Area Size of Flora Identification for Species Diversity Assessment

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Abstract. The problem of the area of flora identification in a particular territory is one of the most difficult and little discussed. Flora as a list of species of higher vascular plants is inextricably linked with two most important parameters: the size of the territory (in sq. km) and the number of species. The number of species must be sufficient to represent the main features of the flora for the climatic zone and local characteristics. For this, it is necessary to survey areas of different nature conservation status and anthropogenic transformation. We studied ten floras of the Samara-Ulyanovsk Trans-Volga region. The species discovery curve shows that with an increase in area from 100 km², the number of species continues to grow and the end of a significant increase corresponds to an area of 400 km², which is optimal. This area can be considered as minimum range of species composition of flora. The species composition of vascular plants of the considered territories reflects the main characteristic features of the flora: the number of species of vascular plants (610-812 species); the leading families are Asteraceae, Poaceae, Fabaceae, Rosaceae, Brassicaceae and genera: Carex, Galium, Salix, Artemisia, Potentilla. We have come to a conclusion that on the territory of the forest-steppe zone of the Middle Volga it's necessary to use test plots of at least 400 km² when studying the geographical distribution of floras or carrying out their comparative analysis.

1. Introduction

In the process of studying the flora of any territory, the question of the area of its identification is one of the most difficult and little discussed. Results from regional studies can help solve this problem, since the obtained data may differ in the geographical aspect.

Concerning this issue, it should be emphasized that we are approaching the understanding of the term "flora" in the interpretation of A.I. Tolmachev, that is, his concept of a specific (elementary) flora [1]. In a sense, this is the complete flora of a given geographical area, identified in the minimum possible territory, which includes all ecotopes of the terrestrial part of the territory. Flora as a list of species of higher vascular plants is inextricably linked with two most important parameters: the size of the territory (in sq. km) and the number of species. The corresponding list of species is able to provide "the main floristic" portrait "of a specific flora" [2]. It not only determines the main features (characteristics) of the flora of the studied area, but also serves as a basis for comparison with other sample plots. This, in turn, makes it possible to reveal the floristic uniqueness of any territory.

The aim of our study is to substantiate the size of the minimum area and the number of species that characterize the flora of the forest-steppe part of the Samara-Ulyanovsk Trans-Volga region.
2. Methods and Materials

In order to try and find a solution of this problem, we chose a model territory: the forest-steppe part of the Trans-Volga region, administratively belonging to Samara and Ulyanovsk oblasts. According to the available physical and geographical zoning [3], the territory belongs to two provinces: the province of the Low Trans-Volga region (Melekess-Stavropol lowland-plain area of pine forests on hilly sands) and the province of the High Trans-Volga region (Soksky upland-plain area with ridge relief).

The initial data on the flora are presented in the form of floristic lists (species lists), which were accumulated in the course of expeditionary studies from 2003 to 2020 by the staff of the Laboratory of Phyto-Diversity Problems of the Institute of Ecology of the Volga River Basin RAS, with the involvement of researchers from other organizations. As a result, we have collected a fairly extensive material, including the territories of natural monuments, the environs of settlements, tracts and other natural objects. The data are presented in the form of separate floristic lists compiled by the route method taking into account the species composition of all encountered ecotopes for geographical points with an area of 5-7 km². The available lists differ in the number of species (30-600), phytocoenetic confinement of the description, as well as in the frequency of observation (one-time visits, regular visits in different periods of the growing season). This information forms the basis of the FD SUR database [4]. We then used the species discovery curve.

3. Results and Discussion

3.1. The relationship of the number of species with the area (some history)

The question of the relationship between the number of species of higher vascular plants and area has its own history of study, the result of which is the maps of species diversity of rather extensive territories. There are known maps of the world's floristic richness. Wulff [5] published one of the first inventory world map of vascular plants in 1935. Subsequently, biodiversity mapping has developed into a special problem area of thematic mapping. L.I. Malyshev compiled maps-schemes of phytodiversity based on the materials of the report "Flora of the USSR" for the territory of the former USSR [6-7]. The data on the number of species in 51 floristic regions, taking into account the ecological parameters of the territory, were used as the initial material. Plant species numbers the Samara-Ulyanovsk Volga region show somewhat 600-700 for 100 km², according to the obtained map of the levels of floristic richness of the USSR. Morozova O.V. received similar data [8-9]. Her map is more detailed as it covers only the territory of Eastern Europe. According to this map, the species richness within the Samara-Ulyanovsk Volga region is about 800 species per 100 km². Assessments of this kind can be considered initial, rather preliminary for determining more accurate parameters at the regional level. A. Seregin, for example, carried out a more detailed research on the territory of Vladimir oblast [10-11].

3.2. Relationship between the number of species and the area for the model territory

The question of what is the minimum number of species that flora should contain in the study area is rather important for the problem under discussion. We studied this issue from the point of view of the parameters of taxonomic spectra for the Soksky physical-geographical region (Samara forest-steppe Trans-Volga region). It was shown that the studied parameters of the flora with an increase in the area acquire the necessary values. In this regard, we have proposed a scale for the levels of floristic sampling. It is noted that the triad of leading families in the spectrum is correctly established at 700 species in the sample. In a sample of this size, there are representatives of all leading genera, and most of them are located in the head of the spectrum of genera [12].

Traditionally, most attention is paid to protected areas when studying biodiversity. Moreover, special attention should be paid to small area territories, since in the end we should answer the question: how many species in our area are actually distributed on an area of 100 km². We presented the data on the distribution of vascular plant species for the model territory in the form of a regular grid with a size of 10×10 km² (figure 1). The different number of species of natural flora
in squares reflects both the diversity of local natural conditions and the degree of anthropogenic transformation of the territory. The territory of the Samara-Ulyanovsk Trans-Volga region has a high degree of anthropogenic transformation: 50-60% is occupied by agricultural land, settlements, roads, railways. This makes it difficult to assess the state of natural flora and leads to an uneven spatial distribution of information.

**Figure 1.** Data on the number of species per 100 km² for a fragment of the forest-steppe Trans-Volga region

Natural monuments to a certain extent meet the requirements of conservation of vascular plant species. There are about 200 of them in Samara oblast [13]. The study of the flora of natural monuments in Samara oblast began in the 1900s and continues to the present day. Most of the lists were formed on the basis of the field trips, which also covered the territory of Ulyanovsk oblast. Some lists of floras of natural monuments are published [14-17, etc.]. Natural monuments of Samara and Ulyanovsk oblasts, studied to varying degrees, have an area of 0.02-23 km². The number of species in their composition ranges from 170 to 480. Undoubtedly, such data indicate the comparative floristic richness of these territories. They are a kind of refugia of biodiversity and territories, in this sense, atypical.

For Ulyanovsk oblast, there is a number of data collected during the study of the flora of small towns and villages [18 19 20, etc.]. Each of them has been studied over a number of years and several seasons, that is, the species composition has been identified rather thoroughly. The percentage of adventive species in these floras is 20-40 and slightly higher, which is a fairly high percentage. For comparison: the percentage of adventive species of the flora of the considered natural monuments varies in the range of 6.4-21.8%. When identifying the species composition small towns and villages, one studied the territory within the range of 6-41.5 km². Thus, the presence of a serious anthropogenic transformation of the territory (highways, artificial plantations, agricultural land, etc.) does not cause a significant depletion of the species composition of the flora, but rather is the reason for its change towards greater adventitization and synanthropization. This fact is widely known from literature sources [21]. Surely, in small towns and villages there are fragments of territories with preserved natural vegetation cover, as well as squares, parks, etc., which are habitats for species of natural flora. The question of how long they can exist in a given state of populations of some species deserves a separate study. However, it is more important for us to conclude that the regional flora (even in the minimal version) cannot be represented exclusively by natural monuments, or only by anthropogenically modified territories. For a complete understanding of the flora, it is necessary to
survey territories that are different in nature conservation status and anthropogenic transformation, which brings us to an expansion of the surveyed area.

3.3. The species discovery curve
The available data on the floristic richness of the Samara-Ulyanovsk forest-steppe Trans-Volga region to a greater extent reflect the real picture. When analyzing, one should focus on the maximum numbers. The maximum number of species per 100 km$^2$ is 500-600, provided that these squares are located in the vicinity of settlements (the city of Togliatti, the village of Arkhangelskoye near the city of Ulyanovsk). The percentage of adventive species is 22-36%. Some squares with 300-400 species geographically correspond to natural monuments with a fairly high degree of flora conservation. Obviously, the minimum floristic threshold under the conditions of the study area can be reached over an area of 100 km$^2$ only in some cases.

The study area has local differences in terms of natural conditions and anthropogenic transformation. For example, the widespread plowing of lands excludes the preservation of formed steppe communities with a full floristic composition in their vegetation cover. Not every square with an area of 100 km$^2$ contains water bodies that are habitats of aquatic and semi-aquatic flora or forest ecotopes with a full composition of forest flora. In this regard, it would be incorrect to assert that there is a certain standard area, which is the same in all parts of the research territory, ensuring the identification of flora. Consequently, if we determine a certain average trial area for the research territory, then it should be larger than 100 km$^2$.

When one combine pairs of squares located next to each other, the number of species in the corresponding lists increases to 400-540. And only when 4 squares are combined, the number of species is in the range of 600-800 (figure 2). With a further enlargement of the area, the number of species continues to increases, but the rate of increase slows down significantly (figure 3). The nature of the course of the curves corresponding to different sections is different. It reflects the uneven distribution of species richness due to anthropogenic disturbance, as well as the degree of flora conservation in the surveyed areas. Of the six sites considered (figure 3), it is possible to distinguish: I - with the greatest species diversity, on the territory of which a number of natural monuments are located, which total area is 5.7%. Site III is characterized by a slightly lower species richness, due to significant anthropogenic transformation and the absence of natural monuments.

![Figure 2](image-url)
In Samara oblast there is the Zhigulevsky reserve and Samarskaya Luka National Park, which occupy a fairly large area - 1,340 km$^2$. The floristic regions highlighted on its territory also give an idea of the ratio "number of species - area" characteristic of Samara oblast: Zhigulevsky (440 km$^2$; 690 species), Vinnovsky (380 km$^2$; 480 species), Aleksandrovsky (490 km$^2$; 510 species), Perevoloksko-Usinsky (100 km$^2$; 550 species) [22].

The trial area of 400 km$^2$ does not provide the most complete identification of the flora of the Samara-Ulyanovsk Trans-Volga region, however, it is the minimum area of flora of a particular area. There is some data in the literary sources regarding the size of the minimum areas of flora of various natural zones. So, for the forest-tundra, the figure is 300 km$^2$, in the southern zone of the middle taiga - up to 600 km$^2$ [23]. In Latvia, the value of this parameter is 600-650 km$^2$ [24]. There is no reliable information regarding the steppe and forest-steppe zones. R.V. Kamelin indicates a possible range "for a zone of broad-leaved forest or forest-steppe, steppe ... up to 400-450 km$^2$" [25, p. 154]. He also notes that this value changes depending on the conditions of a natural zone. It is very likely that even inside the natural zone it does not remain strictly constant, however, for an approximate value in the forest-steppe zone, it is quite possible to operate with a value of 400 km$^2$.

3.4. Analysis of taxonomic indicators of floras for trial plots (family and genera spectrum)
The taxonomic parameters of ten trial plots (figure 2), which are the minimum ranges of local floras, should correspond or approach the parameters for regional floras. A certain control - a reference spectrum (according to AP Khokhryakov [26]) - can be the spectra of the floras of the physical-geographical regions of the Samara-Ulyanovsk Trans-Volga region. We note that the composition and arrangement of the head part of the families is similar, when comparing the obtained parameters for ten sites with these data [27] (table 1).
The selected plots have a sufficient area, including the main set of ecotopes. Consequently, their floristic composition may represent regional flora. The first two families - *Asteraceae* and *Poaceae* - rank first and second. This "is typical for almost the entire Holarctic, excluding some areas of the Arctic, deserts and highlands" [28, p. 12-13]. The third place in the considered flora belongs to the family, which determines its type [26]. According to this indicator, our floras differ. It reflects the difference in the natural conditions of the two regions under consideration as part of the model territory. The order of the remaining families from the top ten may vary somewhat for the ten floras under consideration, but the general list remains the same.

There are 2 groups of flora. In the first, we included I-VII, which form the flora of the *Fabaceae* type; in the second - VIII-X, belonging to the *Rosaceae* type (see figure 2 and table 1). Drawing on additional information on the distribution of species (figure 1), we have built a flora type change graph (figure 4). The resulting graph shows that the transition from one type of flora to another is about 10 km.

**Figure 4.** Change in the type of flora in the longitudinal direction (*Z* - the size of the transition zone)

The order of the leading genera in the considered floras is not as unambiguous as in the case of families. The abundance of the genus *Carex* is an unambiguous feature of all Eurasian floras [25]. In regional floras, this genus should lead the spectrum, and its share should be significantly higher than that of the rest. This is confirmed by data on physical and geographical provinces, as well as regions, the floristic lists of which are quite complete [29]. This fact once again suggests that the sample of
600-800 species does not fully reflect the complete list of flora characteristics, but only its main features. The genus Carex is among the leading one, but not always the most numerous one (table 2).

**Table 2. Share of species in leading genera**

|     | I    | II   | III  | IV   | V    | VI   | VII  | VIII | IX  | X   |
|-----|------|------|------|------|------|------|------|------|-----|-----|
| Carex | 0.032 | 0.013 | 0.020 | 0.024 | 0.019 | 0.023 | 0.024 | 0.027 | 0.029 | 0.025 |
| Potentilla | 0.019 | 0.012 | 0.016 | 0.016 | 0.019 | 0.016 | 0.010 | 0.014 | 0.01 | 0.016 |
| Galium | 0.019 | 0.016 | 0.021 | 0.024 | 0.022 | 0.021 | 0.019 | 0.019 | 0.014 | 0.016 |
| Artemisia | 0.018 | 0.020 | 0.017 | 0.015 | 0.019 | 0.018 | 0.013 | 0.008 | 0.013 | 0.014 |
| Viola | 0.017 | 0.010 | 0.016 | 0.015 | 0.014 | 0.016 | 0.007 | 0.013 | 0.008 | 0.012 |
| Astragalus | 0.015 | 0.021 | 0.017 | 0.016 | 0.016 | 0.016 | 0.003 | 0.004 | 0.004 | 0.005 |
| Salix | 0.015 | 0.012 | 0.016 | 0.013 | 0.014 | 0.010 | 0.015 | 0.016 | 0.014 | 0.014 |

The proportion of almost all other genera in the ten floras under consideration differs. This is due to the greater sensitivity of the composition of the genera spectrum in comparison with the family one. The composition of the generic spectrum more accurately reflects the local natural conditions of the territory. In this example, according to the share of the genus Astragalus, all the 10 floras under consideration can be divided into two groups. In the first group, this genus is one of the leading (Soksky physical-geographical region), and in the second group it is represented by a smaller number of species and occupies an average position (Melekess-Stavropol region, Low Volga region). Thus, analysis of the genera spectrum provides definite information about the individual characteristics of local floras.

Figure 5 illustrates the general features of the combined flora of the entire territory under consideration (forest-steppe part of the Samara-Ulyanovsk Trans-Volga region). This flora belongs to the Fabaceae-type, has a characteristic leading position of the Asteraceae with a significant margin from the rest.

![Figure 5](image)

**Figure 5.** Taxonomic characteristics of the combined flora: a - the proportion of species in the leading families; b - the proportion of species in the leading genera

**Conclusions**

The dominant conclusion which emerges from the facts given above, the area of flora research should be at least 400 km²; and its floristic capacity is 600-800 species for the Samara-Ulyanovsk Trans-Volga region. We studied ten floras of the Samara-Ulyanovsk Trans-Volga region and can consider them as reference flora units appropriate for comparative analysis, as well as for studying various
aspects of biodiversity at the level of floras ($\gamma$-diversity) [30, 31]. Such reference units (minimal areas of the local flora) reflect both regional and local features and allow considering the entire mosaic of the diversity of the flora of the territory, reflecting the diversity of environmental conditions.

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