Integrative assessment of anthropogenic transformation of the flora in the Uzyukovo forest massif (Low Trans-Volga region)

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Abstract. The authors give a physical and geographical description of the Uzyukovo district forestry (Low Zavolzhye) in the Novo-Buyansky forestry of Samara forest management with a forested area of about 8.5 thousand hectares. An inventory of the species composition of the flora of the Uzyukovo district forestry revealed about 400 species of vascular plants. We carried out a comprehensive ecological analysis of floristic fractions: taxonomic, biomorphic, phytocoenotic, and geographical. Comprehensive ecological analysis as a whole reflects the confinement of flora to the forest-steppe zone. The results of a comprehensive ecological analysis are supported by a physicochemical analysis of the soil cover of the Uzyukovo forest massif. The tendencies of anthropogenic dynamics of flora are considered, the degree of anthropogenic disturbance of floristic complexes is revealed by means of soil analysis, analysis of the adventive component and the preservation of rare species of flora. In the adventive flora of the Uzyukovsky forest massif, 98 species of plants, mainly woody, have been identified. The authors provide a list of rare species in need of conservation, of which 2 species are included in the Red Data Book of the Russian Federation and 21 species in the Red Data Book of Samara Region. Under the influence of anthropogenic factors, on the one hand, ecological-floristic complexes are enriched with eurytopic weed species, and on the other, the number of anthropophobic rare species is reduced, which is steadily leading to the unification of the flora. In this regard, the authors recommend assigning the Uzyukovsky forest massif the status of a regional natural monument and regularly carrying out environmental monitoring.

1. Introduction
Uzyukovo district forestry with total area is 8723 hectares, belongs to the Novo-Buyansk’s forestry of the Samara forest management with a total area of 44781 hectares. Uzyukovo district forestry is represented by 82 blocks which located on the territory of the Stavropol administrative region by Samara region [1]. The territory of the Uzyukovo district forestry is assigned to the forest-steppe region of the European part of the Russian Federation in accordance with the forestry zoning approved by the order of the Federal Forestry Agency dated 09.03.2011 No. 61 10 «On approval of the List of forest growing zones of the Russian Federation and the List of forest regions of the Russian
Federation». The need for an integrative ecological and biological assessment, as well as the degree of anthropogenic transformation by the flora of the Uzyukovo district forestry, is due to an ever-increasing anthropogenic load: timber harvesting by the population for their own needs, construction of pipelines and power lines, landfills, placement of summer cattle camps, hunting, harvesting non-timber and food forest resources, off-road transport. Also, a number of permitted works are carried out on the territory of the forestry: logging (quarters 1-82), harvesting food forest resources and collecting medicinal plants, hunting (quarters 13, 20, 21), farming (beehkeeping and haymaking), growing planting materials forest plants. In addition, in accordance with the forestry regulations of the Novo-Buynsk forestry [2], the Uzyukovo district forestry is classified as a forest of scientific or historical significance (quarters 13, 20, 21), as well as a forest park zone (quarters 1-12, 14-19, 22-82). In addition, in the course of the study, a number of species from the Red Data Book of the Samara Region were discovered, which in the future would make it possible to refer it to specially protected natural areas, along with the protected areas "Mastryukovskie lakes" and "Pine tree stand" (Zadelmensky pine forest), also located on the territory of the Novo-Buynsk forestry. Also, on the territory of the Uzyukovo district forestry, a number of key biotopes were discovered that are of particular importance for the conservation of biodiversity: groups of old-growth trees, small swampy depressions, areas around groundwater pinching out, forest areas around water bodies.

2. Materials and methods

2.1. Natural conditions

In accordance with the physical and geographical zoning [3], the territory of the Uzyukovo district forestry belongs to the Melekessko-Stavropol lowland-plain area of pine forests on hilly sands. The nature of the relief is due to the geological history and geological structure of the territory. By the nature of the relief, the territory of the forestry belongs to the Low Zavolzhie. The Uzyukovo’s pine forest is located on the surface of the third above-floodplain terrace of the Late Pleistocene age, and since the structure of the terrace is dominated by yellow-brown loams, sands and sandy loams [3], the terrain is uneven, raised by sand dunes with a common slope from north-east to south-west, subject to weathering. Erosional landforms are practically not represented. The absolute marks in the southeastern part of the forestry (quarters 77-79) are about 95 meters, at the north-eastern part reaches 150 meters.

The territory of the forestry belongs to the northern region of the Volga terraces of the Cis-Ural province, according to the soil zoning of Samara region, proposed by L I Prasolov [4]. This area is composed of ancient alluvial deposits. Chernozem and gray forest soils, predominantly of light sandy loam texture, as well as podzolic soils (pine sands) prevail here under forest plantations [5]. We analyzed a number of physical and chemical indicators of the soils of the Uzyukovo district forestry, which revealed that the average humidity (according to the gravimetric method) is about 70%, the actual acidity varies from 5.1 to 6.7, the humus content is about 4.5%, No carbonates were found in the soil (the method of boiling with hydrochloric acid); in most samples, the soil is lumpy and poorly compacted.

The climate of the territory of the Uzyukovo district forestry is characterized by high continentality, lack of atmospheric precipitation and moisture, rapid transition from a long cold winter (lasts about 5 months, the snow cover is 140-150 days) to a hot summer (duration about three months, with relatively little precipitation). The average annual air temperature is 4.0°C. The absolute minimum is –46°C, maximum + 40°C. The average annual amount is 410 mm.

As of 01.01.2014, the forested area was 8723 hectares, of which 6945 hectares or 89.2% are pine, 471 hectares or 6.0% - aspen, 214 hectares or 2.7% - birch, 52 hectares or 0.7% is coppice oak and 106 hectares or 1.4% is accounted for by other species. Due to the peculiarities of the climate and vegetation by a larger area of the Uzyukovo district forestry, about 8422 hectares, the second class of natural fire hazard was assigned. Most often, ground fires occur here. Analysis of data on forest fire
rate in the forestry showed that the frequency of fires averages 280 cases per 1 million hectares of forests per year, which corresponds to "extreme" fire rate.

2.2. Initial data and processing
Information about the vegetation cover of the Uzyukovo’s pine forest is contained in the works of P S Pallas, G N Vysotsky, T I Plaksina [6], A A Ustinova et al [7].

The study of the flora of the forest in the last decade has been carried out by botanists from the Laboratory of Phyto-diversity Problems of the Institute of Ecology of the Volga river Basin of the Russian Academy of Sciences under the guidance of prof. S Saxonov [8, 9, 10, 11]. The studies of the flora of the Uzyukovo’s district forestry were carried out in 3 stages:

1. Preparatory stage - acquaintance with the object of study and the selected area; determination of the degree of research detail; long-term organizational, material and financial planning of expeditionary operations; choice of techniques. The herbarium material on the territory of the Uzyukovo district forestry, as well as the forest management plan, was studied. The volume of flora was determined. The main problem was the inclusion of cultivated plants in the annotated list. The solution was the inclusion of those cultivated species which are able to stay in the landing sites for at least two years.

2. Field research was carried out by the traditional route method, quarterly, in combination with a detailed study of flora in a number of main biotopes. In the course of floristic research, it is desirable to document the growth of all species of this flora. Therefore, we collected, taking into account the peculiarities of collection and storage, and transferred to the herbarium of the Institute of Ecology of the Volga River Basin of the Russian Academy of Sciences, more than 150 herbarium sheets.

3. Processing of floristic materials carried out by analyzing herbarium labels and field diary entries, a summary of the flora of the Uzyukovo district forestry was compiled. At the flora’s list, information on each species is given in the following order: 1. The serial number of the plant. 2. Latin name of the species [12]. 3. Life form according to I G Serebryakov and H K Raunkier [13]. 4. Ecotype. 5. Phytotype. 6. Characteristics of the adventive species. 7. Geographic area [13]. 8. Occurrence, rarity status. For the list of cultivated plants, a number of notes have been made on the peculiarities of growth. In relation to the plants that we did not find for the territory of the Uzyukovo district forestry, but previously indicated for it, a column was highlighted explaining where and by whom this or that species was indicated.

3. Results and discussion
As a result of the conducted studies, the general floristic composition of the Uzyukovo’s forestry was revealed: in the modern flora of the Uzyukovo forest were identified 513 species of vascular plants, which are part of 67 families, of which: 363 species (82.9%) are land plants, 32 species (10.1%) - aquatic, 22 species (7%) - amphibious plants.

1. Life form according to I G Serebryakov and H K Raunkier [13]

The basis of the classification of H K Raunkier - the location of buds or shoot tops during an unfavorable season in relation to the soil surface. In accordance with this principle, all plants were subdivided by him into five types: 1. phanerophyte: a) mesophyte b) microphyte c) nanophyte 2. hamephite; 3. hemicryptophyte: 4. cryptophyte: a) geophyte, b) helophyte, c) hydrophyte; 5. therophyte.

The percentage distribution of species in these five main groups of life forms in various phytocenoses is called the biological spectrum (figure 1).

From the above diagram, it can be seen that hemicryptophyte plants (Dryopteris filix-mas (L.) Schott, Pulsatilla patens (L.) Mill., Stellaria graminea L., Dianthus arenarius L., Malva pusilla Smith, Geranium sanguineum L., etc.), which is typical for boreal forests confined to fairly light sandy soils and sands with rich aquifers along the Volga, for communities of the middle belt. The predominance of the hemicryptophyte group is a common feature for meadow communities. The second largest numbers are represented by therophytes (Salvinia natans (L.) All., Stellaria media (L.)
Will., *Amaranthus retroflexus* L., *Chenopodium rubrum* L., *Chenopodium urbicum* L.), which is typical for steppe communities, as well as for anthropogenic of altered habitats, and a significant participation of therophyte group of plants in the herbage indicates a gradual weed infestation.

**Figure 1.** Biomorphic structure of vegetation of the Uzyukovo district forestry according to the classification of H K Raunkier, %

Another system of life forms, developed by Professor I.G. Serebryakov, is based on the specific habit characteristics of plants. The results of flora analysis of the Uzyukovo’s forestry using this classification are presented in table 1.

**Table 1.** Life forms of the flora of the Uzyukovo district forestry according to the classification of I G Serebryakov

| No. | Life form                        | % of the total number of species |
|-----|----------------------------------|----------------------------------|
| 1   | Bush                             | 4.8%                             |
| 2   | Shrub                            | 6.9%                             |
| 3   | Subshrub                         | 0.3%                             |
| 4   | Dwarf subshrub                   | 1.9%                             |
| 5   | Polycarpic grass (herbaceous perennials): | 67.2% |
|     | a taproot                        | 17.4%                            |
|     | b tassel                         | 3.2%                             |
|     | c short rhizome                  | 9.4%                             |
|     | d long-rhizome                   | 16.4%                            |
|     | e dense bush                     | 1.6%                             |
|     | f loose shrub                    | 4.4%                             |
|     | g aboveground                    | 1.9%                             |
|     | i creeping                       | 2.2%                             |
|     | g liana-like                     | 3.5%                             |
|     | k root sucker                    | 4.4%                             |
|     | l tuberous                       | 1.9%                             |
|     | m bulbous                        | 0.9%                             |
| 6   | Monocarp grass                   | 15.8%                            |
|     | a perennial monocarpic           | 4.1%                             |
|     | b biennial                       | 5.1%                             |
|     | c annual                         | 6.6%                             |
| 7   | Floating and underwater          | 3.1%                             |
|     | a rooting submerged              | 0.9%                             |
|     | b floating                       | 2.2%                             |
| TOTAL: |                                   | 100%                             |
Consideration of the biotypic spectrum shows that the studied flora is characterized by the predominance of herbaceous perennials (67.2%). Among them, rhizome perennials predominate (25.8%), which indicates rather unstable conditions of phytocenoses in the Uzyukovo forestry. There are quite a few tap-root plants (17.4%), which indicates good aeration of the substrate, because the physical and mechanical properties of the mother soil are indicated precisely by the structure of the plant root systems. Monocarpic herbs are in second place in terms of quantitative composition. Of these, annuals predominate (6.6%), biennials are much smaller (16 species, or 5.1%). The predominance of annuals indirectly indicates a fairly strong anthropogenic transformation of the flora.

Woody plants are placed at third place in terms of quantitative composition (13.9%). Of these, shrubs predominate (6.9%), slightly fewer trees (4.8%), which indicates a sufficient prevalence in the past in the studied area of forest communities.

4. Ecotype and phytotype.

Traditionally, the division into ecological groups was carried out in relation to the conditions of soil moisture. The ecological structure of the flora of the Uzyukovo district forestry is shown in Table 2.

| Environmental groups     | % of the total number of species |
|--------------------------|---------------------------------|
| Xerophytes               | 17.5                            |
| Xeromesophytes           | 8.2                             |
| Mesoxerophytes           | 7.0                             |
| Mesophytes               | 47.2                            |
| Mesohygrophytes          | 1.5                             |
| Hygromesophytes          | 3.8                             |
| Hygrophytes              | 6.9                             |
| Hygrohelophytes          | 0.5                             |
| Helophytes               | 2.8                             |
| Hydrophytes              | 4.6                             |
| Total:                   | 100                             |

The nature of the flora of the Uzyukovo district forestry is mostly mesophytic, which is due to climatic and soil conditions. Mesophytes are represented by forest, meadow-forest, forest-edged, forest-meadow and meadow flora, if we talk about phytocenotic classifications. The xerophytic fraction, represented by a number of steppe species that have adapted to moisture conditions, remains at the edges of the forest, also along the side of the Vasilyevka-Musorka road, along the Kirillovka forest belt. The number of hydrophytes is insignificant due to insufficient moisture and drying out of bogs and reservoirs.

6. Geographic area. Arealogical analysis of the flora [7, 13] allows us to draw some conclusions on its origin, revealing the migration routes of species. Having identified the similarities in the modern distribution of species, we combined similar types of habitats into 8 groups (figure 2).

In the flora of the Uzyukovo district forestry, species of the Eurasian arealogical group prevail, in which most of the species have the European-West Asian and Eurasian type of areas. Also, Euro-Siberian-Central Asian and Euro-Siberian species, whose ranges mostly cover the south of Western Siberia and, in part, Eastern Siberia, account for about 10% of the Eurasian species. Among them, species are numerically distinguished, the ranges of which in the latitudinal direction extend from Central Asia and the south of Western Siberia, partly covering the Caucasus, to the southern regions of Eastern Europe, in the meridional direction localized on the border of the Boreal and Ancient Mediterranean floristic subkingdoms. Along with the Eurasian type, the Holarctic type of areal plays a significant role in the arealogical spectrum of the studied region. In their distribution, these elements
are confined to the temperate zone of the continent. Within the Uzyukovo district forestry, there are plants of its multiple subelements: actually Holarctic - Comarum palustre, Potentilla anserina, etc.; boreal - Ranunculus sceleratus, Geum aleppicum, etc. plurizonal - Chamerion angustifolium, Plantago major, etc. The European group is in third place in terms of its share in the flora - 12.6% of the total flora. This group is markedly dominated by Eastern European species, which represent the most distinctive part of the studied flora, in which all endemic species are concentrated. boreal - Ranunculus sceleratus, Geum aleppicum, etc. plurizonal - Chamerion angustifolium, Plantago major, etc. The European group is in third place in terms of its share in the flora - 12.6% of the total flora. This group is markedly dominated by Eastern European species, which represent the most distinctive part of the studied flora, in which all endemic species are concentrated. boreal - Ranunculus sceleratus, Geum aleppicum, etc. plurizonal - Chamerion angustifolium, Plantago major, etc. The European group is in third place in terms of its share in the flora - 12.6% of the total flora. This group is markedly dominated by Eastern European species, which represent the most distinctive part of the studied flora, in which all endemic species are concentrated [8].

![Figure 2. Arealogical structure of the flora of the Uzyukovo district forestry](image-url)

In the flora of the Uzyukovo’s district forestry, 98 adventive plant species have been identified, which is 19.5% of the total number of species. Its flora synanthropization index is 0.155. It also took into account cultivated plants that have been kept in place of planting for more than two years. The main centers of synanthropization are roads: the highway of regional significance Togliatti - Kirillovka, an asphalt road with. Uzyukovo and N. Buyan. Through the forest fund passes a dirt road of public use from the village. Uzyukovo to the road to Samara. The average density of forest roads per 1,000 hectares of the forestry area is 17 km. Also, the factors of anthropogenic load on the territory of the forestry include: power lines, gas pipelines and product pipelines, cutting sites, the banks of water bodies. The most represented families are Asteraceae, Brassicaceae, Poaceae, Chenopodiaceae and Fabaceae, which account for 57.1% of the species diversity of the synanthropic flora. Adventive, rather dynamic plant species can serve as one of the many indicators of anthropogenic transformation in direct proportion.

But along with them, rare, rare plant species can serve as an indicator of anthropogenic disturbance. Here the relationship is reversed. In the flora of the Uzyukovo forestry, 28 rare and needing species have been identified [14]:

- Adonanthe vernalis (L.) Spach [Chrysocyathus vernalis (L.) Holub; Adonis vernalis L.]: rare. KKSO (V).
- Artemisia latifolia Ledeb.: rare. KKSO (monitoring list).
- Athyrium filix-femina (L.) Roth: rare, southwestern part of the forest [15]. KKSO (V).
- Carex bohemiaca Schreber.: rarely, Lake Mokhovoe (square 77). KKSO (III).
- Chimaphila umbellata (L.) WPC Barton: rare. KKSO (V).
Chondrilla graminea M. Bieb.: rare. KKSO (III).
Cirsium heterophyllum (L) Hill: rare. KKSO (monitoring list).
Comarum palustre L.: rarely. KKSO. KKSO (II).
Corydalis solida (L.) Clairv.: rare. KKSO (monitoring list). Note: previously shown also Corydalis intermedia (L.) Merat (square 36).
Delphinium cuneatum Steven ex DC.: KKSO (monitoring list).
Dianthus volgicus Juz.: rarely [Plaksina, 1998]. KKSO (III). Endemic to the Middle Volga region.
Fritillaria ruthenica Wikstr.: rare (sq. 41, 46, 47). KKRF, KKSO (V).
Gymnocarpium dryopteris (L.) Newm.: rare, southwestern part of the forest [Saksonov et al., 2012]. KKSO (V).
Helichrysum arenarium (L.) Moench: Occasionally. KKSO (III).
Lilium pilosiusculum (Freyn) Miscz. [L. martagon auct. non L.]: rare (square 41). KKSO (V).
Lycopodium clavatum L.: the species is collected in 1976 year... in env. from. Uzyukovo T.I. Plaksina [1976 and others]; currently not found. KKSO (I).
Maianthemum bifolium (L.) FW Schmidt: Occasionally. KKSO (II).
Matteuccia struthiopteris (L.) Tod.: rarely. KKSO (V).
Molinia caerulea (L.) Moench: rare. KKSO (monitoring list).
Platanthera bifolia (L.) Rich.: rare. KKSO (III).
Potamogeton acutifolius Link: rare, southern env. from. Uzyukovo (PVB, 2006). Needs protection.
Potentilla erecta (L.) Raeusch.: rarely (square 25). KKSO (II).
Pulsatilla patens (L.) Mill.: occasionally. KKSO (V).
Pyrola rotundifolia L.: occasionally. KKPO (V).
Salix alba L.: occasionally. KKSO (monitoring list).
Salvinia natans (L.) All.: rarely, Lake Mokhovoe (square 77). KKSO (III).
Stipa pennata L.: rarely. KKRF, KKSO (III). Note: populations are represented by subsp. sabulosa (Pacz.) Tzvelev [S. borysthenica Klokov ex Prokud.].

4. Conclusions
A comprehensive ecological and biological assessment of biodiversity, carried out for the flora of the Uzyukovo district forestry, made it possible to draw the following conclusions:
1. The floristic diversity of the Uzyukovo district forestry, according to the results of floristic research and analysis of literature data, is 513 plant species, of which 98 are adventive species;
2. The obtained ratios of classification groups by biomorphic, ecological-phytonetic and arealogical analysis are expected and confined by the zonal and ecological-topological belonging of the flora;
3) The flora is changing as a result of the ever increasing anthropogenic impact: on the one hand, the emergence of new floristic complexes with highly tolerant species, on the other hand, the disappearance of indigenous floristic complexes with vulnerable and anthropophobic plant species.

References
[1] Detailed design of the fire-prevention device for the forests of the Uzyukovo’s forestry of the Novo-Buyan’s forestry enterprise of the Samara forest management. Federal Forestry Service of Russia Russian State Design and Research Institute "ROSGIPROLES" Saratov branch.. Volume III, Book I, Explanatory Note. (Saratov).
[2] Forestry regulations of the Novo-Buyan’s forestry 2018 Approved by order of the Ministry of Forestry, Environmental Protection and Nature Management of the Samara Region 405 (Samara)
[3] Physical and geographical regionalization of the Middle Volga region 1964 ed. A V Stupishin (Kazan: Publishing house of Kazan University)
[4] Natural conditions of the Kuibyshev region 1990 (Kuibyshev)
[5] Natural conditions of the Samara region 2017 (Samara)
[6] Abstract of the flora of the Volga-Ural region 2001 ed T I Plaksina (Samara: Samara University, 2001)
[7] Vascular plants of the Samara region 2007 eds A A Ustinova and N S Ilyina. (Samara: LLC IPK "Commonwealth")
[8] Savenko O V 2008 Anthropogenic transformation of the flora of the Melekess-Stavropol landscape region The author’s abstract dis.... Cand. Sc. (Togliatti)
[9] Savenko O 2007 Biomorphic analysis of the flora of the Uzyukovsky forestry (Stavropol district of the Samara region) Ecological collection. Works of young scientists of the Volga region (Togliatti) pp 146–150
[10] Savenko O, Saxonov S and Senator S 2011 Materials (edit) for flora Uzyukovo’s forest array (Samara Zavolzhye) Research in areas natural sciences and education (Togliatti) pp 48-54
[11] Saksonov S, Senator S and Ivanova A 2012 The first addition to the flora of the Uzyukovo’s forest massif (Samara Low Trans-Volga region) Structural-functional organization and dynamics of vegetation cover: Proceedings of the All-Russian. scientific-practical conf. from international participation, dedicated. 100th anniversary of the birth. Doctor of Biological Sciences, prof. V.E. Timofeeva (Samara) pp 92–95
[12] Mayevsky P F 2006 Flora of the middle zone of the European part of Russia (Moscow: KMK).
[13] Vascular plants of Tatarstan 2000 eds O V Bakin, T V Rogova and A P Sitnikov. (Kazan)
[14] Red Data Book of the Samara Region. Rare species of plants and fungi 2017 Vol 1. eds S A Senator and S V Saxonov. (Samara: Publishing house of the Samara State Regional Academy (Nayanova))
[15] Senator S, Rakov N, Saksonov S, Vasyukov V and Ivanova A 2013 New and rare alien plants in the middle Volga region Russian Journal of Biological Invasions 3 98–104