1.5	292	II
16	Pure Scots pine	43	13.2	12.5	3917	47.69	1.4	245	II
17		43	10.1	12.8	3183	40.95	1.4	208	III
18		43	13.6	16.6	2117	45.84	1.4	257	II
5		44	16.9	18.9	1500	42.26	1.1	247	I
7		44	14.4	16.1	2367	48.44	1.5	268	II

PIP: Permanent Inventory Plot

High density planting of the pine seedlings provided fast canopy closure of the plantation. Thus, delay of thinning was explained by the following reasons. Since mixing was not carried out in the rows, there was no need in the species composition care. In addition, the high density of formed pine plantations ensured the formation of the forest environment, eliminating the need of silvicultural treatment, contributed to a better clearance of the trunks from branch timber and differentiation in height and diameter. The latter is very important because high

density natural forest stands of the Kazakh forest sites often die from the weak differentiation of trees in the extreme drought years. Thinning is necessary to increase their drought resistance, as evidenced by research in other regions with a lack of moisture (Giuggiola et al., 2013; Sánchez-Salguero et al., 2013; Yurtseven et al., 2018).

The first stage of logging was carried out at the age of 25 and this allowed to reduce the cost of their implementation, since some of the wood from logging was sold. This is explained by the fact that even in the

investigation area the wood from thinning is not used for sale. Thinning over the age of 25 offers wood for commercial use, and this is confirmed by many researchers (Mäkinen & Isomäki, 2004; Elfving, 2010; Bose et al., 2018).

Realization of the first step thinning had certain technological difficulties. At high density of growing stock, the most of trees left for growing could be damaged in the process of cutting and skidding (Jablonski & Stempski, 2018). It is recommended not to apply uniform thinning over the area. It is necessary to apply a linear method of thinning to minimize the number of damaged trees. According to Melekhov (2005), the linear method thinning has several disadvantages. In particular, it is likely to leave diseased and oppressed trees in rows that are not assigned to thinning. It is also possible to cut down the best trees in the assigned row for cutting.

The advantages of linear thinning include ease of work. Trees intended for thinning are not marked, so it is very simple to cutting. Cutting of trees is carried out not on the wall of the forest, but along the portage on the already fallen trees. This minimizes the risk of damage of reserved for growing trees. An empty strip 3 m wide is formed after cutting down the row. This strip can be used as a skidding corridor and a place where cleaning is performed from cutting residues. This corridor makes it possible to create mineralized bands that prevent forest fire.

Silvicultural care of the line method of the thinning will consist of the reduction of stand density and increase of solar radiation on the assimilative organs of reserved for growing trees by diffused or reflected sunlight. In addition to this, as it was noted previously, dead trees cleaning leads to the breaking of dry branches, which in combination with a reduction of soil combustible materials increases the resiliance of thinned stands against wild fire.

Despite of the delay of the first step thinning, thinned pine plantations had a positive effect on forest inventory indicators of the pine plantation. The positive effect of thinning at both sites showed increase main forest inventory indicators of stands, such as the height, average diameter at breast height (1.3 m) and wood stock (Table 2). According to some studies, changing the density of planting does not increase growth in the average height of the stand (Malenko, 1980; Eker & Ozcelik, 2017), but on the other side some scientists say that changing of the fullness and density of planting may increase the growth in height (Smirnov, 1970; Hasenauer et al., 1997; Zeide, 2001; Mehtatalo et al., 2014), and some authors consider that greatest increase in height is inherent in forest stands with the optimum density (Pamfilov, 1951; Keles et al., 2009). Makarenko & Mukanov (2002) states that the change in the density of plantation in Scots pine forests of older age do not have a significant impact on the value of growth of the average tree height; in the thickened stands these indicators have a positive impact on the increase in growth in height, though not in all cases.

Table 2. Forest inventory indicators of Scots pine plantation 18 years after thinning

PIP	Species composition	The intensity of thinning, %	Average height, m %	Average diameter at breast height (1.3 m), cm, %	Stand density, individuals per 1 ha, %	Basal area, $m^2 \cdot ha^{-1}$ %	Wood stock, $m^3 \cdot ha^{-1}$ %
			Site №1				
17		0	10.1	12.8	3183	40.95	208
			100	100	100	100	100
16	Pure Scots Pine	10	13.2	12.5	3917	47.69	245
			130.7	97.7	123,1	116.5	117.8
15		25	14.3	15.1	3000	53.54	292
			141.6	118.0	94,3	130.7	140.4
18		25	13.6	16.6	2117	45.84	257
			134.6	130.9	66.5	111.9	123.6

(Table 2. Continued)

PIP	Species composition	The intensity of thinning, %	Average height, m %	Average diameter at breast height (1.3 m), cm, %	Stand density, individuals per 1 ha, %	Basal area, m²·ha⁻¹ %	Wood stock, m³·ha⁻¹ %
			Site №2				
7	Pure Scots Pine	0	14.4	16.1	2367	48.44	268
			100	100	100	100	100
5		25	16.9	18.9	1500	42.26	247
			117.4	117.4	63.4	87.2	92.2

PIP: Permanent Inventory Plot

It is natural that most of permanent inventory plots implemented with thinning have decreased density. However, the reduction of density is not proportional to the intensity of thinning, and in the variant with 10% intensity of cut in permanent inventory plot №16, the thickness of grown stands after 18 years after thinning was even higher than in the controlling permanent inventory plot. Figures 3 and 4 show images of pine plantations after thinning and without thinning.

Figure 3. Permanent inventory plot №15 18 years after thinning with an intensity of 25%

Figure 4. Permanent inventory plot №17 without thinning

The best silvicultural effect was achieved on permanent inventory plot №15, where after 18 years after thinning the growing wood stock at the age of 43 years was 292 m³·ha⁻¹ and was 40.4% more high than in the controlling permanent inventory plot. In this case, the stand density on the permanent inventory plot №15 was three thousand individuals·ha⁻¹ at the time of the research.

At the site №2, growing wood stock on the controlling permanent inventory plot №7 was 7.8 % higher than in the permanent inventory plot, implemented with thinning of 25% intensity 18 years ago. Pine stand with implemented thinning has stand density of 1.5 thousand individuals·ha⁻¹ at the time of research, and higher values of height and diameter than in the controlling permanent inventory plot. Reduction of stand density increases the average size of trees, even with line method thinning. The latter is interesting because thinning, made by line method thinning directly during or as a result of cuts, do not change the values of average height and diameter as opposed to the equal felling system performed thinning by the lagged behind in growth and the tallest trees. The increase in average height and diameter after thinning, performed by line method thinning felling is a result of growth in the stands after cut.

As a result of the research, it was found that for majority of permanent inventory plots the complex estimated figures value varies from 6.03 to 7.99 cm·cm⁻². This value is optimal or close to optimal values. The only exception is the permanent inventory plot №16 where complex estimated figures value reaches 10.76 cm·cm⁻².

This research confirm that the complex estimated figure is an objective indicator of

the resistance pine plantations. Increase of complex estimated figure above the optimum value highlights the need for the implementation of thinning or other silvicultural measures aimed to reducing the growth of tension. At the research permanent inventory plots (№15-18, №5 and №7) only pine stands permanent inventory plot №16 with a stand density of 3917 individuals·ha^{-1} require thinning. At the rest permanent inventory plots stand density is much lower and there is no need of next procedure of thinning. More precisely, thinning on the rest pine plantations will not pursue the task of reducing the stand density, but it will be harvesting of dead wood and irreversibly oppressed trees. Thinning should be carried out at a low intensity.

A large number of scientific papers are devoted to the analysis of economic efficiency and silvicultural thinning (Timofeev & Georgievski, 1957; Smirnov, 1970; Izuyminski, 1970; Davydov, 1971; Sennov, 1984; Zalesov, 1986; Zalesov 1988; Zalesov & Luganski, 1989; Chibisov, 1992, Zhang et al., 1997; Bonyad, 2006; Verschuyl et al., 2011). All researchers have noted a positive change does not affect only quality but also quantity indicators stand after thinning. Changing the density and structure of the stand after thinning, improving commodity structure, increases the stability of the stand against the adverse effects of wind and snow. Thinning contribute to an increase in radial growth of trees. In dense forest stands, the ratio of height and diameter is violated, so trees often break down by wind storm or a heavy snow load. After logging, the diameter of trees left for rearing increases, which allows the trees to be resistant to damage by wind and snow (Smirnov, 1970; Izuyminski, 1970; Davydov, 1971; Sennov, 1977; Sennov, 1999; Zalesov & Luganski, 1989; Sohn et al., 2016).

Optimal values of complex estimated figures for Scots pine stands of the south-east of the European part of Russia are as follows: in stands of up to 20 years: 15 - 25; 20 to 30 years: 10 - 18; 40 to 70 years: 5 - 8, and more than 100 years: 2 - 3 cm·cm^{-2} (Iskakov et al., 2013).

Conclusions

The results of this research are summarized as follows:

1. Plantation forests of Scots pine in the conditions of dry fescue feather-grass steppe (*Festuca valesiaca - Stipetum capillatae* Sillinger 1930) should be preferably established on soils potentially suitable for the wood production. Planting pine in arid conditions should be carried out with high density in order to reduce silvicultural treatment.

2. Thinning enables to form pine plantations with a wood stock to 292 m^3 · ha^{-1} at the age of 43 years.

3. The maximum silvicultural effect is achieved with three methods thinning of the plantation forest. The first step of thinning is made in 10-15 years for the purpose of cleaning of withered trees and trees with excessively developed crown. The second steps of thinning are made in 25-30 years with an intensity of 25% in a linear way. The third steps of thinning are planned at the age of 40-50 years. When thinning, dry dead trees and irreversibly oppressed trees are removed.

References

Boczon, A., Dudzinska, M. & Kowalska, A. (2016). Effect of thinning on evaporation of Scots pine forest. *Applied Ecology and Environmental Research*, 14, 367-379.

Bonyad, A. (2006). Silvicultural thinning intensity effects on increasing the growth of planted loblolly pine (*Pinus taeda* L.) stands in Northern Iran. *Taiwan Journal of Forest Science*, 21(3), 317-326.

Bose, A. K., Weiskittel, A., Kuehne, C., Wagner, R. G., Turnblom, E. & Burkhart, H. E. (2018). Tree-level growth and survival following commercial thinning of four major softwood species in North America. *Forest Ecology and Management,* 427, 355-364.

Chibisov, G. A. (1992). Thinning of forest in the European North, silvicultural and biological bases and zonal typological programs. Thinning of forests in the European North,

Kastamonu Uni., Orman Fakültesi Dergisi, 2020, 20(3): 220-228   Zalesov et al.

Kastamonu Univ., Journal of Forestry Faculty

silvicultural and biological framework and zonal-typological program. St-P.: Synopsis of diss.dr.agr.sc., 41p.

Dancheva A.V. & Zalesov S.V. (2016). The use of an integrated assessment indicator in assessing the state of recreational pine forests in the Bayanaul State National Natural Park (BSNNP). Bulletin of the Altai State Agricultural University (Vestnik Altayskogo gosudarstvennogo agrarnogo universiteta), 7(141), 51-61.

Davydov, A. V. (1971). Forest thinning. - M., Timber Industry, 184p.

Ebel, A. V., Ebel, Y. I., Zalesov, S. V. & Ayan, S. (2019). The effects of different ıntensity of thinning on the development in Scots pine (Pinus sylvestris L.) stands in Kazakh Uplands. Alınteri J. of Agr. Sci., 34(2), 182-187.

Eker, M. & Ozcelik, R. (2017). Estimating recoverable fuel wood biomass from small diameter trees in brutian pine (Pinus brutia ten.) stands. Fresenius Environmental Bulletin, 25(12), 8286-8297.

Elfving, B. (2010). Natural mortality in thinning and fertilisation experiments with pine and spruce in Sweden. Forest Ecology and Management, 260 (3), 353-360.

Gavinet J., Vilagrosa A., Chirino E., Granados M., Vallejo R. & Prevosto B. (2015). Hardwood seedling establishment below Aleppo pine depends on thinning intensity in two Mediterranean sites. Annals of Forest Science. 72(8), 999-1008.

Giuggiola, A., Bugmann, H., Zingg, A., Dobbertin, M. & Rigling, A. (2013). Reduction of stand density increases drought resistance in xeric Scots pine forests. Forest Ecology and Management, 310, 827-835.

Hasenauer, H., Burkhart, H. E. & Amateis, R. L. (1997). Basal area development in thinned and unthinned loblolly pine plantations. Canadian Journal of Forest Research, 27(2), 265-271.

Iskakov S. I., Zhorabekova Z. T. & Yelemesov M. M. (2013). The current state of artificial pine plantations in the belt forests of the Irtysh region. Proceedings of the International Scientific-practical Conference "Development of a green economy and the preservation of biological diversity" in Schuchinsk Kazakhstan, 8-10 October 2013, 117-123.

Izuyminski, P. P. (1970). Influence of improvement felling on the growth of plantings. Forestry, 2, 23-26.

Jablonski, A. & Stempski, W. (2018). Damage to trees from wood extraction in motor-manual wood harvesting technologies in thinning in pine stands. Baltic Forestry, 24(2), 313-320.

Kabanov, S., Filatov, V., Eskov, D., Samsonov, E. & Zaigralova, G. (2018). Resistance of pure and mixed coniferous forest stands in the conditions of the southern forest steppe. Journal of Pharmaceutical Sciences and Research, 10, 964-968.

Kabanova, S., Rakhimzhanov, A. & Danchenko, M. (2017). The creation of green zone of astana city: history, current state and prospects. Forestry Engineering Journal, 6(2), 16-22.

Kazuhiko, M., Hajime S., Hiroyuki T., Hirokazu K. & Minoru F. (2013). Thinning effect on height and radial growth of Pinus thunbergii Parlat. trees with special reference to trunk slenderness in a matured coastal forest in Hokkaido, Japan. Journal of Forest Research, 18(6), 475-481.

Keles, S, Baskent, E. & Kadiogullari, A. (2009). Orman Amenajman Planlarının Simülasyon Tabanlı Planlanması: Kavramsal Çerçeve. Kastamonu University Journal of Forestry Faculty, 9(2), 136-145.

Lagergrena, F., Lankreijera, H., Kucerab, J., Ciencialac, E., Moldera, M. & Lindrotha, A. (2008). Thinning effects on pine-spruce forest transpiration in central Sweden. Forest Ecology and Management, 255(7), 2312–2323.

Makarenko, A. A. & Mukanov, B. M. (2002). Improvement felling in pine trees of Kazakhstan. Almaty: Bastau.

Mäkinen, H. & Isomäki, A. (2004). Thinning intensity and growth of Scots pine stands in Finland. Forest Ecology and Management, 201(2-3), 311-325.

Malenko, A. A. (1980). Influence of improvement felling on the number and fractional composition of defoliation (mortality). Shchuchinsk: KazSRIF, 78-81 p.

Melekhov, I. S. (2005). Forestry, textbook, 3-rd edition, revised and supplemented. Moscow state forest university, Moscow.

Mehtatalo, L., Peltola, H., Kilpelainen, A. & Ikonen, V. P. (2014). The response of basal area growth of scots pine to thinning: A longitudinal analysis of tree- specific series using a nonlinear mixed-effects model. Forest Science, 60(4), 636-644.

Paivinen, R. & Yli-Kojola, H. 1989. Permanent sample plots in large-area forest inventory. Silva Fenn, 23(22), 43-252.

Pamfilov, V. V. (1951). Influence of thinning plantations on physical and mechanical properties of wood at the southern border of the forest-steppe zone-Works of Bryansk forestry institute.

Ruano, I., Rodríguez-García, E. & Bravo, F. (2013). Effects of pre-commercial thinning on

growth and reproduction in post-fire regeneration of *Pinus halepensis* Mill. *Annals of Forest Science*, 70(4), 357-366.

Sánchez-Salguero, R., Camarero, J. J., Dobbertin, M., Fernández-Cancio, Á., Vilà-Cabrera, A., Manzanedo, R. D. & Navarro-Cerrillo, R. M. (2013). Contrasting vulnerability and resilience to drought-induced decline of densely planted vs. natural rear-edge *Pinus nigra* forests. *Forest Ecology and Management,* 310, 956-967.

Sennov, S. N. (1977). Improvement felling of forests. - M.: Timber industry, 160p.

Sennov, S. N. (1984). Forest tending: ecological basis. - M., Timber industry, 128p.

Sennov, S. N. (1999)**.** The results of 60 years' observations of the natural dynamics of the forest- SPb: SPbSRIF, 98p.

Smirnov, N. T. (1970). Ten years' experience of improvement felling in Ilmen Reserve- Sverdlovsk: *The Ural forests and their management*. 5, 171-175.

Sohn, J. A., Hartig, F., Kohler, M., Huss, J. & Bauhus, J. (2016). Heavy and frequent thinning promotes drought adaptation in *Pinus sylvestris* forests. *Ecological Applications,* 26(7) 2190-2205.

Timofeev, V.P. & Georgievski, N.P. (1957). Density and layering of forest stands as the condition of their productivity. Goslestehizdat.

Verschuyl, J., Riffell, S., Miller, D. & Wigley, T. B. (2011). Biodiversity response to intensive biomass production from forest thinning in North American forests - A meta-analysis. *Forest Ecology and Management,* 261(2) 221-232.

Yurtseven, I., Serengil, Y., Gökbulak, F., Şengönül, K., Ozhan, S., Kılıç, U., Uygur, B., & Ozçelik, M. S. (2018). Results of a paired catchment analysis of forest thinning in Turkey in relation to forest management options. *Science of the Total Environment*, 618, 785-792.

Zalesov, S. V. (1986). *Increment felling in pine forests of southern taiga subzone of the Ural*. Sverdlovsk; Diss. Cand. agr. sc. 215p.

Zalesov, S. V. (1988). Influence of increment felling on the weight and productivity of assimilation apparatus of pine. - Sverdlovsk; The Ural forests and their management. 14, 152-160.

Zalesov, S. V. & Luganski, N. A. (1989). *Increment felling in pine forests of the Ural. Sverdlovsk.* Publishing House of Ural University, 128p.

Zeide, B. (2001). Thinning and growth: A full turnaround. *Journal of Forestry*, 99(1), 20-26.

Zhang, S., Burkhart, H. E. & Amateis, R. L. (1997). The influence of thinning on tree height and diameter relationships in loblolly pine plantations. *Southern Journal of Applied Forestry,* 21(4), 199-205.