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Influence of Improvement Cutting on Decorativeness and Vitality of Maple (Acer negundo L.), Elm (Ulmus pumila L.), Willow (Salix alba L.) and Loch Narrow-Leaved (Elaeagnus angustifolia L.) Young Trees Under Dry Steppe Conditions

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Abstract

The creation of artificial plantings in the conditions of the kovylno-tipchak steppe makes it possible to form long-lasting high-density and productive plantings, however, despite the accumulated knowledge, the rate of afforestation of the steppe is hindered by the fleeting or delayed death of plantings due to the effects of droughts. Fast-growing young trees become especially vulnerable in areas with deep groundwaters. The study was conducted in green zone of Astana, the capital of the Republic of Kazakhstan. The main value of the forests of the region lies in the creation of environmentally favorable environmental conditions, their performance of recreational, aesthetic, soil protection, erosion control, water protection, climate control and water regulation functions. Work on the study of the impact of improvement cutting on plantings of various formations in the green zone of the city of Nursultan has not been carried out before, which determines the scientific novelty of the project.

Keywords: Longevity of plantations, Improvement cutting, Thinning intensity, Decorative qualities, Sanitary condition

1. Introduction

Biodiversity is the main factor for sustainability of ecosystems. The problem of sustainability of tree and shrub plantations near large cities is relevant both for Kazakhstan and other countries (Aanderaa et al., 1996; Cadotte and McMahon, 2006; Sjöman et al., 2015; Cowett and Bassuk, 2017; Ghafari et al., 2020). There is currently industrial and public interest in Europe in further increased production of wood as a renewable resource. At the same time, green spaces should also be functional for ecological and socio-cultural values in forest landscapes (Alexander et al., 2019).

Forests have been used commercially for a long time in Sweden where the forestry and related industries continue to be an important part of economic life (Mattsson and Stridsberg, 1981). In the 1970s and early 1980s, there was the interest in moving from concept of forestry to concept of greater use of forests (Hytönen, 1995) and there was emphasis on management of forests adjacent to cities and districts that are used for recreation. However, it was not until the late 1980s that ideas for greater use of forest management, especially those relating to biodiversity, started having significant impact on Swedish forestry (Hytönen, 1995). In the 1990s, Sweden, more attention was paid to multi-purpose use of forests for social needs due to increased interest in urban forestry (Rydberg and Falck, 2000). In China, at the household level, studies have examined the impact of community forest management on the receipt of forestry products (Lu et al., 2018).

Experiments on improvement cutting in plantings of various breeds are carried out in many countries. Positive results of improvement cutting obtained in Lithuania (Juodvalkis and Kairiukstis, 2005), West Virginia (Miller et al., 2001), Canada (Moreau, et al., 2022), Turkiye (Unver et al., 2017), in Iran at the Emamzadeh-Abdullah experimental site (Hasani and Amani, 2004).

Plantings can be quite decorative only when the stands forming them are adapted to specific conditions. Increasing longevity of artificially created plantations within green zones of large cities is one of the most important and difficult problems of the modern forestry. The cultivation of plantings of optimal composition, creating environmentally favorable conditions of the urban environment and performing the functions assigned to them, requires regular forest maintenance.

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The cultivation of highly productive plantings from species with valuable commercial wood on the territory of the green zone of the city of Nur-Sultan, in the conditions of the kovyl-tipchak steppe is difficult, therefore preference is given to the species that are most adapted to these growing conditions (ash maple (*Acer negundo* L.), squat elm (*Ulmus pumila* L.), white willow (*Salix alba* L.), narrow-leaved loch (*Elaeagnus angustifolia* L.)).

As the plantings grow, it becomes necessary to carry out forest maintenance, primarily improvement cutting, which allows you to regulate the density of the plantings, the degree of closeness of the crowns, and, accordingly, to increase the area of nutrition of individual trees illumination, thereby improving the conditions of preservation and decorativeness. In this study, the purpose was to determine the effectiveness of improvement cutting in clean stands of ash-leaved maple (*A. negundo* L.), squat elm (*U. pumila* L.), white willow (*S. alba* L.), narrow-leaved loch (*E. angustifolia* L.) of 16-19 years of age in the green zone of the city of Nur-Sultan.

For the first time in this region, studies have been conducted to increase the decorative effect and improve the living condition of plantings throughout the green zone of the city of Nur-Sultan, in the conditions of the kovyl-tipchak steppe by methods of logging care. As a result of the research work, the main methodological approaches used in world practice have been applied.

2. Materials and Methods

2.1. Study Area

The studies were carried out within the territory of green zone of the city of Nur-Sultan, capital of the Republic of Kazakhstan, National State Enterprise (NSE) “Zhasyl Aimak” (Figure 1). Total area of NSE “Zhasyl Aimak” is 53984 hectares.

Artificial plantations created within the territory of NSE “Zhasyl Aimak” are important as they perform sanitary and hygienic functions, improve air features within the city of Nur-Sultan and settlements of green zone, protect them from strong winds, dry winds, dust storms and mitigate other unfavorable natural and climatic effects. In addition, artificial forests are intended for mass recreational purposes for the people. Therefore, the entire territory of the enterprise is assigned to the green zone.

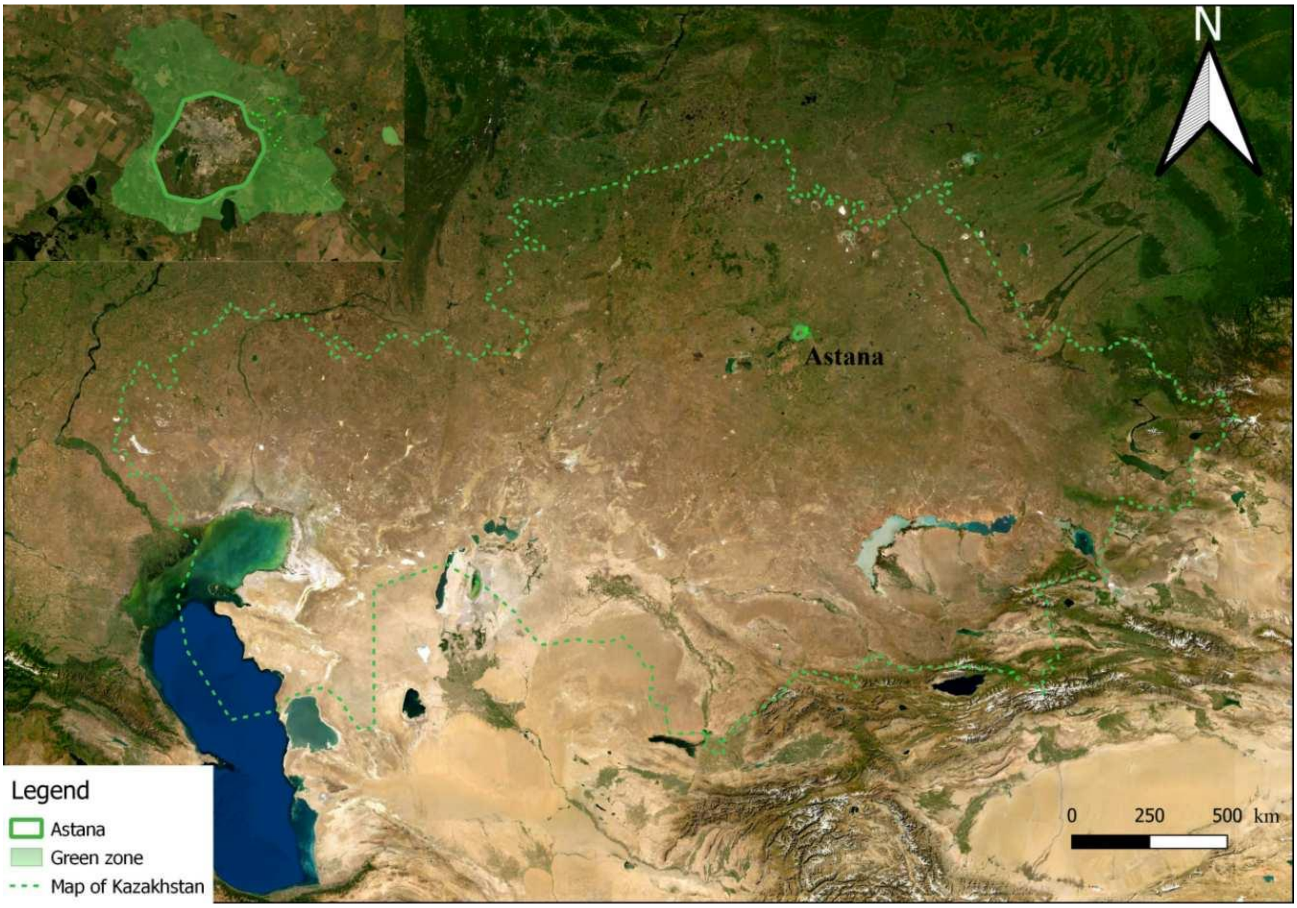

Figure 1. Location of the green zone of the city of Nur-Sultan

2.2. Natural and Climatic Conditions

Territory of the green zone of the city of Nur-Sultan is located in the steppe, in the subzone of dry fescue and feather grass steppes with sharply continental climate. It has very low level of humidity, severe winters with little snow, long term strong winds and sharp temperature changes during the day. Average annual air temperature is 1.4°C. Atmospheric droughts often occur during the warm season.

Average monthly values of relative air humidity reach their minimum (54-56%) values in May and June and maximum levels in the winter (83-84%). Low air humidity and high air temperature as result of frequent atmospheric droughts cause a decrease in soil moisture reserves to levels that are inaccessible for plants. Average annual wind speed is 3-5 m/s. Annual precipitation within the study area is 300 mm on average. Average snow depth is 25 cm. Average depth of soil freezing is 1.3 m (0.8-1.5 m). Thus, analysis of long-term meteorological data shows that the climate for the trees within the studied area is harsh. In the summer, evaporation levels severely exceed the amount of precipitation. So the conditions are considered to be dry. Dry periods are dangerous as there is dry windy weather with frequent dust storms at the end. Frosts also have negative impact on the stands as they come during periods of intensive growth of young shoots and the formation of crown buds.

As for relief, the territory of the green zone is a slightly undulating plain. In some locations, flatness is disturbed by hills and hilly heights in the northeastern direction. Such a variety of relief has a significant impact on formation of soils and makes soil cover very diverse. Deep subsoils are closely linked with geological structure and geomorphology of the territory. The most widespread are surface clay loams, sedentary and diluvial deposits. Saline deep subsoils caused salinization of significant areas of soil cover to certain degrees. In terms of salinity degree, the soils are divided into low, average, high and very high. There are large areas of alkali soils within the territory of the green zone in the northern and northeastern parts.

2.3. Selection and Planting of Growth Plots

All growth plots (GP) in improvement cutting are in Kyzylzhar Forestry, National State Enterprise “Zhasyl Aimak”. The area of the forestry is 12605 ha. Camera treatment of taxation materials of the forestry was carried out prior to the start of field works. Sites were selected for designation GPs and then a visual inspection and analysis of the state of growing plantations was carried out.

The test field were laid in the best preserved and in good condition areas, which were planned after a preliminary reconnaissance survey of artificial forest plantations. All PP (probability plots) were laid in accordance with the methodological recommendations for laying test areas for logging and establishing the taxation indicators of planting components (Sennov, 1972; Svalov, 1982; Dancheva and Zalesov, 2015; Bunkova et al., 2020).

When laying the PP, the following conditions were observed: all PP were laid retreating from quarterly glades, roads, cuttings, edges and other areas not covered with forest by at least 30 m, the size of the test sites, or rather each of the sites included in the PP, was set so that there were at least 150-200 trees on it. The shape of the test sections and their sections is rectangular. Picket posts were installed at the corners of all sections of the PP.

Coordinates of laid downs GPs were identified with the use of GPS navigator. Since all studied areas are forest plantations, year of planting and age of planting material were taken into account in order to determine the age (Table 1).

Table 1. Age indicators for forest plantations, stand composition and location of growth plots planted in Kyzylzhar Forestry of National State Enterprise “Zhasyl Aimak”

GP	Quarter	Allotment	Allotment Area (ha)	Stand Composition	Age (years)	GP coordinates
8	107	6	21,2	*Ulmus pumila* L.	18	N51.1480343 E71.6679939
9	107	6	21,2	*Ulmus pumila* L.	18	N51.1473874 E71.6694859
14	63	9	2,52	*Salix alba* L.	16	N51.2168590 E71.6889845
15	63	4	2,82	*Salix alba* L.	16	N51.2188180 E71.6899836
17	63	2	2,0	*Salix alba* L.	16	N51.2204116 E71.6899746
20	39	10	10,4	*Elaeagnus angustifolia* L.	18	N51.2412570 E71.6660649
21	38	7	15,0	*Acer negundo* L.	18	N51.2537729 E71.6583701
22	38	3	5,9	*Acer negundo* L.	18	N51.2545670 E71.6490136
24	57	11	2,8	*Acer negundo* L.	18	N51.2193879 E71.5922037
29	67	1	9,1	*Acer negundo* L.	18	N51.2039415 E71.6206435

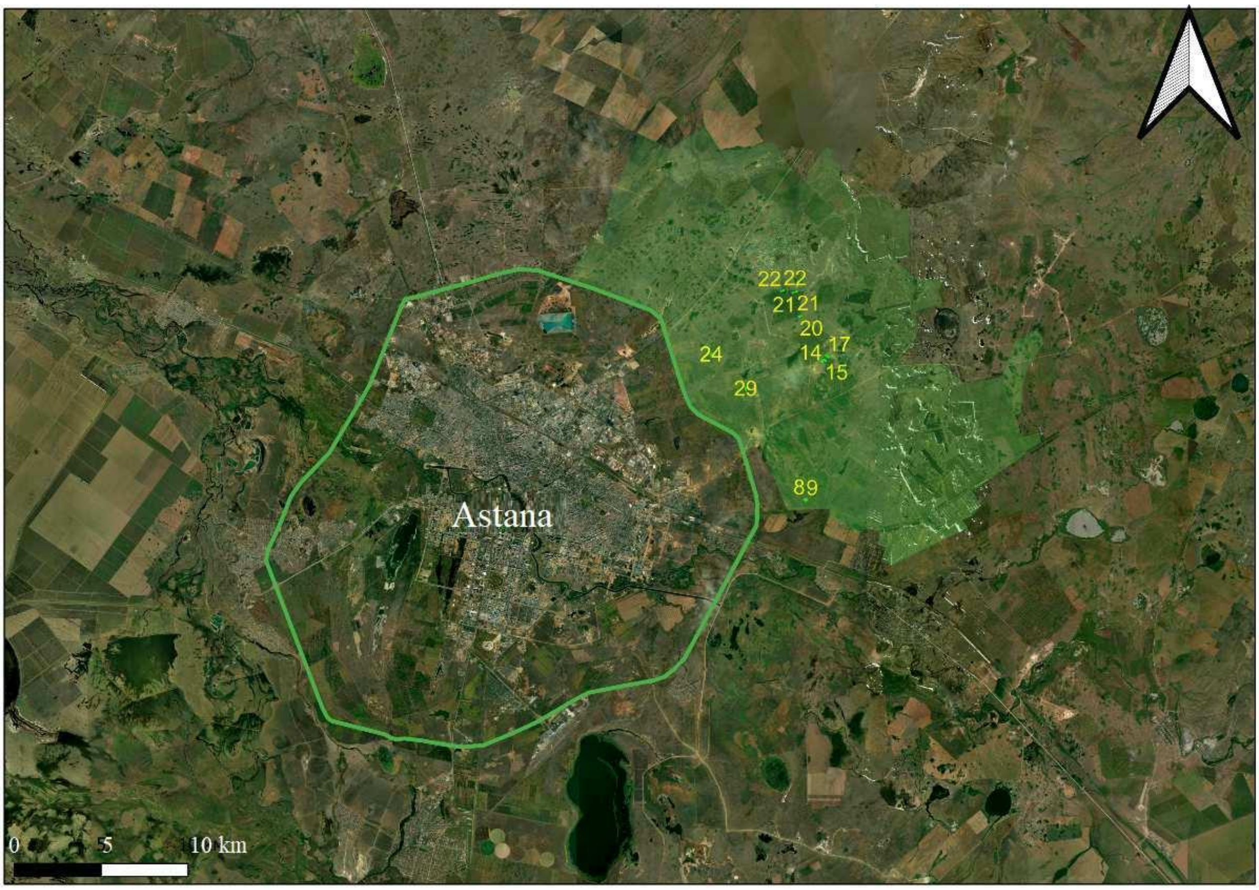

Figure 2. Map of growth plots

2.4. Assessment of Vitality

Trees that are subject to cutting were selected according to their vitality level. Calculation of vitality was carried out according to the method of V.A. Alekseev (1989) and the use of the following formula:

$$L_v = \frac{(100M_1+70M_2+40M_3+50M_4)}{\Sigma M} \quad (1)$$

where LV is relative vitality of forest stand that is calculated taking into account size of trees; M1 is stock of healthy trees at trial plot or per 1 ha, m3; M2, M3, M4 is stock of damaged (weakened), severely damaged and dying trees on trial plot or per 1 ha, respectively, m3; 100, 70, 40 and 50 are coefficients that reflect vitality of healthy, damaged, severely damaged and dying trees, %; ΣM is total stock of the wood in forest stand at growth plot or per 1 ha (including volume of dead wood), m3.

When Lv = 100-80%, vitality of forest stand is considered to be "healthy"; when it is 79-50%, forest stand is considered to be damaged (weakened), 49-20% is severely damaged (very weakened), and 19% and below is completely destroyed. On the laid down trial areas, three variants of improvement cutting were carried out with a different sample by the number of trees (sections B, C, D) and one control section was left without felling (section A) for comparative analysis.

2.5. Carrying Out Improvement Cutting

Care felling were performed in autumn period with the use of combined method (the cutting was carried out both lower and upper parts of the canopy) with various intensity of sampling expressed in percentage according to the number of all studied species. Low intensity is up to 15; medium is up to 35; high is up to 45%.

Complete enumeration of trees in GP sections was carried out according to forest elements, while diameters of trees were measured with caliper in two directions (N-S; W-E) with accuracy of 1 mm before and after clear cutting.

2.6. Assessment of Sanitary Condition and Decorativeness

Points of sanitary condition and decorativeness were calculated on the basis of categories for their condition (Lindeman, 2003) that was adjusted for scoring of trees of the green zone (Table 2).

Points for sanitary condition were calculated as arithmetic mean for points of all trees of each species. Then the points were added up for the plantings as a whole. For example, average points on sanitary condition of single-species plantation from all studied trees was calculated as follows:

$$(4 + 3 + 2 + 4 + 3 + 3) / 6 = 3.2 \quad (2)$$

Points on other indicators were calculated the same way (decorative qualities of trunk and crown). When there was a large number of a tree (shrubs) at the object of the study, each n-th tree was assessed for further statistical processing of data obtained by methods of small and large sampling (Dvoretsky, 1971).

Table 2. Categories of sanitary condition and decorativeness points

Tree category	Sign	Decorativeness points
Relatively healthy	No signs of deviation from normal development	4
Weak	There are mottles on the leaves, damages by leaf beetles (up to 25%). Dying off of branches (up to 15%). There are water shoots, defects of non-parasitic origin on trunks (trunk is twisted or inclined, bark blaze, etc.)	3
Very weak	Damage to leaves by blotches, leaf-eating and sucking insects (up to 50%). Death of branches in the crown is up to 50%. Top drying. Numerous water shoots on trunk and young growth at the base of trunk. Dry sides, tumor cancer of branches and trunk.	2
Experience mortality	Damage to leaves by blotches, leaf-eating and sucking insects (up to 50%). Death of branches in the crown is up to 50%. Top drying. Numerous water shoots on trunk and young growth at the base of trunk. There are signs of fruiting pathogens on branches and trunk.	1
Dead standing trees	Leaves dried up but survived or fell prematurely. Small twigs and bark remained. Trunk and branches are inhabited by stem pests.	0

Assessment of decorativeness for tree crowns within the plantation was carried out according to 4-points system: 4 points are trees that have clearly expressed general shape of the crown having original structure (including unusual shape); 3 points are trees that have retained their structure and have well-formed trunks and crown branches; 2 points are trees with noticeable oppression and deformed crowns, they have dry shoots and branches, trunks are damaged; 1 point are trees that are severely depressed, branches die off by 60...70%, crowns are severely deformed, trunks are severely damaged. Average points for decorativeness of plantations were calculated the same way as for the sanitary condition.

3. Results

When carrying out field works, inventory index was collected. Vitality and decorative points within control sections and working sections after care felling were taken into account: figures 3a, 3b Siberian elm (*U. pumila* L.), figures 4a, 4b maple ash (*A. negundo* L.), figures 5a, 5b white willow (*S. alba* L.), figures 6a, 6b narrow-leaved loch (*E. angustifolia* L.).

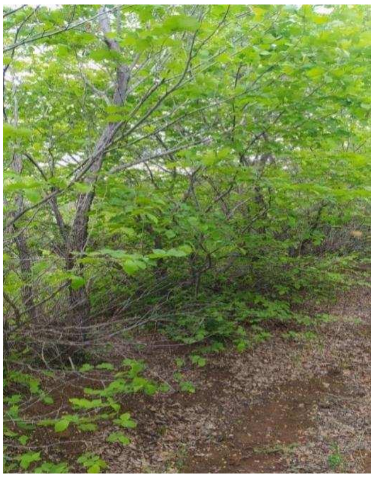

Figure 3a. Control section of pure plantings for Siberian elm *(U. pumila L.)*

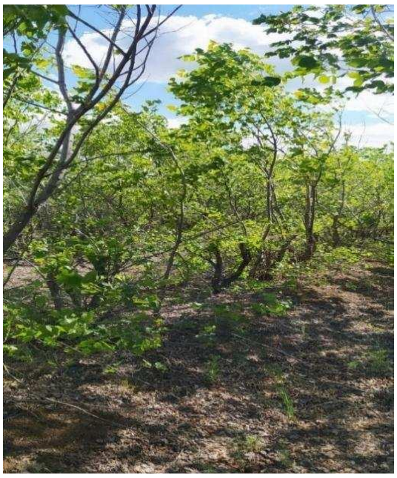

Figure 3b. Working section of pure plantings for Siberian elm (*U. pumila* L.)

Figure 4a. Control section of pure plantings for maple ash (*A. negundo* L.)

Figure 4b. Working section of pure plantings for maple ash (*A. negundo* L.)

Figure 5a. Control section of pure plantings for white willow (*S. alba* L.)

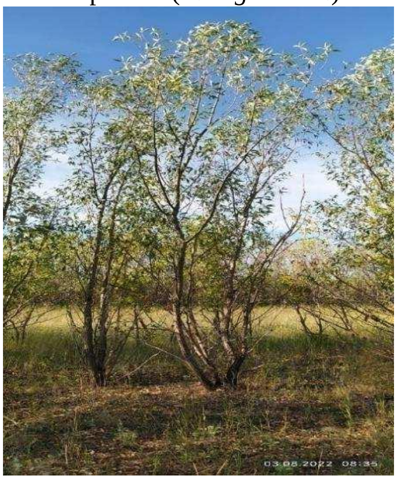

Figure 5b. Working section of pure plantings for white willow (*S. alba* L.)

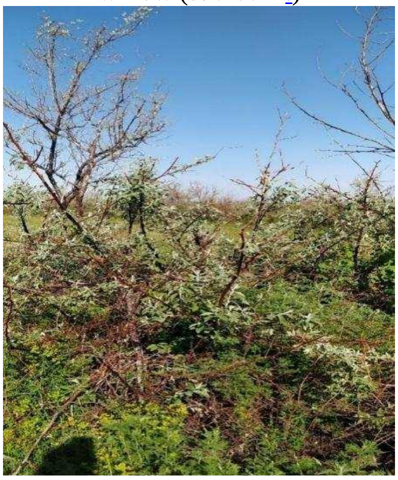

Figure 6a. Control site of clean plantings of narrow-leaved loch (*E. angustifolia* L.)

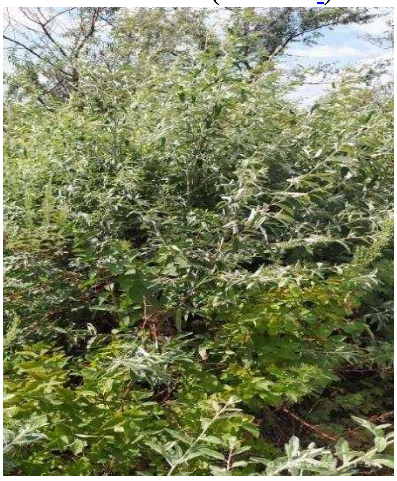

Figure 6b. Working section of clean plantings of narrow-leaved loch (*E. angustifolia* L.)

For the analysis in Table 3, we have performed the distribution of PP sections by the intensity of care felling. In Table 3, we distributed sections of GPs according to intensity of clean cutting for analysis purposes. Data shown in Table 3 and Figures 7-10 allows us to analyze the total number of trees and number of planting spots (because of multi-stemming, several trees may grow from one planting spot) after care felling, expressed in ha, as well as average diameter after felling (taking into account all trees), assessment of vitality in percentage and decorativeness point after care felling.

Analysis of Table 3 and Figure 7 shows that for plantations with maple ash (*A. negundo* L.), maximum number of planting spots after care felling and total number of trunks on 1 ha are observed in control sections; the largest average diameter after care cutting is in sections with low intensity; maximum values of vitality are on sections with low intensity and decorativeness points are on sections with low and average intensity of care felling.

Table 3. Indicators for sections exposed to care felling with various intensity (numerator is average value, denominator is minimum and maximum values for a group of sections)

Intensity of clean cutting	Index for growth plot and section*	Number of planting areas after cutting, ha spec.	Total number of trunks, ha spec.	Average diameter after cutting (with consideration of all trunks)	Assessment of vitality for forest stands, %	Decorativeness points
Ulmus pumila L.						
Control without care	8-A, 9-A,	2297 1914-2680	5646 4571-6720	3,75 3,5-4,0	96,3 92,7-99,8	2,8 2,7-2,9
Low	9-B	1940 1940	4800 4800	4,5 4,5	97,4 97,4	2,8 2,8
Average	8-B, 8-C, 9-C	1626 1557-1720	3539 3157-3860	4,4 3,8-4,9	98,0 95,2-99,2	3,1 2,9-3,3
High	8-D, 9-D	1409 1357-1460	3376 3071-3680	4,6 4,2-4,9	98,2 96,6-99,8	3,2 3,0-3,3
Salix alba L.						
Control without care	14-A, 15-A, 17-A	1900 1460-2300	4710 2900-5950	5,1 4,1-5,6	84,8 83,2-85,9	2,8 2,3-3,3
Low	14-B, 15-B	1823 1420-2225	5120 3640-6600	5,3 5,0-5,6	91,5 87,8-95,1	3,5 3,0-3,9
Average	14-C, 14-D, 15-C, 15-D, 17-B, 17-C, 17-D	1499 1280-1825	4530 3280-6300	4,6 3,8-6,0	87,7 74,2-100,0	2,9 1,7-4,0
Elaeagnus angustifolia L.						
Control without care	20-A	1525	2825	3,2	58,2	2,2
Low	20-B	1325	3025	2,5	58,8	2,3
Average	20-C	1325	2200	2,5	85,7	2,6
High	20-D	800	1150	4,5	89,3	2,9
Acer negundo L.						
Control without care	21-A, 22-A, 24-A, 29-A	2144 1600-2600	3508 2180-4300	5,5 4,6-6,0	90,6 78,5-97,5	3,1 2,9-3,1
Low	21-B, 21-C, 22-B, 24-C, 29-B	1763 1540-2275	2999 2425-4325	6,5 5,4-7,7	93,2 84,9-96,6	3,2 3,1-3,4
Average	21-D, 22-C, 22-D, 24-B, 24-D, 29-C, 29-D	1595 1300-2033	3026 2175-4500	6,2 5,1-7,5	92,9 87,7-96,2	3,2 3,1-3,3

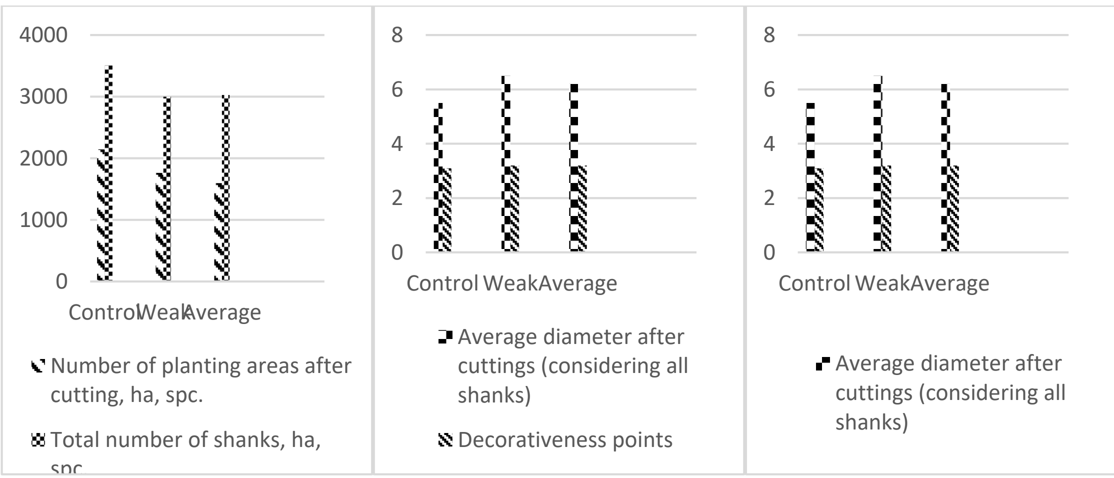

Figure 7. Maple ash (*A. negundo* L.). Indicators for sections exposed to care felling of various intensity - number of planting spots after clean cutting and care number of trunks, in ha; average diameter after care cutting; decorativeness points; assessment of vitality in percent

Minimum numbers of planting spots after care felling are observed in sections with average intensity and minimum total number of trunks per ha is in sections with low intensity; the lowest indicators of average diameter after care cutting are in control sections; the lowest vitality indicators and lowest decorativeness points are also in control sections.

Data in Table 3 and Figure 8 for Siberian elm (*U. pumila* L.) show that maximum numbers of planting spots after care felling and total number of trunks per 1 ha are observed in control sections and minimum values of the same indicators are observed in sections with high intensity of care felling. Maximum average diameters after clear cutting are in sections with high intensity and the minimums are in control sections. The lowest vitality indicators were control sections and lowest decorativeness points were in control sections and those with low intensity of care felling. The highest indicators for vitality and highest decorativeness points are in sections with high intensity.

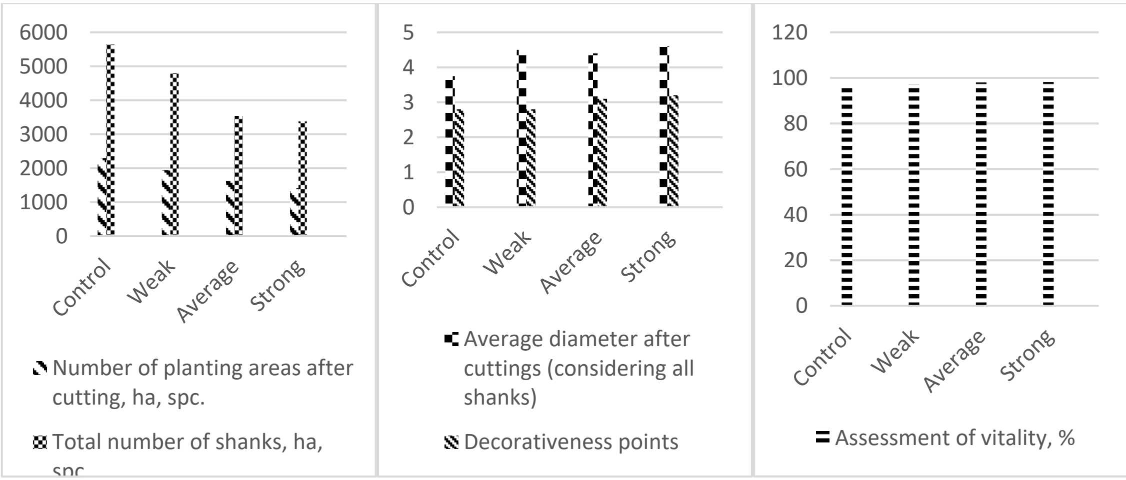

Figure 8. Siberian elm (*U. pumila* L.). Indicators for sections exposed to care felling of various intensity - number of planting spots after care cutting and total number of trunks, in ha; average diameter after care cutting; decorativeness points; assessment of vitality in percent

According to Table 3 and Figure 9 for white willow (S. alba L.), control sections have the maximum number of planting spots after care felling and section with low intensity of care felling has the largest number of trunks. The largest values of average diameter aftercare felling are also observed in sections with low intensity of care felling, and the lowest values are in sections with average intensity. The highest indicators of vitality and decorativeness points are in sections with low intensity and the lowest indicators are in control sections.

Collected data in Table 3 and Figure 10 for narrow-leaved loch (E. angustifolia L.) show that control sections have the largest number of planting spots after care felling and the largest number of trunks per hectare is in sections with low intensity of care felling, and minimum values of these indicators are in sections with high intensity. Maximum average diameters are observed in sections with high intensity, and the minimum ones are in sections with low and average intensity of care felling. The highest vitality indicators and highest decorativeness scores are observed in section with high intensity, and the lowest indicators are in control section.

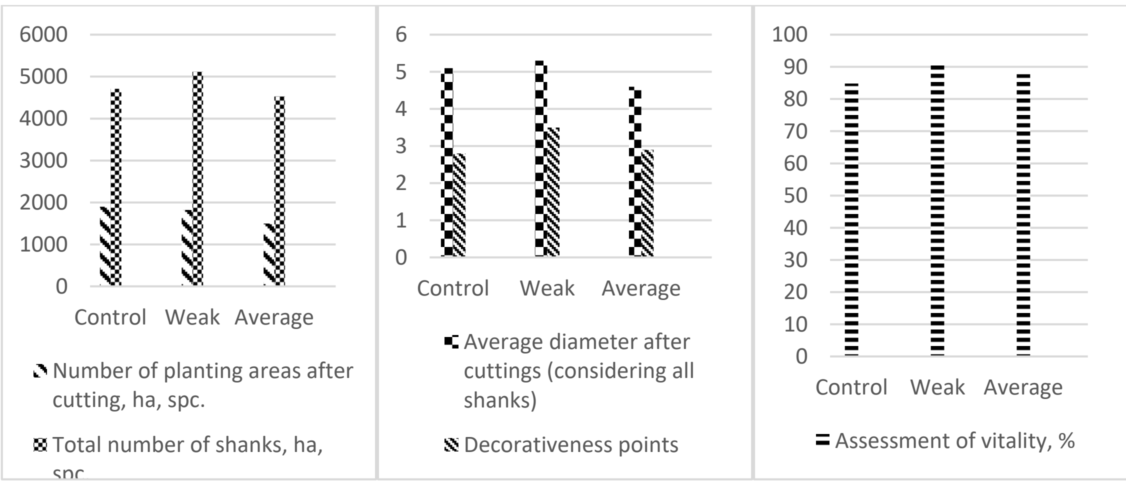

Figure 9. White willow (*S. alba* L.). Indicators for sections exposed to care felling of various intensity - number of planting spots after care felling and total number of trunks, in ha; average diameter after care felling; decorativeness points; assessment of vitality in percent

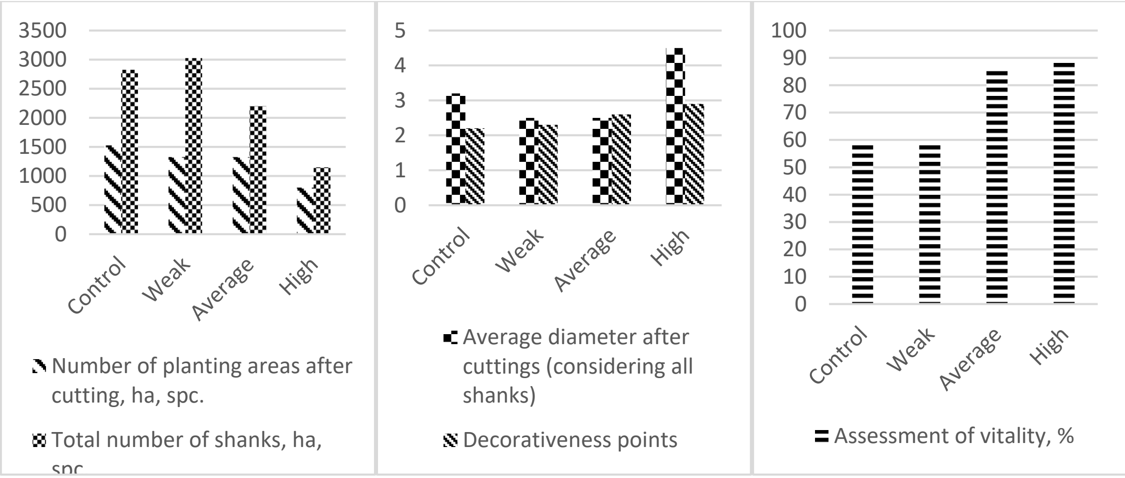

Figure 10. Narrow-leaved loch (*E. angustifolia* L.). Indicators for sections exposed to care felling of various intensity - number of planting spots after care felling and total number of trunks, in ha; average diameter after care felling; decorativeness points; assessment of vitality in percent

4. Discussion

In this paper, improvement cutting done in a broad-leaf secondary forest for recreational use, was appraised by a standard presented in this paper. This improvement cutting was done by the 'Forest for Safeguarding Living Environment Project (FSLEP)' in Gifu City. This standard, based on data collected in two plots of the study forest, shows correlations among the average DBHs of the trees remaining after cutting and other parameters of stand structure, when trees having a larger DBH in the descending order are given preference for saving over cutting. The other parameters are the STD of DBH, stand density, the number of species, the diversity index and the spatial pattern of trees. The average DBHs of the two plots after improvement cutting, were 8.7cm and 10.0cm respectively. The parameters of actual stands after cutting - except stand density - were bigger than those simulated by standards. Therefore, it may be concluded that this kind of improvement cutting enhances the variety of in-stand scenic view variation. Nevertheless, the spatial patter of remaining trees belonged to the Ca_1 type, both in the actual stands and the standard (Tsukamoto, 1995).

In Lithuania, experiments on thinning conducted for 10-60-year-old stands of ash, aspen, birch, oak, pine and spruce have shown increase in crown projection area of residual trees. Thinning also contributed to increase in diameter and height, especially in young stands, and increase in these indicators also positively correlated with intensity of thinning. The results show that a significant increase in volume is possible when the thinning is performed for young forest. For instance, 10-20-year-old stands of pine, birch and ash, or 10-30-year-old oak, aspen, and spruce (Juodvalkis, 2005).

It is well known that thinning may increase tree growth and use of wood volume in hardwood stands but the impact on tree quality and value is less likely to occur (Miller et al., 2001). There is strong evidence that thinning (especially if severe), reduces effects of drought and risk and severity of fire when burning or removing the ground wood. Thinning also increases the growth and vitality of abandoned trees and makes them less sensitive to eruptive insects and pathogens that can slow down their spread (Moreau et al., 2022).

At Emamzadeh-Abdullah experimental plot, thinning was performed for plantings of maple (Acer Velutinum Boiss). The results show that the effect of severe thinning on future growth rate of tree diameter, crown diameter, and slenderness coefficient was significantly greater than that of control thinning. As a result, potential for high quality of wood increased (Khasani and Amani, 2004).

According to experience on silvicultural efficiency of care cutting that is highlighted in the papers of Sennov (1987; 2005), Debkov (2020), Ebel et al. (2015) and others, certain methods were selected. It allows determining the effect of care felling on improving productivity of plantations and is the main direction for their study. However, in all of above mentioned papers, main purpose of thinning is to form highly productive plantations with maximum stock of high-quality wood.

Our work, relies on its outcomes, we propose fundamentally new approach to selection of trees for care felling. It is based on formation of plantations with high decorative properties, their safety by increasing feeding area of individual trees as suburban plantations also perform ecological functions and shall also be used for recreational purposes, and therefore, have to be attractive for city residents to visit. We propose silvicultural operations to include not the stock of stand (since obtaining marketable wood is not the final goal of growing suburban plantations), but density, that is, leaving such a number of trees on the site that will be provided with the necessary meal area and the area looks really nice.

Data obtained may be the basis of recommendations for optimizing care felling of artificial plantations for green areas created in under dry conditions of feather grass and fescue steppe.

5. Conclusions

Harsh forest conditions for woody plants within the studied area contribute to their short lifespan. The lifespan of trees and forest stands may be increased with logging felling. Intensity of care felling has a certain impact on safety and increased vitality of forest stands. Competition for light and provision of trees with moisture and nutrients depend on such felling. Care felling was carried out according to combined methods with various sampling of number of trees for all the studied species.

It has been experimentally proven that decrease in the number of planting spots and total number of trunks in the studied areas resulted in increase of the average diameter in the forest stand and also improved safety and decorativeness of plantations. Sanitary condition and decorative features take important place in formation and use of urban green areas. Sometimes unusual shape of trunk or even obvious “defect” of tree may be very decorative and be considered as “original structure” with 4 points.

As a result of the study, it was revealed that optimal intensity of care felling for plantations with maple ash (*A. negundo* L.) and white willow (*S. alba* L.) is low, for Siberian elm (*U. pumila* L.) and narrow-leaved loch (*E. angustifolia* L.) is high. This is all works with trees of 16-19 years old. Considering that the work on the study of care felling in artificial plantings of the sanitary protection zone has been started recently, it is necessary to continue conducting research on PP in order to further develop practical recommendations on care felling in arid conditions.

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