Vegetation dynamics of Kulikovo Field agrosteppes: the contribution of environmental factors

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Abstract. On the territory of the Kulikovo Field Museum-Reserve (Tula region) the restoration of meadow-steppe communities is carried out by different methods: the sowing grass mixtures, seed material and using a combined approach. The aim of the work is to assess of structure phytodiversity of plant communities on the gradient of reconstruction succession. The using DCA-ordination analysis of geobotanical descriptions is allowed us to select 4 groups of communities that differ by age of sowing. In phytosociological spectrum of youngest communities the activity of species of the classes of natural and synanthropic vegetation is approximately the same. With an increase in the age of experiments the activity of apophyte species from natural vegetation classes increases and the activity of synanthropic species decreases. The revealed trend is confirmed by the analysis of the activity of species of different life forms: with an increase in the age of communities, there is a decrease in the activity of monocarpic one- and two-year-old weed species, which have high activity at the initial stages of succession. In the middle stages of succession, dense-sod species are more active in communities, and in the latter stages, the activity of loose-sode and rod-root species increases. During the succession of agrosteps, there is an increase in the activity of meadow-steppe and steppe species from the classes Festuco-Brometea, Molinio-Arrhenatheretea, Trifolio-Geranieta and a decrease in the activity of synanthropic vegetation species (Papaveretea rhoeadis, Sisymbrietea, Artemisietea, Epilobietea angustifolii). The results obtained indicate a succession in the direction of formation of steppe meadows.

1. Introduction
The territory of the Kulikovo Field Museum-Reserve is located in the southeastern part of the Tula Region, in the subzone of the northern forest-steppe. Prior to the period of intensive agricultural development, the region was characterized by a combination of steppe vegetation, widespread in watersheds, and forests, confined mainly to the beams and slopes of river valleys [1]. The natural conditions and fertile soils contributed to the active development of the territory by humans. The anthropogenic transformation of landscapes, especially in the XXth century, led to a sharp reduction in the area occupied by steppe cenosis [2]. GIS analysis of the modern ratio of land areas for the allocated territory "Kulikovo Field and Monuments on It" (Order of the Ministry of Culture of the Russian Federation of 21.08.2014 No. 1462, area 7550 hectares) demonstrated that 47% of the territory is occupied by arable land, 37% by abandoned fields and secondary meadows [3].

Since 2000 project of meadow-steppe vegetation restoration has begun in accordance with the development program of the Kulikovo Field Museum-Reserve. It aimed at preserving natural objects
and reconstruction the historical landscape of the time of the Kulikovo Battle (1380). Currently, long-term experiment fields are presented on the territory. They are laid down in different years (2002-2018) by different methods: sowing of grass mixtures, seed material (wide sowing) and using a combined approach. The purpose of the study is to analyze the structure of phytodiversity of plant communities on the gradient of vegetation restorative succession of the territory of the Kulikovo Field Museum-Reserve.

2. Material and Methods

The Kulikovo Field is located in the northern part of the Mid-Russian Upland, in the Upper Don basin, in the south-eastern part of the Tula region. The terrain is quite complex and is represented by a preglacial erosion-denudation plain, processed by subsequent geomorphological processes [4]. Watersheds are a system of narrow extended vertex surfaces with altitudes of 180-220 m. River valleys are deeply cut - up to 40-60 m. The climate of the territory is temperate continental. The average annual precipitation is 500-600 mm, the average annual temperature is 8 °C, average temperature of July is 18 °C, January -10 °C. The soil cover is represented by zonal types of soils of the northern forest-steppe - chernozems and gray forest, as well as a group of intrazonal soils - alluvial floodplain, meadow-black earth, swamp lowland. Zonal vegetation is meadow steppes and broad-leaved forests [5].

The experiment to restore meadow-steppe communities is carried out on an area of 64 hectares using three different methods.

1. Method by D.S. Dzybov [6-8] are based on sowing grass mixtures of steppe plants mowed on a natural site on arable land.

2. Method by V.I. Danilov (wide-row sowing) [9]. Arable land was sown in rows with seeds of Stipa pennata L., S. pulcherrhima K. Koch, S. capillata L. with a 40 cm distance between rows in the first year of the experiment. In the next growing season, experimental fields with feather grasses seedlings were weeded to reduce competition with other species. Feather grasses formed turf and became more competitive to the end of the season. In this time, seeds of steppe herbs (Linum flavum L., Delphinium cuneatum Steven ex DC., Elisanthe viscosa (L.) Pers., Centaurea ruthenica Lam., Iris aphylla L., Trinia multicaulis (Poir.) Schischk., Lavatera thuringiaca L., Onobrychis arenaria (Kit.) DC., Coronilla varia L., Galium verum L., Genista tinctoria L., Medicago falcata L., Veronica teucrium L., Pyrethrum corymbosum (L.) Scop., Allium oleraceum L.) were sown in the row-spaces. In subsequent years, weeding was not carried out. At the end of the season, grass was mowed to prevent the litter accumulation.

3. Combined sowing. This method was used to form the «agrosteppe» horizontal structure, which is as close as possible to natural communities, and preserve the feather grasses abundance. Grass mixtures (mowed from the natural steppe slope) and seed material (feather grasses and steppe herbs) were sown on arable land.

To asses species composition 88 sample plots (10*10 m) were placed in experimental fields in the 2019-2020 vegetation seasons. Relieves were performed with indication of the total cover (%) and for each species of the grass layer. Indirect ordination analysis (DCA-ordination) with additional assessment of environmental variables contribution was carried out to identify leading environmental factors of community differentiation using Canoco 4.5 package [10]. To estimate trends of community structure dynamic, a species activity indicator was determined as the root of the product of species occurrence to the average cover [11]. For analysis of phytosociological spectrum dynamics species affinity to diagnostic groups of ecological-floristic classification classes is determined in accordance with "Survey of vegetation of Europe" [12]. Analysis of the phytosociological spectrum [13] and the spectrum of life forms by I.G. Serebryakov [14] was carried out using the table processing package JUICE [15].
3. Results and Discussion

The floristic and ecological differentiation of experimental field communities is illustrated by the results of the DCA ordination (figure 1). Communities of the most "young" fields (crops in 2014-2018) are localized on the left side of the diagram, the most "age" crops (2000-2002) – on the opposite side. This allows us to interpret the first axis of ordination as a time or community age factor. This assumption is confirmed by sufficiently high eigenvalues of axis (35%) and a high value of the correlation coefficient of the ecological variable "sowing year" vector with the axis (r = 0.81).

![Figure 1. DCA- ordination of Kulikovo Field sample plot communities.](image)

Notes: Axis 1, 2 – ordination axes; 1-4 – age of communities (years): 1 – 2-6, 2 – 9-11, 3 – 12-15, 4 – 18-20 years.

Based on the results of the ordinal analysis, the communities were allocated into 4 groups according to the age of the communities and interpreted as stages of restorative succession. The first group united the youngest communities aged 2-6 years (sowing 2014-2018), the second group - age 9-11 years (sowing 2009-2011), the third group - age 12-15 years (sowing 2005-2008), the fourth group united the oldest communities (age - 18-20 years) formed as a result of sowing in 2000-2002 years.

Comparison of phytosociological spectrum (figure 2) by 4 age groups revealed the following patterns. In the phytosociological spectrum of the youngest communities, the activity of species of natural and anthropogenic vegetation classes is approximately the same. Further, with an increase of the community age, the activity of apophytes from natural vegetation classes increases (from 386 to 689) and the activity of anthropogenic species decreases (from 378 to 135). In the phytosociological spectrum of the oldest communities, the activity of natural classes species in the cenoflora is more than 5 times higher than the anthropogenic. Note, that there is a slight decrease in the activity of apophytes from natural classes of vegetation in the second class of age (2009-2011). It is associated with the loss of some meadow-steppe species sowed in the beginning of experiment.

The activities of natural vegetation classes species are add up from activities of steppe species of the class Festuco-Brometea Br.-Bl. et Tx. Ex Soó 1947, to a lesser extent - species of meadows of the classes Molinio-Arrhenatheretea R. Tx. 1937 and edges of thermophilous forests from the class Trifolio-Geranietae T. Müller 1962. The last one presence is caused by species pool of complex landscape, mosaic territory and location in forest-steppe zone. We emphazise that significant increase of the total activity of natural classes species in the last stages of succession is associated with an increase in the activity of meadow species. Thus, in general, we can talk about the stability of steppe
species during restorative succession, the high proportion of meadow species at its final stages. This may indicate the mesophytic character of the final climax zonal communities that this restorative succession leads to - the communities of steppe meadows.

![Figure 2. Comparison of phytosociological species groups activity in plant communities of different stages of restorative succession.](image)

This assumption is also confirmed by the analysis of the activity of species of different life forms (figure 3). With an increasing of community age, the expected decrease of the monocarpic species activity occurs due to a decrease in the number and total cover of annuals and biennials species of weed plants, which have high activity in the initial stages of succession. At the same time, if in the middle stages of succession dense-sod plants are more active in communities, then in the last stages of succession the activity of loose-sod and rod-root plants increases sharply, the activity of dense-sod species decreases and become the same with the activity of rhizomatous plants.

![Figure 3. Comparison different life-form species activity in plant communities of different stages of restorative succession.](image)

Considering the ratio of life forms in the group of "target species" (those species that were purposefully planted or sown on fields during the experiment) (figure 4), we can noted that the increase in the proportion of loose-sod grasses reflects the processes that based on a species pool of natural flora, but not at the expense of newly introduced germs (seed material or seedlings).
Thus, activity dynamics (decrease for dense-sod species with an communities age increasing, an increase for rod-root and rhizomatous species, an increase for planted loose-sod species) characterize the direction of succession not towards steppe communities with a high role of dense-sod grasses, but in the direction of formation of steppe meadows and communities with a predominance mesophylous herbs.

A more detailed analysis of activity dynamics for cenoflora core species (species noted with a more than 40% constancy in at least one of the four community groups) allows us to clearly illustrate the described patterns (table 1). Most species associated with anthropogenous vegetation types significantly reduce activity or "fall out" of communities composition with an increase in the age of fields. Among them, as annual monocarpic herbs of the classes Papaveretea rhoeadis S. Brulo et al. 2001, Sisymbrietea Gutte et Hilbig 1975 (Polygonum convolvulus L., Lactuca serriola L., Lathyrus tuberosus L., etc.), as well as perennial short-root polycarpics (Artemisia absinthium L., A. vulgaris L.) and biennials (Carduus acanthoides L., Cynoglossum officinale L.) of class Artemisietea Lohmeyer et al. in Tx. ex von Rochow 1951. Among the species for which an activity increase in is noted, the long-rhizomatous grass Calamagrostis epigeios (L.) Roth., which grows in old-growth fields due to a decrease in the competitiveness of turf grasses, draws attention.

Among species of natural vegetation classes, a group of increasing activity is quite numerous. It includes steppe species of the class Festuco-Brometea (Poa angustifolia L., Bromus inermis Leyss., Medicago falcata, Centaurea scabiosa L.), species of meadows of the class Molino-Arrhenatheretea (Vicia cracca L., Achillea millefolium L., Centaurea jacea L.) and species of edges of thermophilous forests from the class Trifolio-Geranieta (Gallium verum, Agrimonia eupatoria L., Hypericum perforatum L.). Most of the "target species" are part of a groups with stable (Linum flavum, Onobrychis arenaria, Stipa pennata, Salvia pratensis L.) or decreasing activity (Festuca valesiaca Gaudin, Stipa capillata, Pyrethrum corymbosum).

| Table 1. Activity trends of cenoflora core species of different years communities. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| (a) Species | Class | Activity |
| Age of community (years) | | 2-6 | 9-11 | 12-15 | 18-20 |
| Species of antropogenic vegetation classes |
| Activity decreased: |
| Polygonum convolvulus | PAR | 41.86 | 1.59 | 5.30 | 0.28 |
| Artemisia absinthium | ART | 38.58 | 9.47 | 11.51 | 0.00 |
| Artemisia vulgaris | ART | 34.63 | 3.71 | 3.64 | 1.92 |

**Figure 4.** Comparison different life-form species activity among target species in plant communities of different stages of restorative succession.
### Table 1: Activity of Species in Different Age Classes

| Species                        | Class | Age of community (years) | Activity |
|--------------------------------|-------|--------------------------|----------|
|                               |       |                          | 2-6      | 9-11 | 12-15 | 18-20 |
| Carduus acanthoides            | ART   |                          | 26.01    | 5.84 | 5.60  | 0.99  |
| Lactuca serriola               | SIS   |                          | 22.75    | 2.06 | 5.79  | 0.57  |
| Cirsium arvense                | PAR   |                          | 22.42    | 13.98| 11.95 | 3.46  |
| Lathyrus tuberosus             | PAR   |                          | 14.39    | 3.28 | 2.60  | 4.32  |
| Linaria vulgaris               | ART   |                          | 10.04    | 2.09 | 0.16  | 1.92  |
| Delphinium consolida           | PAR   |                          | 9.41     | 4.48 | 1.74  | 0.00  |
| Galeopsis bifida               | EPI   |                          | 8.44     | 5.57 | 1.71  | 0.99  |
| Cynoglossum officinale         | ART   |                          | 3.36     | 5.94 | 4.77  | 1.56  |
| Plantago major                 | POL   |                          | 3.29     | 0.00 | 0.00  | 0.00  |
| **Activity increased:**        |       |                          |          |      |       |       |
| Calamagrostis epigejos         | ART   |                          | 2.03     | 15.34| 3.46  | 30.53 |
| Vicia hirsuta                  | ETC   |                          | 3.05     | 13.92| 3.46  | 16.55 |
| Potentilla argentea            | ART   |                          | 4.60     | 6.61 | 3.85  | 9.04  |
| Verbascum nigrum               | EPI   |                          | 0.71     | 0.93 | 0.16  | 1.92  |
| **Activity stable:**           |       |                          |          |      |       |       |
| Convolvulus arvensis           | PAR   |                          | 19.48    | 19.04| 14.00 | 18.85 |
| Tanacetum vulgare              | ART   |                          | 7.37     | 3.94 | 1.76  | 8.72  |
| Senecio jacobaea               | PAR   |                          | 2.32     | 1.34 | 4.23  | 2.27  |
| Thlaspi arvense                | PAR   |                          | 2.07     | 0.97 | 3.00  | 1.62  |

### Activity increased:

| Species                        | Class | Age of community (years) | Activity |
|--------------------------------|-------|--------------------------|----------|
| Poa angustifolia               | FES   |                          | 28.00    | 42.69| 40.13 | 55.27 |
| Galium verum                   | GER   |                          | 2.93     | 11.49| 9.81  | 35.55 |
| Agrimonia eupatoria            | GER   |                          | 2.90     | 17.31| 7.62  | 44.72 |
| Coronilla varia (ts)³          | GER   |                          | 14.95    | 26.62| 30.62 | 38.86 |
| Stipa pulcherrima (ts)         | FES   |                          | 12.25    | 42.38| 40.42 | 36.95 |
| Fragaria viridis               | FES   |                          | 8.71     | 4.71 | 3.35  | 33.19 |
| Vicia cracca                   | MOL   |                          | 10.39    | 11.62| 4.60  | 24.22 |
| Trifolium montanum (ts)        | FES   |                          | 0.00     | 2.00 | 0.55  | 16.92 |
| Achillea millefolium           | MOL   |                          | 2.51     | 1.36 | 1.60  | 14.97 |
| Centaurea jacea                | MOL   |                          | 0.00     | 0.21 | 0.00  | 14.95 |
| Bromus inermis                 | FES   |                          | 9.82     | 17.19| 4.10  | 14.49 |
| Medicago falcata               | FES   |                          | 0.00     | 1.88 | 0.35  | 13.18 |
| Centaurea scabiosa             | FES   |                          | 0.00     | 1.08 | 0.00  | 12.30 |
| Carex contigua                 | GER   |                          | 0.27     | 0.21 | 0.35  | 12.86 |
| Hypericum perforatum           | GER   |                          | 3.52     | 4.61 | 1.37  | 10.79 |
| Helicotrichon pubescens        | FES   |                          | 0.35     | 0.19 | 0.00  | 9.91  |
| Dactylis glomerata             | MOL   |                          | 4.31     | 5.85 | 1.41  | 9.71  |
| Trifolium medium (ts)          | GER   |                          | 0.89     | 1.34 | 0.16  | 8.49  |
| Campanula rotundifolia         | FES   |                          | 0.35     | 0.43 | 0.95  | 7.81  |
| Galium boreale                 | MOL   |                          | 0.00     | 0.30 | 0.35  | 7.45  |
| Stellaria graminea             | MOL   |                          | 0.00     | 0.19 | 0.00  | 6.82  |

### Species of natural vegetation classes

| Species                        | Class | Age of community (years) | Activity |
|--------------------------------|-------|--------------------------|----------|
|                                |       |                          | 2-6      | 9-11 | 12-15 | 18-20 |
| Calamagrostis epigejos         | ART   |                          | 2.03     | 15.34| 3.46  | 30.53 |
| Vicia hirsuta                  | ETC   |                          | 3.05     | 13.92| 3.46  | 16.55 |
| Potentilla argentea            | ART   |                          | 4.60     | 6.61 | 3.85  | 9.04  |
| Verbascum nigrum               | EPI   |                          | 0.71     | 0.93 | 0.16  | 1.92  |
| **Activity increased:**        |       |                          |          |      |       |       |
| Poa angustifolia               | FES   |                          | 28.00    | 42.69| 40.13 | 55.27 |
| Galium verum                   | GER   |                          | 2.93     | 11.49| 9.81  | 35.55 |
| Agrimonia eupatoria            | GER   |                          | 2.90     | 17.31| 7.62  | 44.72 |
| Coronilla varia (ts)³          | GER   |                          | 14.95    | 26.62| 30.62 | 38.86 |
| Stipa pulcherrima (ts)         | FES   |                          | 12.25    | 42.38| 40.42 | 36.95 |
| Fragaria viridis               | FES   |                          | 8.71     | 4.71 | 3.35  | 33.19 |
| Vicia cracca                   | MOL   |                          | 10.39    | 11.62| 4.60  | 24.22 |
| Trifolium montanum (ts)        | FES   |                          | 0.00     | 2.00 | 0.55  | 16.92 |
| Achillea millefolium           | MOL   |                          | 2.51     | 1.36 | 1.60  | 14.97 |
| Centaurea jacea                | MOL   |                          | 0.00     | 0.21 | 0.00  | 14.95 |
| Bromus inermis                 | FES   |                          | 9.82     | 17.19| 4.10  | 14.49 |
| Medicago falcata               | FES   |                          | 0.00     | 1.88 | 0.35  | 13.18 |
| Centaurea scabiosa             | FES   |                          | 0.00     | 1.08 | 0.00  | 12.30 |
| Carex contigua                 | GER   |                          | 0.27     | 0.21 | 0.35  | 12.86 |
| Hypericum perforatum           | GER   |                          | 3.52     | 4.61 | 1.37  | 10.79 |
| Helicotrichon pubescens        | FES   |                          | 0.35     | 0.19 | 0.00  | 9.91  |
| Dactylis glomerata             | MOL   |                          | 4.31     | 5.85 | 1.41  | 9.71  |
| Trifolium medium (ts)          | GER   |                          | 0.89     | 1.34 | 0.16  | 8.49  |
| Campanula rotundifolia         | FES   |                          | 0.35     | 0.43 | 0.95  | 7.81  |
| Galium boreale                 | MOL   |                          | 0.00     | 0.30 | 0.35  | 7.45  |
| Stellaria graminea             | MOL   |                          | 0.00     | 0.19 | 0.00  | 6.82  |
4. Conclusion

The changes of the species composition structure are characterized as a result of the restorative succession of vegetation in agrosteppes of the Kulikovo Field. It revealed that the activity of apophyte

| Species                          | Class   | Activity  |
|----------------------------------|---------|-----------|
|                                  |         | 2-6      | 9-11    | 12-15   | 18-20   |
| *Festuca pratensis*              | ETC     | 0.45     | 1.85    | 0.00    | 6.40    |
| *Scabiosa ochroleuca*            | FES     | 0.00     | 1.98    | 0.00    | 6.35    |
| *Campanula bononiensis*          | GER     | 0.22     | 0.33    | 0.32    | 5.76    |
| *Knautia arvensis*               | MOL     | 1.32     | 2.25    | 5.62    | 5.68    |
| *Daucus catoria*                 | MOL     | 0.00     | 0.21    | 0.67    | 5.64    |
| *Pimpinella saxifraga*           | FES     | 0.00     | 0.33    | 0.00    | 5.52    |
| *Lithospermum officinale*        | GER     | 0.16     | 0.09    | 0.00    | 5.23    |
| *Veronica chamaedrys*            | GER     | 0.00     | 0.09    | 0.00    | 5.15    |
| *Thymus marschallianus*          | FES     | 0.35     | 0.60    | 0.00    | 4.79    |
| *Filipendula vulgaris*           | FES     | 0.00     | 0.00    | 0.00    | 4.19    |
| *Genista cruciata*               | FES     | 0.00     | 0.21    | 0.35    | 4.00    |
| *Eryngium planum*                | FES     | 0.99     | 2.02    | 2.21    | 3.16    |
| *Lotus corniculatus*             | MOL     | 0.00     | 0.84    | 0.00    | 2.82    |
| Activity stable:                 |         |          |         |         |         |
| *Linum flavum* (ts)              | FES     | 16.88    | 32.10   | 32.87   | 20.53   |
| *Onobrychis arenaria* (ts)       | FES     | 16.58    | 4.39    | 1.30    | 19.97   |
| *Stipa pennata* (ts)             | FES     | 26.96    | 39.66   | 44.04   | 29.54   |
| *Salvia pratensis* (ts)          | MOL     | 13.95    | 7.81    | 1.58    | 10.75   |
| *Veronica teucrium* (ts)         | GER     | 12.42    | 17.06   | 24.77   | 15.62   |
| *Elytrigia intermedia* (ts)      | ART     | 12.67    | 12.05   | 25.83   | 11.62   |
| *Echinops ritro* (ts)            | FES     | 9.92     | 6.39    | 2.46    | 11.18   |
| *Genista tinctoria* (ts)         | GER     | 1.76     | 6.77    | 9.72    | 6.47    |
| *Allium ibericum* (ts)           | GER     | 1.97     | 7.32    | 8.53    | 5.72    |
| *Galium mollugo*                 | MOL     | 4.89     | 6.58    | 4.99    | 8.58    |
| *Phleum pratense*                | MOL     | 4.10     | 0.27    | 1.82    | 7.07    |
| Activity decreased:              |         |          |         |         |         |
| *Festuca valesiaca* (ts)         | FES     | 47.65    | 51.65   | 34.28   | 2.65    |
| *Stipa capillata* (ts)           | FES     | 30.58    | 29.23   | 31.24   | 7.01    |
| *Leucanthemum vulgare* (ts)      | MOL     | 28.28    | 1.28    | 0.00    | 2.62    |
| *Delphinium cuneatum* (ts)       | ETC     | 13.72    | 12.09   | 18.38   | 0.85    |
| *Lavatera thuringiaca* (ts)      | ART     | 10.02    | 8.06    | 22.61   | 0.90    |
| *Centarea ruthenica* (ts)        | FES     | 9.37     | 10.44   | 8.25    | 1.57    |
| *Pyrethrum corymbosum* (ts)      | GER     | 5.96     | 8.06    | 4.42    | 0.64    |
| *Rumex confertus*                | MOL     | 10.26    | 2.46    | 0.00    | 0.90    |

Notes:

- a - target species.

Classes: PAR - *Papaveretea rhoeadis*, POL - *Polygono-Poeteea annuae* Rivas-Mart. 1975, FES - *Festuco-Brometea*, GER - *Trifolio-Geranietea*, MOL - *Molinio-Arrhenatheretea*, SIS - *Sisymbrietea*, ART - *Artemisietea*, EPI - *Epilobietea angustifolii* Tx. et Preising ex von Rochow 1951, ETC – others.
species from natural vegetation classes (Festuco-Brometea, Trifolio-Geranietea, Molinio-Arrhenatheretea) increases and the activity of anthropogenic vegetation classes species decreases (Papaveretea rhoeadis, Sisymbrietea, Artemisietea etc). The activity of dense-sod grasses (Festuca valesiaca) decreases, while the role of rod-root and rhizomatous species (Calamagrostis epigejos) increases according to the age of communities. Most "target species" that have been planted in the fields have stable activity indicators on the succession gradient or reduce activity. The obtained results indicate the direction of succession not towards typical steppe communities with a high role of dense-sod grasses, but in the direction of formation of steppe meadows.

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References
[1] Burova O V 2005 The history of land use and the formation of the agrolandscape in the forest-steppe of the Upper Don from the XII to XX centuries Izv. Ross. Akad. Nauk. Ser. Geogr. 3 pp 22–37
[2] Burova O V 2018 Stages of development and anthropogenic transformation of forest-steppe landscapes in the Upper Don basin. Problems of study and restoration of forest-steppe zone landscapes: historical, cultural and natural territories ed. O V Burova, E M Volkova et al vol 4 pp 7–11
[3] Rosova I V and Volkova E M 2020 Assessment of the land structure of the Kulikovo Field using GIS technologies Izv. Tula St. Univ. Nat. Sci. 3 pp 27–39
[4] Glistko M P, Gol’eva S A, Sycheva S A and Burova O V 2005 Landscapes of the Don Battle: the return of the lost Proc. of St. Hist. Museum (Moscow) vol 150 pp 227–256
[5] Isachenko T I and Lavrenko E M 1980 Botanical and geographical zoning. Vegetation of European part of USSR (Leningrad) pp 10–20
[6] Dzybov D S 1979 Method of accelerated recreation of herbaceous communities Experimental biogeocenology and agrocenoses (Moscow: Nauka) pp 129–131
[7] Dzybov D S 1995 Basics of biological recultivation of disturbed land (Stavropol: Argus) p 58
[8] Dzybov D S 2001 Agrosteppe method: accelerated restoration of natural vegetation. (Saratov: Nauchnaya kniga) p 49
[9] Danilov V I and Burova O V 2006 Experiments on the restoration of steppe vegetation on Kulikovo field Steppe Bull. 20 pp 34–37
[10] TerBraak C J F and Šmilauer P 2002 CANOCO reference manual and CanoDraw for Windows user’s guide: software for canonical community ordination version 4.5 (Ithaca) p 500
[11] Malyshev L I 1973 Floristic zoning based on quantitative characteristics Botan. J. 58 (11) pp 1581–1602
[12] Mucina L et al 2016 Vegetation of Europe: hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities Applied Vegetation Science 19 Suppl.1 pp 3–264 https://doi.org/10.1111/avsc.12257
[13] Yamalov S M and Bayanov A V 2010 Phytosociological spectrum as an indicator of species richness of plant communities Russian Journal of Ecology. 41 (2) pp 180–182.
[14] Serebryakov I G 1962 Ecological morphology of plants (Moscow) p 378
[15] Tichy L 2002 JUICE, software for vegetation classification J. Veg. Sci. 13 (3) pp 451–453 https://doi.org/10.1111/j.1654–1103.2002.tb02069.x