

**BIOCLIMATIC CONDITIONS IN FOREST
COMMUNITIES ALONG THE TOURIST TRAILS
OF KAMPINOS NATIONAL PARK**

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Abstract

Microclimatic conditions in the forest differ significantly from conditions in non-forest areas, and different forest communities have a different impact on the human organism. Not all forest communities are universally beneficial for everyone. Forests in Kampinos National Park (KNP) show a considerable diversity of habitats and communities. The tourist and recreational function of these forests is very important because of their location close to Warsaw. Taking advantage of the therapeutic role of the particular forest communities and their stimulating effect on human vitality may enhance their attractiveness, e.g. through the development of health tourism. The primary study objective was to assess the bioclimatic conditions in the forest communities of KNP, including the determination of their health properties, and to analyse the tourist trails against the background of these conditions.

Most of the tourist trails in KNP go through communities with favourable bioclimatic conditions. Bioclimate beneficial to people occurs along 94% of the length of KNP trails in the spring and 77% in the summer. Unfavourable bioclimatic conditions occur along 3% of KNP trails. The distribution of tourist trails in relation to the bioclimatic conditions of KNP forest communities is very advantageous from the tourist and recreational perspective.

“No medicine has such an immediate effect
as taking a walk in a beautiful forest”

Qing Li

*Shinrin-yoku. The Art and Science of Forest-Bathing.
How Trees Can Help You Find Health and Happiness*

Introduction

Since ever, forests have played a very important role in human life, and their recreational and tourist significance continues to grow. The beauty and diversity of forest landscapes allow people to rest and regenerate. Based on the stress-relieving properties of forests, various forms of their therapeutic use have been developed, e.g. the Japanese art of shinrin-yoku (LEE et al. 2012, HANSEN et al. 2017). In Poland, forest therapy is referred to as “sylvotherapy” (ZAWADKA-PIETRZAK and ZAWADKA 2015). The air that we breathe in forests is less contaminated with particulate matter and gas pollutants, and is richer in oxygen and aromatic substances, including bactericidal phytoncides emitted by plants (LI et al. 2009, NOWAK et al. 2014). The changes of the meteorological element values (both on a daily and yearly basis) are more subtle in forests, and noise is replaced by the soothing sounds of nature. The ubiquitous forest green restores one’s inner peace and balance (GRAHN and STIGSDOTTER 2003, BERMAN et al. 2008). While the above-mentioned effects improve well-being, the impact of forests on the human organism is much more complex. Staying in the unique forest bioclimate has a positive influence on human health, including the cardiovascular, respiratory and nervous system, and improves the immunity of the body. Various aspects of the influence exerted by the forest environment on the human organism were described by authors such as MAYER and HOPPE (1984), BROWN and CHERKEZOFF (1989), MOSZYŃSKA (2000, 2012), SCHILLER (2001), FORMAL (2004), GRZYWACZ (2011), ZIÓLEK et al. (2012, 2013), KARDAN et al. (2015), ZAWADKA-PIETRZAK and ZAWADKA 2015, BASTEK and PŁOSZAJ-WITKOWSKA (2016).

The conditions vary across different forest areas and differ from those in non-forest areas (BOGUCKI 1988, KRZYMOWSKA-KOSTROWICKA 1997, FALEŃCKA-JABŁOŃSKA 2012, DRAGAŃSKA et al. 2016). Since the particular forest communities differ in terms of habitat properties, age of the trees, species composition and density of tree crowns, their impact on the human organism is also different. Various types of communities can even have opposing effects, e.g. a longer stay in a forest can increase or lower blood

pressure, or can have a soothing or stimulating effect. Thus, not all forest communities are universally beneficial, and longer stays in some of them are not recommended to everyone. In addition, some kind of nuisance can occur in some communities, e.g. stagnant and stuffy air, or the presence of allergens or bothersome insects. Therefore, it is important to assess the bioclimatic conditions in the particular forest communities and demonstrate their impact on human health and well-being.

A set of environmental factors occurring in forests and affecting people visiting them constitutes the so-called recreational bioclimate. According to TOYNE (1979, see KRZYMOWSKA-KOSTROWICKA 1997), recreational bioclimate encompasses all variable external environmental conditions of the air layer, referred to as the "recreational layer." It covers the zone from 20 cm below the ground to 2 m above the ground, i.e. the zone where human tourist and recreation activity is concentrated. KRZYMOWSKA-KOSTROWICKA (1997) lists the following key bioclimate parameters of the recreational layer in forest communities: sun exposure, humidity, ventilation, oxygen production, ozone production, air ionisation, presence of phytoaerosols (essential oils, including phytoncides) and aeroplankton (plant pollen and particles, fungal spores, bacteria, insects).

National parks are areas where tourist traffic takes place along designated routes passing through plant communities, including forest communities, that have a significant impact on tourists' health and well-being. Taking advantage of the therapeutic role of the particular forest communities and their stimulating effect on human vitality may enhance their attractiveness and contribute to the development of health tourism. The primary study objective was to assess the bioclimatic conditions in the forest communities of KNP, including the determination of their health properties, and to analyse the tourist trails against the background of these conditions. The use of GIS software made it possible to create a map of the bioclimatic conditions occurring in the Park. The bioclimate in KNP forests was investigated taking into account the spring (before the full development of the leaves) and summer season when the most intensive tourist traffic occurs.

Materials and Methods

The survey encompasses the area of Kampinos National Park (KNP) established in 1959. Covering more than 38,500 ha, KNP is one of the biggest national parks in Poland. It comprises the Kampinos Forest located in the ice-marginal valley of the Vistula, in the western part of the Warsaw

Basin. The forests in the Park are a remainder of vast primeval forests that used to grow in the Mazovia region. KNP is a typical forest park. Forests account for nearly three quarters of the Park's area. 66 tree species, including 33 native species, were found to occur in the Park and its buffer zone. The most important role in the tree stand is played by scots pine (*Pinus sylvestris*, 69.5%) – the primary forest-forming species, common alder (*Alnus glutinosa*, 12.5%), pedunculate oak (*Quercus robur*) and sessile oak (*Quercus petraea*) (about 10% in total), silver birch (*Betula pendula*) and downy birch (*Betula pubescens*) (6.5% in total) (*Kampinoski Park...* 2019). Coniferous forests are the predominant woodland communities. Forest areas are adjoined by open land occupied by meadow and other communities. Forested dunes and wetland with peat-bog communities are the most characteristic features of the Park's landscape. Such an environment is conducive to flora and fauna diversity, and the abundance of forest communities provides the living conditions for many species of large mammals. Since 2000, KNP has been a UNESCO World Biosphere Reserve.

Located in close proximity to Warsaw, it is one of two “suburban” national parks in Poland, alongside Wielkopolski National Park. Thanks to its location, KNP is a very popular place of recreation for people living in the Warsaw metropolitan area, hence its tourist and recreational functions are very important. According to data published by GUS (Central Statistical Office), KNP is a national park with the greatest length of tourist trails in Poland: about 360 km of hiking trails and more than 200 km of cycling trails as well as 9 educational trails (*Kampinoski Park...* 2019). The Park is visited by about 1 million tourists per year, which makes it the fifth most popular park in Poland (*Ochrona środowiska...* 2017). Tourist traffic in KNP has been studied by OSIŃSKI 2002, CIESZEWSKA 2008, 2009, DZIOBAN 2013, among other researchers.

Digital data on the Park's plant communities were the basis for the assessment of the distribution of tourist trails against the background of bioclimatic conditions in forest communities. Obtained from Kampinos National Park, these data are part of the KNP conservation plan (KNP DIGITAL DATA). According to these digital sources, 17 forest communities were distinguished within the Park. For the purposes of this study, they were combined into 9 groups based on similarities of habitat and bioclimate. The obtained data were processed using ArcGIS 10.1 software, thanks to which a detailed digital map of the Park's forest communities was generated.

Table 1
Characteristic of the bioclimate of recreational layer of groups of the forest communities of the KNP

Groups of forest communities	Participation in the forest area [%]	Insolation	Humidity	Ventilation	Oxygen production	Ozone production	Air ionization	Aeroplankton*	Phytoaerosols	Bioclimate index
Subcontinental pine-oak forest (<i>Quercus robur</i> - <i>Pinetum</i> , <i>Qr-P molinietosum</i> , <i>Serratulo-Pinetum</i>)	51.61	0.5	0.5	0.5	0	0.5	1	0.17	0.5	0.46
Subatlantic and subcontinental fresh pine forests (<i>Peucedano-Pinetum</i> , <i>Leucobrio-Pinetum</i>)	8.57	1	1	1	-0.5	1	-1	0.66	1	0.52
Subatlantic wet pine forests (<i>L-P molinietosum</i> , <i>Molinio-Pinetum</i>)	3.82	0	-0.5	0	-0.5	1	-1	0.17	0.5	-0.04
Pine peatland wood (<i>Vaccinio uliginosi-Pinetum</i>)	0.02	-1	-1	-1	-1	-	-1	-0.33	0.5	-0.69
Riparian forest (<i>Fraxino-Alnetum</i> , <i>Salici-Populetum</i> , <i>Ficario-Ulmetum</i> , <i>Fraxino-Alnetum</i> / <i>Quercus robur</i> - <i>Pinetum molinietosum</i>)	11.04	-1	-1	-1	0	-	0	-1	1	-0.43
Alder woods (<i>Ribesio nigri-Alnetum</i> , <i>Sphagno-Alnetum</i>)	4.29	-1	-1	-1	0	-	0	-1	1	-0.43
Oak-hornbeam forest (wet-ground variety) (<i>Tilio-Carpinetum</i>)	6.99	1* -1	-0.5	-0.5	0.5	1	0	0.33	0	0.23*
Oak-hornbeam forest (dry-ground variety) (<i>Tilio-Carpinetum</i>)	12.29	1* -1	0	-0.5	0.5	1	0	0.33	0	0.29*
Light oak forest (<i>Potentillo albae-Quercetum</i>)	1.36	0.5	0	0	0.5	-	0.5	0.33	1	0.40

* – period before the development of leaves (≈spring), ** – averaged assessment for fungi, bacteria and plant pollen, - - no data

Coniferous forest communities predominate in KNP (about 64% of the Park's forests). The largest area is covered by subcontinental pine-oak forests (*Quercus roboris-Pinetum* and *Serratulo-Pinetum*) – 51%, and fresh pine forests (*Peucedano-Pinetum*, *Leucobrio-Pinetum*) – nearly 9%. Among the deciduous forests (36%), oak-hornbeam forests *Tilio-Carpinetum* (19%) and riparian forest *Fraxino-Alnetum*, *Salici-Populetum* and *Ficario-Ulmetum* (11%) predominate. Other communities do not account for more than 5% of the Park's area (Table 1).

KNP's forest communities, combined into groups, were described using 8 characteristics (parameters) of the bioclimate of the recreational layer. Each characteristic was then assessed in terms of its impact on human health and well-being. Based on the quantitative data and descriptions presented in a study by KRZYMOWSKA-KOSTROWICKA (1997), each of the eight parameters was given an impact score: "1" (favourable impact); "-1" (unfavourable impact); "0" (neutral impact). Intermediate values were also possible: "0.5" (favourable/neutral) and "-0.5" (unfavourable/neutral) (Table 1). The weight of the parameters was equal. The final score reflecting the assessed impact of a given community on people (i.e. the bioclimate index) was calculated as the mean value of all the parameters. The assessment of aeroplankton took into account the content of plant pollen, fungus spores and bacteria in the air. The possible values of the index of bioclimatic conditions ranged from -1 (extremely unfavourable bioclimate) to 1 (very favourable bioclimate). It was assumed that an index value above 0.2 means a positive impact on the human organism while below -0.2 means a negative impact. Values ranging from -0.2 to 0.2 indicate a neutral impact. For oak-hornbeam forest, separate values were calculated for spring (before the development of leaves) and summer because the sun exposure assessment for these communities is fundamentally different in these seasons of the year (Table 1).

After assessing the impact of each community on human health, maps of bioclimatic conditions in KNP were prepared, separately for the spring and summer season. Against this background, the routes of the tourist trails were presented.

Results and Discussion

Based on the digital data obtained, a map of KNP forest communities was created (Figure 1). It shows the arrangement of the Park's plant communities in the form of alternating, east-west oriented strips. The predominant forest communities are pine-oak forests extending over large, higher-lying sand dune areas. They are accompanied by a small number

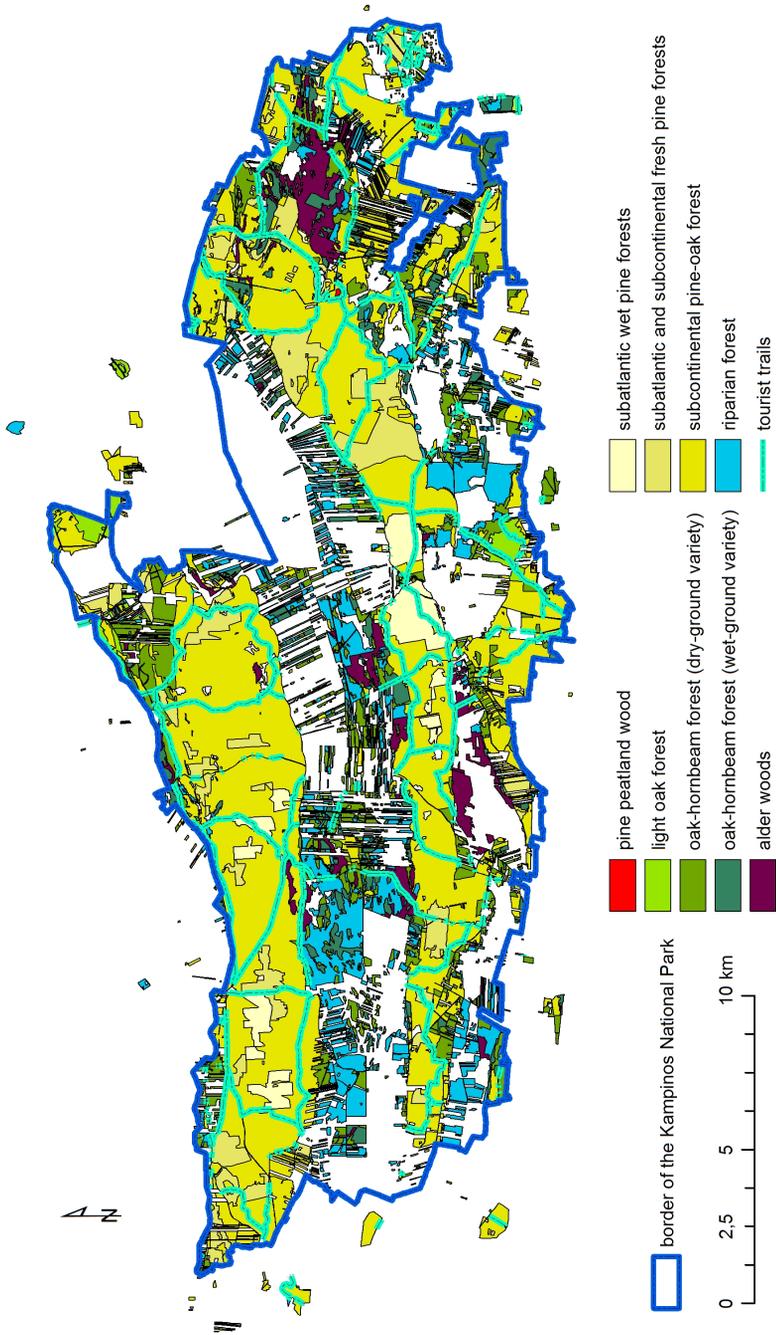


Fig. 1. Forest communities and tourist trails in KNP

of large patches of fresh and wet pine forests. Oak-hornbeam forests grow in the lower-lying, wetter and more fertile areas. In the most humid habitats, in the valleys of the Łasica, Zaborowski and Olszowiecki canals, there are riparian forests and alder woods as well as oak-hornbeam forests (KNP digital data, MOSZYŃSKA 2002). They form a mosaic of numerous small patches of forest communities with the accompanying shrub, meadow and reed communities (Figure 1).

The score of the bioclimate of the recreational layer of KNP forests is in the -0.69 to 0.52 range (Table 1). The best bioclimatic conditions occur in fresh pine forests (sub-oceanic *Leucobryo-Pinetum* and sub-continental *Peucedano-Pinetum*; bioclimate index: 0.52) and pine-oak forests (*Quercus roboris-Pinetum typicum*, *Quercus roboris-Pinetum molinietosum*, *Serratulo-Pinetum*; bioclimate index: 0.46). These communities are characterised by good sun exposure and ventilation, and low humidity. There are no pathogenic bacteria, and the amount of plant pollen is small. On the other hand, there is a large amount of disinfecting essential oils (phytoaerosols). The bioclimate of subcontinental oak-hornbeam forests (typical and wet) varies depending on the season of the year. In spring, their bioclimate is rated as favourable (0.29 and 0.23), while in summer, due to the highly shaded forest floor, the score drops to neutral (0.04 and -0.02) – Table 1. Wet pine forests, *Leucobryo-Pinetum molinietosum* and *Molinio-Pinetum*, also received a neutral score with regard to the bioclimatic conditions (-0.04). Unfavourable bioclimatic conditions occur in wet habitats: pine peatland wood *Vaccinio uliginosi-Pinetum* (-0.69) as well as riparian forest (*Fraxino-Alnetum*, *Salici-Populetum*, *Ficario-Ulmetum typicum*) and alder woods (*Ribesio nigri-Alnetum*, *Sphagno-Alnetum*) communities with a score of -0.43. The conditions in these forests are not suitable for longer stays due to high air humidity, limited ventilation, high concentration of volatile substances as well as animal-related nuisance (mainly bothersome insects) – Table 1.

However, forests with favourable bioclimatic conditions predominate in KNP, accounting for 81% of its forest area in spring and 62% in summer. This variation is related to oak-hornbeam forests whose score in the summer season drops to the neutral value range. 4% of the forests in spring and 23% in summer have a bioclimate that is neutral to human health and well-being. Regardless of the season, communities with an unfavourable bioclimate cover 15% of the Park's forest area (Figure 2).

A spatial analysis of the distribution of bioclimatic conditions in KNP shows their characteristic strip-like pattern resulting from the distribution of the communities and, indirectly, the humidity level in a particular area. Unfavourable conditions occur in depressions between the strips of sand dunes (Figure 3).

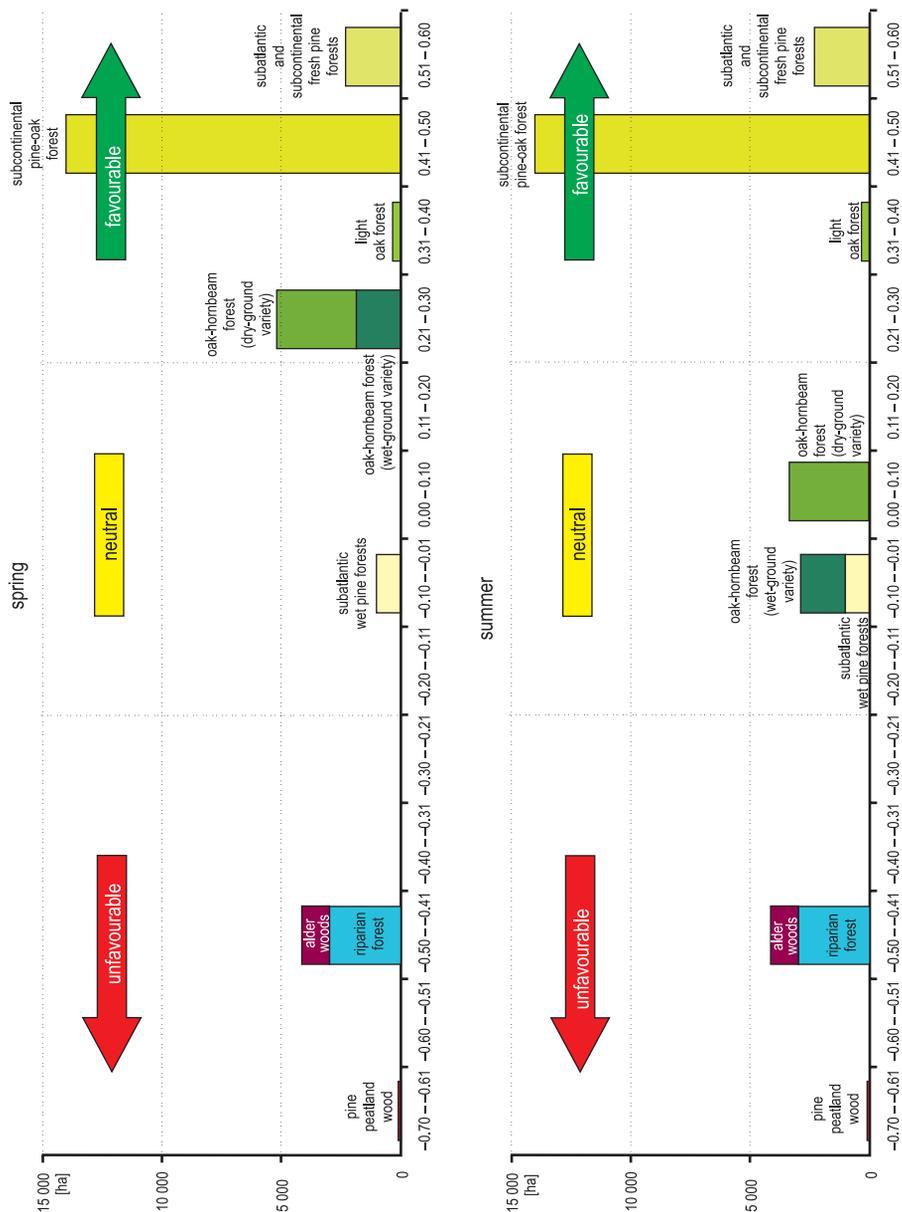


Fig. 2. Bioclimate score ranges for KNP forest communities in spring and summer

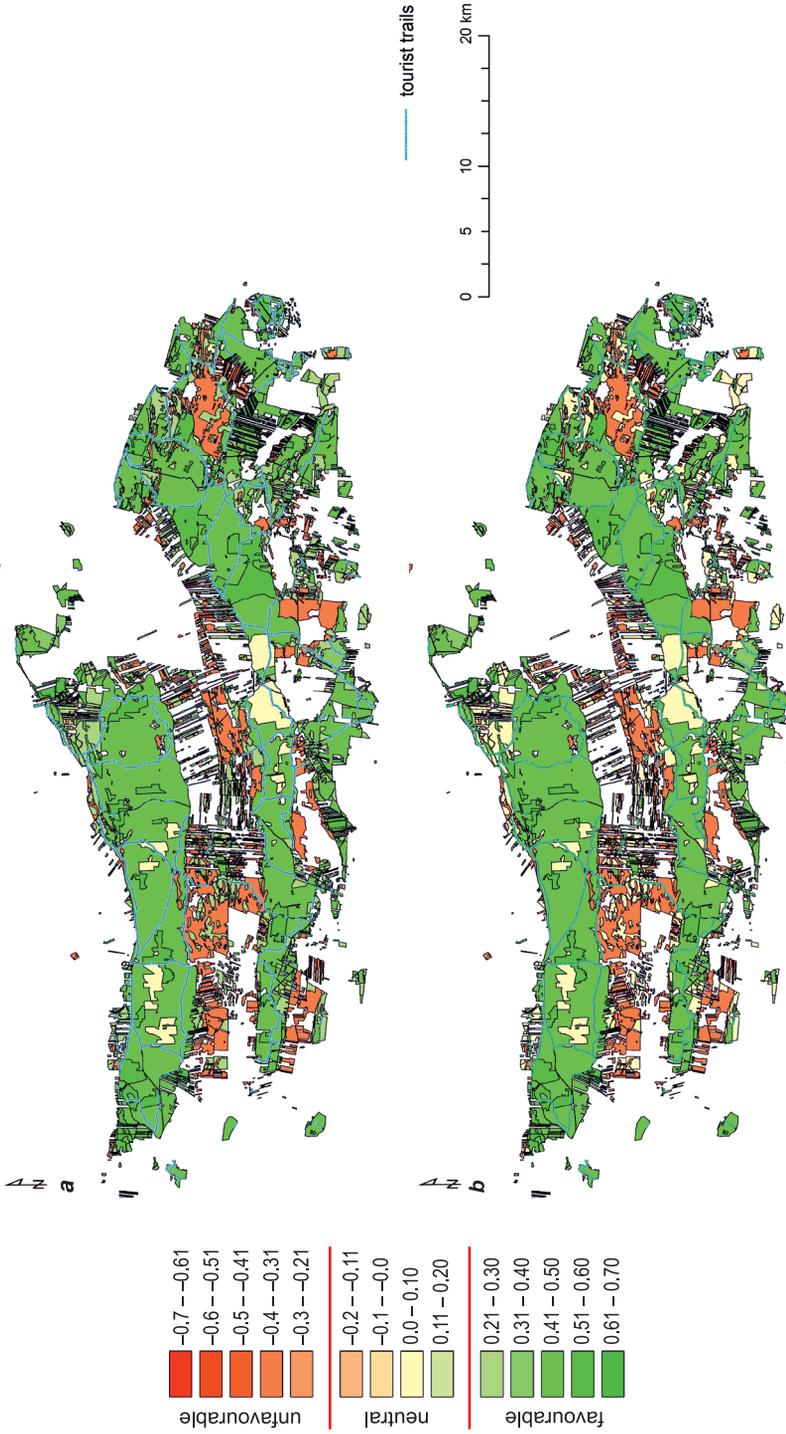


Fig. 3. The distribution of tourist trails in relation to the bioclimatic conditions of KNP forest communities in: *a* – spring and *b* – summer

For the purposes of this study, 270 km of tourist trails passing through forest communities (with forest on both sides of the trail) were analysed. The trails are distributed quite evenly across the entire area of the Park, even though they mostly run across drier, higher-lying areas (Figure 3). The distribution of the trails corresponds to the strip-like pattern of Kampinos landscapes. Most of the east-west oriented trails lead through the most attractive sites in the Park, while the others have a connecting function. The trails pass through 8 out of 9 groups of communities distinguished (all except pine peatland wood). Subcontinental pine-oak forests occur along most of the forest stretches of the trails (67% of their length) (Figure 1). Its bioclimatic conditions were rated as favourable (0.46). However, fresh pine forests, occurring along nearly 8% of the length of the trails, received the highest bioclimate score (0.52) – Table 1. These two coniferous forest communities with the highest score have a slightly different impact on human health and well-being. The climate of pine forests is definitely unifunctional and has a therapeutic effect on respiratory tract diseases. The numerous essential oils occurring there have disinfecting properties, thanks to which the air is free of pathogenic factors. Furthermore, staying in pine forests reduces blood pressure and tones up the nervous system. Thus, long stays in these communities are not recommended to older people, persons with low blood pressure, hypothyroidism, or prone to migraines (particularly on hot and windless days). Bioclimate in pine forests also has a short-term numbing effect and temporarily slows down reflexes (KRZYMOWSKA-KOSTROWICKA 1997, MOSZYŃSKA 2000, FORNAL 2004). Pine forests occur along more than 20 km of KNP trails. The bioclimate of pine-oak forests received a slightly lower score, but it is much more universal. This community has a soothing effect in terms of biotherapeutic and psychoregulatory properties. Large amounts of essential oils, including phytoncides, occur there. Furthermore, allergens and animal-related nuisance pose a low risk. Owing to the above properties and lower intensity of stimuli, the bioclimate of pine-oak coniferous forests is suitable for persons of different age and in different health condition (KRZYMOWSKA-KOSTROWICKA 1997, MOSZYŃSKA 2000, BASTEK and PŁOSZAJ-WITKOWSKA 2016). It is important particularly because these communities received a high recreational usefulness score in surveys based on the age of the tree stand and forest habitat type (CZUBASZEK et al. 2014). 180 km of tourist trails pass through the pine-oak forests in KNP.

A high rating of bioclimatic conditions was also given to light oak forests that occur only along short stretches of the trails (less than 8 km). The bioclimatic conditions of the oak forests are universally favourable to everyone regardless of age and health, except for people allergic to pollen.

Oak forests have a strong bactericidal and stimulating effect, and strengthen the human immune system (KRZYMOWSKA-KOSTROWICKA 1997, BASTEK and PŁOSZAJ-WITKOWSKA 2016). Furthermore, thanks to their strong filtering and detoxifying properties, these forest communities absorb particulate matter and heavy metals (MOSZYŃSKA 2000).

77% of KNP's tourist trails pass through the described communities with favourable bioclimatic conditions in summer. In spring, the length of trails with favourable conditions increases to 94% thanks to the numerous represented oak-hornbeam forests (45 km) – Figure 4. The subcontinental oak-hornbeam forest (typical and wet) is a community where bioclimatic conditions change from favourable in spring to neutral in summer. In spring, the effect of these forests is universally positive. Above all, they have a stimulating and antiseptic effect, enhancing the immunity of the human organism, supporting blood circulation, and increasing blood pressure. However, owing to the high intensity of stimuli, longer stays in oak-hornbeam forests are not recommended to people with hypertension, hyperthyroidism, and those in a state of emotional agitation (MOSZYŃSKA 2000, FORMAL 2004, BŁAŻEJCZYK and KUNERT 2011, FALENCKA-JABŁOŃSKA 2012). In summer, the comfort of staying in oak-hornbeam forests is reduced due to the dense tree crowns inhibiting ventilation and access of solar radiation as well as the presence of ticks, mosquitoes and gadflies. In addition, neutral bioclimatic conditions occur all year around in sub-Atlantic wet pine forests that grow along circa 8 km of the tourist trails in KNP. In total, bioclimate rated as neutral occurs along 3% of the Park's trails in spring and 20% in summer (Figure 4).

The bioclimate of communities occurring in the wet habitats of riparian forests and alder woods was rated as unfavourable to human health and well-being. The conditions in these forests are not suitable for longer stays due to high air humidity and limited ventilation, i.e. conditions that have a strong straining effect on heart action. Furthermore, high concentrations of volatile substances, pollen and fungus spores, and large numbers of insects occur there (KRZYMOWSKA-KOSTROWICKA 1997, MOSZYŃSKA 2000). CZUBASZEK et al. (2014) report that areas with alder woods, particularly those of lower age classes, are unsuitable for rest and recreation. Despite the unfavourable bioclimatic conditions and poor suitability for recreation, riparian forest and alder woods communities show the highest efficiency in absorbing particulate matter, gases and heavy metals; they also have very strong bactericidal properties (MOSZYŃSKA 2012). Short stretches of KNP trails, totalling just over 8 km (only 3% of the total length of the Park's forest trails) pass through the wet communities mentioned above.

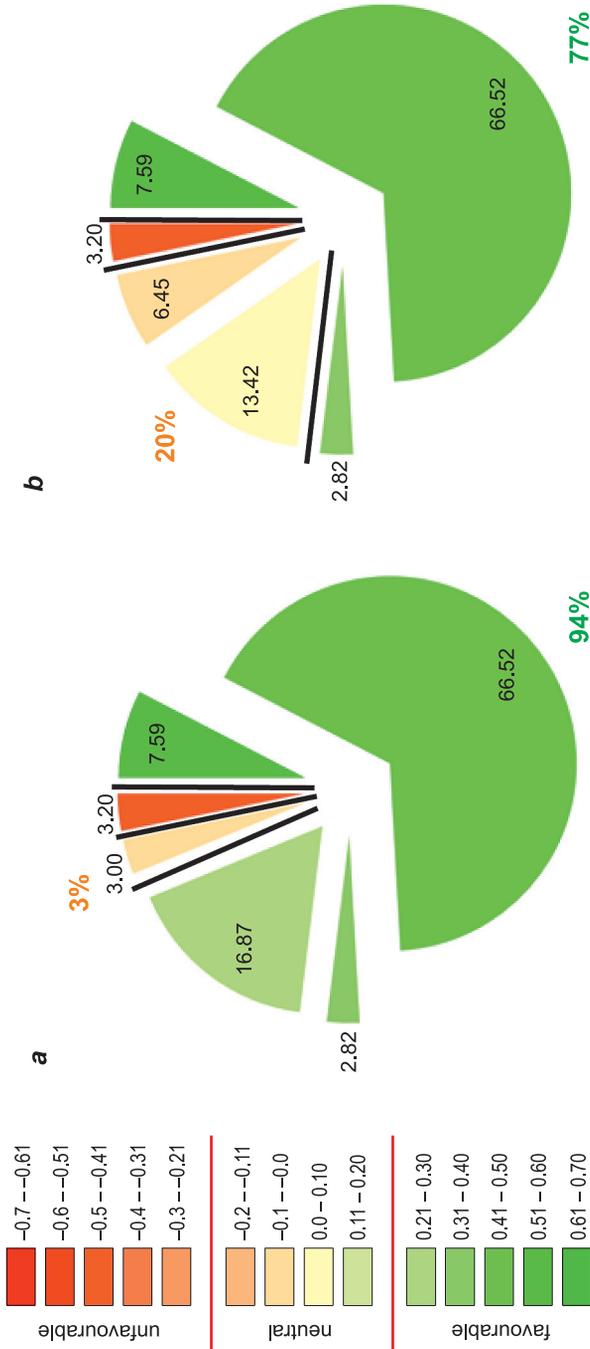


Fig. 4. Percentage share of the length of tourist trails in bioclimate ranges for KNP forest communities a – spring, b – summer

Thus, the distribution of tourist trails in relation to the bioclimatic conditions of KNP forest communities is very advantageous in terms of their close proximity to Warsaw as well as intensive tourist and recreational use. The proximity of sites conducive to leisure and enabling contact with nature and a clean environment makes suburban forest areas very attractive from the perspective of recreation (PAWŁOWICZ and SZAFRANKO 2014). By improving the microclimate conditions, green areas within residential areas have a positive influence on human health, which is confirmed, for example, in studies by KARDAN et al. 2015. However, not every town or housing development has a sufficient share of green areas. In such cases, the proximity of forest areas that people can visit frequently is a great asset. Along with the growing awareness of the benefits of contact with a forest environment, its therapeutic properties conducive to the development of tourism and recreation are also gaining importance (GRZYWACZ 2011, MARSZAŁEK 2010).

Furthermore, large urbanised areas such as the Warsaw metropolitan area face the problem of environmental pollution. Particulate matter, gas pollutants and noise are the biggest nuisance to people. Forest areas located close to cities enable an improvement of air parameters as well as the health and mental state of residents. Alongside its recreational and tourist function, KNP plays the role of “Warsaw’s green lungs”. Therefore, a greater emphasis should be placed on the development of health-promoting nature tourism. KNP’s tourism offer should be expanded to include education and promotion of the health benefits of staying in forest communities. The importance of the awareness of the health-promoting values of this area in the context of tourism was discussed by MOSZYŃSKA (2000, 2012), among other authors. The society should be made aware of how forest therapy can benefit human health and well-being, and the forms and possibilities of using this kind of therapy on an everyday basis (walking, cycling, roller-skating, Nordic walking) should be indicated. Based on the health benefits and attractiveness of the forest environment where people can restore their vitality and improve their health, it is possible to develop forest tourism products used in forest therapy.

Conclusions

In Kampinos National Park, the best bioclimatic conditions occur in the following coniferous forest communities: fresh pine forests (*Peucedano-Pinetum*, *Leucobryo-Pinetum*) and pine-oak forests (*Quercus roboris-Pinetum typicum*, *Quercus roboris-Pinetum molinietosum*, *Serratulo-Pine-*

tum). In total, they cover more than 60% of the Park's area. Unfavourable bioclimatic conditions occur in marshy coniferous forests (*Vaccinio uliginosi-Pinetum*) as well as riparian forest (*Fraxino-Alnetum*, *Salici-Populetum*, *Ficario-Ulmetum typicum*) and alder woods (*Ribeso nigri-Alnetum*, *Sphagno-Alnetum*) communities. These communities cover a small area accounting for 15% of the Park's forests. Most of the tourist trails in KNP pass through communities with favourable bioclimatic conditions: most of them (67%) pass through the subcontinental pine-oak forest. Bioclimate beneficial to people occurs along 94% of the length of KNP trails in spring and 77% of the trails in summer. Unfavourable bioclimatic conditions occur along 3% of the length of KNP trails regardless of the season during which the investigation is conducted. The distribution of tourist trails in relation to the bioclimatic conditions of KNP forest communities is very advantageous from the perspective of tourism and recreation. The proximity of sites conducive to leisure and enabling contact with nature and a clean environment is extremely important for residents of large urbanised areas. Therefore, emphasis should be placed on the development of health-promoting nature tourism. KNP's tourism offer should be combined with education and promotion of the health benefits of staying in the particular forest communities. Based on the attractiveness of the forest environment where people can restore their vital strength and improve their health, it is possible to develop forest tourism products used in forest therapy.

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