Floristic transformation of the steppe area in the lower reaches of the Osyotr River due to anthropogenic impact

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Abstract. The purpose of this study was to survey the steppe site located on the right bank of the Osyotr River, near the village of Argunovo, in the urban district of Zaraysk, Moscow Region. It was required to analyze the key floristic changes that have occurred in its composition to date. For comparison, the floristic description of this site, detailed by R.I. Dyakova in the 1950s. The work takes into account the fact of man-made interference in the 1960s, as a result of limestone mining there in violation of the vegetation cover. In the autumn, 2020 the authors of this article studied a steppe site in the neighborhoods of the village of Argunovo in Zaraisk urban district of Moscow region and collected a herbarium donated to funds [MHA]. This steppe community was first discovered and described in detail by R.I. Dyakova in the 1950s. In the 20th century, due to the extraction of limestone in the lower reaches of the Osyotr River, this biotope was disturbed. It was established that over the past 70 years, the area occupied by the association with Stipa pennata L. and Geranium sanguineum L. significantly decreased and some steppe species disappeared. A factor in the transformation of the steppe censis was also cessation of grazing, which led to the appearance of a number of meadow-steppe species. The studied area near the village of Argunovo can be considered as a unique meadow-steppe reserve. It is located at the northern border of the forest-steppe zone and includes the elements of the Oka steppe flora that has preserved to this day. The populations of rare and protected species have been preserved: Stipa pennata, Aster amellus L., Campanula bononiensis L., Gentiana cruciata L., Rosa villosa L. and Pyrus communis L., included in the Red Data Book of Moscow Region. The studied area is potentially susceptible to the invasion of alien species (Heracleum sosnowskyi Manden, Acer negundo L.) and needs monitoring and protection at the level of the community, population and each species.

1. Introduction
The flora of the Moscow region is experiencing an increasing anthropogenic load every year, due to agricultural and industrial activities. Here the negative influence of technogenic factors is traced in some populations as in many regions of the world [1]. As a result of the economic development of natural territories, the transformation of natural landscapes inevitably occurs, leading to both the depletion of the floristic composition and the appearance of alien elements [2, 3, 4, 5]. The populations located on the border of the area of species are especially vulnerable. One such example is the northernmost section of the steppe, located in the lower reaches of the Osyotr River near the village...
Argunovo, in the urban district of Zaraisk. For the first time, this site was described in detail in the middle of the XX century [6, 7].

The purpose and tasks of this work are the study the modern floristic composition in the steppe area on the right bank of the Osyotr River, near the village of Argunovo, and to analyze the key changes that have occurred over the past 70 years.

2. Materials and Methods
The steppe area is located on the right bank of the Osyotr River, ~ 1 km to the west of the village of Argunovo (figure 1), in Zaraisk urban district, Moscow Region.

![Figure 1](image-url)

**Figure 1.** Fragment of a geobotanical map of the neighborhoods of Argunovo, according to R.I.Dyakova [7].

During the field route in September 2020, a steep (up to 45 °) steppe slope of southern exposure (N 54°52´34´´; E 38°48´23´´) was examined. In the 1960s, limestone was mined here. At the site of the excavated rock, hollows, steps and large trough-shaped niches were formed, included into the main surface of the bedrock bank to a depth of 0.5 m to 3 m. At the foot of the ledges there were pits with steep talus slopes. The soil cover, which was formed on carbonate rubble and larger fragments of limestone, was thin and in some places was absent.

During the field route, herbarium collections of 96 plants were made, 50 sheets were stored in the Herbarium Fund [MHA]. The aboriginal and adventive fractions are distinguished in the studied flora. Latin names are given according to P.F. Maevsky [8]. Accounting for rare and vulnerable plant species was carried out according to the Red Data Book of Moscow Region [9].

The works of R.I. Dyakova [6, 7], reflecting the situation in the middle of the XX century were used as a source for the comparison of data on the species floristic diversity in the neighborhoods of the village Argunovo. During this period, there was already an outflow of the rural population to the cities and agricultural activities were characterized by the increase in intensification. Thus, we compared the floristic composition described under the conditions of the transformation of agricultural landscapes in the 1950s with their current state after the economic changes at the turn of the XX – XXI centuries.

3. Results and Discussion

3.1. Steppe site near the village Argunovo in the 1950s
In 1951 R.I. Dyakova [6] discovered and described a steppe area with a length of 300-400 m. The terrain is uneven due to numerous crops of large slabs and limestone blocks. The slope was in places
overgrown with shoots of *Quercus robur* L. and *Corylus avellana* L. R.I. Dyakova identified two associations on this steppe area.

The first association: *Stipa pennata – Koeleria cristata + Geranium sanguineum. Stipa pennata* (S. joannis Gel. – R.I. Dyakova) occupied a significant area in the upper and middle parts of the steep slope of the right bank of the Osyotr river. At the same time, *Koeleria cristata* (*K. gracilis* (Pers.) – R.I. Dyakova) grew scattered, on a slope between limestone slabs, along the edge of the forest, in places passing to a flat main surface plains.

In addition to the mentioned species, in spring the following ones were found: *Bromopsis inermis* (Leyss.) Holub, *Poa pratensis* L., *Phleum phleoides* (L.) H. Karst., *Festuca rubra* L., *Knauti a arvensis* (L.) J.M. Coul., *Agrimonia eupatoria* L., *Medicago falcata* L., *Centareua scabiosa* L., *Trifolium montanum* L., *Artemisia campestris* L., *Melilotus officinalis* (L.) Pall., *Origanum vulgare* L., *Cichorium intybus* L., *Malva thuringiaca* (L.) Vis., *Solidago virgaurea* L., *Achillea setacea* Waldst. & Kit., *Nepeta pannonica* L., *Coronilla varia* L., *Astragalus cicer* L., *Salvia pratensis* L., *Phlomoides tuberosa* (L.) Moench., *Aster amellus* L. and *Gentiana cruciata* L. [6].

The second association: *Anemone sylvestris* L. – *Geranium sanguineum* located on a stepwise slope. The flora of the association included the following species: *Stipa pennata, Koeleria cristata, Festuca valesiaca* Gaud. (F. sulcata Hack.), *Poa pratensis*, *Carex praeceps* Schreb., *Caryophylllea* Latour., *Vicia cracca* L., *Trifolium montanum*, *Fragaria vesca* L., *Veronica chamaedrys* L., *Knauti a arvensis*, *Polygala comosa* Schkuhr., *Potentilla heptaphylla* L., *P. argentea* L., *Cerastium holosteoides* Fr., *Stachys annua* (L.) L., *Achillea millefolium* L., *Hypericum perforatum* L., *Leucanthemum vulgare* Lam., *Myosotis sylvatica* Ehrh. ex Hoffm., *Taraxacum officinale* F.H. Wigg., *Cichorium intybus*, *Plantago media* L. and *Alchemilla vulgaris* L. [6; 7].

In the 1950s, a steppe site in the lower reaches of the Osyotr River near the village Argunovo was indicated by R.I. Dyakova as the only location of such species as *Stipa pennata, Nepeta pannonica, Aster amellus, Geranium sanguineum* and *Coronilla varia* in the urban district of Zaraisk.

Historically, in the urban district of Zaraisk, including the 1950s, it turned out that steep meadow slopes along the banks of rivers and hollows were used as pastures [7]. R.I. Dyakova believed that livestock grazing significantly reduced the steppe vegetation: «in the past, before human impact, the banks of the Osyotr were occupied by the same [steppe] vegetation, but now everything is disturbed» [6, p. 69].

In 1969, near the village of Argunovo there were “extensive limestone quarries” [10, p. 85]. A part of the high bank was torn down. As a result of the removal of rock, artificial niches, steps, pits and hollows were formed. During the study of this site in 1969 attributed to the Oka flora and located in the Oka river basin, A.K. Skvortsov [10] noted soddy grasses – *Festuca valesiaca* and *Koeleria cristata*, but *Stipa pennata* was not found. As a part of the ecotone he listed *Fragaria viridis* (Duch.) Weston, *Geranium sanguineum, Anemone sylvestris* and shrubs of *Rhamnus cathartica* L.

### 3.2. Steppe site near the village Argunovo in 2020

In September 2020, the authors noticed that in pits and hollows, near ledges that protect from through winds, where moisture conditions are better, woody and shrubby plants grow: *Ulmus laevis* Pallas., *Salix caprea* L., *Rosa cinnamomea* L. (= *R. majalis* Herrm.), *Rhamnus cathartica* and *Rubus caesius* L., including rare and protected species in Moscow region [9] – *Pyrus communis* L. and *Rosa villosa* L.

Among herbaceous plants on limestone crops, the presence of species was confirmed [6; 7; 10]: *Achillea millefolium, A. nobilis, Astragalus cicer, A. glycyphyllus, Briza media, Phleum phleoides, Melilotus officinalis, Coronilla varia, Plantago media, Centareua scabiosa* and *Fragaria viridis*. On this site, the only habitat of *Geranium sanguineum* in the urban district of Zaraisk with significant clumps and single individuals of the protected in Moscow region species of *Aster amellus* were again found [9].
Especially valuable is *Stipa pennata*. It grows on a terrace ledge in the middle of the steep slope of the right bank of the Osyotr River together with *Geranium sanguineum*. Nowadays, the length of the area occupied by *S. pennata* has decreased to 100-150 m. Thus, in spatial terms, the discovered meadow-steppe community corresponds to the second, previously identified [6, 7] of the association *Anemone sylvestris - Geranium sanguineum*, a part of which falls on the hard-to-reach slope and was not affected by limestone mining. Probably, the presence of *Anemone sylvestris*, *Festuca valesiaca*, *Koeleria cristata* should be expected in this community, but these species were not found in autumn.

After the termination of grazing in the beginning of 1990s on the slopes of the Osyotr River valley, *Poa angustifolia* L., *P. compressa* L., *Festuca pratensis* Huds., *Calamagrostis epigeios* (L.) Roth, *Leontodon hispidus* L., *Phlomis tuberosa* L., *Eryngium planum* L., *Seseli annuum* L., *Galium verum* L. and *Campanula bononiensis* L. appeared in the studied community by 2020. These floristic elements, confined to the outskirts of the meadow, grow together with the above mentioned *Centaurea scabiosa*, *Achillea millefolium*, *A. nobilis*, *Astragalus cicer*, *A. glycyphyllos* and *Coronilla varia*.

The population of the protected in Moscow region species *Gentiana cruciata* [9], in the steppe area near the village of Zarunovo is currently represented by ~ 40 individuals of different ages. If in the 1950s *G. cruciata* near the village of Zarunovo was rare and scattered at limestone crops, then by 2020 it was firmly entrenched in this biocenosis, occupying not only moistened depressions, but also open, drier, steppe areas.

In 2020, new species for the urban district of Moscow region [11] were identified: *Lithospermum officinale* L., characteristic of the steppes and stony slopes, as well as two species *Euphrasia brevipila* Burnat & Greml and *E. pectinata* Ten.

At the same time, some of the meadow-steppe and steppe species, such as *Nepeta pannonica*, *Agrostis syreistschikowii* Smirn., *Carex carophylla* Latourr., *Potentilla heptaphylla*, which were found in the middle of the 20th century, were not found on the site and in its neighbourhoods, probably due to anthropogenic interference.

It is necessary to note that the lower part of the slope of the Osyotr River, located in the in the direct neighborhood of the steppe area, turned out to be the most accessible for colonization of alien species. *Acer negundo* L. dominating in coastal phytocenoses [12], which is characterized by a high invasive activity, has been known in the region for several decades. According to our observations in 2019, fruit trees have settled at considerable distances from the river bed. The invasive species *Heracleum sosnowskyi* Manden is successfully occupying the river valley [13], the adult specimens of which are concentrated on the coastal part of the Osyotr River. Separate seedlings and juveniles of aggressive alien species were found in the watershed zone at a distance from the coast. *Bidens frondosa* L. and *Echinocystis lobata* Torr. et Gray classified as invasive species [14] that pose a potential threat to native meadow-steppe communities are found at the bottom of the River.

4. Conclusion
This isolated steppe site in the lower reaches of the Osyotr River near the village Argunovo in the Zaraisk urban district of Moscow region is unique because it is located at the northern boundary of the forest-steppe zone and includes the elements of the Oka steppe flora that has preserved to our days.

The composition of taxa was found in the area of mixed feather-grass steppe and a potential threat of colonization of alien species *Acer negundo* and *Heracleum sosnowskyi* was noted.

In the second half of the 20th century, as a result of limestone mining, the studied steppe area was severely disturbed, while the area occupied by the association with *Stipa pennata* and *Geranium sanguineum* was significantly reduced. Rare and protected species were recorded there: *Rosa villosa*, *Pyrus communis*, *Gentiana cruciata*, *Aster amellus* and *Campanula bononiensis*, included in the «Red Data Book of Moscow Region».

It was found that over the past 70 years, the species composition of the community has also undergone a transformation associated with the cessation of livestock grazing. By 2020, the authors revealed the disappearance of a number of steppe elements and the appearance in the biocenosis of meadow-steppe species, which were absent in the middle of the 20th century.
The steppe site in the lower reaches of the Osyotr River near the village Argunovo in Moscow Region can be considered as a meadow-steppe area, which is of particular importance for the preservation and restoration of the ecosystems of the region. It needs constant monitoring and protection at the community, population and every species level.

Acknowledgement
The research was carried out in accordance with Institutional research projects of MBG RAS No. 118021490111-5, IHST RAS No. 0002-2019-0005 and with financial support from the RFBR, project No 18-311-00224 Mol-a.

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