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RESEARCH PAPER

Syntaxonomy of the xero-mesophytic oak forests in the Republic of Tatarstan (Eastern Europe)

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Abstract

Aims: To develop a syntaxonomic classification of the xero-mesophytic broad-leaved oak forests of the Republic of Tatarstan with a preliminary analysis of their unique ecological features. **Study area:** The Republic of Tatarstan (European part of the Russian Federation). **Methods:** A total of 91 relevés were processed. Most of them (73.6%) were sampled in Tatarstan during 2016 and 2017, the remaining ones (26.4%) were historical published data. They were classified by means of a modified TWINSPAN algorithm using total inertia as a heterogeneity measure. Diagnostic, constant, and dominant species were identified using analytical tools in the JUICE 7.0 program. **Results:** The xero-mesophytic forests of the study area were assigned to four clusters. We describe two of them as new associations: *Astragalo ciceri-Quercetum roboris* ass. nova and *Sanguisorbo officinalis-Quercetum roboris* ass. nova. We classify them within the class *Quercetea pubescentis*. **Conclusions:** Our study is the first attempt to classify thermophilous and xero-mesophytic oak forests of the Republic of Tatarstan using the Braun-Blanquet system.

Taxonomic reference: Czerepanov (1995).

Syntaxonomic reference: Mucina et al. (2016) unless stated otherwise in the text.

Abbreviations: GIVD = Global Index of Vegetation-Plot Databases; NMDS = Non-metric multidimensional scaling.

Keywords

Aceri tatarici-Quercion, *Lathyro pisiformis-Quercion*, oak forest, *Quercetalia pubescenti-petraeae*, *Quercetea pubescentis*, Republic of Tatarstan, xero-mesophytic forest

Introduction

The xero-mesophytic broad-leaved forests of the Republic of Tatarstan (hereafter referred to as Tatarstan) are of interest for several reasons. These forests are characterized by high biodiversity and host many rare and protected plant species. *Quercus robur*, a canopy-forming tree species of these ecological communities, is found here near the northeastern boundary of its native range (Gorchakovskij 1968). The communities of this type form an ecotone between forest and steppe, which has long attracted researchers, starting with the works of Korzhinsky (1888) and Markov (1935).

Xero-mesophytic broad-leaved forests occupy a large area within the forest-steppe zone of Central and Eastern Europe. Communities of this type occur eastward as a gradually tapering belt that extends to the following territories of Eastern Europe: Ukraine (Goncharenko 2003; Onyshchenko et al. 2007; Solomakha 2008; Semenishchenkov and Panchenko 2012; Panchenko 2013); Crimea (Korzhenevskij et al. 2003); the regions of Bryansk (Bulokhov and Solomeshch 2003), Kursk, Tula, Belgorod (Semenishchenkov and Poluyanov 2014), Voronezh, Tambov, Penza, Saratov, Samara, and Ulyanovsk (Blagoveshchenskij 2005); the Republics of Mordovia, Chuvashia, Tatar-

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stan (Markov 1935), and Bashkortostan (Yamalov et al. 2004); and the Orenburg region.

Until recently, the classification of plant communities of Tatarstan has been performed using the dominance approach (Rogova and Shajhutdinova 2000; Pozdnyak 2005). The syntaxonomic position of the xero-mesophytic oak forests of Tatarstan in the Braun-Blanquet system is still unclear.

The westerly distributed analogues have been attributed to the alliance *Aceri tatarici-Quercion* (Semenishchenkov and Poluyanov 2014) and the eastern analogues to the alliance *Lathyro pisiformis-Quercion roboris* (Yamalov et al. 2004; Willner et al. 2016). However, Semenishchenkov and Panchenko (2012) suggested that some associations previously assigned to the *Aceri tatarici-Quercion* should be classified in the *Quercion petraeae*. They also pointed out that the xero-mesophytic oak forests of Tatarstan are distinct from both of the aforementioned alliances. In a recent revision of the thermophilous oak forests of the steppe and forest-steppe zones of Ukraine and Russia, Goncharenko et al. (2020) described the eastern part of the *Aceri tatarici-Quercion* as a new alliance *Scutellario altissimae-Quercion roboris* and the eastern part of the *Quercion petraeae* as *Betonico officinalis-Quercion roboris*.

The aim of this article is to address the following research questions: 1. Are there communities in Tatarstan that may be assigned to the order *Quercetalia pubescenti-petraeae*? 2. To which lower-level syntaxa can they be assigned? 3. What are the compositional, ecological, and chorological characteristics of these syntaxa?

Study area

The Republic of Tatarstan is located in the eastern part of the East European Plain at the confluence of the largest European river Volga with the rivers Kama and Belaya (Figure 1). The northwesternmost point is approximately 56.67°N, 047.26°E, the southeasternmost one 53.97°N, 054.27°E. The total area is 67,600 km^2. The territory is divided by the rivers into clearly separated natural and geographical parts: Cis-Volga region (west and south of the Volga valley), Cis-Kama region (north of the Kama and Volga valleys), Trans-Kama region (south of the Kama valley) (Butakov 1994).

Large uplands alternate with lowland areas across the study area. The lowest elevation in the territory is along the line of the Kuibyshev Reservoir with an average of 53 m, while the maximum elevation of 380 m is reached in the south-east of the study area (Butakov 1994). Being located within the Sarmatian mixed forests and the East European forest-steppe (Dinerstein et al. 2017), the study area has high biodiversity, particularly regarding its vegetation cover (Bakin et al. 2000). The heterogeneity of site conditions due to climatic and soil characteristics, as well as the long-term human impact on vegetation (Bakin et al. 2000), has determined the complexity and diversity of the vegetation cover. The territory is comprised of 18% forests, 21.5% grasslands and 6% water bodies (Shadrikov 2019). The remaining 54.5% of the territory is agricultural and urban land. Young forest stands prevail in the forest vegetation (secondary birch, aspen, and lime coppice), whereas the ancient forests

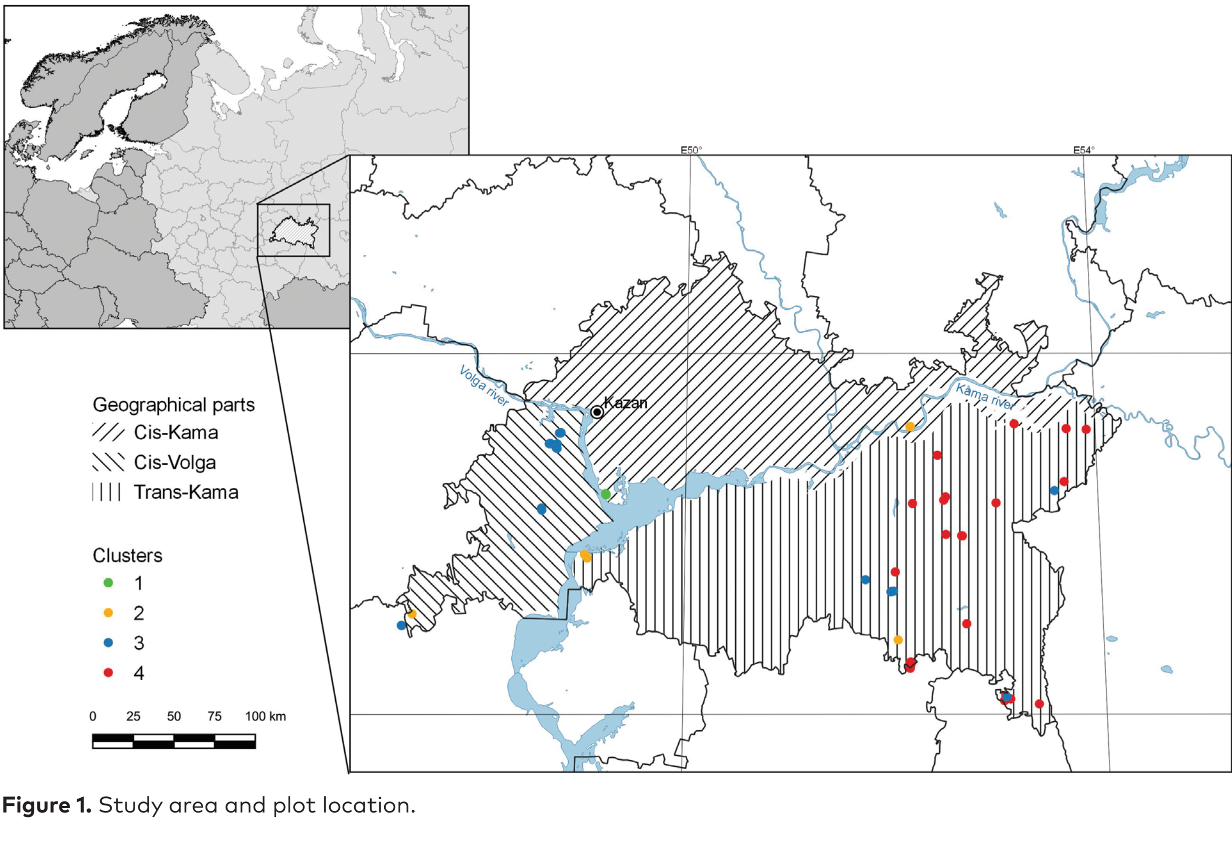

Figure 1. Study area and plot location.

are small and fragmented. Steppe communities occupy very small territories. They are represented by meadow steppes along the edges of deciduous forests and gentle slopes. The steep slopes of southern exposure in the southeastern part of the Tatarstan are occupied by petrophytic steppes (Bakin et al. 2000).

Methods

Vegetation data

All relevés of the oak forests of Tatarstan were previously classified and analyzed to exclude hygrophytic and mesophytic communities (Kozhevnikova et al. 2018). For the present study, a total of 91 relevés of xero-mesophytic oak forests were compiled from the study area. The majority of relevés (n = 67), was sampled in the field during the field seasons of 2016 and 2017, with the aim of investigating the communities of thermophilous oak forests following the construction of a model of their potential distribution (Kozhevnikova et al. 2019). Further 24 relevés were historical data retrieved from the literature (Markov 1935).

The newly collected relevés were sampled using the standard phytosociological methodology (Dengler et al. 2008). In most cases, the plot size was 400 m^2. For each vegetation plot, all vascular plant species were recorded with indications of their layer and abundance based on the Drude scale (Drude 1896). In addition, the geographical coordinates, altitude, exposition, and slope were recorded for each relevé.

The published relevés of Markov (1935) include information on all species of vascular plants, their abundance on the Drude scale and the geographical position, which we georeferenced with an accuracy of 200 m.

To compare the newly sampled relevés with the previously described associations, we used published relevés assigned to the *Aceri tatarici-Quercion* from the Belgorod and Kursk regions (Semenishchenkov et al. 2013; Semenishchenkov and Poluyanov 2014): *Chamaecytiso ruthenici-Quercetum roboris* Semenishchenkov et al. 2014, *Pyro pyrastris-Quercetum roboris* Semenishchenkov et al 2014, *Vicio pisiformis-Quercetum roboris* Semenishchenkov et al. 2014, *Lathyro nigri-Quercetum roboris* Bulokhov et Solomeshch 2003. We also analyzed the published relevés of the *Lathyro pisiformis-Quercion roboris* from Southern Urals (Gorchakovskij 1972; Schubert et al. 1979; Solomeshch et al. 1989; Martynenko et al. 2005, 2008): *Filipendulo vulgaris-Quercetum roboris* Martynenko et al. 2008, *Omphalodo scorpioidis-Quercetum roboris* Martynenko et al. 2008, *Brachypodio pinnati-Quercetum roboris* Grigorjev in Solomeshch et al. 1989, *Aconogono alpini-Quercetum roboris* Gorczakovskij ex Solomeshch et al. 1989, *Calamagrostio epigei-Quercetum roboris* Gorczakovskij ex Solomeshch et al. 1989, *Carici macrourae-Quercetum roboris* Gorczakovskij ex Solomeshch et al. 1989, *Pruno-Quercetum roboris* Solomeshch et al. 1989, *Bistorto majoris-Quercetum roboris* Martynenko et Zhigunov, 2005. All processed relevés are included in the information system "Flora" (Rogova et al. 2010), which contains data from Tatarstan (Prokhorov et al. 2017) and adjacent territories.

Analysis

The relevés of xero-mesophytic communities were exported from the information system "Flora" with simultaneous translation of the Drude abundance grades into cover percentage (soc – 95%, cop_3 – 75%, cop_2 – 50%, cop_1 – 25%, sp – 3%, sol – 2%, un – 0.5%). This file was then imported into the JUICE 7.0 program (Tichý 2002) with the transformation of cover percentage into the Braun-Blanquet scale. The relevés were classified by applying the modified TWINSPAN algorithm (Roleček et al. 2009). For optimizing the number of clusters, the procedure OptimClass proposed by Tichý et al. (2010) was used. The resulting clusters were analyzed by calculating the species frequency and by identifying diagnostic, constant and dominant species. The following threshold values were used: for diagnostic species, a phi value > 0.6, for constant species, a frequency > 60%, and for dominant species, average cover > 80%.

The resulting clusters were compared with the aforementioned associations of the alliances *Aceri tatarici-Quercion* and *Lathyro pisiformis-Quercion* by combining them into a single constancy table. For all vegetation units, the frequency sum of diagnostic species of the following syntaxa was calculated: *Lathyro pisiformis-Quercion roboris*, *Betonico officinalis-Quercion roboris*, and *Scutellario altissimae-Quercion roboris*. Diagnostic species follow Goncharenko et al. (2020).

The names of classes, orders and alliances follow Mucina et al. (2016), except for those newly described in Goncharenko et al. (2020). The newly described associations follow the ICPN, 4th edition (Theurillat et al. 2021). Biogeographic characteristics of the species are given according to Bakin et al. (2000).

The TWINSPAN clusters were compared with the other associations by calculating a distance matrix. As a distance metric we used 1 – Jaccard coefficient following the recommendations of Legendre and De Cáceres (2013). As vectors for paired comparison, we used the species list of each group and the frequency of the species. The results are visualized using a "heat map" combined with a dendrogram, which is computed by complete-linkage clustering method. We also used non-metric multidimensional scaling (NMDS) as a "dimensional reduction" method (Kraemer et al. 2018).

Results

TWINSPAN classification

The OptimClass procedure resulted in four clusters (Table 1, Suppl. material 1).

Cluster 1 contained five relevés located at the single site on the high and steep slope of the Volga terrace. Species identified as diagnostic for this cluster included ruderal and meadow plants (*Asparagus officinalis*, *Crepis tectorum*, *Melandrium album*, *Phleum phleoides*, *Polygonatum odoratum*, *Rumex acetosella*, *Tanacetum vulgare*), which indicates the derivative nature of these communities.

Cluster 2 also contained a small number of relevés (seven) and a mixture of ruderal, meadow and shade-tolerant nemoral species as diagnostic (*Fragaria vesca*, *Glechoma hederacea*, *Tilia cordata*, *Trifolium hybridum*, *Veronica chamaedrys*).

Cluster 3 contained 37 geographically widespread plots, which indicates a regular occurrence of this community type. Only one species was identified as diagnostic – *Laser trilobum*. When the phi value threshold was decreased from 0.6 to 0.3, *Astragalus cicer*, *Adonis vernalis*, *Campanula rapunculoides*, and *Xanthoselinum alsaticum* also became diagnostic.

Cluster 4 contained 42 relevés. Diagnostic species included forest, forest-meadow and steppe plants (*Adenophora lilifolia*, *Aegopodium podagraria*, *Crepis sibirica*, *Dactylis glomerata*, *Euphorbia semivillosa*, *Geranium sylvaticum*, *Heracleum sibiricum*, *Lathyrus vernus*, *Pteridium aquilinum*, *Pulmonaria mollis*, *Rubus saxatilis*, *Sanguisorba officinalis*, *Viola mirabilis*).

In the following, we describe clusters 3 and 4 as new associations. We refrain from describing clusters 1 and 2 formally as new syntaxa because of the small number of relevés and their presumable derivative nature.

Description of new syntaxa

Astragalo ciceri-Quercetum roboris ass. nova

Diagnostic species: *Adonis vernalis*, *Astragalus cicer*, *Campanula rapunculoides*, *Laser trilobum*, *Xanthoselinum alsaticum.*

Geographical range: Communities assigned to this association are found in the southeast of Tatarstan, Cis-Volga region, and the western part of Tatarstan. The most typical of these communities were described from the Central Cis-Volga region, Kamskoe Ust'e and Apastovo districts (a distribution map and a photo of the community are provided in Suppl. material 3).

Floristic composition: These communities represent a sparse open forest. The first tree layer is dominated exclusively by *Quercus robur*, which also occurs in the shrub layer. In the second tree layer, *Betula pendula*, *Tilia cordata* and *Sorbus aucuparia* are found along with oak. The shrub layer is not dense and mainly consists of *Euonymus verrucosa*, *Corylus avellana*, *Rhamnus cathartica*, *Sorbus aucuparia*, and *Lonicera xylosteum*. The proportion of shrubs in these communities increases if there are signs of fire impacts. In case of intensive grazing, the undergrowth density is reduced, and the proportion of herbs increases. The floristic composition is homogeneous; only 94 plant species were recorded at the 37 plots of this association (with most commonly 20–30 species per plot). The composition of dominant species is determined by quite high light availability. Among the dominant species, *Brachypodium pinnatum*, *Carex muricata*, *Fragaria viridis* and *Laser trilobum* prevail.

Habitat characteristics: These communities grow on the middle parts of gentle (5–15°) slopes of southwestern exposure at altitudes less than 150 m a.s.l. The flat surfaces adjacent to the tops of these slopes are usually plowed up or, more rarely, occupied by meadow steppes with a large number of grasses (including *Stipa* species) and legumes. The lower parts of the slopes are most often occupied by a strip of shrubby vegetation with *Cerasus fruticosus*, *Genista tinctoria* and *Spiraea* species. The soils are generally rich in nutrients. The parent rocks are characterized by high content of calcium.

Typus relevé:

Database ID 13,119

20 Jul 2016; Kuralovo; 55.65813°N, 048.77161°E; 97 m; plot size 400 m^2; species richness: 45.

Tree layer: *Quercus robur* 3; shrub layer: *Euonymus verrucosa* r, *Corylus avellana* r, *Prunus spinosa* r, *Rhamnus cathartica* r, *Sorbus aucuparia* r, *Lonicera xylosteum* r; herb layer: *Laser trilobum* 4, *Brachypodium pinnatum* 3, *Vincetoxicum hirundinaria* +, *Galium mollugo* +, *Ranunculus polyanthemos* +, *Crepis praemorsa* +, *Medicago falcata* +, *Pimpinella saxifraga* +, *Pyrethrum corymbosum* +, *Carex rhizina* +, *Viola collina* +, *Campanula rapunculoides* +, *Geranium sanguineum* +, *Carex muricata* +, *Asparagus officinalis* +, *Astragalus cicer* +, *Centaurea pseudophrygia* +, *Stachys officinalis* +, *Adonis vernalis* +, *Viscaria vulgaris* +, *Carex tomentosa* +, *Poa angustifolia* +, *Galium boreale* +, *Silene nutans* +, *Campanula persicifolia* +, *Asarum europaeum* +, *Convallaria majalis* +, *Viola mirabilis* +, *Vicia pisiformis* +, *Rubus saxatilis* +, *Cichorium intybus* +, *Picris hieracioides* +, *Trifolium medium* +, *Vicia tenuifolia* +, *Inula salicina* +, *Serratula coronata* +, *Centaurea scabiosa* +.

Sanguisorbo officinalis-Quercetum roboris ass. nova

Diagnostic species: *Adenophora lilifolia*, *Heracleum sibiricum*, *Pulmonaria mollis*, *Sanguisorba officinalis.* .

Geographical range: The communities assigned to this association occur in the southeast of Tatarstan, within the western slope of the Bugulma-Belebey Upland at the territories of the Bugulma, Leninogorsk, Bavly, Aznakaevo and Almetyevsk districts of Tatarstan (a distribution map and photos of the community are provided in Suppl. material 3).

Floristic composition: The communities are characterized by an extremely high species diversity. The total number of species is 293, while the average number of species per relevé is 50. In the tree layer, *Betula pendula*, *Pinus sylvestris*, *Populus tremula*, *Tilia cordata* and *Ulmus glabra* are found in addition to the dominant *Quercus robur*. Trees are distributed unevenly within the plots: some of them grow close to each other, while others are separated and form open areas (meadows) with sparse tree stands. In the meadow areas, heliophytes are abundant. The shrub layer is not dense, being characterized by high species diversity (total number of species 21) without any clear dominance among them. The most abundant species is *Euonymus verrucosa*. The herb layer is multilayered, polydominated, with tall forest-steppe herbs (*Campanula trachelium*, *Euphorbia semivillosa*, *Heracleum sibiricum*, *Lilium pilosiusculum* and *Pleurospermum uralense*).

Habitat characteristics: In Tatarstan, the communities of this type occur at altitudes of 250–300 m a.s.l. They occupy areas near the water divide and middle parts of the gentle (up to 5°) slopes of mostly southeastern exposure. The soils are leached and typical chernozems. The parent material can be Permian bed rocks, Permian eluvial clays and loams, deluvial deposits on the gentle slopes, and post-Pliocene loess-like loams.

Typus relevé:

Database ID 13,057

21 May 2016; Leninogorsk district, near Tuktarovo-Urdala village; 54.39278°N, 052.15631°E; 262 m a.s.l.; plot size 400 m^2; species richness: 43.

Tree layer: *Quercus robur* 3, *Betula pendula* 1, *Acer platanoides* 1; shrub layer: *Acer platanoides* 1, *Padus avium* +, *Populus tremula* +, *Sorbus aucuparia* +, *Ulmus laevis* +; herb layer: *Calamagrostis arundinacea* 2, *Carex montana* 1, *Adenophora lilifolia* +, *Aegopodium podagraria* +, *Angelica sylvestris* +, *Campanula persicifolia* +, *Carex rhizina* +, *Centaurea pseudophrygia* +, *Convallaria majalis* +, *Crepis sibirica* +, *Dracocephalum ruyschiana* +, *Euphorbia semivillosa* +, *Filipendula vulgaris* +, *Galium boreale* +, *Galium tinctorium* +, *Geranium sylvaticum* +, *Heracleum sibiricum* +, *Lathyrus pisiformis* +, *Lathyrus vernus* +, *Lilium pilosiusculum* +, *Phlomoides tuberosa* +, *Poa pratensis* +, *Pteridium aquilinum* +, *Pulmonaria mollis* +, *Pyrethrum corymbosum* +, *Quercus robur* +, *Rubus saxatilis* +, *Sanguisorba officinalis* +, *Serratula coronata* +, *Silene nutans* +, *Stellaria holostea* +, *Thesium ebracteatum* +, *Trommsdorfia maculata* +, *Veronica chamaedrys* +, *Vicia tenuifolia* +, *Viola mirabilis* +.

Comparison with associations in other regions

The comparison of the identified syntaxa and previously described associations of the *Lathyro pisiformis-Quercion* and *Aceri tatarici-Quercion* (sensu lato) are given in Table 1. The analysis of the table reveals significant differences in both floristic composition and combinations of characteristic species between identified syntaxa and previously described associations.

Table 1. Percentage synoptic table of xero-mesophytic broad-leaved oak forests of Eastern Europe. Only species with a frequency ≥ 40% in one column or ≥ 20% in at least two columns are shown. Diagnostic taxa follow Goncharenko et al. (2020). **BQ** –*Betonico officinalis-Quercion roboris*; **SQ** –*Scutellario altissimae-Quercion roboris*; **LQ** –*Lathyro pisiformis-Quercion roboris*. Diagnostic species of the alliances are shaded in grey.

Cluster/association	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Alliance					LQ	LQ	LQ	LQ	LQ	LQ	LQ	LQ	BQ	BQ	BQ	SQ
Number of relevés	5	7	37	42	23	6	54	5	10	9	14	7	17	24	18	10
Tree layer 1:																
Quercus robur (BQ, SQ, LQ)	100	100	100	93	100	.	.	100	100	100	100	100	.	100	.	100
Tilia cordata	20	86	.	7	17	.	.	80	100	100	100	.	.	13	.	.
Betula pendula	.	43	5	76	39	.	46	100	100	56	21	.	24	13	.	.
Acer platanoides	.	.	.	5	9	.	.	100	100	.	.	86	.	.	.	.
Ulmus glabra	.	.	.	2	.	.	.	60	60	78	.	.	.	.	.	.
Populus tremula	.	.	.	10	.	.	.	40	.	33	.	.	.	25	.	.
Pinus sylvestris	.	43	.	5	.	33	.	.	.	.	7	.	.	8	.	.
Rubus idaeus	.	.	.	.	.	.	.	.	.	.	.	43	.	.	.	.
Sorbus aucuparia	.	.	.	.	.	.	.	.	.	.	.	43	.	.	.	.
Abies sibirica	.	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.
Tree layer 2:																
Quercus robur (BQ, SQ, LQ)	.	.	16	7	78	.	20	.	.	.	.	.	6	83	.	.
Betula pendula	.	14	5	10	13	.	2	.	.	.	.	.	24	13	.	50
Sorbus aucuparia	.	.	.	.	.	.	.	.	.	.	.	.	.	79	.	.
Padus avium	.	.	.	.	13	.	.	.	.	.	.	.	.	46	.	.
Malus sylvestris	.	.	.	.	.	.	.	.	.	.	.	.	.	58	.	.
Shrub layer:																
Rosa majalis (LQ)	.	14	19	12	61	.	.	.	10	33	71	43	.	.	.	.
Caragana frutex (LQ)	.	.	.	.	43	.	.	.	.	33	.	.	.	.	.	.
Chamaecytisus ruthenicus (BQ)	20	.	8	7	57	.	24	.	20	.	.	.	.	83	.	.
Cerasus fruticosa (SQ)	60	29	46	17	65	.	.	.	10	33	71	.	.	.	.	.
Acer tataricum (SQ)	.	.	3	.	.	.	.	.	.	.	.	.	.	4	.	90
Prunus spinosa (SQ)	20	.	3	.	.	.	.	.	.	.	.	.	.	.	.	60
Quercus robur (BQ, SQ, LQ)	20	71	43	38	78	83	22	.	.	.	.	.	29	46	.	80
Sorbus aucupari	.	57	24	48	17	50	33	100	100	33	21	.	59	75	.	20
Euonymus verrucosa	60	100	76	24	.	83	.	.	.	78	100	.	.	4	.	80
Acer platanoides	40	43	32	40	22	.	22	.	.	.	.	.	24	25	.	70
Rubus idaeus	.	.	.	.	13	33	22	60	100	44	.	.	.	.	.	.
Rhamnus cathartica	.	71	41	17	22	.	.	.	.	.	50	.	.	.	.	50
Tilia cordata	.	43	8	7	43	.	.	.	.	.	.	.	.	33	.	70
Padus avium	.	.	14	12	22	.	.	60	.	78	.	.	.	.	.	.
Viburnum opulus	.	.	11	2	.	.	.	20	10	22	36	.	.	.	.	20

Cluster/association	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Alliance					**LQ**	**LQ**	**LQ**	**LQ**	**LQ**	**LQ**	**LQ**	**LQ**	**BQ**	**BQ**	**BQ**	**SQ**
Number of relevés	**5**	**7**	**37**	**42**	**23**	**6**	**54**	**5**	**10**	**9**	**14**	**7**	**17**	**24**	**18**	**10**
Malus sylvestris	.	.	14	.	.	.	.	.	.	.	.	.	.	63	.	20
Lonicera xylosteum	.	14	5	.	.	50	.	20	.	.	7	.	.	.	.	.
Acer campestre	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	90
Euonymus europaea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	90
Pyrus pyraster	.	.	.	.	.	.	.	.	.	.	.	.	.	29	.	50
Ulmus glabra	.	.	.	5	22	.	.	.	.	.	.	.	.	.	.	50
Corylus avellana	.	.	59	7	.	.	.	.	.	.	.	.	.	.	.	.
Frangula alnus	.	.	3	2	.	.	.	.	10	.	50	.	.	.	.	.
Fraxinus excelsior	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	50
Ulmus laevis	.	43	.	5	.	.	.	.	.	.	.	.	.	.	.	.
Herb layer:																
Brachypodium pinnatum	.	86	51	48	87	.	93	60	100	56	79	43	.	33	.	.
Heracleum sibiricum (LQ)	.	.	16	62	65	.	.	60	70	100	71	.	.	17	.	.
Lathyrus pisiformis (LQ)	.	.	46	55	70	.	.	.	90	22	.	43	.	.	.	.
Phlomoides tuberosa (SQ)	20	29	57	55	74	.	.	.	10	.	.	.	.	.	.	70
Pyrethrum corymbosum	.	29	81	88	91	.	.	.	.	.	.	.	.	13	.	.
Pleurospermum uralense (LQ)	.	.	3	31	13	.	.	80	90	33	.	.	.	.	.	.
Seseli libanotis (LQ)	20	14	.	19	78	.	.	.	.	44	.	14	.	.	.	.
Geranium sylvaticum (LQ)	.	.	14	74	22	.	.	60	.	.	.	.	.	.	.	.
Lathyrus gmelinii (LQ)	.	.	.	.	.	.	.	60	40	22	.	14	.	.	.	.
Lathyrus sylvestris (LQ)	.	.	14	5	.	.	.	.	30	67	.	.	.	.	.	.
Carex macroura (LQ)	.	.	.	.	.	.	.	.	.	100	.	.	.	.	.	.
Lathyrus litvinovii (LQ)	.	.	.	.	61	.	.	.	.	.	.	.	.	.	.	.
Cerasus fruticosa (SQ)	20	.	8	5	.	.	.	.	.	.	.	.	.	.	.	.
Origanum vulgare (BQ)	100	57	24	43	96	100	59	.	10	56	.	86	53	17	.	.
Veronica chamaedrys (BQ)	.	100	11	52	30	.	26	.	.	33	14	.	76	58	78	90
Campanula persicifolia (BQ)	20	.	5	36	52	.	37	.	.	.	14	14	35	83	72	.
Digitalis grandiflora (BQ, LQ)	.	.	.	2	52	.	.	60	90	78	.	71	.	.	.	.
Viola hirta (BQ)	20	.	3	17	65	.	.	20	30	78	.	.	.	8	.	70
Vincetoxicum hirundinaria (BQ)	80	.	27	12	.	.	.	.	.	44	.	.	18	21	.	60
Melampyrum nemorosum (BQ)	.	.	.	.	.	.	.	.	.	.	.	.	.	100	.	.
Campanula bononiensis	40	.	.	17	43	.	.	.	.	.	.	.	.	.	.	.
Chamaecytisus ruthenicus (BQ)	40	.	.	2	.	.	15	.	.	.	.	43	.	.	.	.
Trifolium alpestre (BQ)	.	.	.	21	.	.	.	.	.	.	.	.	.	75	.	.
Securigera varia (BQ)	.	.	.	2	.	.	.	.	.	.	.	.	.	58	.	.
Allium oleraceum (BQ)	.	.	.	.	.	.	.	.	.	.	.	.	.	46	.	.
Turritis glabra (BQ)	.	.	3	2	22	.	.	.	.	11	.	.	.	.	.	.
Serratula tinctoria (BQ)	.	.	8	.	.	.	.	.	.	.	.	.	.	21	.	.
Potentilla alba (BQ)	.	.	.	.	.	.	.	.	.	.	.	.	.	21	.	.
Vicia pisiformis (SQ)	.	.	41	2	.	.	.	.	.	.	.	.	.	.	.	90
Euphorbia semivillosa (SQ)	.	.	38	64	.	.	.	.	.	11	.	.	.	.	.	.
Crataegus rhipidophylla (SQ)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	100
Acer tataricum (SQ)	.	.	.	.	.	.	.	.	.	.	.	.	.	79	.	10
Ajuga genevensis (BQ)	40	.	8	.	.	.	.	.	.	.	.	.	.	29	.	.
Vicia sepium (BQ, LQ)	.	29	3	40	26	.	39	60	50	56	14	29	41	17	.	.
Betonica officinalis (BQ)	20	14	19	60	52	.	.	.	10	.	.	57	.	63	.	40
Quercus robur (BQ, SQ, LQ)	.	.	14	43	.	.	2	.	.	.	.	.	.	21	33	.
Lathyrus vernus	.	14	8	79	78	83	87	80	100	100	100	43	65	4	50	20
Poa nemoralis	40	43	11	12	70	.	63	40	100	56	57	100	.	58	83	100
Calamagrostis arundinacea	20	.	.	33	100	50	81	100	100	100	50	100	6	67	22	.
Rubus saxatilis	.	14	16	83	83	50	74	100	100	100	86	71	6	.	.	.
Viola mirabilis	.	.	38	69	52	83	74	100	80	100	100	.	.	17	50	.
Aegopodium podagraria	.	.	24	86	43	67	69	80	100	100	71	.	.	17	56	.
Stellaria holostea	.	14	5	43	91	.	.	60	40	89	100	100	.	4	22	100
Polygonatum odoratum	100	29	5	36	57	67	48	.	10	22	79	14	18	88	17	20
Melica nutans	.	29	14	26	26	.	67	100	.	78	57	57	71	63	.	20
Fragaria vesca	60	100	38	31	30	67	30	.	30	.	.	.	71	33	28	30
Calamagrostis epigeios	40	14	3	33	87	33	26	.	80	33	7	71	24	63	33	.
Solidago virgaurea	.	.	14	29	57	67	41	80	50	.	36	71	12	63	.	.
Galium boreale	.	29	41	71	87	.	.	.	70	.	71	.	53	4	.	30
Dactylis glomerata	.	.	3	45	74	.	50	80	100	.	.	43	.	38	.	20
Asarum europaeum	.	.	11	2	.	50	39	100	60	67	50	29	12	.	22	.
Glechoma hederacea	.	86	5	14	13	.	.	40	10	33	100	14	12	29	11	30
Galium verum	100	100	32	31	52	17	15	.	.	11	.	.	6	25	.	.
Pteridium aquilinum	.	.	3	57	.	.	19	80	100	33	21	.	41	.	33	.
Urtica dioica	.	.	5	21	17	67	13	20	10	56	57	.	47	25	44	.
Geum urbanum	.	.	11	38	48	67	28	.	.	11	.	.	47	50	.	70
Convallaria majalis	40	29	35	52	.	.	.	.	.	.	.	.	94	50	22	40
Hypericum perforatum	80	.	14	24	17	.	.	.	10	44	7	.	41	42	.	80
Galium odoratum	.	.	.	17	26	33	50	100	100	22	.	.	.	.	.	.

Cluster/association	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Alliance					LQ	LQ	LQ	LQ	LQ	LQ	LQ	LQ	BQ	BQ	BQ	SQ
Number of relevés	5	7	37	42	23	6	54	5	10	9	14	7	17	24	18	10
Scrophularia nodosa	.	.	3	10	.	.	39	40	60	67	.	57	.	42	.	30
Pulmonaria obscura	.	14	.	12	.	33	19	100	30	78	.	.	.	4	.	50
Hieracium umbellatum	20	.	3	36	65	17	26	.	.	.	21	14	47	79	.	.
Bupleurum longifolium	.	.	.	7	30	.	.	80	100	44	.	29	.	.	.	.
Fragaria viridis	20	.	46	29	74	.	.	.	.	33	.	29	12	4	39	.
Poa angustifolia	20	14	24	40	26	.	.	.	.	.	.	.	6	96	39	20
Crepis sibirica	.	.	5	48	.	.	.	80	100	44	.	.	.	.	.	.
Achillea millefolium	20	.	3	21	61	33	28	.	.	.	21	14	24	42	.	.
Hylotelephium triphyllum	.	.	.	10	39	50	24	.	.	22	.	100	6	.	.	.
Geranium sanguineum	60	.	54	40	.	.	.	.	.	.	7	.	.	88	.	.
Silene nutans	20	.	30	29	48	33	11	.	.	.	7	.	12	58	.	.
Milium effusum	.	.	.	5	.	.	22	100	80	22	.	14	.	.	.	.
Filipendula vulgaris	.	43	49	48	87	.	.	.	.	.	.	.	.	4	.	.
Angelica sylvestris	.	.	.	14	.	.	9	80	90	.	.	.	24	.	.	.
Vicia tenuifolia	60	.	30	48	74	.	.	.	.	.	.	.	.	.	.	.
Thalictrum minus	80	.	22	26	65	.	.	.	.	.	.	14	.	.	.	.
Asparagus officinalis	100	29	30	5	17	.	4	.	.	.	.	.	12	.	.	.
Agrimonia eupatoria	20	14	49	40	.	.	.	.	.	.	.	.	.	4	.	70
Polygonatum multiflorum	.	.	.	7	.	33	4	80	.	22	.	.	18	4	28	.
Chelidonium majus	.	43	8	.	9	.	17	.	.	33	50	.	.	33	.	.
Carex muricata	.	.	5	.	43	.	.	.	.	56	64	14	.	.	11	.
Clinopodium vulgare	.	.	16	5	.	.	.	.	70	.	.	.	.	50	.	50
Veronica teucrium	.	14	27	43	83	.	.	.	.	.	.	.	.	21	.	.
Aconogonon alpinum	.	.	3	5	70	.	.	.	10	.	.	100	.	.	.	.
Chamaenerion angustifolium	.	.	.	.	22	.	.	80	70	.	.	.	.	13	.	.
Trifolium medium	.	43	8	24	70	.	.	.	10	.	.	.	.	.	.	20
Inula salicina	.	43	35	36	52	.	.	.	.	.	.	.	6	.	.	.
Galium mollugo	.	14	8	14	.	.	.	.	.	.	.	.	59	25	50	.
Viola collina	.	57	46	2	26	.	17	.	.	.	.	.	.	.	17	.
Aconitum lycoctonum	.	.	.	5	.	.	9	80	70	.	.	.	.	.	.	.
Elytrigia repens	20	.	3	7	35	.	.	.	.	.	.	.	24	42	33	.
Fallopia convolvulus	.	.	.	2	22	17	15	.	10	22	36	.	6	.	.	30
Anthriscus sylvestris	.	.	3	26	.	.	.	.	.	67	.	.	.	33	.	30
Vicia cracca	.	43	14	10	22	.	.	.	.	22	29	.	.	.	17	.
Carex praecox	40	.	5	5	74	.	.	.	.	.	.	.	.	29	.	.
Pulmonaria mollis	.	.	30	69	43	.	11	.	.	.	.	.	.	.	.	.
Campanula latifolia	.	.	.	.	.	.	.	40	90	22	.	.	.	.	.	.
Veronica spicata	40	.	11	7	13	17	9	.	.	11	14	29	.	.	.	.
Lysimachia vulgaris	.	.	3	10	.	.	.	.	40	.	.	43	47	8	.	.
Asperula tinctoria (BQ)	20	.	30	17	30	.	.	.	.	.	.	.	.	46	.	.
Lilium martagon	.	.	.	19	26	.	33	.	50	.	.	14	.	.	.	.
Carex rhizina	.	14	5	5	13	.	15	.	.	.	.	.	.	.	.	90
Taraxacum officinale	.	.	16	17	13	.	.	.	.	.	.	.	.	42	28	20
Sanguisorba officinalis	.	.	14	76	35	.	.	.	10	.	.	.	.	.	.	.
Primula macrocalyx	.	.	.	10	57	.	.	20	.	33	.	14	.	.	.	.
Viscaria vulgaris	40	43	11	5	.	.	6	.	.	.	.	.	12	17	.	.
Lysimachia nummularia	.	.	.	.	.	.	.	.	.	.	.	.	24	4	56	50
Galeopsis bifida	.	.	.	.	22	.	.	.	.	.	.	100	.	8	.	.
Bistorta major	.	.	.	.	26	.	.	.	.	.	.	100	.	.	.	.
Euonymus verrucosa	.	.	3	12	.	.	2	.	.	.	.	.	.	96	.	10
Geranium pseudosibiricum	.	.	.	.	.	.	.	.	.	22	.	100	.	.	.	.
Pimpinella saxifraga	.	71	32	19	.	.	.	.	.	.	.	.	.	.	.	.
Torilis japonica	.	.	.	.	.	.	.	.	.	.	.	.	.	42	.	80
Viola canina	.	.	.	7	39	.	.	.	20	11	.	43	.	.	.	.
Adenophora lilifolia	.	.	3	62	22	.	.	.	30	.	.	.	.	.	.	.
Brachypodium sylvaticum	.	.	.	2	.	.	.	.	.	44	.	.	.	.	.	70
Linaria vulgaris	20	.	5	10	30	.	2	.	.	.	7	14	.	25	.	.
Cicerbita uralensis	.	.	.	.	.	.	.	40	70	.	.	.	.	.	.	.
Campanula rapunculoides	20	.	68	7	.	.	.	.	.	.	.	.	.	13	.	.
Dryopteris filix-mas	.	.	.	7	.	.	.	60	40	.	.	.	.	.	.	.
Anemonoides ranunculoides	.	.	3	2	.	.	.	.	.	100	.	.	.	.	.	.
Carex pilosa	.	14	.	7	.	.	.	60	.	22	.	.	.	.	.	.
Phleum phleoides	80	.	3	10	.	.	.	.	.	.	.	.	.	8	.	.
Anomodon viticulosus	.	.	.	.	.	.	.	.	.	100	.	.	.	.	.	.
Veronica longifolia	40	.	.	2	35	.	.	.	10	.	.	.	12	.	.	.
Verbascum nigrum	.	.	.	12	30	.	.	.	.	56	.	.	.	.	.	.
Dicranum scoparium	.	.	.	.	.	.	.	.	90	.	7	.	.	.	.	.
Frangula alnus	.	.	.	.	.	.	2	.	.	.	.	.	6	83	6	.
Astragalus glycyphyllos	.	.	11	2	.	.	.	.	.	.	.	.	.	4	.	80
Paris quadrifolia	.	.	.	5	.	.	.	60	30	.	.	.	.	.	.	.

Cluster/association	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Alliance					**LQ**	**LQ**	**LQ**	**LQ**	**LQ**	**LQ**	**LQ**	**LQ**	**BQ**	**BQ**	**BQ**	**SQ**
Number of relevés	**5**	**7**	**37**	**42**	**23**	**6**	**54**	**5**	**10**	**9**	**14**	**7**	**17**	**24**	**18**	**10**
Carex contigua	.	.	8	26	.	.	.	.	.	.	.	.	.	.	.	60
Campanula glomerata	.	.	.	19	.	.	.	40	20	.	.	14	.	.	.	.
Hylotelephium maximum	60	.	.	2	.	.	.	.	.	.	.	.	.	.	.	30
Adonis vernalis	.	.	51	26	13	.	.	.	.	.	.	.	.	.	.	.
Geranium robertianum	.	.	.	.	.	.	.	20	40	.	.	.	.	.	.	30
Knautia arvensis	20	29	3	21	.	.	.	.	.	.	.	.	.	17	.	.
Trifolium montanum	.	43	14	19	.	.	.	.	.	.	.	.	.	13	.	.
Conioselinum tataricum	.	.	.	2	.	.	.	.	.	.	.	86	.	.	.	.
Peucedanum oreoselinum	.	.	.	.	.	.	.	.	.	.	.	.	.	88	.	.
Melandrium album	80	.	.	7	.	.	.	.	.	.	.	.	.	.	.	.
Tanacetum vulgare	60	.	.	2	.	.	.	.	.	.	.	.	24	.	.	.
Laser trilobum	.	.	65	17	.	.	.	.	.	.	.	.	.	.	.	.
Agrostis tenuis	.	.	3	.	.	.	.	.	.	.	7	.	.	71	.	.
Viola epipsila	.	.	.	.	.	.	.	80	.	.	.	.	.	.	.	.
Poa pratensis	.	.	5	5	13	.	15	.	.	.	.	.	41	.	.	.
Cirsium heterophyllum	.	.	.	7	.	.	.	40	30	.	.	.	.	.	.	.
Dracocephalum ruyschiana	.	.	.	21	30	.	13	.	.	.	.	.	.	13	.	.
Melampyrum cristatum	.	.	.	14	.	.	.	.	60	.	.	.	.	.	.	.
Valeriana wolgensis	.	.	.	.	13	.	.	.	50	11	.	.	.	.	.	.
Serratula gmelinii	.	.	5	24	43	.	.	.	.	.	.	.	.	.	.	.
Knautia tatarica	.	.	.	.	.	.	.	20	50	.	.	.	.	.	.	.
Festuca valesiaca	20	.	14	7	9	.	.	.	.	.	.	.	.	.	.	20
Campanula trachelium	.	.	14	29	26	.	.	.	.	.	.	.	.	.	.	.
Artemisia vulgaris	.	29	3	14	22	.	.	.	.	.	.	.	.	.	.	.
Valeriana officinalis	.	.	.	7	.	.	.	60	.	.	.	.	.	.	.	.
Anemonoides altaica	.	.	.	.	.	.	.	.	.	67	.	.	.	.	.	.
Trommsdorfia maculata	20	.	5	17	.	.	.	.	.	.	.	.	.	25	.	.
Stellaria graminea	.	.	3	17	.	.	4	.	.	.	.	.	.	42	.	.
Serratula coronata	20	.	22	24	.	.	.	.	.	.	.	.	.	.	.	.
Vincetoxicum albowianum	.	.	.	.	22	.	.	.	.	.	.	43	.	.	.	.
Moehringia trinervia	.	.	.	.	.	.	.	.	.	.	.	.	.	54	11	.
Nepeta pannonica	.	.	11	24	30	.	.	.	.	.	.	.	.	.	.	.
Lamium album	.	.	.	.	.	.	.	20	.	44	.	.	.	.	.	.
Stachys sylvatica	.	.	5	10	.	.	4	.	.	44	.	.	.	.	.	.
Verbascum lychnitis	20	29	3	7	.	.	.	.	.	.	.	.	.	4	.	.
Veronica spuria	.	.	.	5	57	.	.	.	.	.	.	.	.	.	.	.
Euphorbia virgata	20	29	8	5	.	.	.	.	.	.	.	.	.	.	.	.
Artemisia armeniaca	.	.	.	.	61	.	.	.	.	.	.	.	.	.	.	.
Ranunculus polyanthemos	.	.	22	26	.	.	.	.	.	.	.	.	.	13	.	.
Genista tinctoria	20	.	.	2	.	.	.	.	.	.	.	.	.	17	22	.
Ptarmica cartilaginea	60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crepis tectorum	60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Veratrum lobelianum	.	.	.	.	.	.	.	60	.	.	.	.	.	.	.	.
Sorbus aucuparia	.	.	3	7	.	.	.	.	.	.	.	29	.	21	.	.
Euphorbia caesia	.	.	.	.	.	.	.	.	.	.	.	57	.	.	.	.
Lathyrus pratensis	.	14	.	21	22	.	.	.	.	.	.	.	.	.	.	.
Carex caryophyllea	40	.	.	2	13	.	.	.	.	.	.	.	.	.	.	.
Maianthemum bifolium	.	.	.	.	.	.	.	20	.	.	.	.	35	.	.	.
Medicago falcata	20	.	24	10	.	.	.	.	.	.	.	.	.	.	.	.
Festuca rubra	.	.	.	2	.	.	.	.	.	.	.	.	.	50	.	.
Padus avium	.	.	.	.	.	.	.	.	.	.	.	.	.	46	6	.
Carex montana	.	.	16	7	.	.	.	.	.	.	.	.	.	29	.	.
Pulsatilla patens	40	.	.	5	.	.	6	.	.	.	.	.	.	.	.	.
Helictotrichon pubescens	.	.	.	5	.	.	.	.	.	.	.	.	.	46	.	.
Lactuca serriola	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30
Hypericum maculatum	.	.	.	.	.	.	.	.	20	.	.	.	29	.	.	.
Populus tremula	.	.	.	7	.	.	.	.	.	.	.	.	6	25	11	.
Euphorbia gmelinii	.	.	.	.	48	.	.	.	.	.	.	.	.	.	.	.
Rumex acetosa	40	.	.	.	.	.	.	.	.	.	.	.	6	.	.	.
Dracocephalum thymiflorum	40	.	3	2	.	.	.	.	.	.	.	.	.	.	.	.
Artemisia campestris	40	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.
Ficaria verna	.	.	.	.	.	.	.	.	.	44	.	.	.	.	.	.
Aristolochia clematitis	20	.	.	.	.	.	.	.	.	.	.	.	24	.	.	.
Scorzonera purpurea	40	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.
Galatella biflora	.	.	.	.	43	.	.	.	.	.	.	.	.	.	.	.
Myosotis sylvatica	.	.	3	.	.	.	.	40	.	.	.	.	.	.	.	.
Senecio schvetzovii	.	.	3	.	.	.	.	40	.	.	.	.	.	.	.	.
Campanula sibirica	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Brachytheciastrum velutinum	.	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.
Lathyrus niger	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40

Compared to the *Chamaecytiso ruthenici-Quercetum roboris*, *Pyro pyrastris-Quercetum roboris*, *Vicio pisiformis-Quercetum roboris* and *Lathyro nigri-Quercetum roboris* associations, the *Astragalo ciceri-Quercetum roboris* has a higher proportion of Euro-West Asian species (41.5% against 30% in the above-listed associations, on average) and a lower number of European species (9.6% against 16%).

Based on the floristic composition, the *Sanguisorbo officinalis-Quercetum roboris* is most similar to the *Filipendulo vulgari-Quercetum roboris*, but it differs from the latter by the absence of such characteristic species as *Galatella biflora* and *Artemisia armeniaca*, as well as because of the lower proportion of *Carex praecox*, *Veronica spuria* and *Campanula bononiensis*. Compared to the *Sanguisorbo officinalis-Quercetum roboris*, the *Filipendulo vulgari-Quercetum roboris* has a much lower proportion of European species (3.4% against 8.5%) and more Eurasian species (23.3% against 19%).

An analysis of "heat maps" shows that all associations have a low similarity. The largest number of pairs being compared has a distance between 0.4 and 0.8 (Figure 2).

The newly identified associations are clustered in the dendrogram into one group with the associations of the *Aceri tatarici-Quercion*. This clustering is generally consistent with the analysis of the composition of diagnostic species. Cluster 2 was grouped with the new associations from the territory of the Republic of Tatarstan, and cluster 1 was grouped with the association *Vicio pisiformis-Quercetum roboris*.

However, the NMDS ordination (Figure 3) shows that the *Sanguisorbo officinalis-Quercetum* is intermediate between the *Lathyro pisiformis-Quercion* and *Aceri tatarici-Quercion* and is closer to the *Filipendulo vulgaris-Quercetum* than to the newly described *Astragalo ciceri-Quercetum roboris*. The left group of points unites the "western" (in relation to the territory of the Republic of Tatarstan) associations of the *Aceri tatarici-Quercion*. Clusters 1 and 2 adjoin them, together with the *Astragalo ciceri-Quercetum roboris*. The right part unites the "eastern" associations of the *Lathyro pisiformis-Quercion*. It is also noticeable that the "eastern" associations are less homogeneous and may require a revision of their syntaxonomic position.

Cluster 1 also has a higher frequency sum of diagnostic species of the *Betonico officinalis-Quercion roboris* alliance (or *Aceri tatarici-Quercion* in the previous concept).

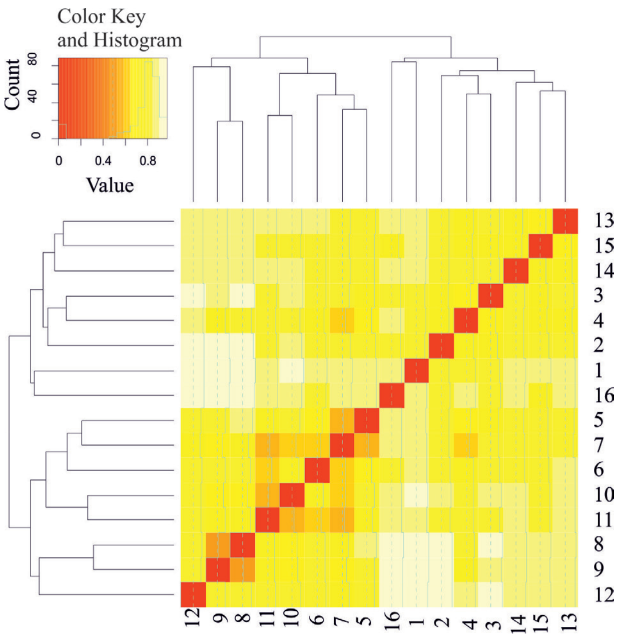

Figure 2. "Heat map" of distance matrix combined with a dendrogram. 1 – cluster 1, 2 – cluster 2, 3 – cluster 3 (*Astragalo ciceri-Quercetum roboris*), 4 – cluster 4 (*Sanguisorbo officinalis-Quercetum roboris*), 5 – *Filipendulo vulgari-Quercetum roboris*, 6 – *Omphalodo scorpioidis-Quercetum roboris*, 7 – *Brachypodio pinnati-Quercetum roboris*, 8 – *Aconogono alpini-Quercetum roboris*, 9 – *Calamagrostio epigei-Quercetum roboris*, 10 – *Carici macrourae-Quercetum roboris*, 11 – *Pruno-Quercetum roboris*, 12 – *Bistorto majoris-Quercetum roboris*, 13 – *Lathyro nigri-Quercetum roboris*, 14 – *Chamaecytiso ruthenici-Quercetum roboris*, 15 – *Pyro pyrastris-Quercetum roboris*, 16 – *Vicio pisiformis-Quercetum roboris*.

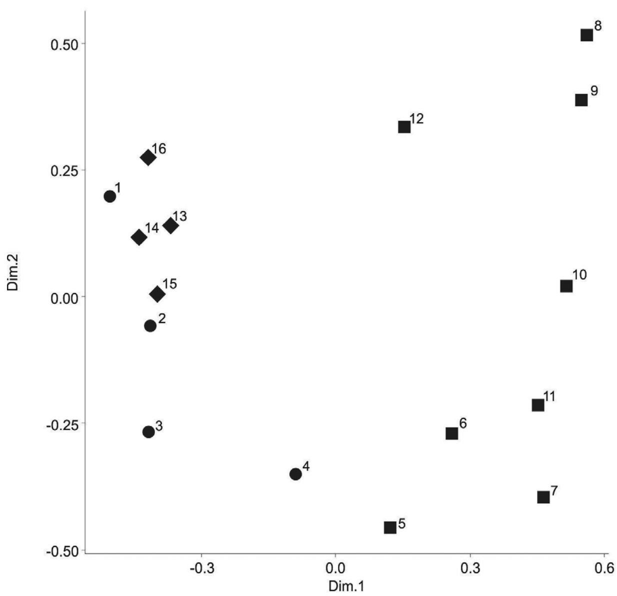

Figure 3. Non-metric multidimensional scaling (NMDS) of the communities similarity matrix. 1 – cluster 1, 2 – cluster 2, 3 – cluster 3 (*Astragalo ciceri-Quercetum roboris*), 4 – cluster 4 (*Sanguisorbo officinalis-Quercetum roboris*), 5 – *Filipendulo vulgari-Quercetum roboris*, 6 – *Omphalodo scorpioidis-Quercetum roboris*, 7 – *Brachypodio pinnati-Quercetum roboris*, 8 – *Aconogono alpini-Quercetum roboris*, 9 – *Calamagrostio epigei-Quercetum roboris*, 10 – *Carici macrourae-Quercetum roboris*, 11 – *Pruno-Quercetum roboris*, 12 – *Bistorto majoris-Quercetum roboris*, 13 – *Lathyro nigri-Quercetum roboris*, 14 – *Chamaecytiso ruthenici-Quercetum roboris*, 15 – *Pyro pyrastris-Quercetum roboris*, 16 – *Vicio pisiformis-Quercetum roboris*. circle – newly described associations; diamond – associations of the *Aceri tatarici-Quercion*; square – associations of the *Lathyro pisiformis-Quercion*.

Table 2. Frequency sum (in %) of diagnostic species of the alliances *Betonico officinalis-Quercion roboris*, *Scutellario altissimae-Quercion roboris* and *Lathyro pisiformis-Quercion roboris* in clusters 1–4 (this paper) and previously described associations. 1 – cluster 1, 2 – cluster 2, 3 – cluster 3 (*Astragalo ciceri-Quercetum roboris*), 4 – cluster 4 (*Sanguisorbo officinalis-Quercetum roboris*), 5 – *Filipendulo vulgari-Quercetum roboris*, 6 – *Omphalodo scorpioidis-Quercetum roboris*, 7 – *Brachypodio pinnati-Quercetum roboris*, 8 – *Aconogono alpini-Quercetum roboris*, 9 – *Calamagrostio epigei-Quercetum roboris*, 10 – *Carici macrourae-Quercetum roboris*, 11 – *Pruno-Quercetum roboris*, 12 – *Bistorto majoris-Quercetum roboris*, 13 – *Lathyro nigri-Quercetum roboris*, 14 – *Chamaecytiso ruthenici-Quercetum roboris*, 15 – *Pyro pyrastris-Quercetum roboris*, 16 – *Vicio pisiformis-Quercetum roboris*.

Number of cluster (association name)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Betonico officinalis-Quercion roboris	440	371	284	470	651	183	220	240	290	456	142	400	258	867	183	440
Scutellario altissimae-Quercion roboris	240	229	369	324	395	83	44	100	120	144	171	100	35	333	33	600
Lathyro pisiformis-Quercion roboris	140	228	288	481	747	83	83	480	570	688	256	314	76	284	33	180

In clusters 2, 3 and 4, the frequency sum of the diagnostic species of the *Lathyro pisiformis-Quercion* is higher than the frequency sum of the diagnostic species of the *Betonico officinalis-Quercion roboris* and *Scutellario altissimae-Quercion roboris* alliances (Table 2).

Discussion

The NMDS ordination diagram shows distinct floristic and ecological composition of the identified syntaxa (Figure 3).

The *Astragalo ciceri-Quercetum roboris* is close to some associations within the *Betonico officinalis-Quercion* alliance, but they are found under more continental conditions. It comprises the following diagnostic species of this alliance (Goncharenko et al. 2020): *Asperula tinctoria*, *Betonica officinalis*, *Campanula persicifolia*, *Origanum vulgare*, *Veronica chamaedrys*, and *Vincetoxicum hirundinaria.*,. However, important species characteristic of *Betonico officinalis-Quercion*, such as *Anthericum ramosum*, *Clematis recta*, *Digitalis grandiflora*, *Melampyrum nemorosum*, *Potentilla alba* and *Trifolium alpestre*, are absent.

Our results suggest that the communities of the *Sanguisorbo officinalis-Quercetum roboris* are close to the group of associations of the *Lathyro pisiformis-Quercion roboris* alliance. However, they differ from the latter by their preference for warmer sites with more light availability. *Sanguisorbo officinalis-Quercetum roboris* includes the diagnostic species of this alliance (Willner et al. 2016) such as *Geranium sylvaticum*, *Heracleum sibiricum*, *Lathyrus pisiformis*, *L. sylvestris*, *Pleurospermum uralense*, *Rosa majalis*, *Seseli libanotis*. Some of diagnostic species of *Lathyro pisiformis-Quercion* are absent: *Caragana frutex*, *Carex macroura*, *Lathyrus gmelinii*, and *L. litvinovii*.

We conclude that the xero-mesophytic oak forests in the Republic of Tatarstan can be assigned to the alliance *Betonico officinalis-Quercion roboris* (ass. *Astragalo ciceri-Quercetum roboris*), and to the alliance *Lathyro pisiformis-Quercion roboris* (ass. *Sanguisorbo officinalis-Quercetum roboris*). However, a syntaxonomic revision of the entire phytocoenotic material of xero-mesophytic oak forests in Europe, including the European part of Russia, is necessary to clarify the exact delimitation of these alliances.

Data availability

The original plot records are included in Suppl. material 1.

Author contributions

Both authors have equally planned the study, conducted field sampling, performed taxonomic considerations, and contributed to writing the article.

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Supplementary material

Supplementary material 1
Ordered table of individual relevés (*.xlsx)
Link: https://doi.org/10.3897/VCS/2021/39583.suppl1

Supplementary material 2
Diagnostic, constant and dominant species of the four clusters. (*.pdf)
Link: https://doi.org/10.3897/VCS/2021/39583.suppl2

Supplementary material 3
Distribution maps and photos of the newly described associations. (*.pdf)
Link: https://doi.org/10.3897/VCS/2021/39583.suppl3