Phytodiversity of the Middle Volga region using FD SUR database

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Abstract. The article illustrates FD SUR database, which contains information on the spatial distribution of vascular plant species in Samara and Ulyanovsk regions. The surveyed area is 90,900 km². The initial data were obtained as a result of studies carried out for the period 2004-2020 by the staff of the Institute of Ecology of the Volga River Basin of the Russian Academy of Sciences and some literary sources. The database contains over 100,000 records for 1935 species from 127 families and 628 genera. We develop a number of areas of flora research using the informational basis of FD SUR. We propose criteria for assessing the sustainability (natural addition) of floras based on the spectrum of family diversity indices. We studied the dependence of the taxonomic parameters of the flora on the number of species on floristic site and determined the values of these parameters for a number of territories of Samara-Ulyanovsk Volga region. We examined the dependence of the species and biomorphological composition of floras on the climatic conditions of the territory: the amount of precipitation and temperatures.

1. Introduction
Phytodiversity is the basis for the conservation of the general biodiversity of the territory. Since the preservation of general biodiversity is one of the main challenges facing modern society [1], it is necessary to ensure the preservation of biodiversity, including vascular plants. The global solution to this problem is based on information at regional levels, when local scattered data are collected into a single system with the help of which the spatial distribution of biodiversity for its sustainable use and conservation is determined [2].

We present FD SUR database which contains information on the spatial distribution of vascular plant species in Samara and Ulyanovsk regions [3]. The use of this database makes it possible to reveal general patterns of the composition of flora at regional level.

2. Materials and Methods
Scientists of the Institute of Ecology of the Volga River Basin of the Russian Academy of Sciences (IEVRB RAS) have developed a database "Floristic descriptions of sites in Samara and Ulyanovsk regions" - FD SUR. The database currently contains 667 floristic descriptions (species lists). The basis of the FD SUR is data obtained as a result of our own field research carried out by the staff of the Laboratory of Problems of Phytodiversity of IEVRB RAS in 2000-2019 and open source data. Species were counted using generally accepted methods.
The territory of these regions (90,900 km²) includes parts of the forest-steppe and steppe natural-geographical zones. A total of 1935 species from 127 families and 628 genera have been registered. For the territory of Samara and Ulyanovsk regions 538 local areas were surveyed (figure 1).

3. Results and Discussion
FD SUR was developed using a relational database management system (DBMS) Microsoft Access, which made it possible to simplify the input, processing and search of data and also provided the ability to display information in the form of tables, graphs, reports, maps. Due to the presence of VBA (Visual Basic for Applications) - an embedded programming language, the database is supplemented with developed subroutines that provide the necessary processing of the initial data. Since Microsoft Access can operate on a local network, information and reference tables are located on one "central" computer, while the program code is stored on different computers, which allows one to correct and use information in parallel, as well as protect data from accidental changes.

The created database combines two parts: informational and computational. The first one is formed in the form of linked tables and provides the user with information about plant taxa (families, genera and species), studied collection points, life forms, etc. The second one performs various calculations at the user's request.

FD SUR has the following functionality due to the formed table structure and developed processing algorithms:
• input, storage and editing of information;
creating a report (with subsequent import into an Excel-table or Word-document), consisting of a list of species belonging to any selected group or a separate local area;
• display in the form of a map-scheme of the locations of individual areas, for which the database contains descriptions of the species composition;
• spatial distribution (illustration of occurrence) of a particular species according to the available descriptions in the form of a map-scheme;
• counting the total number of species for an arbitrarily selected set of sites;
• formation of a general list of flora species in the form of a table based on the totality of individual selected areas;
• automatic formation of lists of flora in municipal districts of regions, taking into account the aboriginal and adventive factions;
• automatic formation of lists of flora by physical and geographical regions of the considered territory, taking into account the aboriginal and adventive factions;
• determination of the similarity of individual local areas by species composition and display of the spanning tree based on the calculated coefficients;
• comparison of the formed groups of lists by indicators of similarity/difference;
• formation of the family spectrum and the spectrum of family diversity indices, both in a separate local area and on a selected set of areas;
• calculation of the average taxonomic distinctness (individuality) and variation in taxonomic distinctness \[5, 6\] to determine the impact of environmental degradation on the taxonomic structure of flora at the local and regional levels.

The generated data structure of FS SUR and software make it possible not only to obtain lists of vascular plant species for different selected territories and their comparison, but also to analyze taxonomic, biomorphological, phytocenotic, ecological and other characteristics.

Currently, there are several dozen coefficients (indices, measures) of similarity (commonality) and differences and their modifications. When comparing the floras of territories with similar floristic capacity (approximately equal number of species), the use of "popular" similarity coefficients like the Jaccard index or the Sørensen–Czekanowski index, which are functionally related, is justified. In our case, when this rule is not observed, it is logical to use other indexes. The calculation of coefficients of similarity or difference between flora is provided. In our case, Preston's difference coefficient \[7\], which has a threshold for determining homogeneity is used as the similarity/difference coefficients; difference coefficient Rp \[8\]; index \[β\]sim \[9\], minimizing the differences.

Possible Rp values lie in the range from 0 to 1 (with values close to zero, we have similar areas in terms of species composition):

\[
Rp = \left[ \frac{(a - c)(b - c)}{ab} \right]^{1/2} = \left[ (1 - K_{shs})(1 - K_{bs}) \right]^{1/2},
\]

where \(a\) is the number of species in one site; \(b\) is the number of species in another site; and \(c\) is the number of species found in both the first and second sites. This difference index is the geometric mean between the Braun-Blanquet \((1 - K_{bb})\) and the Shimkevich-Simpson \((1 - K_{sh})\) indices, and when \(a \approx b\) it’s like the Sørensen–Czekanowski index \((1 - K)\).

The use of Rp, in our opinion, is a convenient measure of difference in determining how much one subset of species is part of another and takes into account the "potential" of differences between the compared sites.

The available opportunities to group descriptions (floristic lists) depending on the objectives of the study and calculate the listed similarity/difference indices, allows one to switch to ordination and cluster analysis methods in the R package.

The most important part of the general analysis of flora is taxonomic analysis, while the family spectrum is necessarily considered. In the current version, on the basis of FD SUR we have developed
software for the formation of the family spectrum and the spectrum of family diversity indices [10], both on a separate local site and on a selected set of sites. The spectrum of family diversity indices (SFDI) of flora is a curve constructed on the basis of the quantitative distribution of species by families. The points of which reflect the family diversity indices of flora under consideration. The construction of the SFDI is based on the methods of fractal analysis in bioecology [11]. The SFDI shape does not depend on environmental conditions and looks the same for floras of different levels (local, regional, etc.). The spectrum characterizes a high proportion of families represented by one species and the level of prevailing (dominant) families.

4. Conclusion
We have determined the criteria for assessing the sustainability (naturalness of addition) of the flora (figure 2, table), based on the calculations (600 descriptions and their combinations).

![Figure 2. SFDI for flora: o – the Margalef index; ∆ - the Shannon index; 1 - SFDI of local flora; 2 - SFDI of regional flora; B - zone of disturbed or underexplored natural flora](image)

| flora      | k    | H    | d    |
|------------|------|------|------|
| Local      | <=0.7| 0.57 | =0.4 |
| Regional   | <=0.66| 0.52 | =0.4 |

Table. Criteria for assessing the sustainability (naturalness of addition) of flora: k — the Margalef index; H — the Shannon index; d — normalized family representation index

Overestimated values of indices k and H, as well as significant deviations of d indicate:
- understudied flora;
- significant anthropogenic influence. The location and percentage of the leading families changes in relation to the reference spectrum of a higher order (rank). The habitats of aboriginal species of natural flora are occupied by synanthropic, adventive species. There are changes in the family spectrum, both in the location of families and in the number of species included in them;
- extreme conditions that prevent the formation of sustainable communities;
- the process of flora formation of the plant community, corresponding, for example, to the initial stage of post-pyrogenic succession ("poorly" structured spectrum of families).
A significant result of the research is the conclusion that the standard "hook-shaped" SFDI form simultaneously reflects both the structure of plant taxonomy (the result of the evolutionary process at the moment) and the real distribution of species by families in specific territories of different scales. The fractal structure of SFDI is presumably preserved within limits: for example, as long as a certain ecological type of environment (homogeneity) is preserved, within which the species structuring takes place (ecotope flora, specific flora). With an increase in the area and number of species, when there is a change in environmental factors (climate, landscape), a decrease in diversity indices is observed. It is shown that the flora of the territories of the Middle Volga and the Volga basin according to the proposed criteria are in a satisfactory condition [12].

We have determined the minimum value (by the number of species) of flora completeness, which is 700 species for the forest-steppe Trans-Volga region [13]. This value was determined from the parameters of the spectrum of the families. The minimum area for flora surveys was 400-1000 sq. Km. In this study we used 96 floristic descriptions (list of vascular plants). The heterogeneity and mosaicism of the flora of the Soksky physical-geographical region (Samara region) using the "number of species-area" curve was shown, as well as the change in the share of leading families in the aggregate of floristic samples depending on the increase in area [14]. We used 110 floristic descriptions. We have identified the leading genus of flora for the territory of Samara-Ulyanovsk Volga region. It has been shown that the spectrum stabilizes after 1000 species [15]. We used about 400 floristic descriptions.

Since the modern climate is a strong predictor of species richness, we constructed models of the dependence of the species diversity of vascular plants on climatic characteristics in the Middle Volga region [16]. The study used information on the composition of vascular plants in 25 squares with an area of 10×10 km. The most significant indicators were revealed - the amount of precipitation and the temperature in March, the temperature in October and the precipitation of winter, which, when combined, determine 74% of the variation in species richness. Under relatively low climatic gradients, we used a special function of the total precipitation in March for analysis. It describes the nonlinear dependence of the richness of vascular plants, expressed as a peak. We gave an ecological interpretation of the connections, built a species richness map. The hypothesis is discussed that, in the territory with small climate gradients, small differences in intra-annual temperature and precipitation indicators can be critical factors for changing the number of vascular plant species in space.

Using the same set of data, we carried out a comparative analysis of the species richness of life forms of vascular plants in the Middle Volga [17]. It is shown that the shares of the dominant life forms of vascular plants in the Middle Volga region, hemicyryptophytes and annual grasses (theophytes), are associated with the illumination of slopes from the southwest, but the species richness of all life forms does not depend on illumination. We have built various regional models as well.

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