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MANAGEMENT OF FOREST PLANTATIONS OF SPECIAL PURPOSES IN THE ZONES OF THE MEDICAL SPAS OF SLATINA AND SERBIAN TOPLICA

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Abstract. *Forests provide important health benefits for people by affecting their physical, mental and social well-being. In order to create more favorable conditions for the functioning of health facilities such as spas and natural spas for the recovery and preventive protection of peoples health, forest cultures are often established in their immediate vicinity as special purpose forests. The goal of the work is to point out the importance of managing these forests, for achieving favorable effects on climatic, recreational, hygienic and aesthetic conditions. The object of research in this work are black pine (Pinus nigra Arnold) forest cultures established near the spas in Srpske Toplice and Slatina. The work method is based on the constant determination of the basic elements of the structure on permanent test surfaces. The null hypothesis about the absence of statistically significant differences in the basic elements of the stand structure was accepted at the significance level of p = 0.05. The results of the work show that management should be based on the silviculture and regulation of forest composition, retention and introduction of tree species with pronounced phytoncide properties and improvement of the visual effect of forests. By management, it is necessary to silviculture mixed deciduous-coniferous forests, which ensures their resistance to negative influences of biotic and abiotic factors. These forests should have a positive impact on air cleanliness, oxygen production, secretion of essential oils and exhibit phytoncide properties.*

Keywords: *Health, health facilities, silviculture, forest plantations*

Introduction

Forests have been a source of health since ancient times. They are producers of oxygen and carbon dioxide absorbents, producers of medicinal plants, healthy forest fruits from wild fruit trees, edible mushrooms and other products that play a significant role in human life and the environment. In order to ensure the benefits of special purpose forests, forests that have been managed in a special way have been set aside since ancient times [1]. The establishment of forest crops in the vicinity of

health resorts and spas is of great importance for the improvement of the multiple benefits functions of forests. The first division of forest functions and its evaluation was done by Prodan at the end of the 70s of the last century, and later expanded by his student Christmann at the end of the 80s [2]. A realistic and comprehensive evaluation of these functions is not easy because this evaluation must often be approached on the basis of relative relations to the primary function [3, 4]. Globally, in relation to the basic functions of forests, the following conditional division is usually performed: forests and forest plantations with a primary production function, followed by forests with a primary protective and sanitary-recreational function. Due to their health functions, forests are often artificially established in the immediate vicinity of health resorts. These are mostly stands of species that are rich in phytoncidal substances, such as black pine (*Pinus nigra* Arn.). The total area of these stands in the Republic of Srpska is 8,072.93 ha (about 16% of the total area of forests purposefully managed by the Public Enterprise "Forests of the Republic of Srpska"). The main constituent of phytoncides are monoterpenes, the characteristics of which depend on the type of trees, the season and meteorological elements [5]. The concentration of monoterpenes is higher in coniferous forests and on warmer days. Some of the best known representatives of monoterpenes is pinene, which is mostly in charge of the smell of coniferous trees, such as pines. Black pine is extremely rich in resin, which contains terpenes. The resin of the black pine tree is secreted in injured areas, and at high summer temperatures, the evaporation of terpenes is intense because they are volatile substances. In addition to resin, terpenes are found in the essential oil of needles in conifers, and each of these sources represents a separate system, since the resin channels of different plant organs are not connected to each other [6]. Pine needles contain 0.4 - 0.5% of essential oils, 29 monoterpenes (64.9% of cetine oils) dominated by α-pinene (42.66%) and ß-pinene (11.64%) [7]. The main function of forests in the vicinity of spas and natural spas (closed-type sanatoriums, convalescent homes, climatotherapy, baneotherapy, etc.) is health, which consists in the use of forests in the process of healing and recovery [8]. The goal of forest management from the aspect of such a health function is to create and maintain a forest that has a beneficial impact on the biological, hygienic, visual and aesthetic atmosphere. These atmospheres can be manifested through the construction of the so-called "educational trails" through which the natural, but also cultural and historical characteristics of the area are interpreted [9]. Areas in the vicinity of spas and natural spas, from the aspect of providing health functions, refer to forest areas of the park structure that does not enter the existing forest fund and health resort forests as typical forest areas with the role of fulfilling the healing function [10]. In these forests, a completely different way of management is carried out than in commercial forests, and it is a very responsible job that must meet the needs of health, function and improvement of the condition of these forests, especially if they are artificially established. During the management of these stands, efforts were made to adapt their structure to the optimal state, i.e. the normal distribution of the number of trees by thickness classes, which is the most favorable from the aspect of the development of these stands, especially in the first half of the rotation and at the time when the stands did not begin with natural regeneration and the formation of the subfloor. The initial hypothesis in this paper is that there are no statistically significant differences in terms

of the distribution of the number of trees by thickness classes between the actual and normal number, i.e. that management measures did not significantly affect the change in the thickness distribution of trees during the last two decades.

Material and methods

The research included two artificially established stands of black pine that are located in the immediate vicinity of the healing spas of Slatina and Srpske Toplice (Fig. 1).

Figure 1. Geographic location of sample plots

The stands were established for the purpose of developing the health function of forests. Based on the analysis of meteorological parameters from the meteorological station in Banja Luka for the period 1951-2022 according to the Thornthwait – Matter method (1956) [11], it can be stated that the climate during the year is predominantly moderately humid climate (B_3) with a climate index of 60 to 80. The growing season lasts an average of 197 days.

The Slatina Stand (SS): The stand is located within the forest park complex "Slatina", near the spa Slatina at an altitude of 200-210 meters. The dominant geological

substrate is the diabase corneal series on which distric cambisols (A – (B) – C profile type) and illimerized soils (A – B – C profile type) are dominantly formed. These are areas with very high production potential. Towards ecological and vegetation reionization of forests of Bosnia and Herzegovina [12] the stand is located within the Pannonian region, i.e. the northwestern Bosnian area. The stand is located in a wider area within the distribution zone of the climatogenic community of sessile oak and hornbeam (*Querco – Carpinetum* illyricum). With these forests, submontane beech forests alternate (*Fagetum submontanum*) In colder positions, beech and sessile forests occur in transitional habitats. The investigated stand was artificially established in 1950 and in forest management plans it belongs to the category of black pine forest crops. A volume of 655.46 m^3/ha was determined in the stand using FieldMap technology [13].

The Srpske Toplice Stand (ST): An artificially erected stand of black pine is located in the immediate vicinity of the Srpske Toplice spa, located at an altitude of 118 m. The stand is exposed to the west, and the slope of the terrain is from 8 to 12 degrees. The stand was erected by order of the Forestry Department of the Kingdom of the Ban's Administration, Vrbas Banovina Banja Luka, when it was pointed out that "the Jajce sides should be afforested with black pine seedlings" (records of the Forest Administration of the Vrbas Banovina, 1934). The total area of the stand is 24.22 ha. The stand is located on a dolomitic geological substrate on which brown soils (chalcoambisol) have developed. Carbonate rocks, including dolomite, belong to a smaller part of the flysch zone between Banja Luka and Kneževo. According to the ecological and vegetation reionization, the stand belongs to the Pripannonian area, the north-western Bosnian area and is located in an area that, according to potential vegetation, belongs to the climatogenic community of sessile oaks and hornbeam (*Querco – carpinetum illyricum*). However, the real vegetation on the object of research is an artificially raised stand of black pine, which is significantly weeded. In 2008, the volume of the stand was 537 m^3/ha at the first site class rating [14].

Data collection was carried out using the usual methods for permanent test areas in ST 2001, 2008, 2018, and for the SS stand in 2019. Permanent sample plots in the shape of squares measuring 20x20 m (ST 2001 and 2008), 30x30 m (ST 2018) and 100x100 m (SS 2019). The diameters of all trees on the sample plots were measured, and the assessment limit of 5.0 cm was used. Data processing was carried out using statistical and dendrometric methods. Descriptive statistics were used, and testing the significance of the differences between the theoretical model of the Gaussian curve (1), which is characteristic of single-age artificially based stands, and the empirical data of the frequency distribution of the number of trees by thickness classes, was performed using the χ^2 test (2) using empirical (Ns) and theoretical frequencies (Nt).

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}}\, e^{-\frac{(x-\mu)^2}{2\sigma^2}} \qquad (1)$$

$$\chi^2 = \frac{(N_s - N_t)^2}{N_t} \qquad (2)$$

Results and discussion

The basic indicators of stand structure refer to the elements that determine the volume of the stand and distribute it in space [15]. The structure of the stand in single-age stands changes during the development of the stands. Most often, the thickness distribution of the frequency of the number of trees is used to determine the structural structure of stands (Table 1). As a rule, this distribution has a flux similar to the Gaussian curve (the so-called normal distribution). In special-purpose stands, the tendency is to bring the actual distribution closer to normal, as this is one of the indicators of the stability of the stand and the fulfillment of multiple benefits functions of forests.

Table 1. Number of trees in sample plots

D (cm)	ST 2001 (400 m^2)		ST 2008 (400 m^2)		ST 2018 (900 m^2)		SS 2019 (10.000 m^2)	
	Ns	Nt	Ns	Nt	Ns	Nt	Ns	Nt
7.5								
12.5							1	0
17.5	1	1					4	2
22.5	6	4	1	1			9	6
27.5	4	6	2	3	7	5	7	14
32.5	7	7	9	6	12	9	24	24
37.5	4	4	3	6	10	11	30	33
42.5	2	1	3	2	7	8	43	35
47.5			1	1	2	4	25	28
52.5					1	1	16	17
57.5					1		11	8
62.5							1	3
Total	24	23	19	19	40	38	171	170

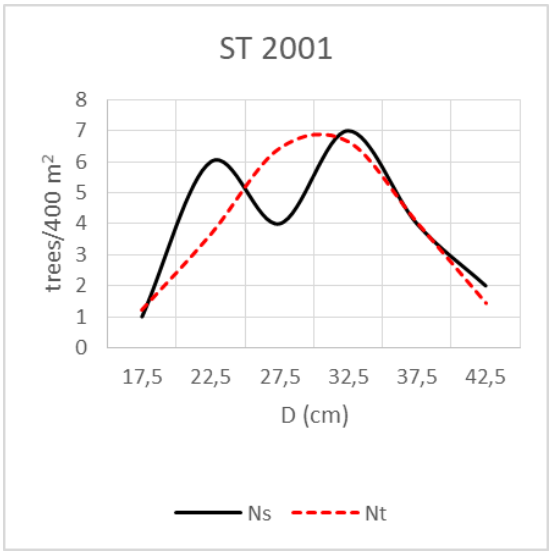
Ns – number of trees per sample area; Nt – theoretical number of trees

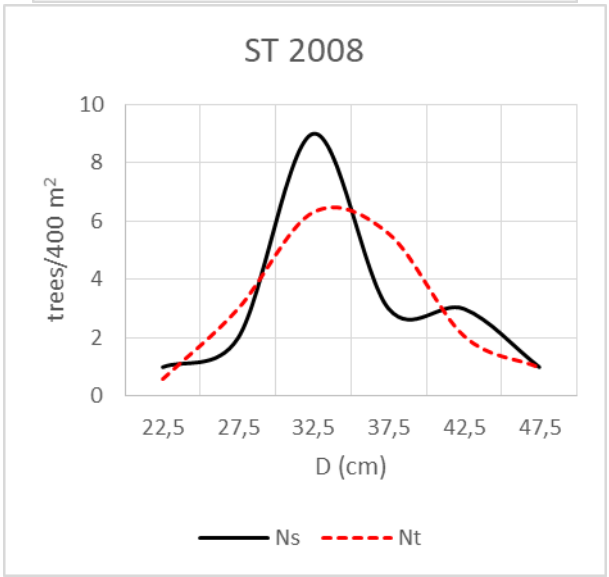
In the ST stand, in different years of the study, a slight to medium right (positive) asymmetry was found, in the ST SS stastoy, mean left (negative) asymmetry was determined. With the increase in the age of artificially established black pine stands and the increase in the diameter of the trees, the asymmetry of the distribution of trees by thickness classes is more pronounced, the volume of the stand moves to higher thickness classes, the ranges of diameter variation and standard deviation increase. Similar results were found in the study of black pine cultures on carbonate substrates in Bosnia [16]. The values of the flattening coefficients (kurtosis) show that only in the ST 2018 stand (Table 2) is the actual distribution of the number of trees more elongated than normal (Figure 2).

Table 2. Basic parameters of descriptive statistics

	ST 2001	ST 2008	ST 2018	SS 2019
Ns	24	18	40	171
Ds (cm)	30.29	34.28	36.80	40.89
Sd (cm)	6.86	5.38	7.29	9.68
CV (%)	22.63	15.69	19.80	23.67
α_3	0.017	0.198	0.808	-0.340
α_4	-0.732	-0.028	0.869	-0.002

Ds – diameter average; Sd – standard deviation; CV – coefficient of variation; α_3 - skewness; α_4 – kurtosis





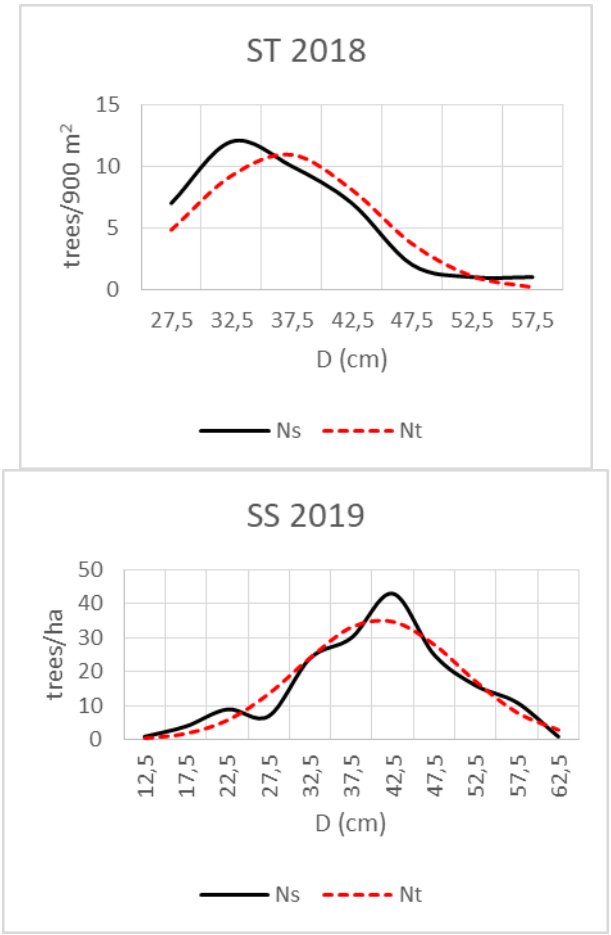


Figure 2. Distributions of trees per sample plots

The results of the χ^2 test show that the obtained values are 95% with probability and the corresponding degrees of freedom (*df*) lower than the tabular ones, so the null hypothesis that there are no statistically significant differences between the actual and theoretical distributions of the acceptance frequencies is accepted (Table 3). The obtained results show that the frequency distribution of the number of trees by thickness classes in the stands does not deviate significantly from the normal distribution. This can be considered as a consequence of management that is based on breeding and sanitary measures after damage of an abiotic nature with a maximum intensity of up to 10%.

Table 3. Results χ^2 of test

Sample plots	ST 2001	ST 2008	ST 2018	SS 2019
χ^2	1.6667	1.0909	2.1986	2.5724
d_f	1	1	1	5
$\chi^2_{(0,05;\ df)}$	3.8145	3.8145	3.8145	11.0705

A larger change in the structure of the ST stand is observed after the survey in 2018 (more pronounced asymmetry and coefficient of externality) because during August 2014, tree falls were formed in the stand after large amounts of precipitation (276.3 l/m², which is the second wettest month in Banja Luka since 1961).

Park forests are a special category of forests, in which the recreational function is a minor part of its overall social function. Usually this part of the forest is located in the immediate vicinity of the settlement [17]. The management of these forests should provide park arrangement with elements of infrastructure that meets the needs of active holidays of citizens and sanitary and hygienic conditions. In such forests, care measures are needed with the aim of growing healthy trees with an optimal slenderness coefficient (Kv = 90) to make the trees resistant to the negative effects of the wind. It is desirable that the composition of the forest be mixed, and that heliophilic and sciophilic tree species are represented at the same time. This condition is partially fulfilled in the ST stand because, in addition to black pine, there are also walnut trees (*Juglans regia* L) (48 trees/ha) in the stand, while there are no trees of other tree species except black pine trees in the SS stand. Therefore, it is necessary to treat the edges of stands by underplanting with decorative species of deciduous trees and shrubs of native species (*Quercus petraea* Matt. Liebl., *Prunus avium* L, *Tilia sp.* et al.). During the farming, the tallest, dominant trees, which are particularly attractive, are of great importance. Such trees have already been formed in both stands with a height of more than 30 m (120 trees/ha in ST and 97 trees in SS). By management, it is necessary to form trees with a crown length greater than 1/3 of the height of the trees. Needed by marked trees that have deformed crowns, poor vitality and damaged. Smaller tree biogroups are preferred, which create smaller areas with contrasting illumination, unusual habitus, different flowering times, leafing, fruit and flower shapes. These silviculture treatments are aimed at creating favorable conditions for treatment, rehabilitation and recovery. The silviculture prerequisites for the basic functions of these forests are the selection of the appropriate stand structure, the representation of trees that make up the natural composition of the forest, the separation of poorly overgrown areas whose degree of overgrowth is less than 0.3 normally overgrown stands, whereby forest care should be focused on increasing the number of tree species. The research stands do not meet the needs for mixed composition, and this is especially noticeable in the juveniles and the subfloor of the stands. Namely, a large weed infestation and a large amount of accumulated organic humus, which is difficult to decompose due to the brushes of black pine, do not allow the emergence of offspring. Future management should be focused on the creation of mixed deciduous-coniferous stands that have a positive effect on air purity

and oxygen production, air ionization, secretion of essential oils, and have a phytoncidal effect (pine, spruce, linden, elm, balsamna poplar) [10, 18] with the elimination of allergen-producing species (*etc*. *Populus* sp.). Recently, biotechnological methods have been used that make it possible to reduce the duration of the production period [19] especially in the forests. Preference should be given to those types of trees that allow the formation of healthy stands. The rotation and the regeneration period are extended in relation to the usual patrol lengths for certain tree species. Some species, such as birch, can be artificially introduced into places with higher intensity of illumination in order to improve the aesthetic atmosphere. Artificial interventions in forests located near spas and spas must take into account the increasing impacts of climate change and the need for adaptation. Therefore, numerous studies have been conducted that have shown that modeling in vitro birch cultures, i.e. adaptive selection, can improve resistance to stress [20]. A very important measure of management in these forests are thinnings that are carried out over the entire area, using selection methods. They should regulate the spatial arrangement of functionally prospective individuals, which are estimated to be trees that carry certain functions. The dominant trees of the main or admixture tree species should be vital, with a very developed crown, but aesthetically beautifully developed and attractive in appearance. At the same time, the ecological significance of the forest is intensified. The most functional silvicultural form is a high forest, and on areas located relatively close to the health resort, it is desirable to grow stands of different tree shapes, folded and thinned forests, as well as clearings with individual trees. At the edge of the forest it is necessary to create a denser insulation belt. Attention should be paid to the aesthetic composition of trees, then provide a greater share of species that release phytoncides, and remove species that secrete allergens (e.g. poplars). The most favorable method of management that ensures structural and functional harmony between the zones of forest ecotypes and the rest of the bare area are compositional felling. The best formation of an aesthetically shaped forest is achieved in the youngest developmental phases of the forest. This is especially true for regulating the composition of the stand, the mixture and the structure of the stand. The protection of these natural health resorts is ensured by the establishment of protective zones around them, and if necessary, by other protection measures [8]. The first protection zone is the area that immediately surrounds the health resorts and there is a complete ban on any tillage, the use of chemicals or fertilization of cultivated crops. The second protection zone is established to eliminate the danger of endangering the health resort or its products at a greater distance, and the third protection zone with its hydrological, geological and vegetation composition primarily affects the preservation of the constant abundance of the health resort or its products, and therefore this zone is actually an infiltration zone.

Conclusion

Based on the results of the research in this paper, the following can be concluded:

– The artificially established stands in the vicinity of the spas of Srpske Toplice and Slatina have a thickness structure that does not differ significantly from the

expected frequency distribution, so the null hypothesis is accepted. This indicates that the current management has preserved the characteristic thickness structure of the single-age artificially established stands.

- Natural regeneration in the stands is not satisfactory due to unfavorable edaphic conditions and high weed infestation.
- In the future, it is necessary to transform the structural shape of stands in the stands by introducing deciduous species and gradually create two-storey stands.
- In the "spa forests", it is important to incorporate the structure, composition and mixture of different types of trees in such a way that the visual and aesthetic effect is emphasized as much as possible, but in such a way that everything is in the function of spa tourism and the health and recreational role for tourists or patients.
- For the purpose of spatial arrangement of stands, it is necessary to form three zones in the wider environment (strict protection, i.e. forests of special importance, protection zone and infiltration zone).

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GAZDOVANJE ŠUMSKIM KULTURAMA POSEBNE NAMJENE U ZONAMA LJEKOVITIH BANJA SLATINA I SRPSKE TOPLICE

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Sažetak: *Šume pružaju važne zdravstvene prednosti za ljude utičući na fizičko, mentalno i socijalo stanje. U cilju stvaranja povoljnijih uslova za funkcionisanje zdravstvenih objekata kao što su banje i prirodna lječilišta za oporavak i preventivnu zaštitu zdravlja ljudi često se u njihovoj neposrednoj blizini osnivaju šumske kulture kao šume posebne namjene. Cilj rada je da ukaže na značaj gazdovanja ovim šumama, za postizanje povoljnih uticaja na klimatske, rekreativne, higijenske i estetske ugođaje. Objekat istraživanja u ovom radu su šumske kulture crnog bora (Pinus nigra Arnold) osnovane u blizini banja u Srpskim Toplicama i Slatini. Metod rada je zasnovan na utvrđivanju osnovnih elemenata strukture na stalnim oglednim površinama. Nulta hipoteza o nepostojanju statistički značajnih razlika u osnovnim elementima strukture sastojina je prihvaćena na nivou značajnosti p = 0,05. Rezultati rada pokazuju da gazdovanje treba biti zasnovano na uzgojno kompozicijskom regulisanju sastava šuma, zadržavanju i unošenju vrsta drveća sa izraženim fitoncidnim svojstvima i poboljšanju vizuelnog efekta šuma. Gazdovanjem je potrebno uzgajati mješovite lišćarsko-četinarske šume kojim se obezbjeđuje njihova otpornost na negativne uticaje biotičke i abiotičke prirode. Ove šume trebaju imati pozitivan uticaj na čistoću vazduha, proizvodnju kiseonika, lučenje eteričkih ulja i ispoljavati fitoncidna svojstva.*

Ključne riječi: *Zdravlje, zdravstveni objekti, gajenje šuma*