GeoJournal of Tourism and Geosites
ISSN 2065-1198, E-ISSN 2065-0817

Year XV, vol. 40, no. 1, 2022, p.253-258
DOI 10.30892/gtg.40130-826

BIOGEOGRAPHIC POTENTIAL OF THE NORTH KAZAKH PLAIN IN THE PERSPECTIVE OF HEALTH TOURISM DEVELOPMENT

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Citation: Makhanova, N., Berdenov, Z., Wendt, J.A., Sarsekova, D., Mursalimova, E., Sansyzbayeva, A., Nurtazina, N., & Safarov, R. (2022). BIOGEOGRAPHIC POTENTIAL OF THE NORTH KAZAKH PLAIN IN THE PERSPECTIVE OF HEALTH TOURISM DEVELOPMENT. *GeoJournal of Tourism and Geosites*, 40(1), 253–258. https://doi.org/10.30892/gtg.40130-826

Abstract: Abstract: The article presents the prospects for the development of natural and recreational activities in the field of medical and health tourism within the ribbon pine forest, located in the southern outskirts of the West Siberian dry steppe lowland. The purpose of the study is to assess the biological and geographical potential of the forest landscape for the development of recreational areas. This is especially true for the Northern region of Kazakhstan, since industry is developed on the territory, it is characterized by technogenesis. Research methods include field reconnaissance, cartographic modeling using GIS technologies, and laboratory experiments to determine the phytoncide activity of the biological material of trees – Scots pine – collected at different intervals of the day. The results of the study are statistical data on laboratory research. For convenience, they are presented in the form of cartographic material, built based on spatial data of the territory. The paper considers and addresses the ecosystem's natural potential and the recreational infrastructure of the studied object.

Key words: potential, recreation, tourism, rest landscape, phytoncide activity, forest bathing

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INTRODUCTION

Landscape components, that have balneological significance in human life and are formed in special landscape-forming factors, contain a huge potential for medical and health tourism development (Tokpanov et al., 2021; Nakonechnykh et al., 2021; Akhmedenov, 2021). One of such fundamental components is plants. During their life activity, plants produce volatile organic compounds, phytoncides, protecting themselves from diseases. Phytoncides are bactericidal, protistocidal, and fungicidal substances produced by higher and lower plant organisms for protection and healing purposes (Tokin, 1951; Li, 2006). Nature-based tourism accounts for 7% of all international travel worldwide (Li et al., 2010; Herman et al., 2019). The current trend will direct priorities in the search for medical and wellness trips of people. The impact of the Covid-19 pandemic has fundamentally transformed the concept of tourism appearance (Rogerson, 2021; Munne et al., 2021). The possibility of using the phytoncide activity of the landscapes to prevent the consequences of the virus is a promising direction of biogeography (Berdenov et al., 2021; Dunets et al., 2019). A special role in the choice of the territory of Northern Kazakhstan is played by the developed industry of the region, the influence of technogenesis (Shomanova, 2019; Safarov and Berdenov, 2021), as well as the transboundary nature of the region (Ilies and Grama, 2010; Dunets et al., 2020; Shumkina, 2015). It is here that the development of recreational recreation, domestic and border tourism is necessary.

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The main role of phytoncidal activity in medical geography, since technogenesis zones are characterized by a predominance of diseases of the upper respiratory tract, and the identification of areas with the highest phytocidal activity makes it possible to scientifically substantiate the placement of health resorts and hiking trails (Akhmedenov, 2021; Dunets et al., 2019). Objects of the natural reserve fund play a key role in the development of cross-border tourism. These objects represent the landscape diversity of the tourist area. However, tourism activity is extremely poorly developed. Most of the tourist routes exist only in projects; infrastructure facilities are concentrated in visitor centers and field hospitals. A search for a compromise between organized tourism activities and the optimal conservation regime is often being conducted. Natural and recreational resources can serve as a solid foundation for further deepening of integration processes between regions only in the case of competent and balanced nature management and coordination of common efforts (Indrie et al., 2020; Ilies et al., 2017; Sansyzbayeva et al., 2020). Less well known as recreational areas, the northern boreal forests have become important for hiking and adventure tourism, which are now becoming increasingly popular as tourist destinations (Kremenetski et al., 1997; Volodarets et al., 2018). The geographical location of sanatoriums and health resorts in ribbon pine forests should be balanced with the indicators of phytoncide activity given in the results of the study.

MATERIALS AND METHODS

The research was carried out in the forest ecosystem of the North Kazakh Plain, represented by a ribbon pine forest within the boundaries of the Semey Ormany State Forest Natural Reserve (Figure 1). The object has a sub-meridian cone shape, 100 km long from north to south. The northernmost part, 5-8 km wide, begins at 81° 08' 27' E and 51° 13' 17' N and widens to approximately 51° 22' with a base along the Irtysh River. The area of the object is 2500 km2. The absolute height ranges from 250 to 330 m. The study proceeded for 2 weeks and was conducted from May 30 to June 12 in 2021.

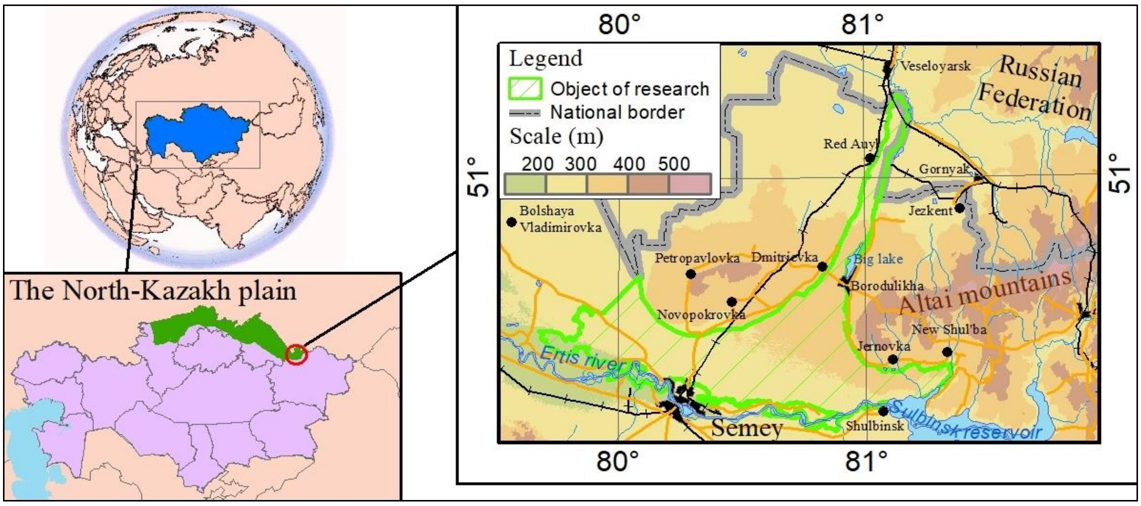

Figure 1. Location of the study area (compiled by the authors in the ArcGIS program)

According to the physical-geographical zoning, the studied area is located in the southern steppe subzone of the dry steppe zone, relative to the lowered accumulative plains. The climate of the territory is continental due to the far distance from the oceans and seas. The coldest month is January, with an average temperature of -15.1°C. In summer, the average temperature reaches +21.7°C. The average annual rainfall is 275 mm. Aeolian sands, formed in the Pleistocene as a result of the re-deposition of ancient alluvium along the now buried valley, with a thickness of up to 20 meters, are an intrazonal landscape component. It determined the growth of a kind of tree and shrub cover in this area. The predominant tree species is Scots Pine (*Pinus Sylvestris L.*), which spread in these places in the Post-glacial period. Scots pine (*Pinus sylvestris L.*) was chosen as the studied component of the landscape due to a naturally high phytoncide activity in the dry steppe zone of Inner Asia. It is the dominant tree species covering the relict ribbon pine forest on the eastern edge of the North Kazakh plain. This unique natural object with an intrazonal soil genesis extends latitudinally (sub-meridianally). The boundaries of the landscape are very clear and are caused by quaternary geology, soil, and vegetation cover. According to radiocarbon analysis of tree pollen in sediments, the age of the landscape covers 12000-9500 years to the present day.

The theoretical and methodological approaches are based on the methods and results of research by Soviet and post-Soviet scientists in the field of phytoncide activity of plants. The phenomenon of phytoncides was discovered empirically in 1928-1929 during the testing of the hypothesis of mitogenetic radiations conducted by the research school of A. G. Gurvich. B. Tokin carried out the experiments in the laboratory of Leningrad University, regarding the effect of volatile substances of onion gruel on yeast, and failed. However, it served as an impetus in those years for extensive research in the USSR (Beloussov et al., 1997). From the 30s to the 70s of the XX century, the USSR had a leading position in the field of studying phytoncides. Danini E. M. developed a methodology for studying the antibacterial properties of phytoncides of higher plants, then widely used phytoncides in medicine. Grodzinsky A.M. founded the direction of phytodesign and, while studying plant physiology, introduced the formula for calculating phytoncide activity. Since the 1960s, Germany expressed wide interest in. J. Jung discovered that the bark of the balsam poplar, Populus candicans, contains substances with fungistatic activity and that these substances can be isolated from the bark by boiling. Muller-Dietz H. developed phytoncide therapy (Li, 2010).

Since the beginning of the 2000s, the effect of phytoncides on the biochemical processes of animals and humans has been widely studied in East Asian countries (Abe, 2008) investigated antioxidant effects and antimicrobial activity. S. Zhang, J.H. Jung, H.S. Kim reviewed the effect of phytoncides on growth rates, nutrient absorption, blood counts, diarrhea rates, and excretion of fecal microflora in pigs. B. Sin, D. Im, K.K. Lee compared hormonal changes in cortisol when visiting forest ecosystems (Park et al., 2011). Taiwan, Japan, and South Korea have developed a therapeutic technique known as "forest bathing," in which people actively inhale phytoncides produced by trees and plants to improve physical health, including blood pressure, autonomic nervous system, and various hormones. There have been many studies on aerotherapy or forest bathing. The objectives of the study were the psychological impact of the forest environment on healthy adults as a potential method of stress reduction (Miyazaki, 2011; Park et al., 2010). During their life cycle, plant organisms emit biogenic volatile organic compounds (BVOCs), phytoncides, of various concentrations into the air. BVOCs in the natural environment affect the vital activity of microorganisms of the host ecosystem and ensure the balance of its pathogenic microflora. Phytoncide activity (PA) is the ability of BVOCs to inhibit the growth and development of bacteria, protozoa, and fungi (Volatile activity VA). PA in the natural environment depends on meteorological conditions, the flowering phase of the studied plant, and the ontogeny of the plant itself. The main methods of this study are comparative geographic analysis, processing of statistical and laboratory data, and the cartographic method.

The desktop GIS Arc GIS v. 10.5 application carried out the construction of maps and diagrams, spatial analysis. We reviewed SRTM models of the study area and local topographic maps for the presence of high-slope landforms. The slope is an important factor in choosing a route. Based on a digital elevation model, we searched the paths with the lowest costs for the tourist route (Beketova et al., 2019; Berdenov et al., 2016). The subject of the study. At the laboratory stage, pathogenic microorganisms were cultivated in an artificial environment in Petri dishes via in vitro. Fungi of the genus *Fusarium* were chosen as indicators of the phytoncide activity of the forest landscape (Figure 2). The nutrient medium was a semi-synthetic meat-peptone agar of a semi-liquid consistency. Fungi grew in a slightly alkaline medium with pH = 7.3 ± 0.1.

Table 1. Geographic coordinates of sampling areas

№	Name of sampling plots (name of settlements)	Coordinates		Coordinate system
		northern latitude	eastern longitude	
1	Tarsk	51° 08' 44.594"	81° 06' 09.010"	WGS-84
2	Aul	51° 01' 28.566"	81° 04' 02.329"	
3	Berezovka	50° 51' 17.767"	80° 59' 35.880"	
4	Borodulikha	50° 44' 12.716"	80° 54' 15.767"	
5	Mikhailoskiye lakes	50° 36' 52.664"	80° 42' 12.795"	
6	Zhernovka	50° 26' 18.786"	81° 04' 59.971"	
7	Ozerki	50° 25' 46.155"	80° 34' 36.843"	
8	Semey	50° 29' 23.170"	80° 16' 55.963"	

Figure 2. Fungi of the *Fusarium* genus in Petri dish (Source: author's)

RESULT AND DISCUSSION

In fieldwork, the needles of trees were selected on sampling plots located inside the studied object and delivered to the place with laboratory conditions and equipment. A total of eight sample plots were established (Table 1) and located at a distance of 15-20 km from each other. The sample plots were stations with an approximate area of 1000 m^3, where 5 to 7 trees were selected. Trees were chosen to meet the requirements to be healthy in appearance, without damage, and to be young trees – aged 30-40 years old. The needles from the trees were selected without damage, signs of disease, and chlorosis, and from different exposures of the lower tier (Figure 3). The time of transportation of materials to the laboratory did not exceed two astronomical hours. In the second stage, work was carried out on the preparation of plant material and observation. Using the hanging drop method in laboratory work, borrowed from Professor Tokin (Tokin, 1980), the crushed material brought close to the pathogenic fungus. The observation recorded the time when the vital signs of fungus stopped. The used equipment was a Motic microscope SFC-100FL model. The names of eight sampling plots were assigned according to nearby settlements and natural objects; the coordinates are given in Table 1.

Phytoncide activity was calculated by the formula (Grodzinskiy, 1973): $A = 100/T$ (min^{-1}),

A – is the phytoncide activity; T – is the time of death, stopping the growth of 50% mycelium of the *Fusarium spp*.

In the border regions of Kazakhstan and Russia, a large number of unique natural and recreational sites are concentrated, as well as a unique network of specially protected natural areas. This is due to the low population density and poor economic development of border areas. Habitats of many rare species of living organisms, unique ecosystems, and landscapes are concentrated along the borders. According to the analysis of the SRTM model, the relief does not have sharp fluctuations in relative heights and is represented by a slightly sloping plain. Only in some parts, there are hilly places, with a relative elevation of 20-25 m. The analysis of the relief and the existing infrastructure of the area were taken into account in choosing tourist routes for hiking Laboratory research results show the distribution of phytoncide activity in the forest ecosystem. Concerning the time factor, there is a correlation of indicators with the solar phase.

The data on graph (Figure 4.) demonstrate the highest activity of phytoncide activity in the morning, then its significant decline in the afternoon – the hottest time section in the day. Deviations in the area of plot № 5 Mikhailovskie lakes are caused by high humidity from a stagnant reservoir. Presumably, the factor of atmospheric humidity and temperature accelerates the physiological processes in trees. The volatile activity of coniferous trees (Pinus sylvestris L.) gradually fades after the morning phase. For the best healing effect, a person should be on foot between 6 am – 12 pm.

Figure 3. Place of collection of Scots pine (*Pinus Sylvestris L.*) needles:
a - Plot № 1 sample of young cones; b - Plot № 2; c - Plot № 7; d - Plot № 8 (photo of the author at sampling sites)

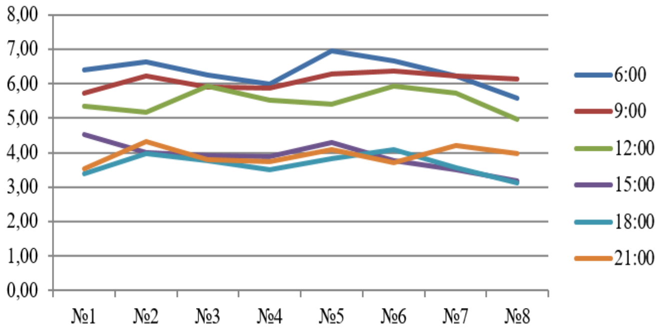

Figure 4. Graph of volatile activity by daily phase

Table 2. Statistical characteristics of PA according to daily chronology

Stats	6 a.m.	9 a.m.	12 p.m.	3 p.m.	6 p.m.	9 p.m.
Minimum:	5.59	5.71	4.98	3.19	3.13	3.52
Maximum:	6.94	6.37	5.92	4.52	4.08	4.31
Sum:	50.68	48.72	43.99	31.12	29.23	31.34
Mean:	6.34	6.09	5.49	3.89	3.65	3.92
Stan. Deviation:	0.397	0.214	0.316	0.395	0.295	0.256

Table 3. Indicators of phytoncide activity (min^{-1})

№	Daily sampling time						Mean
	6 a.m.	9 a.m.	12 p.m.	3 p.m.	6 p.m.	9 p.m.	
1	6.41	5.71	5.35	4.52	3.39	3.52	4.82
2	6.62	6.21	5.18	4.02	3.97	4.31	5.05
3	6.25	5.92	5.92	3.92	3.76	3.80	4.93
4	5.99	5.88	5.52	3.89	3.51	3.73	4.75
5	6.94	6.29	5.41	4.31	3.83	4.10	5.15
6	6.67	6.37	5.92	3.77	4.08	3.70	5.09
7	6.21	6.21	5.71	3.50	3.56	4.20	4.90
8	5.59	6.13	4.98	3.19	3.13	3.98	4.50

Samples collected in the evening produced a minimal impact on fungi. However, in the daily interval of 9 pm, the average value of the activity of BVOCs increases relative to the previous selection at 6 pm (Table 2). In the course of studying the potential of phytoncide activity of the study area, a summary table of the main natural and recreational resources of the territories was compiled. These areas form the tourist attractiveness of the regions and can become links of cross-border cooperation in the field of tourism (Table 3).Based on this data, using the cartographic method and the Thiessen polygons in the Coverage toolset, we modeled a map with potentially higher phytoncide activity (Figure 5) plotted by the route of our study.

The geographical distribution of phytoncide activity is not even. The northern part at latitude 50°50′ n. shows the weakening of the effect of the volatile compounds. The same similar observations are shown in the southwestern part of the forest landscape. The cartographic material (Figure 5) depicts territories with three gradations. Low phytoncide activity is typical for plots № 1, 2, and 8, where the arboreal pine consists of young trees. Sampling plots, with the observation of average values of phytoncide activity, have a relatively developed infrastructure. The dispensary "Berezovka" (№. 3) and the administrative district is the village of Borodulikha (№ 4) are located there. However, the sanatorium is used exclusively for medical purposes for tuberculosis patients. Identified territories with high values of phytoncide activity are plots № 5 and № 6. Near plot № 5, there are about four children's health-improving camps. Given the current urbanization, the existing recreational infrastructure is not sufficient for a wide range of people. It is very important for urban residents to organize such types of tourism as hiking, horseback riding, exercises with a qualified instructor for the respiratory organs, etc. in places with high phytoncide activity.

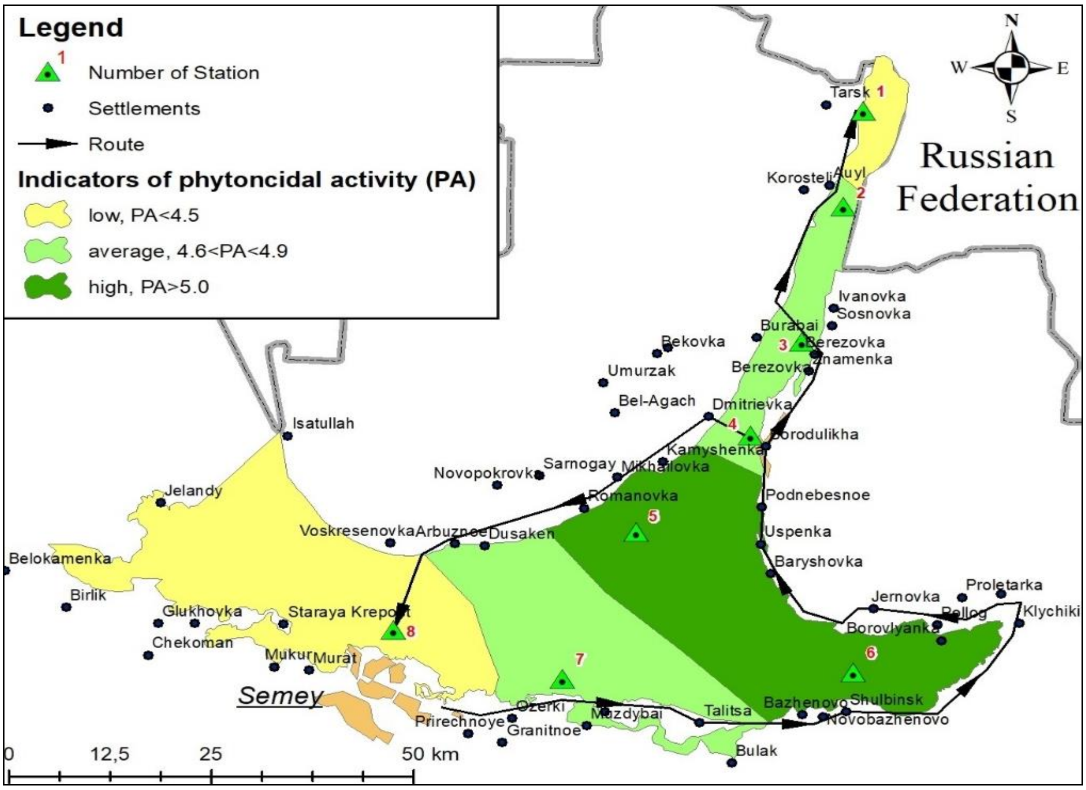

Figure 5. Map of territories with potentially higher phytoncide activity (compiled by the author in the ArcGIS program)

CONCLUSION

The results show that the southeastern part of the North Kazakh Plain is a natural reservoir of antibiotics (phytoncides) in high concentrations in relict pines (Figure 4). The selected methodology for studying the effect of phytoncides on pathogenic fungi made it possible to experimentally show the distribution of volatile activity in ecosystems. There are two places in the world with similar ribbon forests. The first one is in Canada, and the second is in the West Siberian territory of Russia and Kazakhstan. The use of such unique natural objects for health purposes can bring an effective result for people. Today, the proposed method of health tourism refers to aerotherapy or taking forest baths. The proximity of the studied landscape to the cross-border territory raises prospects and trends for the development of tourism. Cooperation in the tourism field and the involvement of integration partners in joint innovative projects for the development of communications and the use of the natural resource potential of the participating countries is possible only with mutually beneficial cooperation and the interest of both sides.

Research and development of balneological resources are closely linked to the health care system. Thanks to properly organized recreation and health improvement of the population, it is included in the complex of organizing a healthy lifestyle and preventing many diseases. The development of these resources is important for the local population, since it is excessive to spend money and time on long trips to places of rest and treatment abroad. It is also important that the population will have the opportunity to relax and be treated in their usual climatic conditions, without wasting vacation time acclimatizing at resorts, and then re-acclimatizing after returning. It is especially important for the population working in the zones of technogenic impact of the Northern region of the country. The article reflects an attempt to assess the forest ecosystem for health tourism based on the therapeutic effect of phytoncides. The foregoing research on the subject requires the necessary study in the future and disclosure in a wider chronological framework.

Acknowledgments

We express our gratitude to the Kazakh Research Institute of Forestry and Agroforestry Reclamation, Shchuchinsk, Kirov st 58 for their intellectual contribution to this work and for providing us with samples of Fusarium spp.

Funding: The given research was carried out within the framework of a project funded by the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan (Grant No. AP08856347).

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Article history: Received: 07.11.2021 Revised: 06.01.2022 Accepted: 09.02.2022 Available online: 09.03.2022