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Syntaxonomy and ecology of thermophilous deciduous open woodlands and scrub vegetation in Tajikistan (Middle Asia)

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Abstract

In this paper we present the first syntaxonomic classification for the thermophilous open wood and scrub vegetation in Tajikistan with some remarks on its environmental gradients. Altogether 143 relevés were sampled between 2014–2021 using the seven-degree cover-abundance scale of Braun-Blanquet. They were classified by the modified TWINSPAN method with the use of the four step interval scale with cutoff levels of 0%, 2%, 5% and 10% and total inertia as a measure of cluster heterogeneity. Diagnostic species were identified using the *phi* coefficient as a fidelity measure. Detrended Correspondence Analysis was used to determine the relation between samples, vegetation units and the major gradients in species composition. Plant communities have been divided into three main groups: (1) dry scrub on screes, (2) mesophilous scrubs in nemoral zone, and (3) open woods. A new class of *Pistacietea khinjuki-verae* has been proposed for open woods. Further classification of vegetation data resulted in the distinction of four plant communities within two provisional alliances: *Roseion kokanicae* and *Ranunculo tenuilobi-Cotoneasterion hissaricae* (communities of *Rosa kokanica* and *R. ecae*, associations of *Aveno ludovicianae-Rhuidetum coriariae* and *Calophacetum grandiflorae*). Additionally, we established the *Pistacion verae* alliance for the pistachio groves of Middle Asia with two subassociations: *Pistacietum verae typicum* and *Pistacietum verae cercidetosum griffithii*. The main factors determining the species composition of the studied communities are: elevation, temperature, precipitation, slope and aspect. Our research showed that the *Pistacia* groves are a distinct vegetation typical of the Irano-Turanian area and that further surveys are needed to present a final classification of scrub vegetation of Tajikistan.

Keywords: *Junipero-Pistacietea*, Middle Asia, groves, wild orchards, *Pistacion khinjuki-verae*, Irano-Turanian Region

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Introduction

The vegetation of so called wild orchards, groves and open woods is relatively poorly known in Tajikistan. This is due to their limited range, mainly to the south-western parts of the country. Besides this type of vegetation was treated as secondary vegetation to the forests and often ignored in synthetic vegetation studies (see Zapryagaeva, 1976). They form complex ecosystems of woody and herbaceous plants and are often included in forest-steppe vegetation that is considered to be shaped by 'two worlds' – closed forests and treeless steppes – very distinct in terms of structure, ecology and function (Erdős et al., 2018). Additionally, there is no unequivocal approach among the Russian and Tajik authors determining how to treat the so-called *šhiblyak,* i.e. thermophilic thickets dominated by taxa such as *Acer* spp., *Crataegus* spp., *Cercis griffithii*, *Celtis* spp., *Zizyphus jujuba*, *Pistacia vera*, *Caragana* spp., *Lonicera* spp., *Zygophyllum* spp., *Amygdalus* spp. (*Prunus* spp.), *Atraphaxis* spp. or *Punica granatum*. Sometimes they are included in mesophilous forest vegetation (e.g. Ovchinnikov, 1967) or classified as xerophytic open woods (*redkolesia*; Safarov, 2018). This latter type is located at the lower montane and colline belts with less precipitation by ca. 200–400 mm/y than the upper montane belt (with ca. 1,500–2,000 mm/y; Safarov, 2018). There is also a clear distinction within the shrubland vegetation with regard to the soil fertility and depth. Along the whole elevational gradient on habitats with cares soil cover and low fertility, the xeric scrub hold the advantage with species from *Rosa* spp., *Rhus* spp. *Rhamnus* spp., *Ephedra* spp. as the dominants (Nowak, et al., 2020). This to some extent extrazonal vegetation can occur within both thermophilous open woods, mesophilous shrubs – known as *šhiblyak* – and woods, as well as juniper stands.

Forests in Tajikistan cover less than 23% of the total country area, with a clear trend of decline due to human impact. The main type of forest vegetation in Tajikistan is juniper forest (*Juniperus polycarpos* var. *seravschanica* [= *J. seravschanica*], *J. pseudosabina* [=*J. turkestanica*] and *J. semiglobosa*). Mesophilous, deciduous woods, referred here as *chernolesa*, cover only ca. 4% of the country. Pistachio groves cover ca. 5% of the Tajik territory and are present mainly in the south-western part of the country. Less than 2% of these open woods can be considered as wild vegetation, while the rest is transformed into cultivated orchards and intensively used for grazing (Zapryagaeva, 1976; Safarov, 2003).

Open woods and mesophilous shrubs are particularly diverse and species rich, and harbour many taxa of special conservation interest such as endemics, threatened species and wild relatives of cultivated plants (Zlotin, 2002; Nowak & Nobis, 2013). Despite some obvious reasons for that, such as habitat heterogeneity, richness of the local flora, suitable environmental conditions and low human population density, it is also related to a long history of this vegetation that is regarded as a Tertiary relict and shaped by favourable conditions during the Last Glacial Maximum (Safarov, 2018; Raduła et al., 2021). Furthermore, this type of vegetation, in particular wild orchards with *Malus sieversii*, *Crataegus pontica*, *Amygdalus* spp., *Pyrus* spp., *Punica granatum*, *Pistacia vera* etc., is of significant importance for both the regional and global economy. It provides important food and forage for local population and unique genotype for breeding and improving different varieties of fruit trees (e.g. Ambarlı et al., 2016). That is why the conservation and proper management of this unique vegetation is of particular importance.

The phytosociological classification of Tajik's vegetation is still not finished. However, recently a summary of forest communities was completed (Nowak & Nobis, 2013; Nowak et al., 2015; Nowak et al., 2017a) and the pseudosteppe grasslands that are the secondary vegetation after pistachio grove clearing have been classified (Świerszcz et al., 2020) or tall-forb vegetation – secondary vegetation related among others to thermophilous shrubland (Nowak et al., 2020). Moreover, publications devoted to shrubs and open wood vegetation have been published in the 20th century by Russian botanists. Contributions to the ecological and phenological data on mesophilous shrubs have been provided by the studies of Ovchinnikov (1947, 1948, 1955; so called *Mesothamnion nemorale* – see Safarov, 2018), Sidorenko (1953), Korovin (1962), Konnov (1974), Ismailov (1974), and Stanyukovich (1982). Additionally, the open woods were studied by Kamelin (1995), Akzhigitova et al. (2003), Safarov (2018) as xeric woods (*Xerodrymion-orientale mediterraneum*). These works do not present a complete insight into the structure of the plant communities and their floristic composition. They only represent some basic formations of vegetation determined on the basis of the dominant species, without distinction of certain syntaxa. The other limitation of these studies is the national scale of the research. As such, the results did not include Eastern Mediterranean or Middle East classifications (e.g. Fayvush & Aleksanyan, 2016; Zohary, 1973).

The open woodlands with *Pistacia* spp. domination is a heterogeneous vegetation type and has its distribution centre in the Irano-Turanian and Eastern Mediterranean phytogeographical regions. It is often described as an arid open woodland, thicket, thin forest, grove, savannah or savannoid, steppe woodland, open arid forest or wild orchard (e.g. Ambarlı et al., 2020; Fayvush & Aleksanyan, 2016; Gianguzzi & Bazan, 2019; Kaya et al., 2010; Zohary, 1973). This vegetation was included in different higher syntaxa,

but generally within the *Junipero-Pistacietea atlanticae* Zohary 1973 (Zohary, 1973; invalid name, art. 2d) or *Quercetea ilicis* Br.-Bl. 1947 class (Mucina et al., 2016). For the Middle East, *Pistacia* groves were reported from the Zagros and Alborz Mts. (e.g. Abkenar et al., 2013; Bahrani et al., 2010; Neumann et al., 2007; Sheibani, 1996; Zohary, 1973) as the transitional vegetation between scrublands and steppes (Zohary, 1973). A number of *Pistacia* spp. dominated vegetation types were reported from the eastern part of the Irano-Turanian region – Tajikistan, Afghanistan, Uzbekistan and Pakistan (Anwar & Rabbani, 2001; Breckle, 2004; Khanazarov et al., 2009; Nowak et al., 2020). This steppe-woodland vegetation is distributed in colline and montane belts between 500 and 2,500 m a.s.l. It is dominated by *Pistacia vera*, *P. atlantica*, *P. khinjuk*, *P. terebinthus* subsp. *palaestina*, *Phillyrea latifolia*, *Rhus coriaria*, *Amygdalus bucharica* (*Prunus bucharica*), *A. fenzliana*, *A. lycioides*, *A. scoparia*, *Celtis glabrata*, *C. caucasica*, *Cercis griffithii*. It has an abundant, species rich herb layer with the majority of Irano-Turanian plants that occur also in pseudo-steppes and, to a lesser extent, steppes (Nowak et al., 2016, 2018; Świerszcz et al., 2020). In the Zagros Mts. this open woodland is considered as a derivative of steppe-forest which was deprived of oaks (Zohary, 1973). However, in the eastern parts of the Irano-Turanian region it is considered as a distinct vegetation with domination of *Pistacia vera* (e.g. Memariani et al., 2016; Popov, 1994).

Šhiblyak was first coined for the scrubland communities with single trees in SE Serbia (Adamovič, 1902). It was also mentioned from Herzegovina, Montenegro, Greece, Macedonia, Dalmatia, Albania and Crimea as dense thicket of *Acer tataricum*, *Buxus sempervirens*, *Corylus avellana*, *Cotinus coggygria*, *Fraxinus ornus*, *Ostrya carpinifolia*, *Paliurus spina–christi*, *Petteria ramentacea*, *Prunus chamaecerasus*, *P. divaricata*, *P. laurocerasus*, *P. mahaleb*, *Prunus spinosa*, *Pyrus amygdaliformis*, *Rhamnus rupestris*, *Ruscus aculeatus* or *Syringa vulgaris* (Adamovič, 1902; Čarni et al., 2018; Didukh & Mucina, 2014). It is mentioned mainly from the climatic zone with a yearly average temperature of approx. 10 °C, length of the growing season ca. 9–9.5 months and the precipitation of approx. 500 mm. The spectacular spring aspect with high abundance of geophytes (e.g. *Crocus*, *Galanthus*, *Erythronium*, *Scilla*, *Euphorbia*, *Anemone*) is typical of this vegetation. The subtype with *Juniperus oxycedrus*, *J. communis* and *J. macrocarpa* was distinguished on the stony substrate by Adamovič (1902). Currently, *šhiblyak* is considered to be a distinct scrub formation dominated by heliophilous (mainly deciduous) shrubs of the genera *Corylus*, *Crataegus*, *Juniperus*, *Paliurus*, *Rhamnus* etc. It is included in the *Crataego-Prunetea* Tx. 1962 – submediterranean vegetation. It is regarded as degradation phases of thermophilous deciduous forests or representant of potential vegetation determined by specific habitat (Čarni et al., 2018). It is considered to be closely related to original warm-temperate deciduous oak and oak-hornbeam forests, and rarely developing as a primary scrub in edaphically extreme habitats (Mucina et al., 2016). Probably this vegetation includes also the pear woods in Armenia (with *Pyrus caucasica*, *P. syriaca*; Fayvush & Aleksanyan, 2016). This type of shrubland occurs mainly as seral to marginal broad-leaved forest in the nemoral zone of submediterranean regions. However, its physiognomy and composition refer to the Koped-Dagh shrublands in Turkmenistan (Popov, 1994) and Pamir-Alai mesophilous shrubs (Stanyukovich, 1982), that were probably erroneously merged with *Pistacia* groves (e.g. Safarov, 2018).

The aim of this paper is to answer the following questions: (i) which open woodland and shrub vegetation types can be distinguished in Tajikistan and how should they be organised in the syntaxonomic system of Eurasia? (ii) what are the compositional, ecological and chorological characteristics of the distinguished syntaxa? (iii) how are the distinguished syntaxa related to others that are known from Asia and Europe?

Material and methods

Study area

The area of the Southtajikistanian phytogeographical region (Goncharov, 1937) is ca. 35,000 km^2 and extends from 37°17' to 38°85' E and from 36°90' to 38°70' N in Middle Asia. The alpine landscape of high mountains surrounds the region with several mountain ranges stretching in the W–E and NW–SE direction from the western Hissar Mts. to the south-eastern Hazratishoh Mts. Gora Imeni Fuchika in the Hazratishoh Mts. (4,479 m a.s.l.) and Hazrat Sulton in the Hissar Mts. (4,643 m a.s.l.) are the highest peaks within the study area (Fig. 1). However, there are the vast plains and lower ridges with more sloping relief between the highest mountain ranges. The sampling was mainly conducted in Nurek, Baljuvon, Khovaling and Dashtijum jamoats in the colline and lower montane belts of the Vaksh, Babatag, Hazratishoh, Sarsarag and Sangloh ranges.

Tajikistan is a mountainous landlocked country with an extremely diverse climate, landscape and habitat conditions located in the central part of the Middle Asia region. In its south-western part, the Khatlon region, the vegetation is determined by the subtropical climate and consists of typical Irano-Turanian species. The mountain ranges there, despite having rugged peaks, have intermediate heights rarely exceeding 4,000 m a.s.l. The Hazratishoh, Sarsarak,

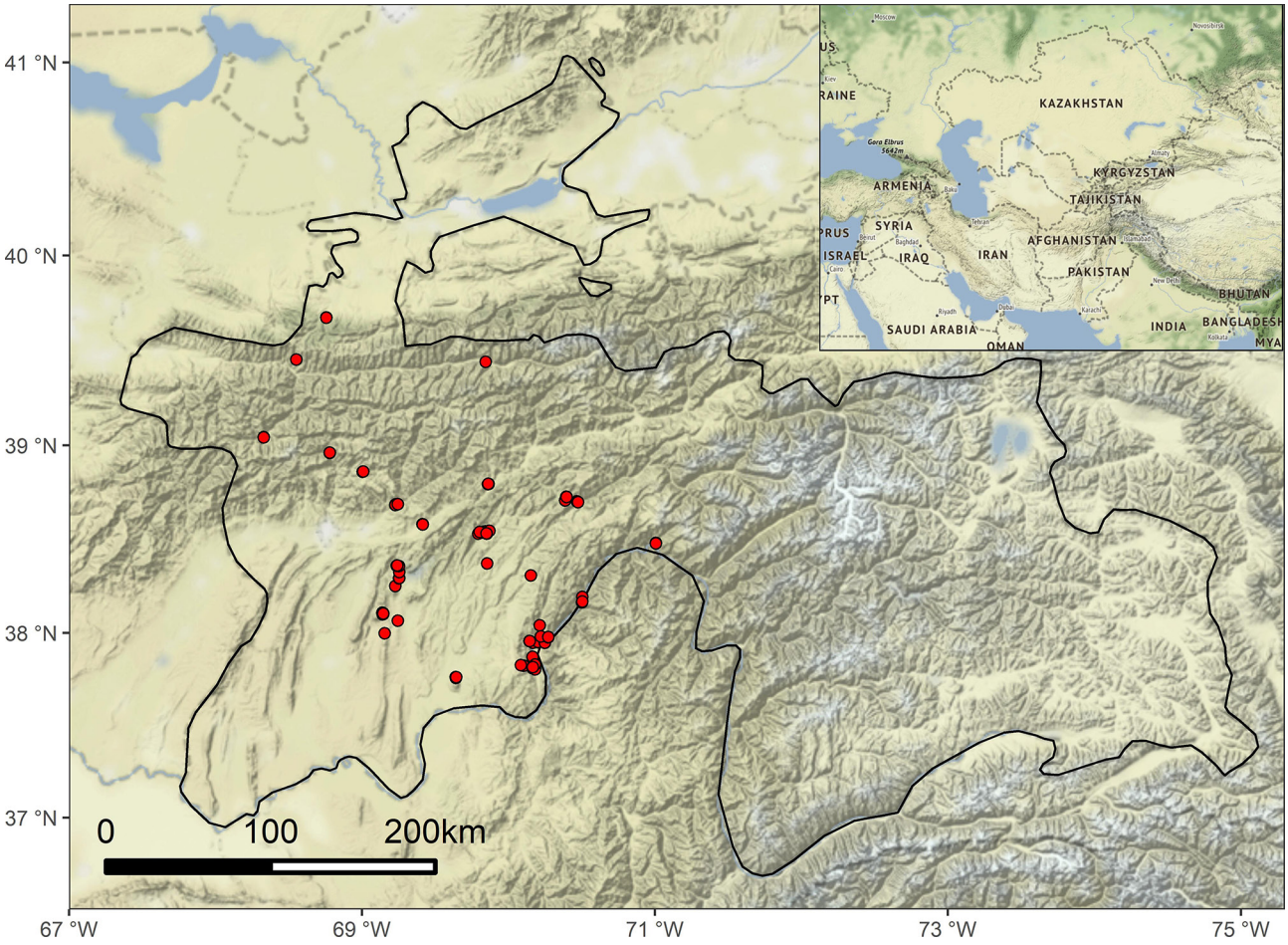

Fig. 1. Study area and distribution of the relevés (n = 143)

Aktau and Vaksh mountains in their montane and colline belts offer suitable conditions for open wood and shrub vegetation (Nowak, Nobis, et al., 2020). The Southtajikistanian phytogeographical region is one of the most unique in the country in terms of plant species richness and endemism (Nowak et al., 2011; Raduła et al., 2021).

The mountainous landscape along with both natural and human history has created today's landscape of colline and montane belts in south-western Tajikistan. The Tertiary relict of mesophilous forests have been influenced by the centuries-old use of wood as a building material and energy source. Moreover, pastoralism – particularly the grazing of sheep, cows and horses – has had a significant impact on its current shape. The area of Tajikistan was not affected by continental glaciations during the Pleistocene and the local mountainous glaciers did not descend into the valleys, where Tertiary flora could persist, however considerably impoverished (Safarov, 2003). The studied sites were located mainly on sloping hills with different aspects, inclination and altitude, with only the loess-bedrock soil as a stable factor. The vegetation plots were located between 605 and 2,472 m a.s.l. (mean 1,208 m a.s.l.).

The study area is situated on the eastern outskirts of typical Irano-Turanian macrobioclimates characterised by spring rather than winter rains and high continentality (Djamali et al., 2012). In south-west Tajikistan (mainly the Khatlon Province) occurs a subhumid climate with the average temperature in June around 28 °C in the colline and montane belts, and 13 °C in the alpine belt. The lower limit of perpetual snow occurs in the south-western Pamir-Alai at the altitude of 3,500–3,800 m a.s.l. The annual precipitation ranges here from about 600 mm in the lowlands and colline belt to ca. 1,700 mm on the southern slopes of the upper montane belt (Latipova, 1968; Narzikulov & Stanyukovich, 1968).

Data sampling and statistical analysis

The phytosociological survey was conducted from 2014 to 2021. In total, 143 relevés were collected in various types of naturally occurring open woodlands and scrub phytocoenoses differentiated in terms of the dominants and floristic composition. Plant material collected during the field studies is preserved in two herbaria: OPUN (Opole University, Poland) and KRA (Jagiellonian University, Poland).

Table 1. Synoptic table of thermophilous deciduous open woodlands and scrub vegetation in Tajikistan. The *phi* coefficient values ×100 (in superscript) in the table are only shown when positive. Main values are species frequencies (in percentages). Species with frequency higher than 30% in all the data set were included in the synoptic table. Abbreviations in layer column: t3 – lower tree layer, s1 – shrub layer, hl – herb layer

Group No.		1		2		3		4		5		6		Frequency
No. of relevés		5		11		6		31		19		71		
	Layer	***Roseion kokanicae***		***Ranunculo tenuilobi-Cotoneasterion hissarici***						***Pistacion verae***				
Comm. of *Rosa kokanica*														
Rosa kokanica	s1	100	94.6	.	–	.	–	10	–	.	–	.	–	8
Potentilla multifida subsp. *multifida*	hl	60	74.5	.	–	.	–	.	–	.	–	.	–	3
Eremurus fuscus	hl	40	54	.	–	.	–	6	–	.	–	.	–	4
Carex pachystylis	hl	40	50.3	.	–	.	–	3	–	5	–	3	–	6
Euphorbia esula subsp. *esula*	hl	60	72	.	–	.	–	3	–	.	–	.	–	4
Geranium regelii	hl	20	41.5	.	–	.	–	.	–	.	–	.	–	1
Ligularia thomsonii	hl	20	41.5	.	–	.	–	.	–	.	–	.	–	1
Trifolium pratense	hl	40	59.8	.	–	.	–	.	–	.	–	.	–	2
Elymus repens	hl	60	74.5	.	–	.	–	.	–	.	–	.	–	3
Astragalus nobilis	hl	60	73.4	.	–	.	–	.	–	.	–	1	–	4
Bunium angrenii	hl	40	59.8	.	–	.	–	.	–	.	–	.	–	2
Adonis turkestanica	hl	40	59.8	.	–	.	–	.	–	.	–	.	–	2
Iris hoogiana	hl	40	59.8	.	–	.	–	.	–	.	–	.	–	2
Astragalus lancifolius	hl	40	59.8	.	–	.	–	.	–	.	–	.	–	2
Ass. *Aveno ludovicianae-Rhuidetum coriariae*														
Rhus coriaria	s1	.	–	100	100	.	–	.	–	.	–	.	–	11
Comm. of *Rosa ecae*														
Rosa ecae	s1	.	–	.	–	83	74.9	26	8.5	.	–	1	–	14
Scutellaria intermedia	hl	.	–	.	–	50	67.4	.	–	.	–	.	–	3
Festuca valesiaca	hl	.	–	.	–	33	54.2	.	–	.	–	.	–	2
Trigonella gontscharovii	hl	.	–	.	–	50	67.4	.	–	.	–	.	–	3
Lactuca orientalis	hl	.	–	.	–	33	49	.	–	5	–	.	–	3
Ferula kokanica	hl	.	–	.	–	33	48	6	–	.	–	.	–	4
Euphorbia inderiensis	hl	.	–	.	–	50	62.2	6	–	.	–	.	–	5
Draba huetii	hl	.	–	.	–	50	67.4	.	–	.	–	.	–	3
Ceratocephalus testiculatus	hl	.	–	.	–	33	52.7	.	–	.	–	1	–	3
Ass. *Calophacetum grandiflorae*														
Calophaca grandiflora	s1	.	–	.	–	.	–	71	77.1	.	–	7	–	27
Cotoneaster hissaricus	s1	.	–	.	–	.	–	35	51.9	.	–	4	–	14
Vinca erecta	hl	.	–	.	–	.	–	29	48.8	.	–	1	–	10
Subass. *Pistacietum verae cercidetosum griffithii*														
Cercis griffithii	t3	.	–	.	–	.	–	3	–	79	84	1	–	17
Artemisia baldshuanica	hl	.	–	.	–	.	–	3	–	42	46.5	17	–	21
Subass. *Pistacietum verae typicum*														
Pistacia vera	t3	.	–	.	–	.	–	3	–	58	–	82	60.8	70
Aegilops triuncialis	hl	.	–	9	–	.	–	6	–	53	–	75	53.4	66
Hordeum bulbosum	hl	.	–	18	–	.	–	26	–	37	–	75	49.7	70
Inula grandis	hl	.	–	.	–	.	–	29	–	16	–	62	51.6	56
Bromus popovii	hl	.	–	.	–	.	–	.	–	11	–	63	69.5	47
Hordeum spontaneum	hl	.	–	.	–	.	–	.	–	.	–	28	49.6	20
All. *Pistacion verae*														
Anagallis arvensis subsp. *foemina*	hl	.	–	18	–	.	–	23	–	89	57.4	52	21.1	63
Arenaria serpyllifolia	hl	20	–	9	–	17	–	23	–	58	28.8	46	17.5	54
Cerasus verrucosa	s1	.	–	.	–	33	–	3	–	58	39.4	35	14.8	39
Medicago rigidula	hl	.	–	.	–	.	–	3	–	42	40.7	28	21.7	29
Phlomoides hissarica	hl	.	–	.	–	.	–	.	–	37	40.4	23	18.9	23
Others														
Origanum vulgare subsp. *gracile*	hl	60	34.2	18	–	17	–	55	29	5	–	3	–	26
Vulpia myuros	hl	.	–	.	–	.	–	19	–	26	–	46	38.6	44

Group No.		1		2		3		4		5		6		Frequency
No. of relevés		5		11		6		31		19		71		
	Layer	***Roseion kokanicae***		***Ranunculo tenuilobi-Cotoneasterion hissarici***						***Pistacion verae***				
Lolium temulentum	hl	.	–	.	–	.	–	.	–	21	–	45	48.6	36
Lepyrodiclis stellarioides	hl	.	–	.	–	.	–	6	–	.	–	39	53.5	30
Galium aparine	hl	.	–	9	–	17	–	10	–	16	–	59	47	50
Crepis pulchra	hl	.	–	.	–	.	–	42	–	79	–	80	44.3	85
Scandix pecten-veneris	hl	.	–	.	–	.	–	19	–	.	–	39	44.6	34
Amygdalus bucharica	s1	.	–	.	–	.	–	42	–	26	–	41	26.3	47
Brachypodium distachyon	hl	.	–	.	–	.	–	3	–	42	–	39	32.5	37
Geranium pusillum	hl	.	–	.	–	.	–	.	–	16	–	34	41.5	27
Papaver pavoninum	hl	.	–	.	–	.	–	13	–	5	–	34	40	29
Parietaria lusitanica subsp. *serbica*	hl	.	–	.	–	.	–	6	–	42	–	42	33.8	40
Avena sterilis subsp. *ludoviciana*	hl	.	–	82	45.6	.	–	.	–	58	–	62	26.8	64
Elaeosticta hirtula	hl	.	–	.	–	17	–	48	–	26	–	56	32.9	61
Bongardia chrysogonum	hl	.	–	.	–	.	–	19	–	11	–	32	32.3	31
Phleum phleoides	hl	20	–	.	–	.	–	10	–	26	–	42	31.3	39
Bromus tectorum	hl	.	–	18	–	50	–	6	–	16	–	34	14.5	34
Vicia sativa subsp. *nigra*	hl	.	–	27	–	17	–	3	–	32	–	48	29.4	45
Thlaspi perfoliatum	hl	.	–	.	–	17	–	19	–	5	–	32	27.4	31
Galium spurium	hl	20	–	18	–	67	–	35	–	26	–	51	13.5	59
Rochelia cardiosepala	hl	40	–	.	–	33	–	13	–	5	–	30	10.5	30
Hypericum scabrum	hl	40	–	.	–	17	–	29	17.6	.	–	4	–	15
Taeniatherum caput-medusae	hl	.	–	45	–	.	–	10	–	26	–	30	–	34
Fritillaria bucharica	hl	.	–	9	–	.	–	42	39.4	5	–	20	–	29
Bromus oxyodon	hl	.	–	.	–	50	–	61	28.8	26	–	51	–	63
Eremurus comosus	hl	.	–	73	34.7	50	–	52	14.9	21	–	18	–	44
Prangos pabularia	hl	20	–	9	–	17	–	32	22.1	11	–	.	–	15
Achillea filipendulina	hl	.	–	45	60	.	–	3	–	.	–	1	–	7
Carex turkestanica	hl	40	–	27	–	50	23.1	45	18.2	.	–	.	–	22
Callipeltis cucullaris	hl	.	–	55	35.2	33	–	23	–	16	–	6	–	22
Taraxacum agg.	hl	40	–	18	–	.	–	26	–	26	–	28	–	37
Artemisia rutifolia	hl	40	45.9	.	–	17	–	.	–	.	–	1	–	4
Polygonum coriarium	hl	40	59.8	.	–	.	–	.	–	.	–	.	–	2
Serratula sogdiana	hl	40	42.2	.	–	17	–	6	–	.	–	1	–	6
Bromus lanceolatus	hl	.	–	27	–	50	33.2	23	–	16	–	6	–	20
Phlomis salicifolia	hl	40	54.3	.	–	.	–	3	–	.	–	3	–	5
Dactylis glomerata	hl	60	–	.	–	17	–	42	18.6	11	–	15	–	30
Eremurus stenophyllus	hl	20	–	.	–	.	–	52	43.6	21	–	3	–	23
Salvia sclarea	hl	.	–	27	–	.	–	45	45.4	.	–	.	–	17
Poa bulbosa	hl	80	–	55	–	33	–	42	–	68	14.3	37	–	64
Koelpinia linearis	hl	.	–	9	–	.	–	16	–	32	27.4	14	–	22
Geranium divaricatum	hl	.	–	27	–	17	–	10	–	37	26.3	3	–	16
Capparis spinosa	hl	.	–	.	–	.	–	.	–	32	44.6	8	–	12
Linum corymbulosum	hl	.	–	18	–	.	–	29	–	58	39.2	25	–	40
Phleum paniculatum	hl	.	–	18	–	17	–	6	–	47	36.4	13	–	23
Torilis arvensis	hl	.	–	18	–	.	–	13	–	32	30.9	.	–	12
Diarthron vesiculosum	hl	40	–	.	–	.	–	10	–	42	31.8	4	–	16
Galium tenuissimum	hl	.	–	.	–	.	–	3	–	37	47.2	8	–	14
Hieracium robustum	hl	40	58.4	.	–	.	–	.	–	.	–	1	–	3
Sibbaldianthe bifurca subsp. *orientalis*	hl	40	59.8	.	–	.	–	.	–	.	–	.	–	2
Stipa richteriana subsp. *jagnobica*	hl	40	59.8	.	–	.	–	.	–	.	–	.	–	2
Veronica arguteserrata	hl	.	–	.	–	50	63.6	3	–	.	–	1	–	5
Scilla bucharica	hl	40	55	.	–	.	–	.	–	5	–	.	–	3
Achillea millefolium	hl	40	46.7	.	–	17	–	.	–	.	–	.	–	3
Gagea capusii	hl	40	59.8	.	–	.	–	.	–	.	–	.	–	2

Group No.		1		2		3		4		5		6		Frequency
No. of relevés		5		11		6		31		19		71		
	Layer	***Roseion kokanicae***		***Ranunculo tenuilobi-Cotoneasterion hissarici***						***Pistacion verae***				
Gagea kunawurensis	hl	40	55.8	.	–	.	–	.	–	.	–	4	–	5
Poa angustifolia	hl	40	58.4	.	–	.	–	.	–	.	–	1	–	3
Euphorbia sarawschanica	hl	40	59.8	.	–	.	–	.	–	.	–	.	–	2
Cousinia umbrosa	hl	.	–	27	16.8	50	45.9	6	–	.	–	1	–	9
Euphorbia franchetii	hl	.	–	9	–	.	–	45	–	26	–	42	–	50
Acer regelii	s1	.	–	.	–	.	–	32	34.4	.	–	25	–	28
Poterium sanguisorba subsp. *lasiocarpa*	hl	40	–	36	–	.	–	29	–	26	–	13	–	29
Medicago lupulina	hl	40	–	18	–	.	–	6	–	11	–	8	–	14
Plantago lanceolata	hl	80	–	36	–	.	–	52	–	42	–	31	–	54

The vegetation plot size was delimited to 100 m² in such a way as to enable providing homogeneity in terms of structure, species composition and habitat conditions of the phytocoenosis following the Braun-Blanquet approach (Dengler et al., 2008). For each vegetation plot, all species of vascular plants and terricolous bryophytes were recorded with the use of 7-degree cover-abundance scale (r, +, 1, 2, 3, 4, 5; Dengler et al., 2008). Species were recorded in four layers of the wood or scrub stands: t3 – lower tree layer, s1 – shrubs, hl – herbs, ml – bryophytes. The analysed vegetation is characterised by the absence of high and medium tree layer. Geographical coordinates, elevation, aspect and slope inclination were recorded for each relevé. Aspect was identified as the compass direction towards N, S, E, W, NE, NW, SE and SW, determined by Suunto MC-2 device. Inclination was measured visually. The geographical coordinates and elevation of the plots were obtained using a GPS device with an accuracy of ± 10 m and the WGS-84 grid reference system.

The relevés were stored using TURBOVEG database software version 2.102 (Hennekens & Schaminée, 2001) in the Vegetation of Middle Asia Database (GIVD ID AS-00-003; Nowak et al., 2017b). They were analysed in the JUICE software version 7.1.18 (Tichý, 2002). A modified TWINSPAN analysis (Roleček et al., 2009) was performed in order to classify the relevés by using cut levels of 0%, 2%, 10% and 25%. Total inertia was used as a measure of cluster heterogeneity (Roleček et al., 2009). Plant species determined only to the genus level were omitted prior to the analysis. Diagnostic species were identified using the *phi* coefficient as a fidelity measure (Chytrý et al., 2002). The size of all groups was standardised to equal size, and the Fisher's exact test ($p < 0.05$) was applied in order to exclude species with non-significant occurrence optimum in a particular cluster. Species with a *phi* coefficient higher than 0.40 were considered diagnostic for a specific cluster, except species which are diagnostic for different vegetation types on the basis of expert knowledge. We define alliance *Pistacion verae* by those species that have a *phi* coefficient ≥ 0.10 in at least two clusters within the alliance, and for provisional alliance by expert knowledge. Species with a frequency higher than 30% in a particular cluster were defined as constant species.

To show the compositional differences between distinguished thermophilous open woodlands and scrub units, Detrended Correspondence Analyses (DCA) was computed using the 'vegan' package version 2.5.4 (Oksanen et al., 2019) in R version 4.0.5 (R Core Team, 2020). Species cover data were log-transformed (log (x+1)) without down-weighting of rare taxa. For ecological interpretation of the ordination axes, environmental and vegetation parameters were passively plotted onto a DCA ordination diagram. Additionally, differences in environmental factors (altitude, temperature, precipitation, inclination) and vegetation variables (cover tree, shrub, herb and moss layer and species richness) between syntaxonomic units were assessed using the Kruskal–Wallis rank sum test (function *kruskal*.test), with multiple comparison based on Dunn's test using the *dunnTest* function in the 'FSA' package (Ogle et al., 2018) in R. Climatic data were extracted from the Chelsa database version 1.2 (http://chelsa-climate.org; Karger et al., 2017).

A synoptic table with the fidelity and relative percentage frequency of all diagnostic species and other plants of frequency ≥ 30% are shown in Table 1. Newly presented syntaxa are proposed according to the International Code of Phytosociological Nomenclature (Theurillat et al., 2021). The association concept follows Willner (2006) and alliance follows Willner (2020). The nomenclature of the vascular plants follows generally Cherepanov (1995) and The Plant List (2020) Version 1.1. (http://www.theplantlist.org/), and bryophytes follows Ignatov et al. (2006).

Analytic table including type relevés (Table S1) and full synoptic table (Table S2) are available in Figshare Digital Repository (https://doi.org/10.6084/m9.figshare.17158475; Nowak et al., 2021).

Results

General floristic and physiognomic features

The number of vascular plant species recorded in the whole data set of open woodlands and scrubs in Tajikistan amounts to 565. The most frequent species recorded in these phytocoenoses include plants typical of open woodlands, pseudosteppes or steppes. Among the typical open woodland taxa, the most frequent were *Pistacia vera* (49%), *Inula grandis* (39%), *Bromus popovii* (32.9%), *Poterium sanguisorba* subsp. *lasiocarpa* (20,3%), *Acer regelii* (19,6%), *Calophaca grandiflora* (18.9%), *Cercis griffithii* (16.8%), *Cousinia grigoriewii* (16.1%), *Bunium chaerophylloides* (14%), *Impatiens parviflora* (14%), *Polygonatum sewertzowii* (14%) and *Lonicera nummulariifolia* (12.6%). Important contributors to Tajik wild orchards and scrubs are also pseudosteppe species: *Hordeum bulbosum* (48.9%), *Avena sterilis* subsp. *ludoviciana* (44.7%), *Aegilops triuncialis* (43.3%), *Euphorbia franchetii* (35%), *Linum corymbulosum* (28%), *Brachypodium dystachyon* (25.9%), *Medicago rigidula* (20.3%) and *Asparagus bucharicus* (15.4%). Morover, plants from dry steppes (*Poa bulbosa* – 44.7%, *Gentiana olivieri* – 21.7%, *Achillea arabica* – 16%), tall-forbs (*Mentha asiatica* – 19%, *Eremurus comosus* – 30.7%, *Fritillaria bucharica* 20.3%) and ruderal vegetation (*Anagalis arvensis* subsp. *foemina* – 44%, *Galium aparine* – 35%, *Scandix pecten-veneris* – 23.8%) were found. In total, 166 species reached a constancy above 5% and 33 taxa above 20%. Among small trees, the most common was *Pistacia vera* (48.9%) and other species were much less frequent (*Celtis occidentalis*

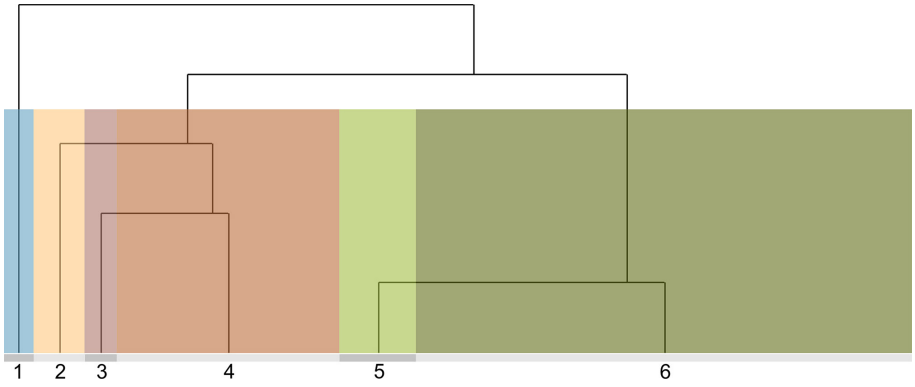

Fig. 2. Dendrogram illustrating the assigment of relevé groups identified by TWINSPAN to particular syntaxonomic units: 1 – community of *Rosa kokanica*, 2 – Ass. *Aveno ludovicianae-Rhuidetum coriariae*, 3 – community of *Rosa ecae*, 4 – Ass. *Calophacetum grandiflorae*, 5 – Subass. *Pistacietum verae cercidetosum griffithii*, 6 – Subass. *Pistacietum verae typicum*

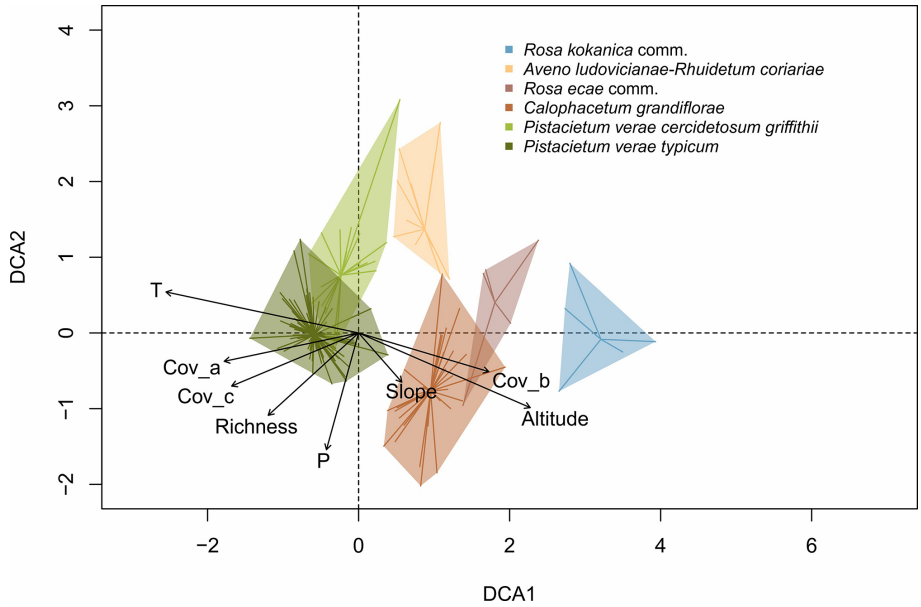

Fig. 3. Detrended correspondence analysis diagram of thermophilous deciduous open woodlands and scrub vegetation in Tajikistan. Environmental and vegetation parameters were passively plotted onto a DCA ordination diagram. The eigenvalues and lengths of gradients were 0.50, 5.37 (Axis 1) and 0.39, 5.10 (Axis 2), respectively. Abbreviations: Cov_a – cover tree layer (%), Cov_b – cover shrub layer (%), Cov_c – cover herb layer (%), P – sum of annual precipitation, Richness – species richness, Slope – inclination of the slope (%), T – annual mean temperature

– 7%, *Acer platanoides* subsp. *turkestanicum* – 0.7%). The most constant shrubs were *Amygdalus bucharica* (32.9%), *Cerasus verrucosa* (27.3%), *Acer regelii* (19.8%), *Calophaca grandiflora* (18.9%), *Cercis griffithii* (16.8%) and *Lonicera nummulariifolia* (12.6%). Several rose species such as *Rosa ecae* (9.7%), *R. ovczinnikovii* (8.4%) and *R. kokanica* (5.6%) contribute significantly to this vegetation as well. The other recorded scrub species include: *Aflatunia ulmifolia* (4.2%), *Exochorda racemosa* (3.5%), *Berberis iliensis* (2.8%), *Punica granatum*, *Atraphaxis pyrifolia*, *Pyrus* × *bucharica* (all 2.8%) and *Prunus mahaleb* (2.1%). Among the herbaceous species, the most frequent among others were *Crepis pulchra* (59.4%), *Hordeum bulbosum* (49%), *Aegilops triuncialis* (46.2%), *Avena sterilis* subsp. *ludoviciana* (44.8%), *Poa bulbosa* (44.8%) and *Anagallis arvensis* subsp. *foemina* (44.1%). Mosses were recorded only occasionally; we found only *Brachythecium albicans*, *Bryum caespiticum*, *B. capillare*, *Syntrichia ruraliformis* and *Pohlia wahlenbergii* with low abundancies (moss layer cover ranges from 0 to 20%).

Numerical classification and DCA ordination

The TWINSPAN classification revealed three main interpretable groups divided into six clusters (Fig. 2). The diagnostic species of the clusters are listed in the synoptic table (Table 1). The clear outlier is cluster one, the community of *Rosa kokanica*, found in the subalpine belt in the Takob Valley. We propose to include this and probably the next three groups (2–4) in one alliance *Roseion kokanicae* despite

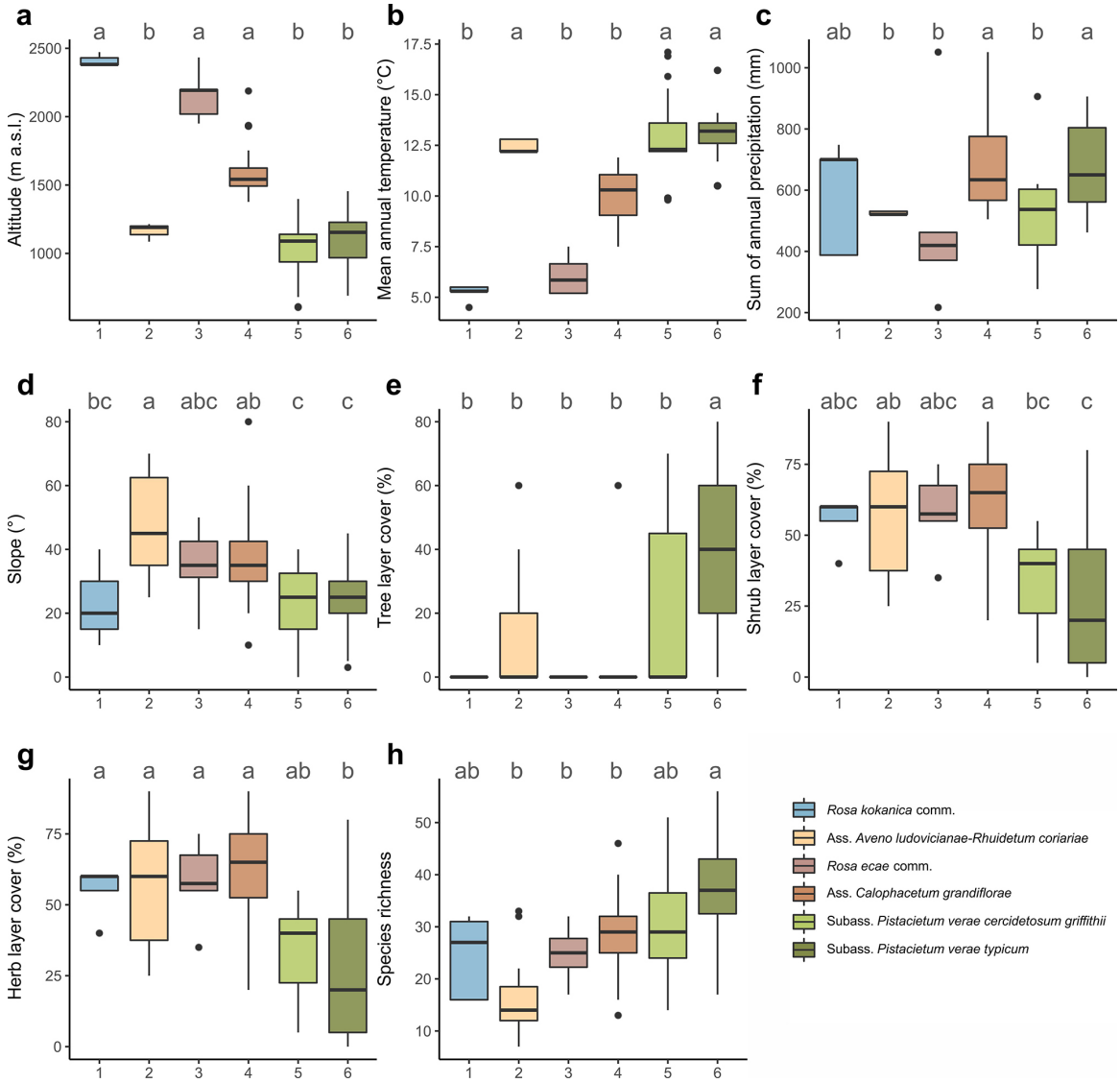

Fig. 4. Boxplots showing median (line), quartiles, outliers and the range of (a) altitude, (b) mean annual temperature, (c) sum of annual precipitation, (d) inclination of the slope, (e) tree layer cover, (f) shrub layer cover, (g) herb layer cover, and (g) species richness for particular syntaxonomic units. Differences between units in all parameters are statisticly significant (K-W test $p < 0.001$). Different letters indicate significant differences among the syntaxonomic units

some considerable differences. Nevertheless, we do not exclude that the fourth cluster, representing the association of *Calophacetum grandiflora*, will be shifted to the *Pistacion verae* alliance (groups 5 and 6), or upgraded to a distinct alliance as being considerably different from the other types of open wood and shrub vegetation. The plots of this vegetation, which were found on relatively low elevations in the lower montane belt, are species rich and have sparse shrub layer cover. The last two clusters (5 and 6) in our opinion represent two subassociation of typical open woodlands with structural domination of *Pistacia vera*. The first one is characterised by the co-domination of *Cercis griffithii* in the shrub or lower tree layer and occurs in the warm, lower montane and colline belts on more stony substrates in southern Tajikistan. The typical subassociation of *Pistacietum verae* prefers higher locations mainly in the montane belt. It grows on more fertile and deeper soils, is more species rich and is frequently dominated by *Pistacia vera*.

Vegetation groups defined in the TWINSPAN classification are clearly shown in the two first axes of DCA analysis (Fig. 3). The first axis of the DCA reflects a strong elevation–temperature gradient, which differentiates clusters 1–4 and 5–6. The second axis is linked to precipitation differentiating between clusters 5 and 6. Plots classified to the class *Pistacietea khinjuki-verae* are found on lower elevations with higher mean annual temperatures compared to plots classified to the class *Crataego-Prunetea* (Fig. 4). The sum of annual precipitation seems to be an important factor distinguishing two subassociations of *Pistacietum verae*, with stands of *Cercis griffithii* related to drier sites (Fig. 4).

Synopsis of syntaxa

Based on the analyses, we propose the following classification for the thermophilous open woodlands and scrubs in Tajikistan:

Xeric scrubs of Irano-Turanian region (scrub and mantle vegetation seral or marginal to broad-leaved forests in the nemoral zone of the Irano-Turanian region – *šhiblyak*)
Class: *Crataego-Prunetea* Tx. 1962
Order: *Crataegetalia ponticae* nom. prov.
Alliance: *Roseion kokanicae* nom. prov.
Community of *Rosa kokanica* (group 1)
Alliance: *Ranunculo tenuilobi-Cotoneasterion hissarici* nom. prov.
Association: *Aveno ludovicianae-Rhuidetum coriariae* A. Nowak et al. 2022 (group 2)
Community of *Rosa ecae* (group 3)
Association: *Calophacetum grandiflorae* A. Nowak et al. 2022 (group 4)
Irano-Turanian open woodlands in warm, subtropical, semi-arid to semi-humid climate
Class: *Pistacietea khinjuki-verae* nom. prov.
Order: *Pistacietalia verae* nom. prov.
Alliance: *Pistacion verae* A. Nowak et al. 2022
Association: *Pistacietum verae* A. Nowak et al. 2022
Subassociation: *Pistacietum verae typicum* A. Nowak et al. 2022 (group 5)
Subassociation: *Pistacietum verae cercidetosum griffithii* A. Nowak et al. 2022 (group 6)

Description of syntaxa of the thermophilous open woodland and scrub vegetation in Tajikistan

Xeric scrubs of Irano-Turanian region (scrub and mantle vegetation seral or marginal to broad-leaved forests in the nemoral zone of the Irano-Turanian region – *šhiblyak*)

I. Dry scrubs on screes
Alliance: ***Roseion kokanicae*** nom. prov.
General remarks: The *Roseion kokanicae* is established provisionally to cover the shrubby vegetation of semi-arid habitats in the upper montane and subalpine belts in Middle Asia. We place it in the provisional order of *Crataegetalia ponticae* (*Crataego-Prunetea*), which encompasses the mantle vegetation seral or marginal to broad-leaved forests in the nemoral zone of the Irano-Turanian region. The final design of this vegetation needs additional sampling in the Khatlon and Central Tajikistanian regions in secondary shrublands, mainly in the Hissar, Darvaz, Hazratishoh and Zeravshan Mts.
Diagnostic species: *Rosa kokanica.*
Constant species: *Carex turkestanica, Galium spurium, Eremurus comosus, E. stenophyllus, Poa bulbosa, Rosa kokanica, R. ecae, R. ovczinnikovii.*
Geographical range: Montane and subalpine belts of Middle Asian mountains (Uzbekistan, Turkmenistan, Kyrgyzstan and Tajikistan).
Habitat characteristics: This vegetation type develops mainly on shallow to moderately deep soils. Sometimes it occurs on scree slopes with different inclinations. Plant communities that are included in this alliance are supposed to grow at elevations of approximately 1,000−2,500 m a.s.l., and consist mainly of species of the Irano-Turanian distributional range. They are mostly a natural vegetation of mountain slopes, but include also the secondary scrublands that developed after clear cuttings of woody vegetation at lower altitudes in the valley of the warmer and more humid areas.

Community of *Rosa kokanica* (group 1)
Diagnostic species: *Adonis turkestanica, Astragalus lancifolius, A. nobilis, Bunium angrenii, Carex pachystylis, Elymus repens, Eremurus fuscus, Euphorbia esula* subsp. *esula, Geranium regelii, Iris hoogiana, Ligularia thomsonii, Origanum vulgare* subsp. *gracile, Potentilla multifida* subsp. *multifida, Rosa kokanica, Trifolium pratense.*
Constant species: *Poa bulbosa, Origanum vulgare* subsp. *gracile, Rosa kokanica.*
Geographical range: Patches representing this community were found in the Fann Mts. in the central Zeravshan Range and in the upper reaches of the Takob Valley in the Hissar Mts. (Fig. 5). The natural distribution of *Rosa kokanica* includes wide territories

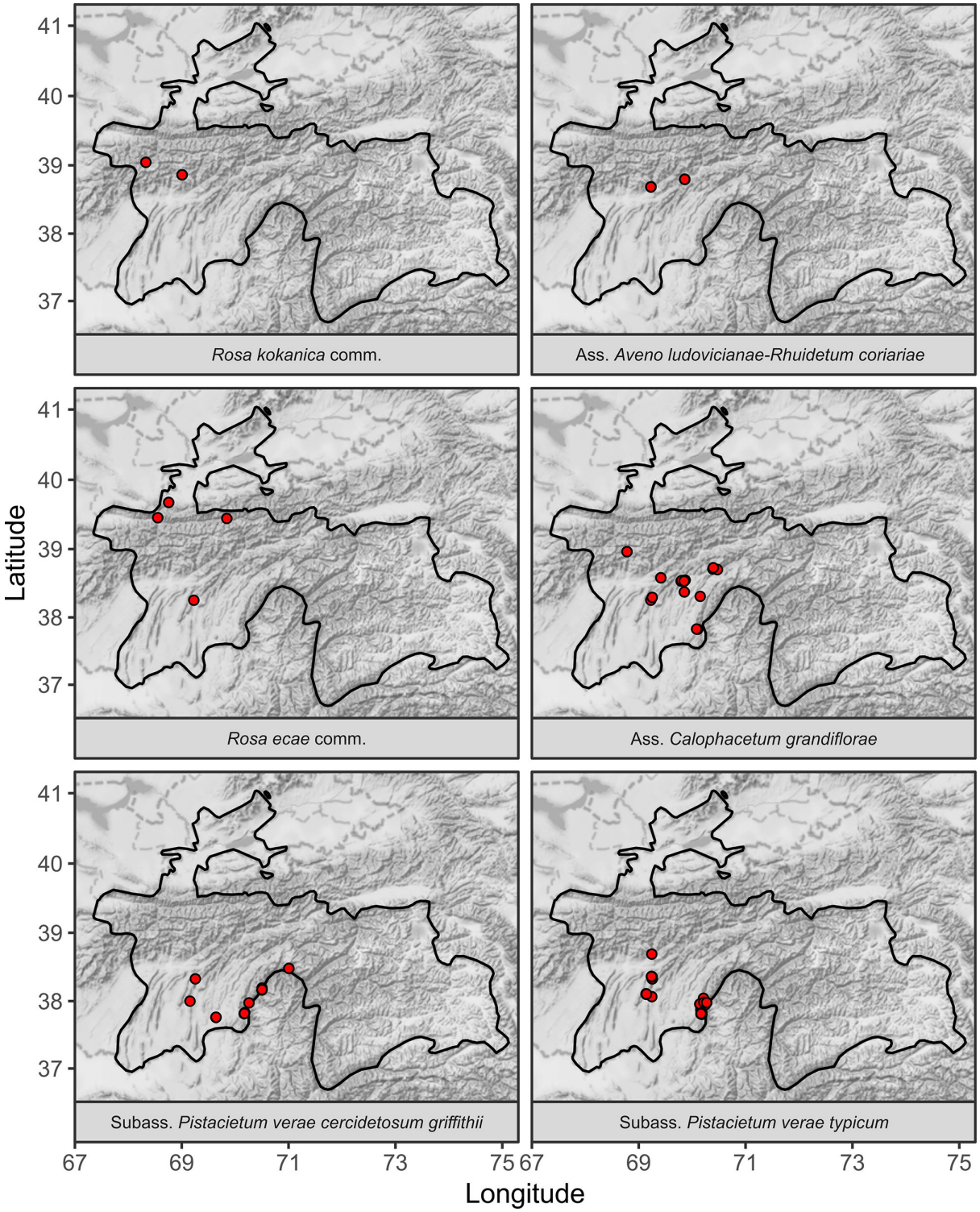

Fig. 5. Distribution of relevés assigned the particular vegetation units (n = 143). Note that due to the scale, some points may overlap. The exact locations of the relevés can be found in Table S1

of the Irano-Turanian province from Iran in the west, through Middle Asia to Xinjiang in the east (eFloras, 2021).

Floristic composition: The shrub layer of the community is dominated by *Rosa kokanica* (40 to 60% cover; Fig. 4f). The herbaceous layer is quite scarce, reaching 30–60% (mean 41%; Fig. 4g) and is composed of 16 to 32 taxa (mean 24; Fig. 4h) with only *Origanum vulgare* subsp. *gracile*, *Eremurus stenophyllus*, *E. fuscus*, *Poa bulbosa*, *Scrophularia heucheriiflora*, *Geranium regelii*, *Ligularia thompsonii* and *Carex pachystylis* having considerable abundance (Fig. 7a). Mosses are not abundant with *Barbula unguiculata*, *Brachythecium albicans* and *Bryum capillare* the most frequent.

Habitat characteristics: The community inhabits relatively dry, stony slopes in the subalpine elevations (2,380–2,470 m a.s.l.; Fig. 4a). Patches representing this community were sampled within large pasturelands on south-east and west-facing slopes (Fig. 6) with an inclination of 10° to 40° (Fig. 4d).

Remarks: Patches of the *Rosa kokanica* community have not been defined as an association because the phytosociological sampling was poor. In terms of habitat conditions, the community is related to continental and subalpine scrubs that are described as *rosaria* in the Russian literature (e.g. Golovkova, 1959), and are built mainly by roses and species from the *Cotoneaster*, *Spiraea* and *Rhamnus* genera.

II. Mesophilous scrubs in nemoral zone

***Aveno ludovicianae-Rhuidetum coriariae* ass. nov. hoc loco (group 2)**

Type relevé: Table S1, sequence number 10, holotypus hoc loco

Diagnostic species: *Rhus coriaria.*

Constant species: *Rhus coriaria.*

Geographical range: *Rhus coriaria* is distributed in Tajikistan along the driest areas in the Zeravshan, Hissar, Aktau, Babatag and Hazratishoh Mts. Its whole range is particularly wide and includes almost the entire Mediterranean, Middle East and western Irano-Turanian regions (Ovchinnikov, 1981). Patches representing this community were found in the Vakhs and northern Hazratishoh Mts. (Fig. 5).

Floristic composition: The *Aveno ludovicianae-Rhuidetum coriariae* creates dense thickets with a shrub layer cover up to 90% (mean ca. 60%; Fig. 4f). The sampled plots are clearly dominated by *Rhus coriaria*, which only occasionally is accompanied by *Acer regelii*, *Atraphaxis pyrifolia*, *Lonicera nummulariifolia*, *Crataegus turkestanica* or *Elaeagnus angustifolia* (Fig. 7b). The floristic composition is quite heterogenous. Plots of the association are composed of 7 to 33 (mean 17; Fig. 4h) species and herb layer cover varies from 15 to 65% (mean 40%; Fig. 4g). The moss layer is not abundant and dominated mainly by *Brachythecium albicans* and *Bryum capillare*.

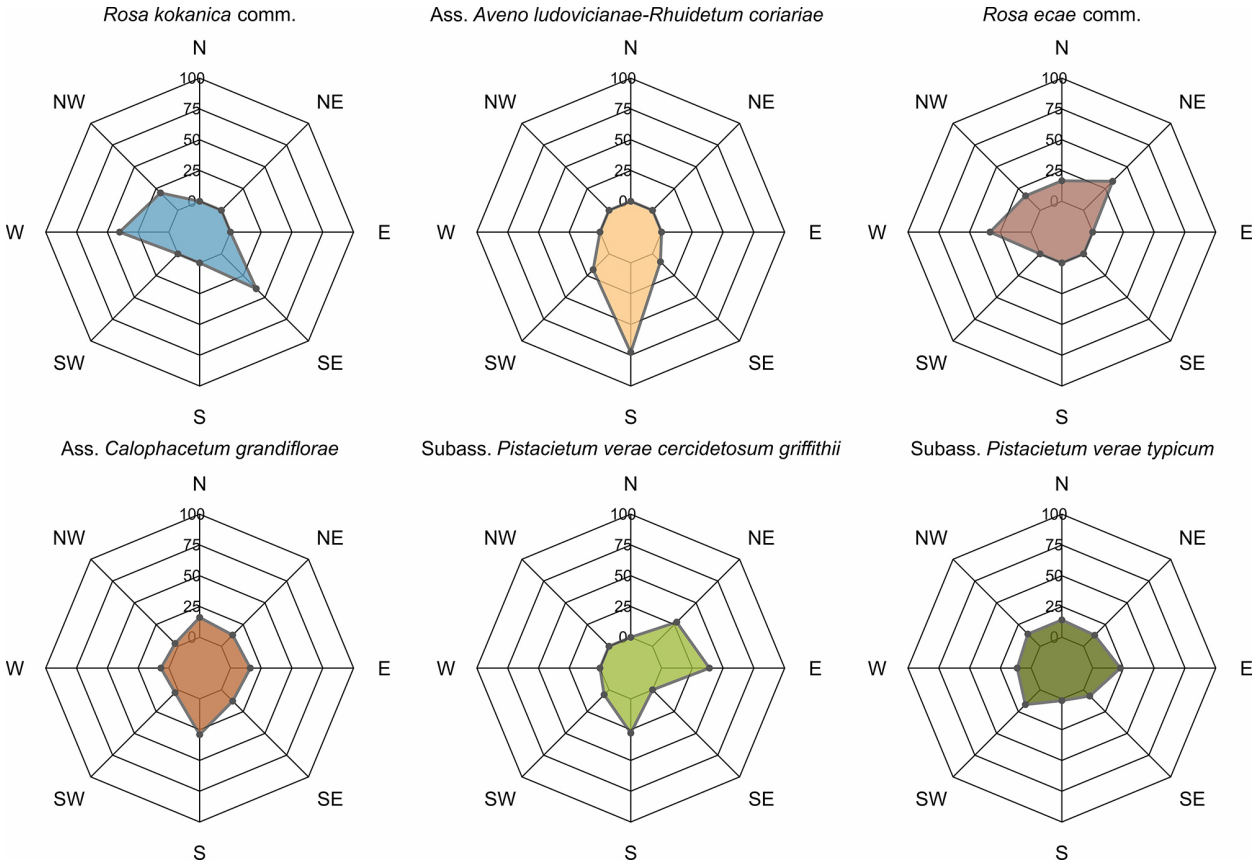

Fig. 6. The exposition preferences of the identified plant communities

Habitat characteristics: The vegetation with domination of *Rhus coriaria* occurs in the warm and dry regions of Tajikistan. The association occurs mainly in southern part of study area (Fig. 5). It inhabits the lower montane up to subalpine belts (1,050 to 1,215 m a.s.l. mean 1,190; Fig. 4a). It prefers slopes and sometimes steep eroding rock walls with preference to southern expositions (Fig. 6) and inclination up to 70° (Fig. 4d).

Remarks: The shrubby association of *Rhus coriaria* is not a dominant type of vegetation in the landscape of south-western Tajikistan. It was recorded only on small land patches that are hard to access for sheep and goats and thus are not intensively grazed. Only exceptionally do they occur in more accessible places for livestock, but then they are protected by the local people from livestock grazing. Because this association occurs in fairly arid areas deforested for pastures, which have most often turned into pseudosteppe, we assigned *Avena sterilis* subsp. *ludoviciana* as the best species to distinguish it from other associations that occur in the Mediterranean region.

Fig. 7. Photographs of the thermophilous deciduous open woodlands and scrub in Tajikistan belonging to the: a) *Rosa kokanica* community near the Rangun, b) *Aveno ludovicianae-Rhuidetum coriariae* near Rangun in Hissar Range, c) *Calophacetum grandiflorae* near Tavildara in Darvaz Range, d) pistachio groves on the slopes near Nurek, e) *Pistacietum verae typicum* with *Inula grandis* in a herb layer in Sarsarak Mts., f) *Pistacietum verae cercidetosum griffithii* in spring aspect with flowering *Cercis griffithii* near Nurek (pictures a, b, c and f were taken by A. Nowak and d and e by S. Świerszcz)

Community of *Rosa ecae* (group 3)
Diagnostic species: *Ceratocephalus testiculatus, Draba huetii, Euphorbia inderiensis, Ferula kokanica, Festuca valesiaca, Lactuca orientalis, Rosa ecae, Scutellaria intermedia, Trigonella gontscharovii.*
Constant species: *Rosa ecae.*
Geographical range: In Middle Asia the distribution of *Rosa ecae* is restricted to the Pamir-Alai and Talas Alatau Mts. in northern Tian Shan and northern Afghanistan (Ovchinnikov, 1975). We found only a few patches of this community in the northern foothills of the Turkestan Mts. (near Buragen), in the Zeravshon River Valley near Pardarok and in the Sanglokh Mts. near Nurek (Fig. 5).
Floristic composition: As other plant communities dominated by roses, this phytocoenosis has a thicket form with dominant *Rosa ecae*. Only in one sampled plot *R. ovczinnikovi* was the main shrub. Species richness differs considerably among the plots, ranging from 17 to 32 plant species (mean ca. 25; Fig. 4h). The shrub layer cover ranges between 35 and 75% (mean ca. 60%; Fig. 4f) and the herbs have intermediate abundance from 25 to 65% (mean 44.2%; Fig. 4g). Mosses occur sporadically, the most frequent are *Brachythecium albicans* and *Bryum capillare*.
Habitat characteristics: The community of *Rosa ecae* was found in upper mountain and subalpine belts in the pastoral landscapes of the western Pamir-Alai ranges (1,950–2,450 m a.s.l., mean 2,150 m a.s.l.; Fig. 4a). The stands grow on gentle north-facing slopes (mean ca. 35°; Figs 4d and 6), with compacted soil and a considerable amount of organic matter.
Remarks: The community of *Rosa ecae* is another example of a typical rose thicket vegetation in Tajikistan. It probably develops as a result of secondary scrub after clearance of juniper stands and intensive grazing. Our data is too scarce to assign this type of vegetation to a particular rank (only 6 relevés). It requires further research, which should focus on dry scrublands.

***Calophacetum grandiflorae* ass. nov. hoc loco (group 4)**
Type relevé: Table S1, sequence number 52, holotypus hoc loco
Diagnostic species: *Calophaca grandiflora, Cotoneaster hissaricus, Vinca erecta.*
Constant species: *Calophaca grandiflora.*
Geographical range: The main diagnostic taxon, *Calophaca grandiflora*, is an endemic to central Tajikistan. It occupies the montane belt of the Darvaz, Hazratishoh and western Hissar Mts. The species forms a distinct shrubland mainly on the southern and eastern slopes of these ranges, sometimes on the vast areas mainly between 1,100 and 1,800 m a.s.l. (Ovchinnikov, 1978). The *Calophacetum grandiflorae* was found mainly in the Yakhsu River Valley and in the vicinity of Tavildara (Fig. 5).
Floristic composition: Phytocoenoses representing *Calophacetum grandiflorae* form a moderately dense thicket made up of shrubs with a clear domination of the main diagnostic species. The cover of *Calophaca grandiflora* in particular patches ranges from 20 to 90% (mean approx. 63%; Fig. 4f). The species may be accompanied or replaced by other shrub species such as *Cercis griffithii, Cotoneaster hissaricus, C. oliganthus, Aflatunia ulmifolia, Acer platanoides* subsp. *turkestanicum, Acer regelii, Amygdalus bucharica, Cerasus verrucosa, Rosa ovczinnikovii, R. ecae, R. kokanica, Exochorda racemosa, Fraxinus raibocarpa, Lonicera nummulariifolia* or *Colutea paulsenii* (Fig. 7c). The herb layer has a cover of 30 – 90% (mean 57%; Fig. 4g) and consists of 13 – 46 species (mean ca. 29; Fig. 4h). The most frequent mosses are *Brachythecium albicans, Bryum capillare* and *Pohlia nutans*.
Habitat characteristics: The shrubland of *Calophaca grandiflora* is associated with the montane belt of humid ranges in central Tajikistan (1,400–2,200, mean 1,600 m a.s.l.; Fig. 4a). It occurs on relatively shallow soils with poorly developed profile. The association prefers moderately sloping sites (mean inclination approx. 35°). On the other hand, it was also noted on almost flat lands or even vertical walls with small shelves with 80° steepness (Fig. 4d).
Remarks: This type of vegetation is of a transitional nature between the typical dense rose-dominant subalpine bush and the more thermophilous pistachio groves. It is possible that *Calophacetum grandiflorae* could be moved during the revision of Tajikistan's shrub vegetation to pistachio open woods or upgraded to a distinct alliance.

Irano-Turanian open woodlands in warm, subtropical, semi-arid to semi-humid climate

III. Open woods
***Pistacion verae* A. Nowak, M. Nobis & S. Nowak all. nov. hoc loco**
Nomenclatural type: *Pistacietum verae* A. Nowak et al. 2022 [holotypus hoc loco].
General remarks: The alliance belongs to the group of the thermophilous open woodlands of Middle Asia. They are formed by *Pistacia vera* and shrubs of semi-arid to subhumid, warm habitats in Irano-Turanian region such as *Ficus carica, F. afghanica, Punica granatum*, and *Cercis griffithii*.
Diagnostic species: *Anagallis arvensis* subsp. *foemina, Arenaria serpyllifolia, Cerasus verrucosa, Medicago rigidula, Phlomoides hissarica.*
Constant species: *Brachypodium distachyon, Scandix pecten-veneris, Vulpia myuros, Galium aparine, Crepis*

pulchra, Lolium temulentum, Geranium pusillum, Ferula tadshikorum.

Geographical range: Middle Asia (Afghanistan, Uzbekistan, Turkmenistan, Kyrgyzstan and Tajikistan).

Habitat characteristics: It is a typical open wood vegetation that forms a zonal belt in a colline and lower montane elevations of Middle Asian mountain ranges. It develops mainly on fertile to moderately fertile habitats in a semi-arid to subhumid climatic zones. As in the case of other woody vegetation in the region, the abundance and frequency of grassland and tall-forb species present in its undergrowth is strongly influenced by grazing (Fig. 7d).

***Pistacietum verae* ass. nov. hoc loco**

Type relevé: Table S1, sequence number 71, holotypus hoc loco

Diagnostic species: *Aegilops triuncialis, Artemisia baldshuanica, Bromus popovii, Cercis griffithii, Hordeum bulbosum, Hordeum spontaneum, Inula grandis, Pistacia vera.*

Constant species: *Aegilops triuncialis, Cercis griffithii, Pistacia vera.*

Geographical range: The diagnostic species are distributed across the colline and lower montane belts of Middle Asian mountains, mainly Kopet-Dagh, Pamir-Alai, western Tian Shan and northern Hindu-Kush. Phytocoenoses are distributed between 400 and 2,000 m a.s.l., but at ca. 900 to 1,800 m a.s.l. they form zonal open woodlands. In Tajikistan, *Pistacia vera* was reported from the foothills of the Mogol-Tau, Zeravshan, Hissar, Sarsarak, Sangloh, Aktau, Babatag, Darvaz and Hazratishoh Mts. (Ovchinnikov, 1981). Patches of this association were found mainly in the Dashtijum, Sarsarak and Nurek provinces (Fig. 5).

Floristic composition: The structure of phytocoenoses of the *Pistacietum verae typicum* stands is marked by the dominance of pistachios that form the lower tree layer (Fig. 7e). The latter reaches cover values up to 80% (mean 40%; Fig. 4e) and is accompanied by a number of shrubs from which the most frequent are *Amygdalus bucharica, Fraxinus raibocarpa* and *Cerasus verrucosa*. The shrub layer cover can reach up to 80% with the mean value of ca. 27% (Fig. 4f). Between the trees there is a lush vegetation of pseudosteppe and sometimes tall-forb plants with the most frequent *Hordeum bulbosum, Vulpia myuros, Lolium temulentum, Trigonella verae, Korovinia tenuisecta, Filago pyramidata, Cryptospora falaca* or *Brachypodium distachyon*. This causes an extraordinary species richness of this vegetation that reaches up to 56 taxa (mean 37; Fig. 4h). The herb layer has moderate to high abundance and its mean cover is ca. 75% (4–90%; Fig. 4g). The most frequent moss species that occur in this community are *Syntrichia ruraliformis* and *Bryum caespiticum*.

Habitat characteristics: The *Pistacietum verae typicum* is a typical colline and lower montane open wood vegetation occurring in arid to subhumid climates with hot summers and mild winters. The vegetation patches develop on fertile, loessic soils, on gentle or moderately steep slopes with mean inclination of 25° (between 3 and 40 grades; Fig. 4d), with no preference for exposition (Fig. 6). It reveals seasonal changes with intensive blooming in early spring and withering of plants during hot summer. The open groves of *Pistacia vera* are used as pastures for sheep, cows and goats and are often converted to pistachio orchards.

Remarks: Pistachio groves in Tajikistan form a distinct type of vegetation that clearly stands out in the landscape. No occurrence of junipers was recorded in the plots of the community, although the presence of individual junipers in the community was observed in the vicinity of Kulob and on Mount Hodzhamumin.

***Pistacietum verae typicum* subass. nov. hoc loco (group 5)**

Type relevé: Table S1, sequence number 71, holotypus hoc loco

Diagnostic species: *Aegilops triuncialis, Bromus popovii, Hordeum bulbosum, Hordeum spontaneum, Inula grandis, Pistacia vera.*

Constant species: *Aegilops triuncialis, Pistacia vera.*

Geographical range: This subassociation is distributed within the range of the *Pistacietum verae*.

Floristic composition: *Pistacietum verae typicum* stands have a typical umbrella-like pistachios dominance and the open woodland structure. It shares the compositional and physiognomical features of the main association.

Habitat characteristics: The habitat of this subassociation fully coincides with the habitat of the basic association both in terms of humidity and temperature conditions.

***Pistacietum verae cercidetosum griffithii* subass. nov. hoc loco (group 6)**

Type relevé: Table S1, sequence number 75, holotypus hoc loco

Diagnostic species: *Artemisia baldshuanica, Cercis griffithii.*

Constant species: *Cercis griffithii, Pistacia vera.*

Geographical range: Patches representing of this subassociation were found mainly on the southern slopes of the Hazratishoh Mts along the border with Afghanistan (Fig. 5). It occupies the foothills within the elevational range of 600–1,400 m a.s.l. (mean ca. 1,050; Fig. 4a). Range of *Cercis griffithii* overlaps mainly with the *Pistacia vera* range, occurring in the Kopet-Dagh, western Pamir Alai, Tian Shan and north-western foothills of the Hindu-Kush (Ovchinnikov, 1978).

Floristic composition: This subassociation shares the most frequent taxa with the typical stands. The distinct feature is a clear dominance or co-dominance of *Cercis griffithii* in the lower tree layer (sometimes also in the shrub layer, Fig. 7f). *Pistacietum verae cercidetosum griffithii* has a moderately dense shrub layer with a mean value of ca. 35% (up to 55%; Fig. 4f) and tree layer with a mean value of ca. 20% (up to 70%; Fig. 4e). The community has an abundant herb layer that reaches up to 85% (mean ca. 65%; Fig. 4g), however it is slightly less dense in comparison to the typical subassociation. It has a higher frequency of the typical warm steppe or scree species such as *Galium tenuissimum*, *Aphanopleura capillifolia*, *Linum corymbulosum*, *Capparis spinosa*, *Trichodesma incanum*, *Andrachne telephioides* or *Vulpia persica*. Simmilar to the typical subassociation, the most frequent moss species that occur in this community are *Syntrichia ruraliformis* and *Bryum caespiticum*.

Habitat characteristics: The subassociation with *Cercis griffithii* occupies the driest sites in comparison to the typical ones (Fig. 4c). It often develops on shallow soils with considerable amount of rock debris, sometimes almost on pebble screes.

Remarks: Patches of the *Cercis griffithii* subassociation were found mainly in the Panj River Valley near the Dashti-Jum Nature Reserve and close to the village of Zigar. It is grazed by sheep and goats and forms a mosaic with *Punica granatum* shrubs that occupies the wetter places.

Discussion

Ambiguity between *šhiblyak* and pistachio open woodlands and position of the described communities in relation to other vegetation types

The vegetation of pistachio open woodlands is one of the most distinctive types of vegetation in Middle Asia and the entire Irano-Turanian region. It creates a distinct zone at the colline and montane belts of most of the ranges across the warm and subhumid climate zone. For years it has been the subject of mainly inconsistent research conducted by local botanists (Ovchinnikov, 1948; Popov, 1994; Safarov, 2018), who included it in the so-called *šhiblyak* (Ovchinnikov, 1948; Zapryagaeva, 1964; Safarov, 2018). Other scientists distinguished it into a separate type called a *'redkolesie'* (sparse forest), or just grove, open arid forest, open woodland or wild orchard (e.g. Kamelin & Rodin, 1989; Memariani et al., 2016; Popov, 1974, 1994). This ambiguous treatment of communities dominated by shrubs and small trees in the warmer zone of Middle Asia resulted from at least two facts. The first is that the word *šhiblyak* is introduced from the Serbian language (Adamovič, 1902; Čarni et al., 2018) and was not precisely applied to a particular type of shrubby vegetation at the beginning of research into Middle Asian vegetation. As in the original language – it means 'bushes' – it was simply assumed that anything with a high cover of bushes would be called *šhiblyak*. The second reason is that typical open woodland dominated by *Pistacia* spp. is often adjacent to xeric shrublands dominated by various *Cotoneaster* spp., *Amygdalus* spp., *Lonicera* spp., *Rosa* spp., *Crataegus* spp., *Prunus* spp. and *Berberis* spp. Some species (e.g. *Punica granatum*, *Ficus carica*, *Celtis orientalis*, *Zizyphus jujuba*) occur in both open woodlands and *šhiblyak* vegetation. Additionally, some authors noted that pistachio groves do not form zonal vegetation (e.g. Popov, 1994). Moreover, our observations have shown that the pistachio formation can be overgrown in a shrub layer with fairly dense herbs (from 5 to 80%, mean 35%), which also serves as diagnosis feature. Of course, intensive grazing – which is carried out in all *šhiblyak* and open woodlands in Tajikistan (including national parks and nature reserves) – does not help in an unambiguous assignment of individual plots, and has a strong influence on the structure and species composition, especially in relation to herbs and shrubs.

Our results show a clear distinction between two main types of vegetation. The first three groups represent *šhiblyak* communities with dense shrub cover and a lack of characteristic gaps with graminoid vegetation. Safarov (2018) calls these phytocoenoses *Mesothamnion nemorale* following the Russian approach (Ovchinnikov, 1948, 1955). It is quite similar to those xeric scrublands known from the Kopet-Dagh or Armenian highlands with domination of *Acer* spp., *Crataegus* spp., *Lonicera* spp., *Cerasus* spp. and *Cotoneaster* spp. (see Fayvush & Aleksanyan, 2016; Memariani et al., 2016). The last two are inevitably typical open woodlands with umbrella-like canopies of *Pistacia vera*. They represent two open pistachio woodland subassociations, one with *Celtis griffithii* typical for more stony, less fertile substrates, which was also reported from Kopet-Dagh in north-eastern Iran (Memariani et al., 2016). In between, there is an association of *Calophaca grandiflora* that was included by the TWINSPAN algorithm in *šhiblyak* vegetation which, however, has some transitional character due to a higher number of pseudosteppe plants from a warmer bioclimatic zone (e.g. *Hordeum bulbosum*, *Bromus oxyodon*, *Crepis pulchra*, *Elaeosticta hirtula*, *Bongardia chrysogonum*) or thermophilous shrubs such as *Amygdalus bucharica* or *Acer regelii*.

Comparative analysis of the xerophytic and mesophilous shrub vegetation of Tajikistan with their vicariants in the Irano-Turanian region needs further detailed studies and additional sampling. Probably there are phytocoenoses that are close to pseudomaquis (Fayvush & Aleksanyan, 2016). Like a

šhiblyak, it was firstly described by Adamovič (1902) from NE Greece as a xerophytic, evergreen, shrub vegetation of the Mediterranean Region that makes a typical thicket cover of the hills and slopes of the colline and montane belts. It prefers the continental climate with shorter vegetation period. Adamovič mentioned that typical species of pseudomacchia are among others: *Buxus sempervirens*, *Quercus macedonica*, *Q. coccifera*, *Prunus laurocerasus*, *Ilex aquifolium*, *Pistacia terebinthus*, *P. mutica*, *Jasminum fruticans*, *Colutea melanocalys*, *Prunus spinosa*, *Cercis siliquastrum*, *Pyrus amygdaliformis*, *Rhus cotinus*, *Paliurus australis*. Currently, the pseudomaquis formation is considered as a transitional vegetation between the typical Mediterranean evergreen macchia/maquis scrub and continental deciduous *šhiblyak* scrub (Mucina et al., 2016), so probably a kind of regeneration stage. It is a secondary vegetation developed after the clearance of sub-Mediterranean oak woodlands or by degradation through intensive woodland grazing. It is related to the sub-Mediterranean zone, but still has a considerable contribution of temperate Euro-Siberian species (*Crataego-Prunetea*). Still, all closely related shrubby vegetation types (macchia, pseudomacchia and *šhiblyak*) are distinguished in Balkans and separated according to diagnostic set of stenomediterranean and Eurasian species and additionally differentiated by perennial grasses (Čarni et al., 2018). This vegetation was mentioned from Anatolia, Armenia, Turkey, Greece, Macedonia and NW Iran (Atalay, 1986; Chasapis et al., 2004; Khoshbakht & Hammer, 2006; Kaya et al., 2010; Fayvush & Aleksanyan, 2016).

Do we need to establish a separate class for Irano-Turanian pistachio open woodlands?

Pistachio open woodlands were classified along with juniper open woods. At a higher rank of the phytosociological division, they were included in the *Junipero-Pistacietea* class (Zohary, 1973). Apart from the fact that this class was described invalidly (Art. 2b, see Mucina et al., 2016), it seems that current knowledge does not justify including both types – juniper and pistachio groves – in one class of vegetation. In the mountains of Uzbekistan, Tajikistan and Kyrgyzstan, they are clearly separated in the landscape as two distinct belts of vegetation. The juniper stands are located in upper montane to lower subalpine belts and only occasionally overlap with the pistachio woodlands (some plots of *Juniperus seravshanica* in the Hodzhamumin and Babatag Mts.). In our data from Tajikistan, juniper was not found in pistachio woodlands and we noticed only two occurrences of junipers in *Calophaca grandiflora* shrubs. Even in the original species lists and descriptions provided by Zohary, there are no patches with both junipers and pistachios with a significant cover. Juniper stands and pistachio woodlands were also distinguished as separate in the description of vegetation in north-eastern Iran (Memariani et al., 2016). In Turkmenistan, in the region of Badghyz, two large open pistachio woodlands of Kushka and Pulikhatum have been described as a distinct zonal vegetation dominated solely by *P. vera* with some admixture of *Ficus carica* and *F. afghanica* (Popov, 1994). It is also a place where *Pistacia badghysi* K. P. Popov, an endemic and threatened species of pistachio, was reported (Annabayramov, 2011). In the entire Middle Asia, the umbrella-shaped crowns of pistachio trees, with distinct seasonal variation of plant cover and herbaceous layer that easily wither during the summer heat, convince botanists to treat this vegetation separately. The seasonal dynamics and plant composition of juniper stands is apparently different. *Pistacia* groves can withstand the fires and young seedlings, due to the high nutrient content in the large seeds, can rapidly develop deep roots which secure the young trees' survival in the first, most critical year of their life (Popov, 1994). There is a clear evidence that floristically these two vegetation types considerably differ. Pistachio woodlands are closely related to pseudosteppes and thus harbour a number of graminoids (e.g. *Hordeum bulbosum*, *H. spontaneum*, *Lolium temulentum*, *Vulpia persica*, *V. myuros*, *V. ciliata*). In contrast the juniper woods are inhabited by a number of tall-herbs like *Campanula glomerata*, *Geranium regelii*, *Ligularia thomsonii*, *Libanotis schrenkiana*, *Prangos pabularia* and others. Both vegetation are rich in endemic species that also constitute the set of diagnostic species. For pistachio groves *Artemisia baldshuanica*, *Astragalus bucharicus*, *A. brachycalyx*, *A. susianus*, *Cousinia bachtiarica*, *C. grigoriewii*, *Fallopia baldshuanica* and for juniper stands *Anemone tschernaewii*, *Corydalis darwasica*, *C. nudicaulis* and *Neopaulia ovczinnikovii* can be mentioned. This high share of regional endemics is also the reason for distinguishing a separate order *Pistacietalia* that represents the western outskirts of Pamir-Alai range and probably the south-eastern Kopet-dagh. This distinct type of woodland was often called savannah or semi-savanna (Ovchinnikov, 1948; Popov, 1994).

Therefore, it seems that there is a justified need to distinguish a new vegetation class of so-called open pistachio woodlands along with the main structural and diagnostic taxa of pistachios (at least *Pistacia vera*, *P. khinjuk*, *P. atlantica*). For now, we propose it as a provisional unit and suggest further research in the whole Irano-Turanian region to fully justify the establishment of this class. It should also be focused on the phylogeny of *Pistacia*. The distinction of open pistachio woods in Middle Asia might be probably supported by the phylogenetic data that shows *Pistacia* as a species which evolved in the northern part of Central Asia, with *P. vera* and *P. khinjuk* as the oldest representatives of the genus (Kozhoridze et al.,

2015). Paleobotanical data indicate that before the Pleistocene, *P. vera* was one of four species of this genus that inhabited Middle Asia (Popov, 1994; Zlotin, 1994).

Can we treat open pistachio woodlands as forest-steppe?

The distinction of pistachio woodlands can be also related to its forest-steppe physiognomy. The foothills of the Middle Asian mountains have a transitional climate (from subhumid to semi-arid), which promotes the development of a mosaic vegetation composed of forest and grassland patches (Walter & Breckle, 1989; Djamali et al., 2011; Erdős et al., 2018). In Tajikistan, pistachio woodlands share these features and consist of species typical of mesophilous woods, juniper stands, steppes and pseudosteppes (Nowak et al., 2016, 2018; Świerszcz et al., 2020). Pistachio woodlands in Tajikistan vary in structure, but are mostly characterised by a typical forest-steppe physiognomy, with *Pistacia vera* as the dominant tree and *Amygdalus bucharica*, *Cercis griffithii*, *Fraxinus raibocarpa* or *Cerasus verrucosa* in the shrub layer. The undergrowth is dominated by typical grassland plants such as *Hordeum bulbosum*, *Aegilops triuncialis*, *Bromus popovii*, *Vulpia myuros*, *Lolium temulentum*, *Cryptospora falcata*, *Brachypodium distachyon*. However, it is difficult to state to what extent it is natural and to what extent it is the result of human activity (grazing, burning). Nevertheless, following the definition of forest-steppe, it can be classified among other plant communities because they can also include semi-natural stands. The southern parts of Middle Asia have been used as grazing lands for centuries by the ancient Indus Valley civilisation (Shortugai) or the local Bactrian Kingdom (Lawler, 2007; Chew & Sarabia, 2016; Sinha et al., 2019). The long history of grazing inevitably has affected the structure and composition of pistachio woodlands. However, they still exhibit features comparable to other forest-steppe communities (e.g. the cover of tree layer between 10–70%; Erdős et al., 2018).

A typical structure of the vegetation that allows species from shrubs, forests, groves and grasses to develop contributes – as in most forest-steppe systems – to an unusually high species richness. The pistachio groves of southern Tajikistan have up to 56 species in patches with an average of 37 taxa. They harbour a number of endemic species such as *Ferula clematidifolia*, *F. tadshikorum*, *Malva bucharica*, *Nigella bucharica*, *Cousinia grigoriewii*, *Astragalus mirabilis*, *A. quisqualis*, *Oxytropis linczewskii*, *Fallopia baldshuanica*, *Iris bucharica*, *Scilla bucharica* and others. They also include Tertiary relicts such as *Ostrowskia magnifica*, *Astragalus xanthomeloides* or *A. hissaricus*.

Conservation

After long-lasting timber exploitation by local communities, woodlands are one of the most threatened ecosystems in Tajikistan (Safarov, 2003). Approximately 90% were legally or illegally logged in the recent centuries, resulting in extraordinary deforestation and consequently landslides and soil denudation. Certainly the researched open woodlands and xeric shrublands are the scarce remnants of their previous coverage in Tajikistan. Despite the implementation of some conservation measures and the establishment of the Dashti-Jum Nature Reserve, the degeneration and retreatment of the open pistachio woodlands still remains a visible process. Even the last refuges of this vegetation continue to be intensively used. A similar situation is in Kyrgyzstan (Ferghana Valley), Uzbekistan (western Hissar foothills) and Turkmenistan. In the Kopetdagh Mountains only a small last islet of about 500 hectares remains of the former wide belt of pistachio woodlands (Popov, 1994). In eastern Turkmenistan, small areas covered by pistachio woodlands are found in the foothills of Kugitang. These communities recently have been completely cut, subsequently producing stump shoots (Popov, 1994). In all corners of Middle Asia, intensive year-round grazing by sheep and goats considerably hamper seed germination and regeneration of the pistachio stands.

As part of the project carried out in 2021 in the Baljuvon jamoat, we proposed 5 microreserves to protect different vegetation types, including open woods and scrubs. This is important because these communities have a high degree of endemism. With this type of community are associated endemics such as *Anemone bucharica*, *Astragalus bucharicus*, *A. hissaricus*, *A. macropodium, Bunium hissaricum, Ferula clematidifolia, Iris bucharica, Nigella bucharica* or *Tulipa subquinquefolia*. Management within microreserves is carried out by local people. This shows how important is to cooperate with politicians and resource-using residents to permanently preserve the remains of these valuable plant communities.

Conclusions and outlook

The paper is the first attempt to classify the deciduous, thermophilous open woodlands and scrublands in Tajikistan. In our research, we focused on open pistachio woods, expecting considerable complexity in the classification of shrubland communities in southern Tajikistan. Relationships between *šhiblyak*, pistachio woodlands, mesophilous shrubs with *Aflatunia* and *Cotoneaster*, and woods with apple, pear, maples and juniper stands will require further detailed studies. Here, we propose to distinguish new syntaxon: *Pistacietea khinjuki-verae* class, which still needs to be verified and compared with similar vegetation in the Eastern Mediterranean and western Irano-Turanian regions. Nevertheless, our

long-lasting observations and detailed studies on the open woodlands in south-western Tajikistan can, in our opinion, be summarised at this stage.

The strong impact posed by local communities through intensive grazing, logging and burning, on Tajik woodlands along with the lack of effective conservation measures and forest management is causing a gradual decline in the range of this species-rich vegetation, which harbours many rare, endemic and relict taxa.

Author contributions

Ar.N. planned the research, Ar.N., S.Ś., M.N. conducted the field sampling, Ar.N. and S.Ś. wrote the draft of the manuscript, S.Ś. performed the statistical analyses, M.N. dealt with taxonomic issues, while all authors contributed to the writing.

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