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Creation of GIS-maps for information structuring and an integrated approach in the use of resource species of forest ecosystems

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Abstract. Populations of species living at the edge of their range need long-term and constant monitoring to analyze the number and condition of individuals of the species. When populations fall out of natural phytocenoses in conditions of regulated nature management, it is possible to restore these cenopopulations by repopulation. For optimization of work on structuring of data on populations, a GIS-map of medicinal plants was created. A full set of studies has been carried out for *Bupleurum aureum* populations, which are experiencing significant anthropogenic pressure near the western border of its range. The species has practically disappeared from the broad-leaved forests of the Predvolga region. The created GIS-map contains information with precise georeferencing of the identified cenopopulations in relation to landscape and soil type. Another block of the GIS-map database contains information on productivity and genetic polymorphism of cenopopulations, which should be taken into account when restoring lost populations.The conducted studies have shown that the share of generative plants of *B. aureum* in the population decreases when the light intensity decreases in the forest. In this case, individuals preserved in meadows adjacent to the forest are of great importance. It can be assumed that forest edge communities are important key sites for the conservation of forest biodiversity.

1 Introduction

Forest ecosystems of the European part of Russia are subject to significant transformation. Tatarstan belongs to the low forested regions of Russia. A negative trend of forest area reduction has been observed since the 18th century. If in 1793 the forest cover of the territory amounted to 51.2%, at present the average forest cover in the republic is 17.1%, varying in administrative districts from 2.6 to 41.1%. The lowest area occupied by forests is typical for the administrative districts of the Predvolzhye region. At the same time, forests and the ecotone communities created by them, as well as specially protected natural areas, contribute to the conservation of populations of rare and medicinal plants [1].

The flora of the Republic of Tatarstan (RT) contains 357 species of medicinal plants, of which about 20% are officially acknowledged medicinal plants. Structural and functional

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analysis showed that among the official medicinal plants species with disturbed habitats are widely represented - 36.6%. The share of species of forest phytocenoses is also high, about 30%. About 15% are species that can exist in both forest and meadow communities of different moisture regimes. Ecotone areas of forest ecosystems are considered as important territories contributing to the conservation of herbaceous species diversity of forest [2], meadow and steppe phytocenoses.

At the moment, forestry in the RT is characterized by intensive processes of increasing the area of forest plantations [3]. At the same time, the establishment of forests on agricultural lands leads to a significant decrease in the species of the grass and shrub level. In this regard, it is necessary to work on the restoration of populations of herbaceous species, in forest phytocenoses, that previously existed on the territory. Herbaceous medicinal plants with high vulnerability criteria, such as species at the edge of their range, species with decreasing numbers and shrinking habitats, deserve special attention in these studies [4]. Work on these plants is aimed at studying the population structure and developing recommendations for the restoration of populations in the conditions of the original forest communities. One of such plants is the golden sagebrush *Bupleurum aureum* FISCH. Ex HOFFM (APIACEAE).

The aim of the work is to create a GIS-map “Medicinal Plants” for visualization, structuring, generalization of diverse information on the population structure of medicinal plants and creation of replenishable spatial data for long-term monitoring studies.

2 Materials and methods

To carry out this study, expeditionary studies were conducted to identify populations of the species in the Republic of Tatarstan in 2018-2023. The study of the ontogenetic structure of the species' cenopopulation was carried out, based on the ratio of plants of different ontogenetic groups. The spectrum of ontogenetic states was compiled [5]. Genetic polymorphism of the identified natural populations [6] was studied by random amplified polymorphic DNA (RAPD) method and phenolic compounds of the species individuals were analyzed [7].

In the territory of the Republic of Tatarstan *B. aureum* inhabits near the western border of its area. The species has developed similar habitats; lightened coniferous-broad-leaved and broad-leaved forests of the Volga region. At present there is a tendency for reduction of natural habitats of the species. If M.V. Markov [8] noted that *B. aureum* occurs in all districts of the republic, then the current studies conducted from 2018 did not reveal a population of the species in the Predvolzhye region. Several populations were found in the Predkamye and Zakamye regions. For a more thorough multi-year studies, we selected three cenopopopulations of *B. aureum*, a brief characterization of which is presented in Table. 1.

Table 1. Characteristics of habitats.

Phytocenological units		**Natural-historical region of the Republic of Tatarstan and Mari El**	**Habitat**
Zone types	**Subzonal subtypes**		
Dark coniferous and broad-leaved-dark coniferous forests	Subtaiga	The northern area of mixed spruce-fir forest (Zelenodolsk district)	CP 1. (The edge of the oak grove)
		The northern area of mixed spruce-fir forest (Baltasinsky district)	CP 2. (The spruce forest)

Broad- leaved forests	North forest steppe	Central region of the (West Zakamsk) forest-steppe, (Alekseevsky district)	CP 3. (Glade in broadleaf trees forest).

3 Results and discussions

Modern geosystem technologies are universal systems that combine methods of visualization and processing of large, multifunctional databases. The results of the research, concentrated in a single database, are the initial accurate information for further monitoring of the development and state of the population. It also offers the possibility of using plant objects to create plantations, restore natural populations in previously existing areas and study the spatial and age changes of the population when the vegetation changes. For species with promise for introduction into resource cycles, productivity indicators and analysis of genetic structure are important information. Detecting the pattern of genetic diversity in space allows us to identify areas that contain a greater amount of genetic variation. These hotspots of evolutionary potential can then become the center of management efforts to conserve biodiversity.

In the work, the "Soil Map of the Tatar ASSR 1:600000" was used to create the GIS map. The "Medicinal Plants" GIS map was developed in the ArcMap application.

The GIS project was developed in several stages:

1) Preparation of cartographic material. The paper version of the Soil Map of the Tatar ASSR was digitized.

2) Georeferencing of the raster image of the scanned map in geographic space along the borders of the Republic of Tatarstan.

3) Creation of geodatabase schemes. A file geodatabase DATASOIL was created, which contains two sets of object classes: 1) SOIL - data on the description of soils and complexes; 2) TOPO - data on the terrain. The geodatabase also includes a separate class of spatial objects PLANTS, which is represented by point objects with coordinates of plant locations and their descriptions. The structure of the geodatabase is shown in Fig. 1.

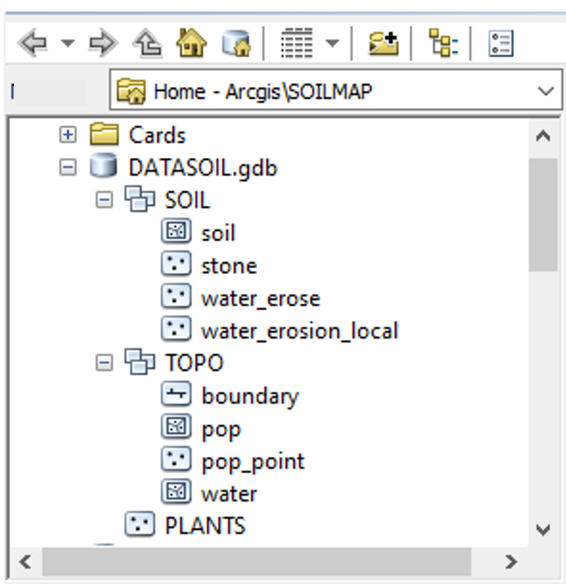

Fig. 1. External view of the geodatabase map catalog.

4) Digitizing spatial map objects and filling in attribute data.

5) Adding plant locations to the soil map. The data on plant populations of *B. aureum* are represented by point objects that were obtained in the field. Spatial objects had X, Y coordinates and were displayed on the map from a text file.

6) Linking passports of medicinal plant raw materials (MPRM) to point objects on the map. In addition to location data, each point of the medicinal plant includes the following indicators: information on phytocenotic units, descriptions of natural and historical zones of the Republic of Tatarstan, soil types, content of biologically active substances, productivity and genetic structure. To systematize the obtained data and for further implementation in the geoinformation system, passports of collection sites of goldenrod plant raw materials were developed. Further, using the “Hyperlink” tool, links to the information cards of the passports were prescribed (Fig. 2).

The project is stored in the document “Medicinal Plants of Tatarstan”.mxd. All data referenced by the project layers are stored in the ...\SOILMAP catalog. This project includes layers from the pilot project as well as new datasets that were contributed as materials became available.

The map document consists of one data frame “Medicinal Plants of Tatarstan”, including a separate layer “Medicinal Plant Species” and a group of layers “Soil Map”. All vector layers refer to spatial object classes of the DATASOIL.gdb geodatabase.

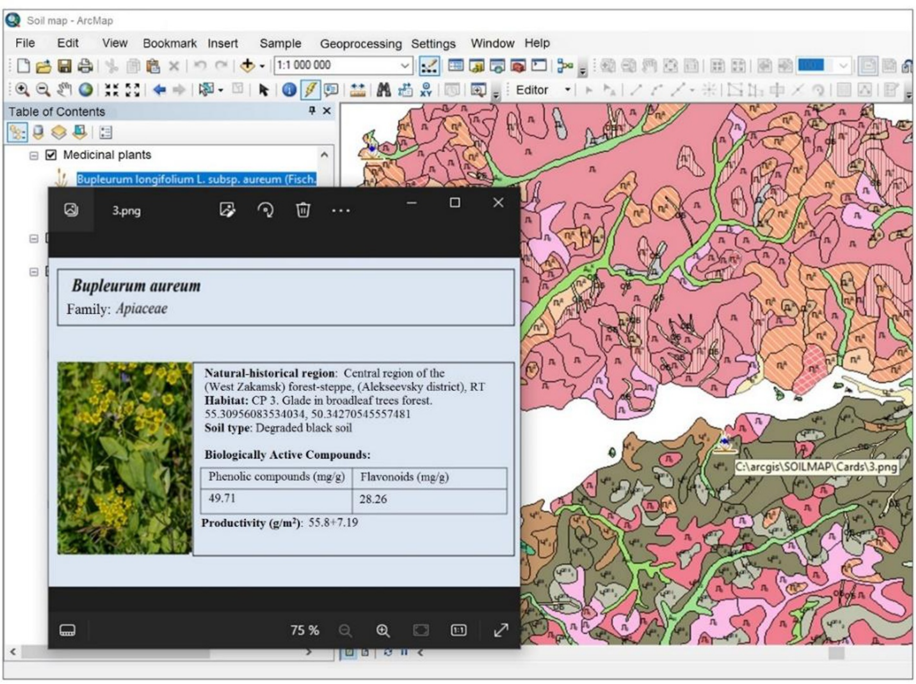

Fig. 2. Hyperlink to the passport of the population of *B. aureum* in the Alekseevsky district of the RT

The genetic polymorphism of the studied natural populations of *B. aureum* was analyzed (Table 2). Three estimates of genetic variability were obtained for each population: the percentage of polymorphic loci, the Shannon information index, and the average expected heterozygosity based on Nei's unbiased estimate. When studying intrapopulation polymorphism, it was found that samples collected from Zelenodolsky district (CP 1) had the highest genetic diversity (h = 0.2144, I=0.3109), and from Alekseevsky district (CP 3) - the lowest (h = 0.1401, I=0.2070), which is consistent with the idea of the influence of isolation on the decrease in genetic polymorphism.

Table 2. Characterization of intrapopulation genetic heterogeneity of natural populations

	h = Nei's (1973) gene diversity	**I = Shannon's Information index [Lewontin (1972)]**	**The percentage of polymorphic loci**
Alekseevsky district	0.1401	0.2070	37.84
Baltasinsky district	0.2001	0.2888	48.65
Zelenodolsky district	0.2144	0.3109	51.35

The higher indices of genetic polymorphism in populations of the Zelenodolsky district allow the use of this plant material for reintroduction of the population in the Predvolzhye region.

For a successful reintroduction process, it is necessary to take into account the peculiarities of the species life cycle and factors determining the species' extinction from the community. For *B. aureum,* sexual reproduction is a priority method of reproduction. To study the influence of light on the formation of the ontogenetic structure of *B. aureum*, survey plots were established at the edge of a complex spruce forest CP 2 (canopy closure 0.4) and under the forest canopy, where the closure was 0.8. When comparing the ratio of plants of different ontogenetic groups of the cenopopulation loci, it was noted that the proportion of generative plants decreased with decreasing light, but the proportion of plants of subsenile and virginile ontogenetic states increased. The difference in the proportion of plants of different ontogenetic groups of the *B. aureum* population loci was statistically significant (x^2=92.932; ν=7; p<0.01). Probably, when the illumination decreases, the process of seed formation and seed germination becomes more difficult, which does not ensure replenishment of the population with new young plants and leads to the loss of the species from the community. In that case, replenishment of the cenopopulation is carried out at the expense of individuals existing in light meadows adjacent to the forest. In the conditions of preserved mosaic meadow-forest and forest-forest complexes a full-fledged turnover of the species generation is realized, which should be taken into account when creating artificial populations of the species [9]. The forest edge communities can be referred as the key sites, the maintenance of which will ensure the preservation of biodiversity of forest communities.

4 Conclusion

1. GIS-map “Medicinal Plants” with inclusion of geoinformation data in the identified populations of medicinal plants on the territory of the RT with full resource characteristics of species, structure of natural populations, productivity, accumulation of biologically active substances and genetic structure has been developed and created.

2. The spatial distribution of the identified populations of *B. aureum* is shown. Genetic polymorphism of the populations was studied; it is shown that high indices of genetic polymorphism in the populations of Zelenodolsky district allowthe use of this plant material for population restoration in the Predvolzhye region.

3. It is shown that for the sustainable existence of the population of *B. aureum,* it is necessary to maintain mosaic communities of field-forest and forest-forest complexes.

5 Recommendations

1. Forest edge communities can be important key sites. The diversity of ecological factors ensures the survival of species of different vegetation types.

2. Restoration of natural populations should be carried out taking into account genetic polymorphism of natural populations.

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References

1. O.V. Smirnova, V.N. Korotkov, A.P. Geraskina, Proceedings of the International Conference “Longevity Interventions 2020”, ICLI, 20–22 (Ekaterinburg, Russia, 2020)
2. D.V. Belyakov, O.A. Konyushatov, S.A. Korchagov, M.M. Andronova, Izv. Sankt-Peterb. Les. ak. **248**, 89-102 (2024)
3. R.N. Minnikhanov, Kh.G. Musin, R.Kh. Gafiyatov, N.F. Gibadullin, Lesov. **1**, 55–63 (2020)
4. S.L. Chen, H. Yu, H.M. Luo et al, Chin Med **11**, 37 (2016)
5. G.O. Osmanova, L.A. Zhivotovsky, Bio. Bull. **47**, 141-148 (2020)
6. S.L. Dellaporta, J. Wood, J.B. Hicks Plant Mol. Biol. Rep. **1(4)**, 19–21 (1983)
7. S.A. Dubrovnaya, L.Z. Khusnetdinova, A.N. Akulov, L.V. Ryzhova, O.A. Timofeeva, Chem. of pla raw mat. **1**, 132-139 (2024)
8. M.V. Markov, Key to plants of the Tatar Auton. Sov. Soc. Rep. (1979)
9. O.V. Smirnova, V.N. Korotkov, L.B. Zaugolnova, Lesov. **5**, 367-378 (2015)