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Evaluation of artificial agricultural landscapes biodiversity in Stavropol Botanical Garden

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Abstarct. The meadow steppes recreated in the Stavropol Botanical Garden, Russia, by planting sod blocks after more than 40-year period of cultivation have preserved species composition similar to zonal steppes. The aim of our research is to evaluate the restored artificial cultivated land biodiversity. A parallel measurement of species saturation per 100 m², yield, botanical analysis by crops was conducted on model experimental sites and in nature. Systematic and biomorphological flora study, analysis of variance were carried out. Useful plant species were identified. The restored steppes represent a multispecies community including 236 species, 149 genera, and 36 families. It consists of 5 biomorphs which comprise 2.9% of phanerophytes, 3.0% of chamephytes, 74.6% of hemicryptophytes, 14.4% therophytes that have a high degree of similarity in quantity to the steppes of Central Fore-Caucasus. The cenoses are dominated by plants having life cycles of perennial ones which accounts for 81.0%, annuals, and biennials make up 19.0%, cereals and sedges amount to 32 species (13.5%), legumes represent 28 speies (11.9%), mixed herbs are 176 (74.6%). The projective cover of grass stand is 80.0–100.0%, that corresponds 73–109 species per 100 m². An average yield of the restored steppes grass stand is 2.8–3.8 t ha^{-1}. It exceeds the productivity of natural cenoses by 2.1–3.3 t ha^{-1}. The botanical analysis by crops demonstrated that in the grass stands samples of cereals (19.6–43.9%) and mixed herbs (18.3–31.2%) dominated. 18 rare plants are preserved in the cenoses. 171 species have useful properties. The site of the restored meadow steppe is an exposition and serves for sightseeing and educational purposes. Lately, sod blocks planting was widely used in experimental phytocenology and landscape design. Its implementation for natural vegetation restoration on the large areas is time-consuming and expensive compared to the method of cultivated lands, therefore it can be used in small sites as a component of combined options.

Key words: artificial agrarian landscapes, method of sod blocks planting, biodiversity, floral analysis, yield.

INTRODUCTION

Since the foundation of the Botanical garden in Stavropol, Russia, the most important task of its scientific team was the study, reproduction, protection and rational use of flora and vegetation of the North Caucasus. Under the leadership of V.V. Skripchinsky, artificial models of some types of natural vegetation were created on

the territory of the garden: forest - oak, pine, fir-spruce; herbaceous phytocenoses (by sod blocks planting) - meadow steppe, subalpine meadow, etc. (Skripchinsky et al., 1971; Skripchinsky, 1973). The research was the initial stage of work on experimental applied phytocenology in our region and became the basis for the creation of new technologies - the D.S. Dzybov's method of agrosteppes - the theory and technology of accelerated (40–50 times) restoration of the primary steppe analogues of the zonal type compared to self-restoration. They became the basis for the transition from the depletion practice of resource use to the restoration one (Dzybov, 2010). Models of meadow-steppe cenoses restored by sod planting method has been preserved in the botanical garden till nowadays on the area of 2 hectares. They have species composition close to natural steppes and are considered to be a reserve for the conservation of biological diversity of zonal meadow steppe species including wild relatives of cultivated, forage, medicinal, food plants, and rare species (Kozhevnikov et al., 2012). The meadow steppe is the richest ecosystem by the number of species in the Eurasian area. The species saturation per 100 m^2 can reach 100 or more species. *Brachypodium rupestre* (Host) Roem. et Schult., 1817, *Bromus riparius* Rehmann, 1872, *Carex humilis* Leyss., 1761, *Filipendula vulgaris* Moench., 1794., *Stipa pulcherrima* K. Koch, 1848, dominate in the meadow steppes. The projective cover of grass stand is, on average, 89% (fluctuation 65-100%), the true cover is from 3 to 7%. The yield is 2,6–10.6 t ha^{-1} (Dzybov, 2018).

In the 19^{th}–20^{th} centuries in Russia, the creation of demonstration areas of the steppe by the sod blocks planting method from natural steppes for scientific and educational purposes was carried out by a number of scientists such as A.N. Krasnov in Kharkiv University Botanical garden, G.I. Tanfilyev in Petersburg Botanical garden, V.N. Kononov in Stavropol (Voroshilovsk) Pedagogical Institute (Krasnov, 1890; Tanfilyev, 1901; Kononov, 1940). In the 30s–50s of the XX century in Wisconsin University, the USA, American geobotanist J. Curtis conducted experiments on prairie restoration using sod transplantation with addition of seedlings grown from direct planting of seeds in nurseries, hay distribution, transplanting plants from prairies. According to his opinion, sod method gives good results, but it is quite expensive that limits it usage in large areas (Archer & Bunch, 1955; Cottam & Wilson, 1966). In 1969–1983 in Donetsk Botanical garden a forb-fescue-feather grass steppes exposition 'Donbass Steppes' with an area of 8.5 hectares was created using seeds and sod blocks planting. Artificially created phytocenoses were rich in floristic variety including 359 species, 220 genera and 50 families. Perennial plants (63.7%), biennial plants (12.4%), annuals (12.6%), shrubs (6%) small bushes (5.3%) dominate in life-forms vegetation. Formed species resistance after the period of 20-year experiment was maintained by the wide range of species and ecological ones including grasses (Kondratyuk & Chupyrina, 1989). Since 1970s, D.S. Dzybov has grassed the sites with disturbed natural vegetation in subalpine ecoregion and in the meadow steppe of Central Caucasus. He drew attention to such method disadvantages as ecological damage of steppe biogeocenose when harvesting sod; slow overgrowing of sod harvesting sites; prolonged period of artificial cenoses creation; time-consuming of the method (Dzybov, 2010). The agrosteppe method is recognized in Russia as the most promising and technological one (Abdullin & Mirkin, 1995; Abdullin et al., 2003; Nezdiyminoga, 2010; Suyundukov et al., 2010).

Experimental restoration of natural system solves the problems of nature conservation. It also contributes into the maintenance of biodiversity of zonal vegetation

types and agricultural landscapes (species and pasture communities) (Isselstein et al., 2005; Plantureux et al., 2005).

A 25-year experiment on reciprocal replanting of sod blocks following the gradient of snow cover thickness and reducing vegetation period along the slope of Mount Malaya Khatipara, Karachay-Cherkess Republic, Russia, has been conducted since 1988 in the Teberda Nature Reserve. It was studied the rate of microsuccessions that is the structure and flora saturation of alpine phytocenoses restoration. It has been shown that the higher the difference amounts between donor and acceptor communities, the higher the rate of succession in transplanted sod blocks. Abiotic conditions are also influential (Kipkeev et al., 2015).

The sod method is widely exploited in landscape design. Z.V. Dutova used forbbed-grassed steppe sod adding 20 perennial introduced species when creating landforms in city of Pyatigorsk (Dutova, 2019).

The purpose of the article is to evaluate the biodiversity of recreated artificial steppe agricultural landscape of the Stavropol Botanical garden.

MATERIALS AND METHODS

The recreated meadow steppe area is located in the Botanical garden in Stavropol, Russian Federation, (N45.036416°, E41.910240°) 640–660 m above sea level in unstable humidity zone HTC 1.00–1.09 with an average annual temperature 9.7–110 °C; the coldest month is January when the temperature reaches 4.9° below 0° degree C, the warmest month is July with the average temperature 19.6° above 0° degree C, absolute temperature minimum is 31° below 0° degree C, absolute temperature maximum is 39.7° above 0° degree C in August. The average annual precipitation is 633–720 mm. The sum of temperatures above 10 °C is 3,300–3,650 °C. The soil is leached degraded chernozems. The humus horizon depth is 31–45 cm. The upper Kholodnorodnikovsky horizon of the Stavropol Formation, which is composed of limestones, shell rocks, sandstones and sands, is located in Stavropol and its suburbs withing the research sites. Its depth varies. Thus, under the restored meadow steppes areas shell rock is found at a depth of 35 to 100 cm, while in the research sites in nature it is located at a depth of 10 to 30 cm, often with an exit to the surface. (Shalnev & Oleinikova, 2010). The weather conditions in 2017–2020 (Fig. 1) are characterized

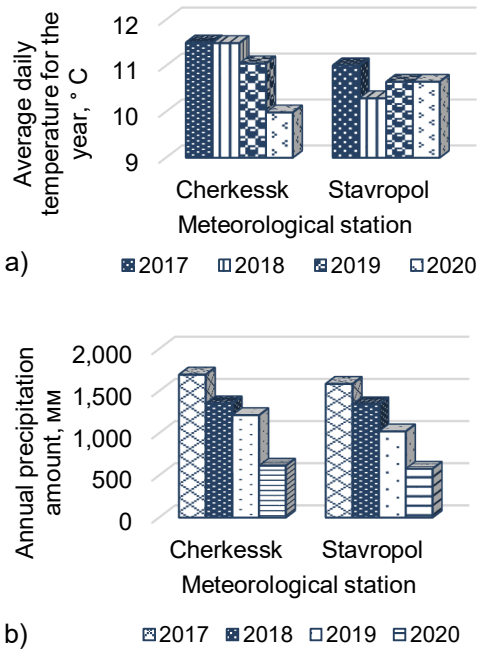


Figure 1. Weather conditions of meteorological stations in the places of research performance by years (a – average annual temperature, b – total annual precipitation).

by higher daily average temperatures in Stavropol that amounts to 7.5° above C compared to average multi-year ones (+8.3 °C) in Cherkessk ranged from +9.9 °C to +11.5 °C. Total precipitation in Stavropol varies from 578.2 mm (2020) to 1,584.8 mm (2017) with the average annual norm of 720 mm. In Cherkessk precipitation ranged from 615.0 mm (2020) to 1,694.8 mm (2017) that is below the average annual norm. According to both weather stations, precipitation in 2020 was less than the multi-year average, and the summer period was characterized by prolonged droughts (SCH, 2021). The material for sod blocks planting was prepared in 1963–1984 from previously studied natural zonal meadow-steppe virgin lands with a typical floral composition located in the natural boundaries Vishnevaya (N45.021602°, E41.816896°) and Novomaryevskaya Polyana (N45,106962°, E41,886296°), mountains Strizhament (N44.799451°, E42.005252°), Buchinka (N45.116671°, E41.846201°) in Stavropolskiy Kraii and mount Bavuko (N44.205345°, E41.932923°) in the Karachay-Cherkess Republik, Russian Federation (Fig. 2). (Skripchinsky et al., 1971; Skripchinsky, 1973).

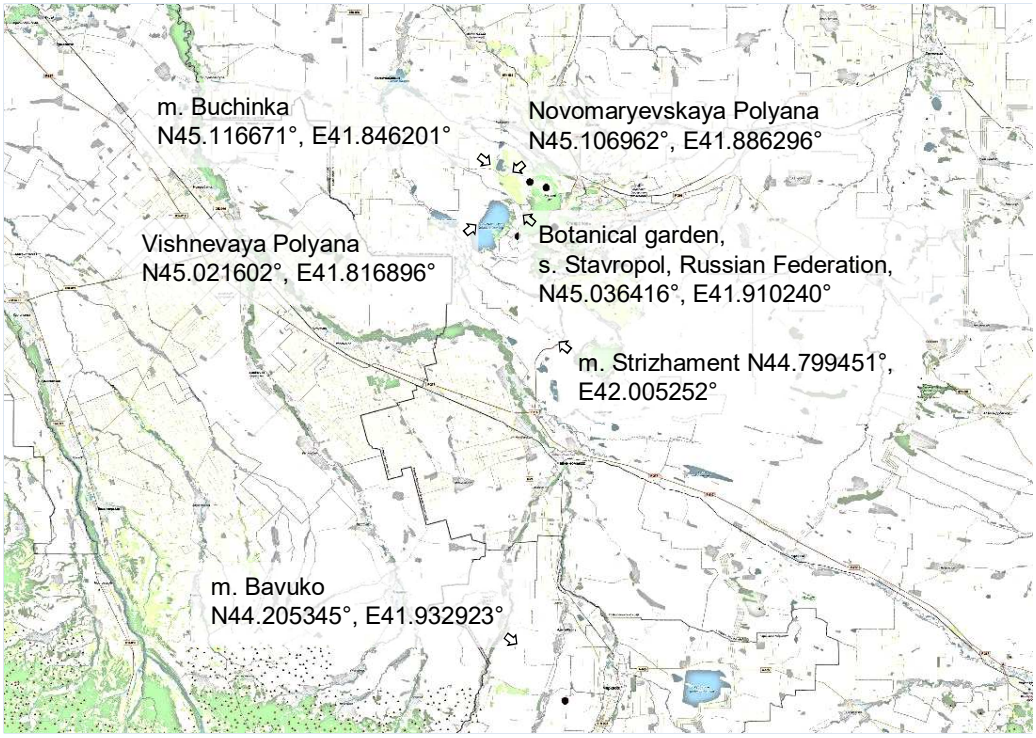


Figure 2. Coordinates of research sites in the Stavropol Territory and the Karachay-Cherkess Republic, Russia.

Planting was carried out in the botanical garden on a plot with soil specially prepared by dead fallow type alongside with preliminary autumn plowing followed by spring and summer peeling, and 3–4 cultivations. In the experimental field, harvested blocks of sod were planted on model plots corresponding to the origin place name: in 1963 it was 'Vishnevaya Polyana' with 1,210 m^2 area; in 1967–1968 it was 'Strizhament' with 5,240 m^2 area. The 'Bavuco' site (1,100 m^2) was laid in 1975–1979,

'Novomaryevskaya Polyana' (4,000 m²) in 1967–1970, 'Buchinka' (2,200 m²) in 1984. The prepared blocks of sod were transported to the experimental site and placed in the appropriate size excavated holes by hand, followed by rolling and watering. Average size of harvested sod blocks was 27.9×23.5 cm with a thickness of 27.0–19.4 cm. Planting density variants were 60×60 cm, 1×1 m (with alternating uncovered sod soil in a staggered pattern), and solid arrangement (control) (Dudar, 1976). No additional replanting or reseeding was carried out. During the first two to three years after planting (until the uncultivated soil overgrown with sod), hand pulling with removal of weeds and irrigation were performed (Dudar, 1976). The total area of the recreated steppe is 2 ha. The options for maintaining recreated cenoses are: a) annual single mowing is carried out on 77.7% of the territory, b) without mowing on 22.3% (protected area). All studies cited in this article were conducted both in nature and in experimental sites. Evaluation of species saturation was carried out on 100 m² during the maximum grass stand development period. The biomorphs determination is based on the Ch. Raunckiaer classification (Raunkiaer, 1937; 'Field geobotany', 1964). According to the standard methodology, grass stand yield was measured once during the vegetation period on the sample area of 0.5×1.0 m in sixfold replications. Botanical analysis by crop groups was performed (Dudar, 1976; Kutuzova et al., 2015).

For statistical processing we used the package of variance analysis included in the Microsoft Exel program to calculate the null hypothesis deviation (*P-value*) at the level of significance (α) 0.05 (Kosova et al., 2015). Latin plants names are given according to 'The Plant List' (TPL, 2010).

RESEARCH RESULTS

Nowadays, the formed artificial cenosis in the Stavropol Botanical garden is a multi-species community with a predominance of *Brachypodium rupestre* (Host) Roem. et Schult., 1817; *Briza media* L., 1753; *Bromus riparius* Rehmann, 1872; *Carex humilis* Leyss., 1761; *Chamaecytisus ruthenicus* (Fisch. ex Woł.) Klásk., 1958; *Festuca rupicola* Heuff., 1858; *Festuca valesiaca* Schleich. ex Gaudin, 1811; *Genista tinctoria* L., 1753*; Medicago caerulea* Less. ex Ledeb., 1842; *Medicago falcata* L., 1753; *Phleum phleoides* (L.) H. Karst, 1880; *Rosa spinosissima* L., 1753; *Securigera varia* (L.) Lassen, 1989; *Stipa pulcherrima K. Koch,* 1848; *Trifolium medium* L., 1753; *Trifolium alpestre* L., 1763; *Trifolium ambiguum* M. Bieb., 1808; *Trifolium montanum* L., 1753; *Trifolium repens* L., 1753; *Vicia tenuifolia* Roth, 1788; *Vicia cracca* L., 1753.

The flora of the recreated cenoses includes 236 species belonging to 149 genera and 35 families. Of these, the share of dicotyledons (*Magnoliopsida* Brongn, 1843) accounts for 201 species (85.2%), monocotyledons (*Liliopsida* Batsch, 1802) justifies 35 species (14.8%). The largest families including more than half of the species composition are *Apiaceae* Lindl, 1836; *Asteraceae* Bercht & J.Presl, 1820; *Lamiaceae* Martinov, 1820; *Poaceae* Barnhart, 1895; *Rosaceae Juss*., 1789, which correlates with the typical spectrum of boreal territories of the Holarctic kingdom (Takhtadzhyan, 1978). Floristic groups of cenosis include cereals and sedges - 32 species (13.5%), legumes - 28 (11.9%), wild grasses - 176 (74.6%) (Table 1).

Table 1. Systematic analysis of the restored meadow steppes plants

No.	Families	Number		Share, %	No.	Families	Number		Share, %
		genera	species				genera	species	
1.	*Asteraceae* Bercht & J.Presl, 1820	27	40	17.0	19.	*Orchidaceae* Juss., 1789	2	3	1.3
2.	*Poaceae* Barnhart, 1895	18	30	12.7	20.	*Scrophulariaceae* Juss., 1789	2	3	1.3
3.	*Apiaceae* Lindl., 1836	12	28	11.9	21.	*Asparagaceae* Juss., 1789	2	2	0.8
4.	*Lamiaceae* Martinov, 1820	14	18	7.6	22.	*Brassicaceae* Burnett, 1835	2	2	0.8
5.	*Rosaceae* Juss., 1789	10	15	6.4	23.	*Cyperaceae,* Juss., 1789	1	2	0.8
6.	*Apiaceae* Lindl., 1836	10	11	4.7	24.	*Gentianaceae* Juss., 1789	2	2	0.8
7.	*Plantaginaceae* Juss., 1789	3	10	4.2	25.	*Linaceae* DC. ex Perleb, 1818	1	2	0.8
8.	*Caryophyllaceae* Juss., 1789	5	9	3.8	26.	*Polygalaceae* Hoffmanns. et Link., 1809	1	2	0.8
9.	*Ranunculaceae* Juss., 1789	4	6	2.6	27.	*Violaceae* Batsch, 1802	1	2	0.8
10.	*Rubiaceae* Juss., 1789	3	7	3.0	28.	*Convolvulaceae* Juss., 1789	1	1	0.4
11.	*Boraginaceae* Juss., 1789	3	6	2.5	29.	*Geraniaceae* Juss., 1789	1	1	0.4
12.	*Caprifoliaceae* Juss., 1789	4	5	2.1	30.	*Hypericaceae* Juss., 1789	1	1	0.4
13.	*Iridaceae* Juss., 1789	3	5	2.1	31.	*Liliaceae* Juss., 1789	1	1	0.4
14.	*Orobanchaceae* Vent., 1799	5	5	2.1	32.	*Polygonaceae* Juss., 1789	1	1	0.4
15.	*Apocynaceae* Juss., 1789	2	4	1.7	33.	*Primulaceae* Batsch ex Borkh., 1963	1	1	0.4
16.	*Amaryllidaceae* J.St.-Hil., 1968	1	3	1.3	34.	*Rutaceae* Juss., 1789	1	1	0.4
17.	*Campanulaceae* Juss., 1789	1	3	1.3	35.	*Santalaceae* R.Br., 1810	1	1	0.4
18.	*Euphorbiaceae* Juss., 1789	1	3	1.3	36.	*Paeoniaceae* Raf., 1815	1	1	0.4
	Total:						149	236	100

In accordance with the classification of Ch. Raunkier, the species of the restored cenoses can be attributed to five biomorphs: Ph – phanerophytes (arboreal), Ch – hamephites (shrubs), HC – hemicryptophytes (perennial grasses, rosete-formimg biennials, winter-annuals), C – cryptophytes (bulbous crops, root crops, tuberous plants) and T – therophytes (annuals) (Raunkiaer, 1937) (Table 2).

The biomorph range of the of restored meadow steppes in terms of quantitative composition has a high degree of similarity with steppes of the Central Fore-Caucasus ($r = 0.99$). In both cases, in the meadow steppes cenoses the hemicryptophytes dominance of grasses whose renewal buds are located near the soil surface is preserved.

Table 2. Comparative indices of the flora biomorphological spectrum of the restored meadow steppe and Central Fore Caucasus meadow steppes

Plants communities	Parameters	Biomorph					
		Ph	Ch	HK	K	T	Total
Restored meadow steppe	Species number	7	7	176	12	34	236
	percentage	2.9	3.0	74.6	5.1	14.4	100%
Meadow steppes of Central Caucasus	percentage	2.4	1.8	69.1	4.9	21.8	100%

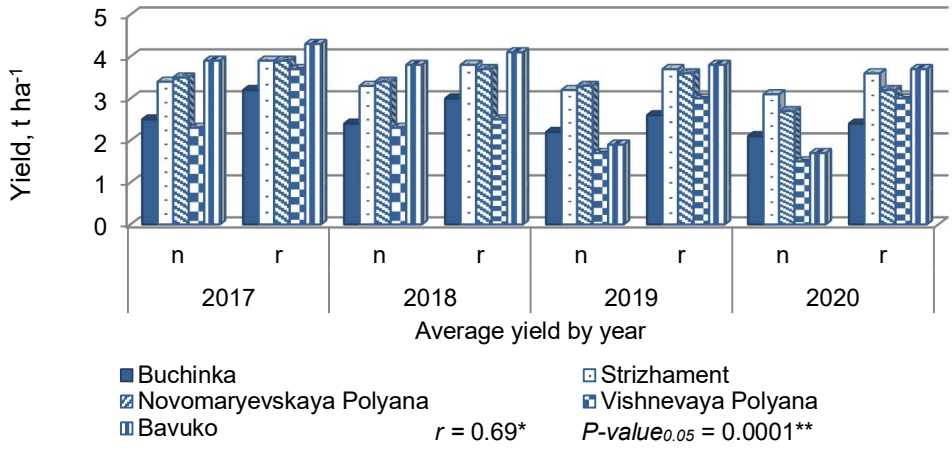
Similarity degree in species composition to the steppes of Central Caucasus $r = 0.99$*;

*r – correlation coefficient.

Another indicator of the proximity of the restored meadow-steppe cenoses flora to natural virgin lands is the predominance of perennials in its life cycles species which accounts for 81%, annuals and biennials make up only 19%. The current ratio indicates a significant phytocenotic isolation and stability of the grass stand species composition, and its ability to resist the introduction of invasive species.

The grass stand of the restored cenoses is closed with a height of 85.0–135.0 cm (in nature it reaches 65.0–95.0 cm). The projection coverage is 75–100%. There are 109 species per 100 m^2 of individual model cenoses: Strizhament includes 109 species; Vishnevaya Polyana has 78 species; Novomaryevskaya Polyana amounts to 79 species; Buchinka has 84 species; Bavuco accounts for 73 species.

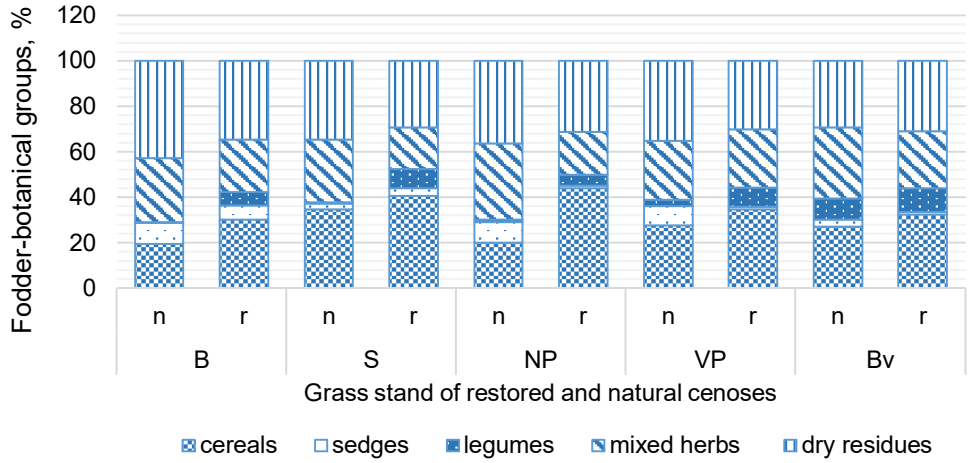
The average yield of restored steppes grass stand in 2017–2020 is 2.8 t ha^{-1} in Buchinka and 3.8 t ha^{-1} in Strizhament and Novomaryevskaya Polyana. It exceeds the yield indicators of similar cenoses in nature representing 2.1 t ha^{-1} in Vishnevaya Polyana, and 3.3 t ha^{-1} in Bavuko, the correlation coefficient is 0.69. It is shown that at the significance level (α) of 0.05 there are reliable differences between the average values in the variants (nature and restored steppe), (*P-value* is 0.0001). It has been noted that the amount of the grass stand yield decreases with the lowering of precipitation values from 2.3–3.9 t ha^{-1} (nature), 3.2–4.4 t ha^{-1} (restored) in 2017 to 1.5–3.1 t ha^{-1} (nature), 2.4–3.7 t ha^{-1} (restored) in 2020. The correlation coefficient is $r = 0.9$ (Fig. 3).



*r – correlation coefficient, **$P\text{-value}_{0.05}$ – null hypothesis deviations.

Figure 3. An average grass stand yield in natural and restored steppes in 2017–2020 (n – natural steppes; r – restored area).

The analysis of the fodder-botanical groups in the grass stand of the restored and natural steppes showed that samples were dominated by cereals 19.6–43.9% and mixed herbs 18.3–31.2%, in all cases. Sedges make up only 1.1%, while legumes account for 0.3% (Fig. 4). The share of sedges and dry residues in natural cenoses is higher than in restored ones. While conducting the variance analysis it was found that the natural and climatic features of the restored cenoses are more significant for higher yields of cereals and legumes botanical groups (for cereals at the significance level (α) of 0.05 *P-value* is 0.024, for legumes at the significance level (α) of 0.05 *P-value* is 0.03. On the contrary, natural steppes conditions (at the same level of significance (α) of 0.05 the *P-value* is 0.009 are more significant for the value of mixed herbs productivity. No significant differences were found for the other groups.



Cereals *P-value* $_{0.05}$ = 0.024, sedges *P-value* $_{0.05}$ = 0.062, legumes *P-value* $_{0.05}$ = 0.030, mixed herbs *P-value* $_{0.05}$ = 0.009, dry residues *P-value* $_{0.05}$ = 0.095.*

**P-value*$_{0.05}$ – null hypothesis deviations.

Figure 4. Economic and botanical grass stand groups of restored and natural cenoses as a percentage of the air-dry mass sample, % (n – natural steppes; r – restored area; B – Buchinka; S – Strizhament; NP – Novomaryevskaya Polyana; V – Vishnevaya Polyana; Bv – Bavuko).

Phytocenoses with a diverse set of life forms such as shrubs, semi-shrubs, perennial and annual grasses have the highest phytomass biological productivity and yield. These communities, due to the location of above-ground organs at different heights and their roots at different depths of soil horizons, have more densely packed ecological niches, they are better adapted to the ecological features of the habitat and make better use of the environment resources (Mirkin et al., 2002).

Flora of the restored meadow steppes of the botanical garden is rich in plants with useful properties: 29 species are forage plants, 65 – medicinal, 48 – nectariferous, 6 – food, 23 – ornamental:

Forage

Cyperaceae: *Carex humilis* Leyss., 1761.

Fabaceae: *Anthyllis vulneraria subsp. polyphylla* DC. 1825; *Lotus corniculatus* L., 1753; *Medicago caerulea* Less. ex Ledeb., 1842; *Medicago falcata* L., 1753; *Medicago sativa* L., 1753; *Onobrychis inermis* Steven, 1856; *Securigera varia* (L.) Lassen, 1989; *Trifolium alpestre* L., 1763; *Trifolium ambiguum* M.Bieb., 1808; *Trifolium medium* L., 1753; *Trifolium montanum* L. 1753; *Trifolium repens* L. 1753; *Vicia cracca* L. 1753; *Vicia tenuifolia* Roth, 1788.

Poaceae: *Brachypodium rupestre* (Host) Roem. et Schult. 1817; *Bromus inermis* Leyss., 1973; *Bromus inermis* Leyss., 1973; *Bromus riparius* Rehmann, 1872; *Dactylis glomerata* L. 1753; *Elymus hispidus* (Opiz) Melderis, 1978; *Festuca pratensis* Huds. 1762; *Festuca rupicola* Heuff., 1858; *Festuca valesiaca* Schleich. ex Gaudin, 1811; *Koeleria pyramidata* (Lam.) P.Beauv., 1812; *Phleum phleoides* (L.) H. Karst., 1880; *Phleum pratense* L., 1753; *Poa compressa* L. 1753.

Medicinal

Apiaceae: *Daucus carota* L., 1753.

Asteraceae: ***A****chillea nobilis* L., 1753; *Achillea. millefolium* L., 1753; *Artemisia absinthium* L.,1753; *Cichorium intybus* L., 1753; *Tanacetum vulgare* L., 1753.

Caprifoliaceae: *Valeriana officinalis* L., 1735.

Fabaceae: *Anthyllis vulneraria* subsp. *polyphylla* (DC.), 1825; *Melilotus officinalis* (L.) Pall., 1778; *Trifolium pratense* L., 1753.

Gentianaceae: *Gentiana cruciate* Juss, 1789; *Centaurium littorale* (Turner) Gilmour, 1937.

Hypericaceae: *Hypericum perforatum* L., 1753.

Lamiaceae: *Origanum vulgare* L., 1753; *Stachys officinalis* (L.) Trevis., 1842; *Thymus pulegioides subsp. pannonicus* (All.) Kerguelen, 1993.

Orobanchaceae: *Euphrasia tatarica* Fisch. ex Spreng., 1825.

Paeoniaceae: *Paeonia tenuifolia* L., 1759.

Plantaginaceae: *Plantago lanceolata* L., 1753; *Plantago major* L., 1753; *Veronica chamaedrys* L., 1753.

Primulaceae: *Primula veris* L., 1753.

Ranunculaceae: *Adonis vernalis* L., 1753; *Thalictrum foetidum* L. 1753; *Thalictrum minus* L., 1753.

Rosaceae: *Agrimonia eupatoria* L., 1753; *Crataegus curvisepala* Lindm., 1918; *Crataegus monogyna* Jacq., 1775; *Filipendula vulgaris* Moench, 1794; *Fragaria viridis* Weston, 1771; *Potentilla argentea* L., 1753; *Rosa canina* L., 1753, *Rosa spinosissima* L., 1753.

Rubiaceae: *Dictamnus albus* L., 1753.

Violaceae: *Viola arvensis* Murray, 1770.

Nectariferous

Asteraceae: *Achillea millefolium; Achillea nobilis.*

Boraginaceae: *Echium vulgare* L., 1753.

Caprifoliaceae: *Valeriana officinalis.*

Euphorbiaceae: *Euphorbia iberica* Boiss., 1860; *Euphorbia stepposa* Zoz ex Prokh., 1949.

Fabaceae: *Anthyllis vulneraria subsp. polyphylla; Chamaecytisus ruthenicus* (Fisch. ex Wol.) Klask., 1958; *Genista tinctoria* L., 1753; *Lotus corniculatus*; *Medicago falcata; M. caerulea; M. sativa; Melilotus officinalis; Onobrychis inermis; Securigera varia; Trifolium alpestre; T. ambiguum; T. medium; T. repens; Vicia cracca; V. tenuifolia.*
Lamiaceae: *Origanum vulgare; Lamiun album* L., 1753; *Thymus pulegioides subsp pannonicus.*
Plantaginaceae: *Plantago lanceolata, P. major,*
Rosaceae: *Crataegus curvisepala; C. monogyna; Crataegus pentagyna Waldst. & Kit.,* 1799; *Filipendula vulgaris; Fragaria viridis; Malus orientalis* Uglitzk., 1932; *Potentilla argentea; Pyrus communis* Fritsch, 1892; *Rosa canina, Rosa spinosissima* L., 1753.

Food

Rosaceae: *Crataegus curvisepala; Crataegus pentagyna*; *Fragaria viridis; Malus orientalis; Pyrus communis.*

Ornamental

Asparagaceae: *Muscari racemosum* (L.) Lam. & DC., 1806.
Asteraceae: *Centaurea dealbata* Willd., 1803; *Leucanthemum vulgare* (Vaill.) Lam., 1779; *Pyrethrum corymbosum* (L.) Scop., 1844;
Caprifoliaceae: *Dianthus armeria* L., 1753; *Dianthus capitatus* Balb. ex DC., 1813.
Fabaceae: *Chamaecytisus ruthenicus; Genista tinctoria.*
Geraniaceae: *Geranium sanguineum* L., 1753.
Iridaceae: *Crocus reticulatus* Steven ex Adam, 1805; *Crocus speciosus* M.Bieb., 1800; *Gladiolus tenuis* M. Bieb., 1808; *Iris aphylla* L., 1753.
Lamiaceae: *Dracocephalum austriacum* L., 1753.
Orchidaceae: *Orchis morio* L. *subsp. picta* (Loisel.) K. Richt. 1890; *Orchis tridentate* Scop., 1772; *Platanthera chlorantha* (Custer) Rchb., 1829.
Paeoniaceae: *Paeonia tenuifolia.*
Poaceae: *Stipa pennata* L., 1753; *Stipa pulcherrima* K. Koch, 1848.
Primulaceae: *Primula veris.*
Ranunculaceae: *Adonis vernalis; Anemonoides caucasica* Willd. ex Rupr., 1869.
Rosaceae: *Rosa canina; Rosa spinosissima* L.
Rutaceae: *Dictamnus albus.*

18 protected plant species listed in the 'Red Book of the Stavropolskii Krai' grow on the restored meadow-steppe cenoses (RDBSK, 2013), 10 of which are listed in the 'Red Book of the Russian Federation' (RDBRF, 2008) (Table 3). According to the 'Red Book of Stavropolskii Krai', two taxa are considered endangered (category 1). There are six vulnerable species (category 2) are six. The rest ones belong to species with decreasing numbers (category 3).

Ten rare species are also represented in the 'Red Book of the Russian Federation': 4 as vulnerable species, 6 as species with decreasing numbers. The most abundant rare species in the cenoses are represented by 28–40 samples. Their populations are quite vital, full-membered, most plants are in the generative phase (Rabotnov, 1950), they bloom and bear fruit, and form self-seeding.

Most of the plants are randomly located and preserved at the sites of mount Strizhament, mount Buchinka, natural boundaries Novomaryevskaya Polyana, and

Vishnevaya Polyana. Species with abundance of 5–12 specimens are predominantly found on the sites of mount Strizhament, and Vishnevaya Polyana. A number of ornamental and medicinal plants such as *Adonis vernalis, Gymnadenia conopsea, Iris aphylla, Paeonia tenuifolia, Platanthera chlorantha, Orchis picta* periodically reduce their amount due to being picked up by visitors.

Table 3. Rare and endangered species in artificially recreated cenoses

No.	Species name	Predominant age groups	Amount of samples	Category of rarity status in the Red Book		Allocation to the model restored cenoses
				The Russian Federation	Stavropolskii Krai	
1.	*Colchicum laetum* Steven, 1829	g_2	40	3	3	Vishnevaya Polyana
2.	*Gladiolus tenuis* M.Bieb., 1808	$g_{1–2}$	37	-	2	Novomaryevskaya Polyana, Strizhament, Buchinka
3.	*Anemone caucasica* Willd. ex Rupr., 1869	$g_{1–2}$	28	-	2	Novomaryevskaya, Vishnevaya Polyana
4.	*Diphelypaea coccinea* (M.Bieb.) Nicolson, 1975	$g_{1–2}$	12	-	3	Strizhament, Vishnevaya Polyana
5.	*Neotinea tridentata* (Scop.) R.M.Bateman, Pridgeon & M.W.Chase, 1997	g_2	11	3	3	Strizhament, Novomaryevskaya Polyana,
6.	*Crocus speciosus* M.Bieb., 1800	$g_{1–2}$	8	2	1	Strizhament, Vishnevaya Polyana
7.	*Iris aphylla* L., 1753	g_1	7	2	3	Novomaryevskaya Polyana,
8.	*Stipa pulcherrima K.Koch, 1848*	$g_{1–2}$	6	3	2	Strizhament
9.	*Iris spuria subsp. notha* (M.Bieb.) Asch. & Graebn., 1906	g_1	6	2	2	Strizhament
10.	*Stipa pennata* L., 1753	$g_{1–2}$	5	3	2	Vishnevaya Polyana
11.	*Dactylorhiza viridis* (L.) R.M.Bateman, Pridgeon & M.W.Chase, 1997	ss	5	-	3	Novomaryevskaya Polyana,
12.	*Platanthera chlorantha* (Custer) Rchb., 1829	v	4	-	3	Novomaryevskaya Polyana,
13.	*Gymnadenia conopsea* (L.) R.Br., 1813	v	4	3	3	Strizhament
14.	*Adonis vernalis* L., 1753	g_2	3	-	3	Novomaryevskaya Polyana,
15.	*Orchis picta* Raf., 1808	g_1	3	3	3	Novomaryevskaya Polyana, Strizhament
16.	*Paeonia tenuifolia* L., 1759	$g_{1–2}$	3	2	3	Novomaryevskaya Polyana,
17.	*Campanula persicifolia* L., 1753	g_2	3	-	2	Strizhament
18.	*Crambe tatarica* Sebeók, 1799	g_1	3	-	1	Strizhament

Economic efficiency

According to the modern prices, calculation of economic efficiency of meadow steppes restoring by sod blocks planting method has shown that when performing all the required agrotechnical techniques for preparing soil, harvesting, planting and watering of the planted sod blocks the cost of establishing of 1 ha of conducted experiment (excluding further maintenance work) was €33,157.7 (at a rate of 87.0748 roubles for 1 euro under federal standards) (TUP, 2014, CRB, 2021). In accordance with our data, average hay yield per hectare is 2.8–3.8 t ha^{-1}, which in money equivalent, at a rate of €57.4 per 1 ton of hay in Stavropolskii Krai, amounts to €160.8–218.2 a year for an annual average hay yield per 1 ha cost. Thus, estimated period of covering the performed work on the restoring meadow steppe by sod block planting method (excluding weeding and watering) is 152.0–206.3 years.

CONCLUSIONS

Long-term experience on experimental phytocenology of botanical garden showed that when restoring steppe sites by planting sod blocks only zonal vegetation types should be used to preserve the biodiversity of the original natural cenosis. It is important that the area of experimental planting meets the same soil-ecological conditions in which the steppe-standard plot was formed. Some attempts to recreate in the botanical garden cenoses from other soil and climatic zones such as dry, feather-grass steppes, subalpine meadow have resulted in gradual destruction of these communities. Mesophilic species were progressively introduced into the dry steppes restored cenoses, while xerophilic species fell out.

Eventually, species of subalpine meadows also fell out, and the experimental sites were overgrown with rhizomatous grasses (FECC, 2020). Meadow steppes recreated in 1963–1984 in the Stavropol Botanical Garden by sod blocks planting on an area of 2 hectares have preserved species composition close to the zonal steppes till nowadays and are being a reserve of their biological diversity, including wild relatives of cultivated forage, medicinal, food plants, and rare species. Current flora of restored meadow steppes cenoses includes 236 species belonging to 149 genera and 35 families. Its 5 biomorphs comprise 2.9% of phanerophytes, 3.0% of chamephytes, 74.6% of hemicryptophytes, 14.4% therophytes that have a high degree of similarity in quantity to the steppes of Central Fore-Caucasus. The cenoses are dominated by plants having life cycles of perennial ones which account for 81.0%, annuals and biennials make up 19.0%, cereals and sedges amount to 32 species (13.5%), legumes represent 28 species (11.9%), mixed herbs are 176 (74.6%).

The species composition of the restored cenoses is greatly influenced by the correlation with the soil horizon heights of donor and acceptor communities. Apparently, a higher grass stand yield in experimental meadow steppe cenoses can be explained by the high thickness of the soil soil horizon which reaches 1 m in some places (variations of 35–100 cm). In nature it is usually equal 10–30 cm.

To prevent grass stand degradation the maintenance mode of restored steppe should include annual mowing. It is important to improve recultivation methods of sod extraction sites. The necessity of studying the natural cenoses restoration methods by scientists of Stavropolskii Krai is dictated by the high degree of economic development of its territory. The natural plant communities of the north-eastern and eastern part of the

region's lowlands are 70% or more plowed up. Significant disturbance of vegetation is noted in other zones of the area as well. The surviving remnants of virgin lands are mostly located on erosion-hazardous elements of the terrain that ae not suitable for arable farming.

The sod blocks planting method has recently found an application in experimental phytocenology and landscape design. Restoration of natural vegetation by sod blocks planting in large areas is quite time-consuming and expensive compared to agrosteppe method. Therefore, it can only be used in a limited way in small areas as a component of combined options.

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