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Conservation strategy and diversity of *Tulipa* (Liliaceae) in Uzbekistan

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ABSTRACT

In light of the ongoing biodiversity crisis, appropriate conservation strategies are urgently needed. The steadily increasing anthropogenic pressure on nature in Central Asian countries seriously threatens the fate of local species and their habitats. Here, we analyze the threats to the genus *Tulipa* (Liliaceae) in Uzbekistan and propose an appropriate conservation strategy based on field surveys, observations and literature review. Among the threats evidenced for these species, the most relevant are overgrazing, land use, urbanization, and fragmentation. Analysis of *Tulipa* distribution in Uzbekistan revealed that 27 species of *Tulipa* occur in 19 protected areas. Among them, the most important are Ugam-Chatkal State National Natural Park, Chatkal State Biosphere Reserve, Hissar and Surkhan State Nature Reserves, harboring 10, 9, 9 and 8 species respectively. However, 8 species (of which five species are red-listed) occur in unprotected areas. In addition to the two major conservation approaches, *in situ* and *ex situ*, civic awareness is proposed as a third important conservation component. Besides, home garden conservation is proposed as an effective tool for conservation of *Tulipa* that requires support from the government.

Key words: conservation, protected area, spatial distribution, *Tulipa*, *in situ*, *ex situ*, civic awareness

Introduction

There is a global consensus that conservation of biodiversity must be prioritized and pursued at global, national, and regional levels (Convention on Biological Diversity 2023). Currently, the IUCN Red List includes more than 42,100 species threatened with extinction (IUCN 2023). The importance of conservation issues for sustainable ecological and socio-economic development was discussed and recognized already in 1992 (Rio de Janeiro, Brazil). As a result of this event, the Convention of Biological Diversity (CBD) was approved and signed by 227 nations (Convention of Biological Diversity 2023).

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Uzbekistan is one of the members of CBD, and since 1995 agreed to protect biodiversity in terrestrial and inland water ecosystems (Environmental Performance Review 2020). The flora of Uzbekistan lists 4,384 species of vascular plants (Sennikov et al. 2016), of which 314 species are threatened (Khasanov 2019).

The rapid growth of the population (Statistics Agency under the President of the Republic of Uzbekistan 2023) and economy lead to an over-exploitation of natural resources, an increase of urbanization rate and fragmentation/loss of natural habitats. Currently, 187 species (60%) out of 314 red-listed taxa of the flora (7.13%) require special protection measures or lack any protection. According to the National Science Foundation Organization (2019), approximately 40% of the world's flora is exceptionally rare and vulnerable to climate change. In Uzbekistan, 36.3% of the red-listed species are in categories 0 (10 species) and 1 (104 species), which correspond to EW (extinct in the wild), EX (extinct), and CR (critically endangered) categories of the IUCN Red List.

The territory of Uzbekistan consists mainly of arid zones and plains, while mountains and foothills make up only 15-20% of its area (Tojibaev & Beshko 2014). The first edition of the flora of Uzbekistan (1941-1962) listed 4,148 vascular species (138 families, 1023 genera), including 3,663 native and 485 alien plants (Li et al., 2020). The endemism rate is 8%, which represents 1% of the flora of the world (Myers 2000).

The genus *Tulipa* L. (Liliaceae, Tulipeae) includes ca. 150 species (Peruzzi 2016). Central Asia, with 80 species, of which 33 occur in Uzbekistan (WCSP 2021; Tojibaev et al. 2022a), is the primary center of diversity of wild species of *Tulipa* (Zonneveld 2009; Tojibaev & Beshko 2014; Dekhkonov et al. 2022a), Despite the long history of Central Asian *Tulipa* research (Vvedensky & Kovalevskaja 1971; Botschantzeva 1982; Pratov & Sharipov 2006; Tojibaev & Kadirov 2010; Tojibaev & Beshko 2014; Tojibaev et al. 2022a), conservation of the species of *Tulipa* in this region can and should be improved (Zhang et al. 2023). Currently, 19 species of *Tulipa* are listed in the Red Data Book of Uzbekistan (Khasanov 2019) of which five (26.3%) do not occur in any protected area. Despite the fact that conservation of species of *Tulipa* was a subject of several recent works (Wilson et al. 2021; Dekhkonov et al. 2021; Wilson 2023), a detailed analysis of *Tulipa* threats and effectiveness of the existing measures of their conservation is still lacking.

Developing an effective species conservation strategy involves recognizing threats and identifying actions that prevent or mitigate the most serious threats. The objective of this work was to: (a) identify the threats, (b) analyze the current state of conservation, and (c) develop an effective conservation strategy for wild species of *Tulipa* in Uzbekistan.

Materials and Methods

The study area

The Republic of Uzbekistan is located in Central Asia and is bordered by Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Afghanistan (Fig. 1). The eastern part of the area is surrounded by the western Tian-Shan (Kurama, Chatkal, Fergana ridges) and Pamir-Alay (Alay and Turkistan ridges) mountain systems, which occupy 13% of the land area. The northwest part of the Republic is covered by the Ustyurt plateau and the central and northern part by the Kyzylkum deserts. The area of Uzbekistan stretches 1,425 km from the west to the east and 930 km from the south to the north (Soliev 2014).

According to the phytogeographical regionalization of Uzbekistan by Tojibaev et al. (2016), Uzbekistan is divided into Mountainous Central Asia and Turan provinces, 16 regions and 38 districts (Fig. 1).

Study species

The species names follow Zonneveld (2009) and Tojibaev et al. (2022a) (Table 1). The taxonomic status of the species was cross-checked by the World Checklist of Selected

Plant Families (2021) and POWO (Plants of the World Online, 2023). Red Data Book status is derived from Khasanov (2019), while category and criteria of threatened species of *Tulipa* follow the IUCN protocol (IUCN 2023).

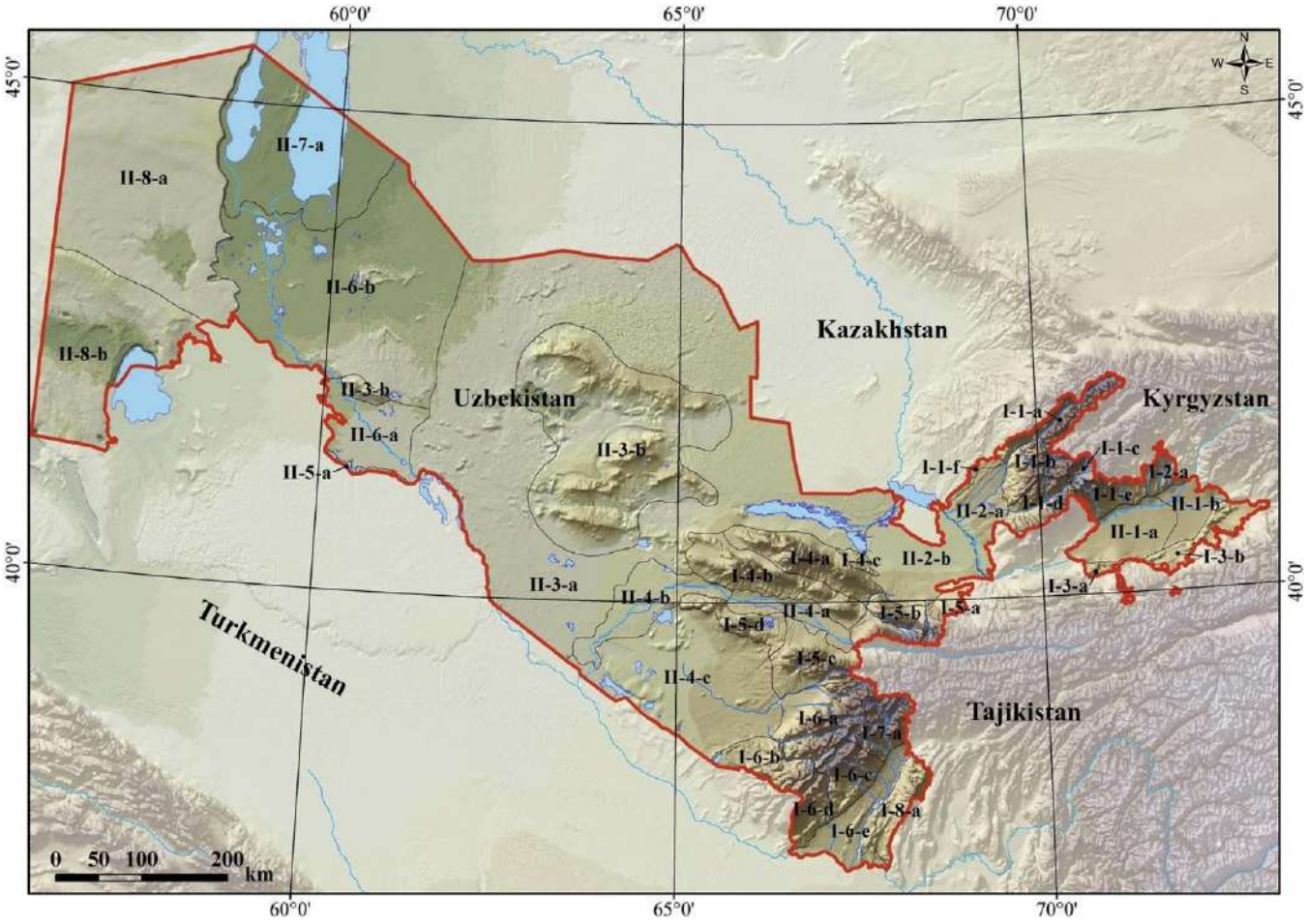

Fig. 1. Spatial view and phytogeographical regions of Uzbekistan

Central Asian Mountain Province: I-1 Western Tian-Shan (districts: I-1-a Ugam-Pskem, I-1-b Western Chatkal (Chimgan), I-1-c Arashan, I-1-d Kurama (Akhangaran), I-1-e Chorkesar, I-1-f near-Tashkent), I-2 Fergana (I-2-a Southern Chatkal district), I-3 Fergana-Alay (districts: I-3-a Western Alay, I-3-b Eastern Alay), I-4 Nuratau (districts: I-4-a Nuratau, I-4-b Aktau, I-4-c near-Nuratau outlier mountains), I-5 Kuhistan (districts: I-5-a Northern Turkestan, I-5-b Malguzar, I-5-c Urgut, I-5-d Ziadin-Zirabulak), I-6 Western Hissar (districts: I-6-a Kashkadaryo, I-6-b Tarkapchigay, I-6-c Baysun, I-6-d Kuhitang, I-6-e Surkhan-Sherabad), I-7 Hissar-Darvaz (I-7-a Sangardak-Tupalang district), I-8 Panj (I-8-a Babatag district).

Turan Province: II-1 Central Fergana (districts: II-1-a Kayrakum-Yazyavan, II-1-b Eastern Fergana), II-2 Middle Syrdarya (districts: II-2-a Chinaz, II-2-b Mirzachul), II-3 Kyzylkum (districts: II-3-a Kyzylkum, II-3-b Kyzylkum outlier mountains), II-4 Bukhara (districts: II-4-a Middle Zaravschan, II-4-b Lower Zaravschan, II-4-c Karshi-Karnabchul), II-5 Karakum (II-5-a North-Eastern Karakum district), II-6 Southern Aral (districts: II-6-a Khorezm, II-6-b Amudarya delta), II-7 Aral (II-7-a Aral sea bottom district), II-8 Ustyurt (districts: II-8-a Northern Ustyurt, II-8-b Southern Ustyurt).

Table 1. Species of *Tulipa* of Uzbekistan, known number of occurrences, Red Data Book status and category and criteria of threatened species based on IUCN criteria

#	Species	Number of occurrences	RDB status	IUCN category and criteria
	Sect. *Lanatae* (Raamsd.) Zonn.			
1	*Tulipa tubergeniana* Hoog	26	3	NT B2b(iii,v)
2	*Tulipa bactriana* J.de Groot & Tojibaev	1		CR B1ab(iii)+2ab(iii)
3	*Tulipa lanata* Regel	32	3	NT B2b(ii,iii,iv,v)
4	*Tulipa ingens* Hoog	41	3	NT B1b(ii,iii,iv,v) +2b(ii,iii,iv,v)
5	*Tulipa carinata* Vved.	28	3	VU A4ac
6	*Tulipa fosteriana* W.Irving	37	2	VU A3cd
7	*Tulipa affinis* Botschanz.	53	3	VU A4ac
	Sect. *Kopalkowskianae* Raamsd. ex Zonn. & Veldk.			
8	*Tulipa lehmanniana* Mercklin	81	3	NT A3c; B2b(ii,iii,v)
9	*Tulipa borszczowii* Baker	13		NT B2b(ii,iii,iv,v); C2a(i)
10	*Tulipa korolkowii* Regel	132	3	NT B2b(i,ii,iii,iv,v)
11	*Tulipa ferganica* Vved.	24	2	LC
12	*Tulipa scharipovii* Tojibaev	22	2	EN 1ab(i,ii,iii,iv,v) +2ab(i,ii,iii,iv,v)
13	*Tulipa intermedia* Tojibaev & J.de Groot	20	2	
14	*Tulipa talassica* Lazkov	10		EN B1ab(iii,v) +2ab(iii,v)
15	*Tulipa hissarica* Popov & Vved.	5		LC
16	*Tulipa korshinskyi* Vved.	7		
	Sect. *Vinistriatae* (Raamsd.) Zonn.			
17	*Tulipa greigii* Regel	57	3	LC
18	*Tulipa mogoltavica* Popov & Vved.	14		
19	*Tulipa micheliana* Hoog	46	3	VU A4ac
20	*Tulipa vvedenskyi* Botschantz.	41	3	NT A4ac; B1b(ii,iii,iv,v) +2b(ii,iii,iv,v)
21	*Tulipa butkovii* Botschantz.	17		VU B1ab(i,ii,iii,v) +2ab(i,ii,iii,v)
	Sect. *Spiranthera* Vved. ex Zonn. & Veldk.			

22	*Tulipa kaufmanniana* Regel	84	3	NT B2b(i,ii,iii,v)
23	*Tulipa tschimganica* Botschantz.	16		
24	*Tulipa dubia* Vved.	58	3	NT B1b(ii,iii,v) +2b(ii,iii,v)
25	*Tulipa uzbekistanica* Botschantz. & Scharipov	9	1	CR B1ab(iii)
	Sect. *Biflores* A.D.Hall ex Zonn. & Veldk.			
26	*Tulipa sogdiana* Bunge	47		
27	*Tulipa biflora* Pallas	6		
28	*Tulipa buhseana* Boiss.	53		
29	*Tulipa turkestanica* (Regel) Regel	106		LC
30	*Tulipa bifloriformis* Vved.	114		LC
31	*Tulipa dasystemon* (Regel) Regel	63	3	LC
32	*Tulipa dasystemonoides* Vved.	12		
33	*Tulipa orithyioides* Vved.	6	1	EN B2ab(iii,v)

*The order number in the table corresponds to species of *Tulipa* presented in the text

Protected areas of Uzbekistan

Information on the protected areas (PA) of Uzbekistan (Table 2) was retrived from the relevant sources (6th National Report of the Republic of Uzbekistan on conservation of biodiversity 2018; Recommendations for Expanding the System of Protected Natural Areas of Uzbekistan 2012; WDPA 2022). Maps of the PAs were processed in ArcView GIS (ESRI 1999). Correspondence of the National categories of PA to IUCN follows Recommendations for Expanding the System of Protected Natural Areas of Uzbekistan (2012).

Table 2. List of protected areas of Uzbekistan (I–IV categories by IUCN)

#	Name of PA	Category by IUCN	Area (ha)	Date of establishment	Number of species of *Tulipa*
	1. State reserves				
1	Chatkal State Biosphere Reserve	Ia	24,706	1947	9
2	Hissar State Nature Reserve	Ia	80,986	1983	9
3	Kyzylkum State Nature Reserve	Ia	10,311	1971	4
4	Nurata State Nature Reserve	Ia	17,752	1973	4
5	Surkhan State Nature Reserve	Ia	23,802	1986	8
6	Zaamin State Nature Reserve	Ia	26,840	1959	5
7	Aktau-Tamdy State Nature Reserve	Ia	40,000	2022	2
8	Lower Amudarya State Biosphere	N/A	68,717.8	2011	0

	Reserve				
9	Ugam-Chatkal State Biosphere Reserve	N/A	42,952,81	2018	5
	2. Complex (landscape) reserves				
10	Saigachiy Complex (landscape) Reserve	Ib	628,300	2016	4
	2. National parks				
11	Durmon National Natural Park	II	32.4	2014	0
12	Khorezm National Natural Park	II	21,687.5	2019	0
13	Kitab Geological National Natural Park	II	3,938	2020	2
14	South Ustyurt National Natural Park	II	1,447,143	2020	0
15	Ugam-Chatkal State National Natural Park	II	506,898	1990	10
16	Zaamin National Natural Park	II	24,110	1976	4
17	Zarafshan National Natural Park	II	2,426.2	2018	0
18	Central Kyzylkum National Natural Park	II	1,200,000	2022	4
19	Aralkum National Natural Park	II	700,000	2022	1
20	Pap National Natural Park	II	6,000	2022	3
21	Omonquton National Natural Park	II	1,500	2022	0
22	Upper Tupalang National Natural Park	II	18,000	2022	3
23	Babatag National Natural Park	II	8,000	2022	4
	3. Natural monuments				
24	Akbarobod State Natural Monument	III	39.5	2004	0
25	Bustonbuva State Natural Monument	III	8.5	2003	0
26	Chust Natural Monument	III	96	1990	0
27	Mingbulak Natural Monument	III	1,000	1991	0
28	Paykent Natural Monument	III	30	2010	0
29	Urungoch State Hydrological Natural Monument	III	43	2019	0
30	Varakhsha State Natural Monument	III	7	2010	0
31	Vardanzi Natural Monument	III	124	2013	0
32	Yangibozor State Natural Monument	III	470	2004	0
33	Yazyavan Natural Monument	III	1,962.9	1994	0
34	Zilkha State Natural Monument	III	22.2	2003	0
	4. State wildlife				
35	Aktau State Wildlife Sanctuary	IV	15,420	1997	3
36	Arnasay State ornithological Wildlife Sanctuary	IV	66,300	1983	0
37	Dengizkul State Ornithological Wildlife Sanctuary	IV	50,000	1992	0
38	Kara-Kir State Wildlife Sanctuary	IV	30,000	1992	0

39	Karnabchul State Wildlife Sanctuary	IV	25,000	1998	0
40	Khadicha State Wildlife Sanctuary	IV	11,300	2010	0
41	Koshrabad State Wildlife Sanctuary	IV	16,500	1992	2
42	Mubarak State Wildlife Sanctuary	IV	264,469	1998	0
43	Nurobod Wildlife Sanctuary	IV	40,000	1992	0
44	Qumsulton State Wildlife Sanctuary	IV	4,900	2010	0
45	Sayxun State Wildlife Sanctuary	IV	372	2019	0
46	Sudoche-Akpetki State Wildlife Sanctuary	IV	280,507	2021	0
47	Borsa-Kelmas State Wildlife	IV	280,000	2022	1
	5. Specialized nurseries				
48	Bukhara Specialized Nursery 'Jayron'	IV	16,522	1976	0

*The order number in the table corresponds to the PA presented in the text

Field surveys

Extensive field surveys were conducted during the *Tulipa* blooming season from mid-March to August during 2014-2023 at elevations ranging from 200 m to 3,600 m a.s.l. In total, 1,300 occurrence points were recorded. Different habitat types were surveyed to ensure a comprehensive geographical coverage. The coordinates of the occurrence locations were obtained, in addition to field observations from previously published data (Botschantzeva 1982; Tojibaev & Kadirov 2010; Everett et al. 2013; Tojibaev & Beshko 2014; Dekhkonov et al. 2022a). In addition, over 3,000 herbarium specimens stored in TASH were checked.

Abbreviation

CBD Convention of Biological Diversity, IUCN – International Union for Conservation of Nature, UNEP – United Nations Environment Programme, WRI – World Resources Institute, WCSP World Checklist of Selected Plant Families, WDPA World Database on Protected Areas, RDB – Red Data Book, PA – Protected area(s), SNR – State Nature Reserve, NNP – Natural National Park, BR Biosphere Reserve, NM Nature Monument, SWS State Wildlife Sanctuary, BG – Botanical garden.

Results

Threats

Uncontrolled grazing, habitat loss, fragmentation, urbanization, land use for agricultural purposes, and overcollection were found to be the major threats in unprotected areas. Below we provide a detailed description of the major threats to *Tulipa* according to the field surveys during 2019 2023 and literature reviews.

Abiotic stress factors

The main abiotic factors affecting species of *Tulipa* in Uzbekistan are presented in Fig. 2A. Abiotic factors mainly affect the species distributed on the plains (250-500 m.s.l.). Some species, such as. *T. biflora*, *T. buhseana*, and *T. sogdiana* occur in unfavorable conditions on the Ustyurt plateau and in the Kyzylkum desert. Edaphic factors affect *T. biflora*, which suffers from soil salinity on the Ustyurt plateau (mainly near the exposed Aral seabed). In some cases, the elevated temperature of the Kyzylkum deserts and Ustyurt plateau cause early desiccation of the plants before blooming (Suppl. Fig. 1A).

Rainfall regime is another key factor that negatively affects six species in Uzbekistan. As an example, *T. bactriana* has not been found

since 2007 at the type locality (Sherabad district, Surkhondaryo region) as a result of low precipitation. In some dry years, the number of individuals of *T. uzbekistanica* decreases sharply. Floods resulted in a decrease in population size of *T. borszczowii* in Sardoba, Syrdarya region, in 2020 and in the next two years the species was not observed there (Suppl. Fig. 1B).

Biotic factors

Biotic factors not related to human activities were found to be less detrimental than abiotic and anthropogenic factors. Nevertheless, they are important for 11 species, of which 10 are Red-listed (Fig. 2B). According to field observations and available literature, predation by insects, mainly affecting the tepals and fruits, was observed for 5 species (*T. lehmanniana, T. tubergeniana*, and *T. ingens*, personal observations; *T. albertii* and *T. kolpakowskiana*) (Suppl. Fig. 2). Also a microbial invasion of *T. affinis* was observed in the vicinity of Molguzar.

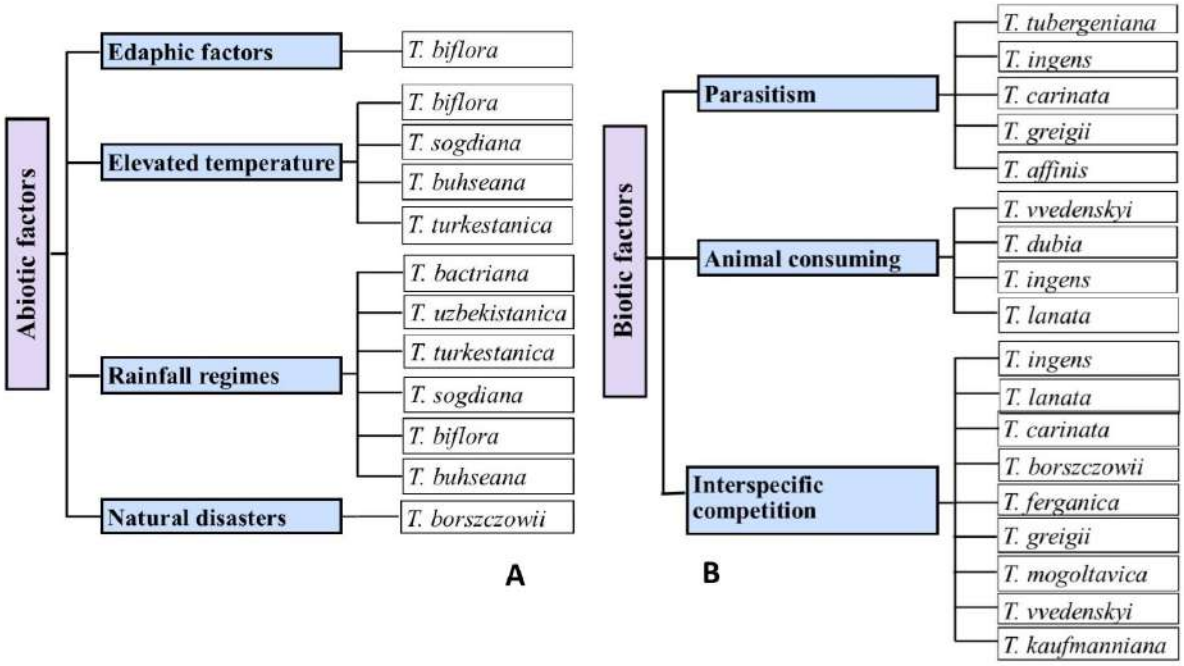

Fig. 2. Effects of abiotic (A) and biotic (B) factors on species of *Tulipa.*

Grazing of species of *Tulipa* by wild animals was observed for four species. For instance, 20-30% of total bulbs of *T. vvedenskyi* and *T. dubia* were eaten by wild boars and bears in Maydantal (Tashkent region); the same was observed for *T. lanata* and *T. ingens* by porcupines in Baysun (Surkhondaryo region). In addition, some wild animals consume the vegetative parts of tulips in early spring when vegetation is scarce. Interspecific competition of *Tulipa* mainly occurs in the middle mountain ranges. As an example, the blooming period of middle mountain species (*T. kaufmanniana* and *T. vvedenskyi*) continues from the mid and final 10 days of March to mid-April when other plants are growing exponentially. These species mainly compete with others for sunlight, soil nutrients and water.

Anthropogenic factors

Anthropogenic factors have a huge impact on biodiversity worldwide. Current work demonstrates five anthropogenic factors

having high impact on species of *Tulipa* in Uzbekistan.

Urbanization

Uzbekistan has a population of over 36 million people (Statistics Agency under the President of the Republic of Uzbekistan 2023) and is continuing to grow. The rapidly growing population of humans and domestic stock in Uzbekistan has a strong negative effect on the country's flora and vegetation, including tulips. The effects are especially detrimental in the Fergana valley and Tashkent region, which show the highest population density in Uzbekistan, and host 15 species of *Tulipa*. Populations in the foothills and middle mountain belt are affected most heavily. We found that 44% (25 out of 57) of the populations of *T. greigii* in the vicinity of Gulkam and Chimgan villages (Tashkent region, Chatkal range) and 38% (10 out of 26) of the populations of *T. tubergeniana* in the foothills of Pashkhurt village (Sherabad district) disappeared as a result of urbanization during 2013-2017.

Agriculture

Agricultural land use leads to irreversible habitat transformation in Uzbekistan (Suppl. Fig. 3) and mainly affects the foothills and middle mountain regions of the Fergana valley, Tashkent and Surkhondaryo regions. Currently, habitats of *T. scharipovii*, *T. intermedia*, and *T. bifloriformis* at the foot of the Kurama range (Chap badlands), as well as *T. ferganica*, and *T. turkestanica* in the foothills of Arbagish (Namangan region) have been used intensively for agricultural development. Also, the scale of land use for agricultural purposes is increasing in the southern (Surkhondaryo and Kashkadaryo regions) and in the central part of the country (Kyzylkum desert), negatively affecting species of *T.* sect. *Lanatae*, sect. *Kopalkowskianae,* and sect. *Biflores.*

Overexploitation

Species of *Tulipa* are mainly collected for ornamental purposes and sale in Uzbekistan (Suppl. Fig. 4). Collecting of *T. vvedenskyi* and *T. kaufmanniana* in Kamchik pass (Kurama range), *T. tschimganica, T.greigii,* and *T. kaufmanniana* (Chimgan range), *T. fosteriana* in Takhtakaracha pass (Zarafshan range), and some species of sect. *Lanatae* in the Surkhondaryo region are increasing year by year. According to our ethnobotanical survey, about 5,000-7,000 tulips were sold daily in 2021 at Kamchik pass from mid-March to mid-April.

Overgrazing

Overgrazing is the main negative factor affecting species of *Tulipa*, since it does not allow the species to complete their reproductive cycle and usually prevents the accumulation of nutrients in the bulbs for the next year's generation (Reynolds 2006). Livestock is a major source of income in rural areas and plays a key role in the economy of the country. It contributes 40% of the overall production of agricultural products. The unforested area of forest land is covered by 26.4% (2,979.9 thousand ha) of pastures (6th National Report of the Republic of Uzbekistan on conservation of biodiversity 2018). In January 2022, 23,623,700 sheep, 13,857,600 cows, and 269,100 horses were recorded in Uzbekistan (Statistics Agency under the President of the Republic of Uzbekistan 2023). According to our field surveys and observations, all species of tulips in Uzbekistan suffer from uncontrolled and unregulated grazing in areas ranging from foothills to alpine zones (3,650 m.s.l.). The impact of overgrazing on species of *Tulipa* is exemplified in Suppl. Fig. 5 for *T. intermedia.*

Other factors causing habitat loss and fragmentation

Infrastructure works and mining result in loss of habitat and fragmentation of *Tulipa* in Uzbekistan. One such example is a recently established solar power station in the vicinity of Galla-aral (Djizzakh region), which affected *T.*

affinis, *T. micheliana*, and *T. lehmanniana*. Also, in the vicinity of the foothills of Varzik and Gova villages (Chust district, Namangan region), where *T. intermedia* and *T. bifloriformis* occur, habitats have been partly destroyed because of mining (Suppl. Fig. 6).

We found that 14 species of *Tulipa* are undergoing the impact of fragmentation. Ten populations of *T. lanata*, 25 populations of *T. greigii*, 11 populations of *T. sogdiana* and 21 of *T. turkestanica* became fragmented in the last 30-40 years as a result of agricultural land use, mining and infrastructure works. Most affected by habitat fragmentation are *Tulipa* populations located in the plains, foothills and low mountains. The impact of anthropogenic factors on the species of *Tulipa* is summarized in Fig. 3.

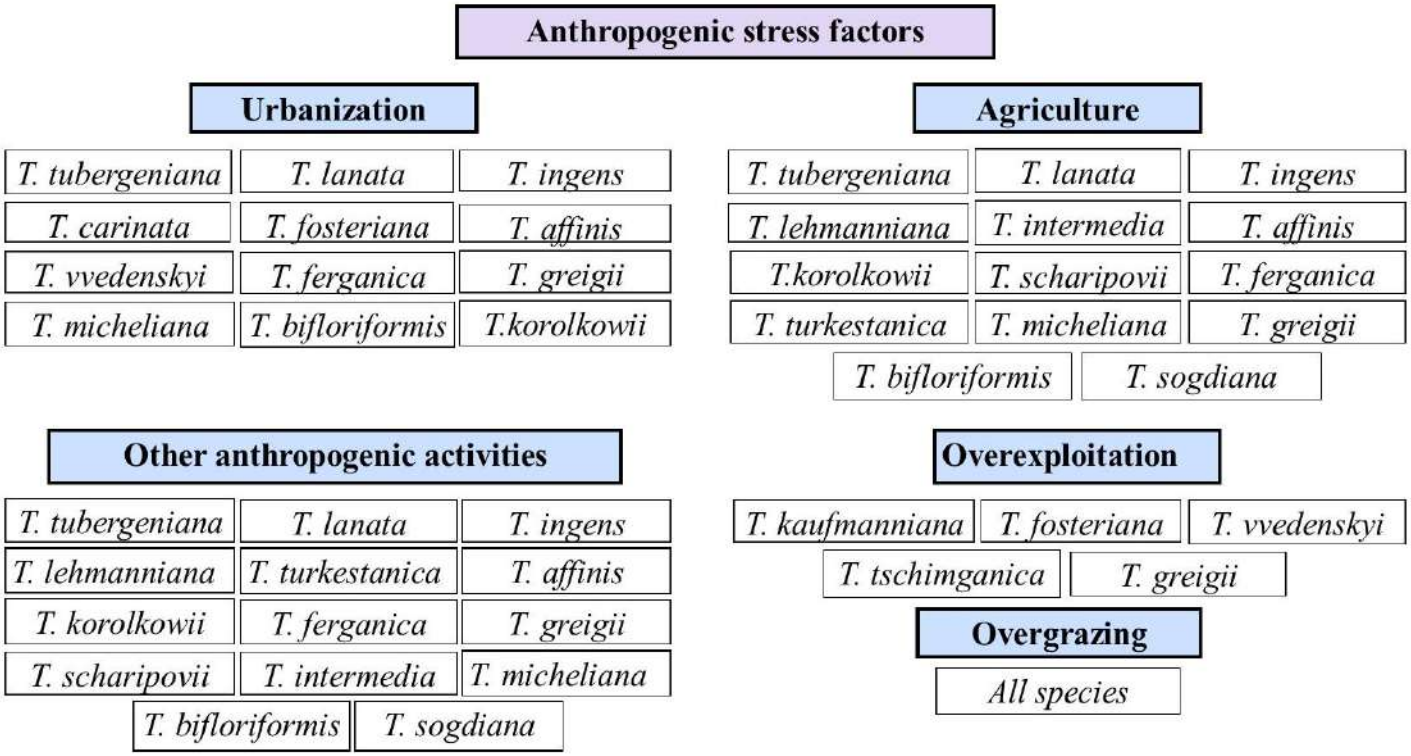

Fig. 3. Anthropogenic factors and their impact to species of *Tulipa*

The current state of Tulipa conservation in PAs of Uzbekistan

Area-based approaches are a crucial tool of biodiversity conservation. The National Strategy and action plan for the development of the PA system was one of the main priorities of biodiversity conservation in Uzbekistan. At present, the 48 PAs include 152 (47.4%) RDB species, and will be increased to 70% of threatened plant species (6th National Report of the Republic of Uzbekistan on conservation of biodiversity, 2018). The location of the protected areas in Uzbekistan is shown in Fig. 4.

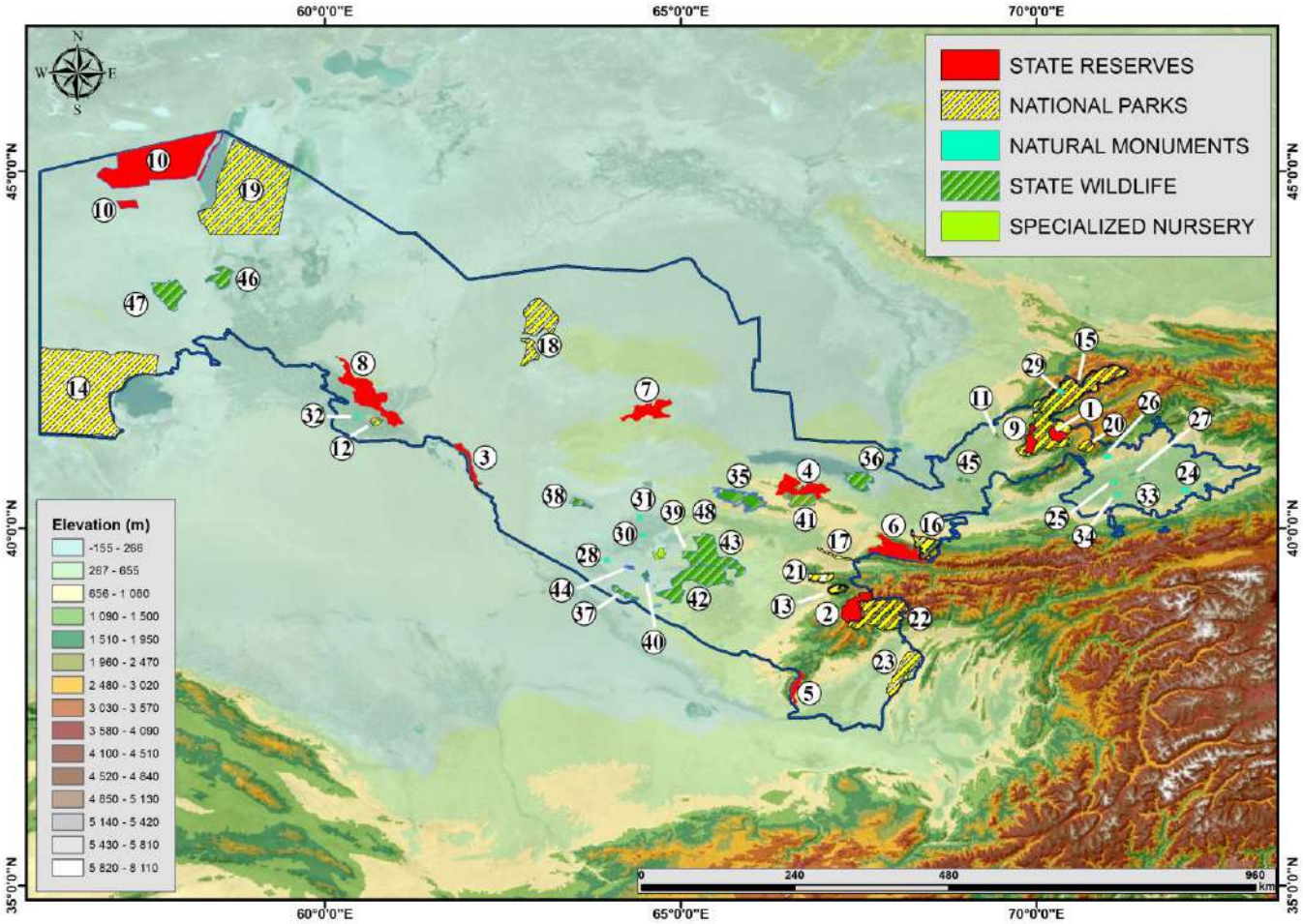

Fig. 4. Protected areas of Uzbekistan (the numbers in the figure correspond to those in Table 2).

The PAs of Uzbekistan cover 5,992,173.81 ha, which is 13.38 % of the country area. Most PAs belong to categories II and IV (13 and 14 respectively) and constitute 83.6% of the total area of PAs. Despite the large number, category III occupies only 0.063% of the total area of PAs. PAs are distributed in the administrative regions of Uzbekistan as follows: Bukhara – 8, Karakalpakstan – 6, Tashkent – 5 and Samarkand, Fergana, Navoi, Djizzakh – 4 PAs each; one region (Andijan) has no PA. According to the latest data (WDPA, 2022), the area of PAs of Uzbekistan is larger than in most neighboring countries (Afghanistan, Kyrgyzstan, Kazakhstan and Turkmenistan), but is smaller than the area of PAs of Tajikistan by approximately 1.7 times.

Approximately 8% (365 species) of the flora of Uzbekistan is endemic (Sennikov et al. 2016). The greatest endemic species richness is in the Nurata mountains (22 species) and the lowest is in the Zaravshan and Pskem ranges (2 species in each) (Fig. 5A). For *Tulipa*, the greatest number of endemic specis is in the Kurama Range (2 species – *T. intermedia* and *T. scharipovii*). One endemic species is in the Chatkal Range (*T. butkovii*), Hissar Range (*T. uzbekistanica*) and Surkhan-Sherobod foothills (*T. bactriana*) (Fig. 5B).

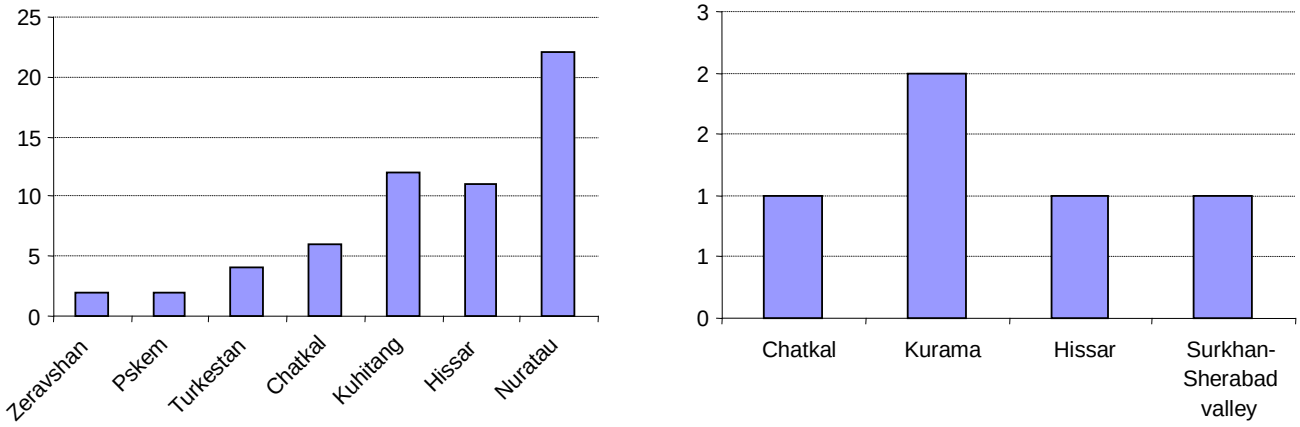

Fig. 5. Distribution of endemic species (A) and species of *Tulipa* (B) in different mountains ranges of Uzbekistan

About 60% of the red-listed species of the flora are not adequetly protected and 70% of the red-listed species are not protected in any PA or *ex situ.* Ugam-Chatkal SNP is considered a hotspot area for 49 red-listed species of the flora of Uzbekistan (Fig. 6A).

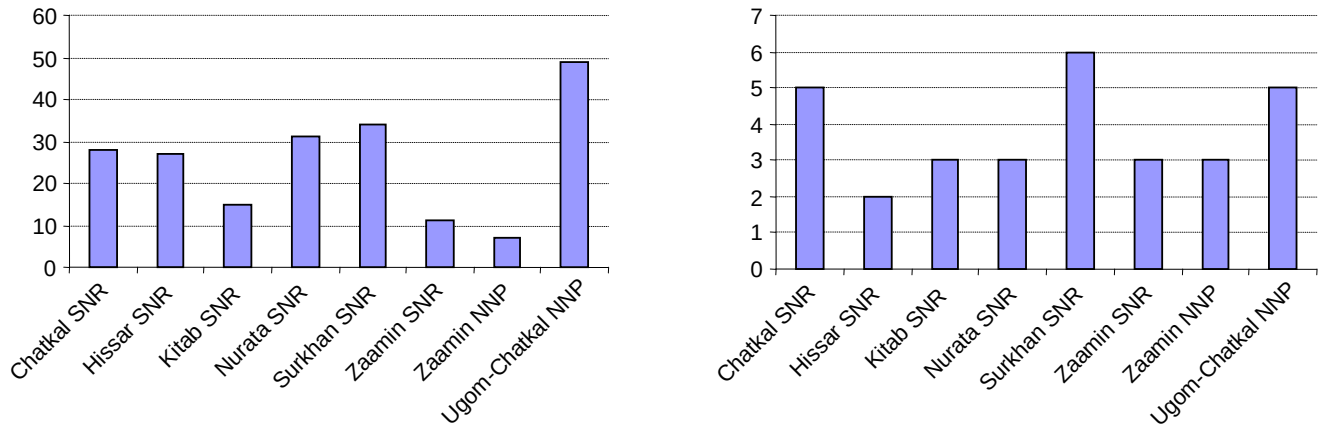

Fig. 6. Distribution of red-listed species (A) and species of *Tulipa* (B) in PAs of Uzbekistan.

Red-listed species of *Tulipa* can be found in Surkhan (6 species – *T. micheliana, T. korolkowii, T. lanata, T. tubergeniana, T. ingens, T. carinata*), Chatkal SNR and Ugom-Chatkal NNP (5 species each – *T. vvedenskyi, T. dasystemon, T. kaufmaniana, T. dubia, T. greigii*). Five red-listed species (*T. ferganica, T. orithyoides, T. uzbekistanica, T. scharipovii,* and *T. intermedia*) do not occur in any protected area. The highest concentration of

red-listed species of *Tulipa* is in the Kurama and Hissar ranges (8 species each) followed by the Kuhitang and Chatkal ranges with 7 and 6 species, respectively.

Currently, 26 species of *Tulipa* (78.7%) are protected in 7 state nature reserves and 2 state biosphere reserve. The spatial distribution of tulips in SNR and SBR is illustrated in Fig. 7. Hissar (9 species) and Surkhan (8 species) SNRs host the highest number of tulips. Ugam-Chatkal NNP and Chatkal SBR include 5 and 9 species, respectively. The distribution of tulips across seven SNNP is shown in Fig. 8. In total, nineteen species occur in NNP. The area protected by Ugam-Chatkal NNP was found to be a hotspot for *Tulipa* diversity (10 species).

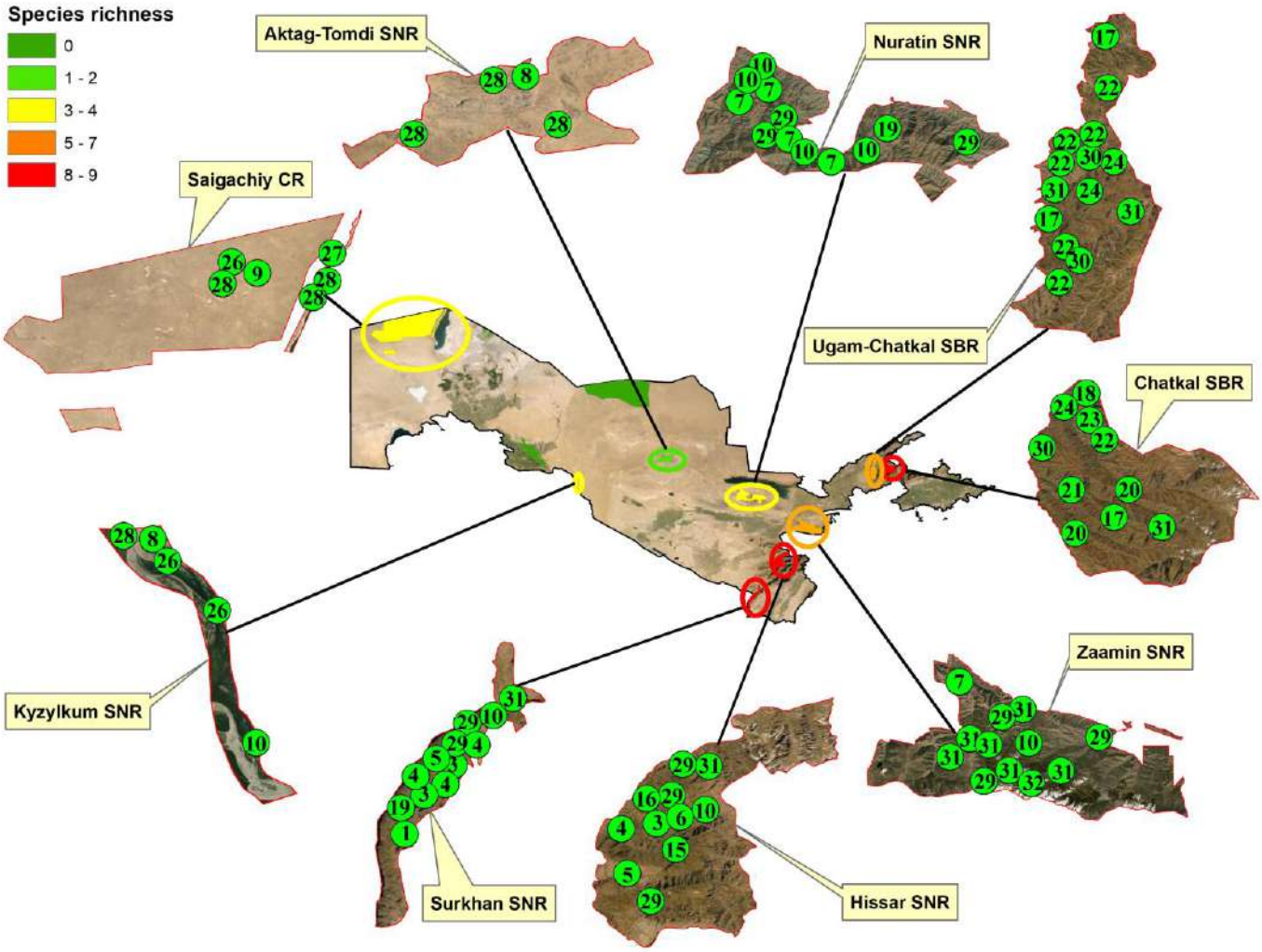

Fig. 7. Spatial distribution of species of *Tulipa* in State nature reserve and State biosphere reserve (the numbers in the figure correspond to those in Table 2).

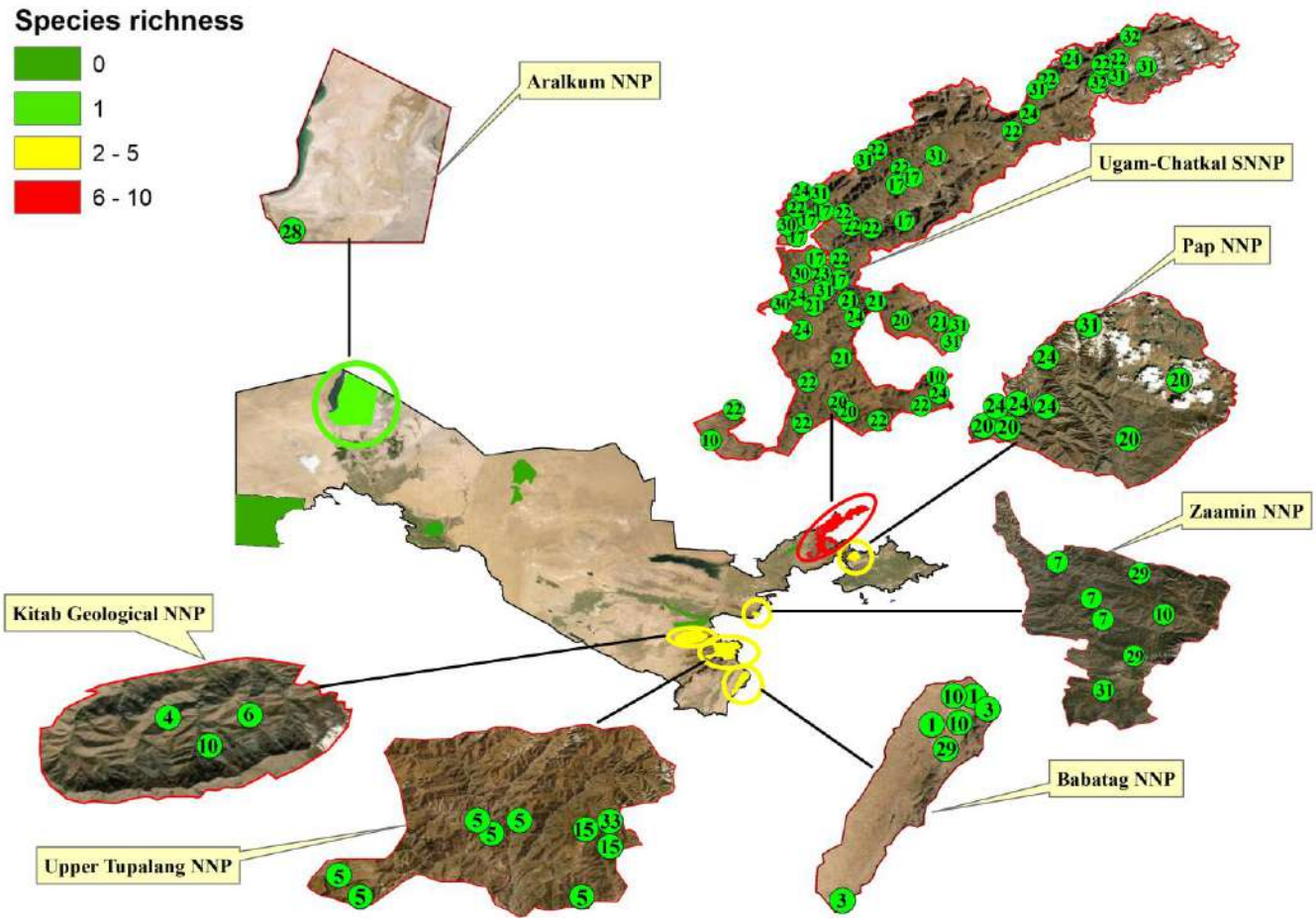

Fig. 8. Spatial distribution of *Tulipa* in NP (the numbers in the figure correspond to those in Table 2).

The role of 13 wildlife sanctuaries in the conservation of *Tulipa* is low. There are only four species in two PAs with the number of species ranging from 2 (Koshrabad SWS) to 3 (Aktau SWS). No species of *Tulipa* have been recorded in any natural monuments.

Discussion

The present study complements our previous work (Dekhkonov 2021) and clearly demonstrates that conservation of *Tulipa* in Uzbekistan must deal with a whole spectrum of negative impacts, both anthropogenic and environmental. Among the abiotic factors, aridification (decrease in precipitation and increase in temperature) has the most severe effect on tulip vegetation but currently its impact is limited mostly to the low-altitude areas, i.e. deserts and foothills. The effects of the other three biotic factors are species-specific, and although the latter factors affect to some degree 11 taxa, they do not cause a severe reduction in the size of *Tulipa* populations. On the contrary, anthropogenic impacts on *Tulipa* are widespread. The major threat is overgrazing, affecting all species at altitudes ranging from 50 to 3600 m s.l. The already high impact of urbanization, agricultural land use, mining and infrastructure development on *Tulipa* is rising too, as well as the collecting of some species for sale.

The majority of species of *Tulipa* are distributed in the eastern (western Tian Shan ranges) and southern (Pamir Alay ranges) parts of the country. Protected areas situated in those regions have high species richness. Species richness and diversity of *Tulipa* in the study area decreases from the central to the western part covered by the Kyzylkum desert and Aral seabed.

A proposal for a conservation strategy for Tulipa in Uzbekistan

The two currently existing conservation approaches are *in situ* and *ex situ*. However, we propose 'civic awareness' as an additional strategic component at the national level (Schwartz et al. 2000; Lindenmayer et al. 2006; Eigenbrod et al. 2009).

In situ conservation

Off-reserve management (Hale & Lamb 1997) is an approach gaining in popularity for biodiversity protection ranging from species to ecosystems (Torquebiau et al. 2009; Ervin et al. 2010). Only 12-13% of the Earth is covered by protected areas (Hunter & Heywood 2011), and a huge part of existing biodiversity is outside protected areas. Uzbekistan is no exception, and the existing PAs in Uzbekistan cover only a small part of the country. Five taxa of red-listed tulips of Uzbekistan are outside PAs, and their off-reserve management appears to be necessary.

Overgrazing imposes a huge negative impact on *Tulipa* populations. As a legislative solution, we propose a '*Phenology-based pasture*,' which bans domestic stock grazing during the period of growth of the species of *Tulipa* up to seed maturation in 27 phytogeographic districts. In the plains, the species of *Tulipa* flower from mid-March till mid-April, in the middle mountains from the last 10 days of March till mid-April. In the northern part of Uzbekistan species of *Tulipa* flower later (July) than in the southern part (from the middle to end of June). Fig. 7 shows the difference between irregular pasture and pasture-limited areas; Table 2 shows periods of recommended prohibition of domestic stock access for 23 phytogeographic districts. Also, we recommend for Uzbekistan the practice of rotating pasture areas with rare and endangered species to allow natural regeneration, a practice successfully used in Armenia (Hunter & Heywood 2011).

Inclusion of species in national and international red lists

Creation of Red Lists is a common legislative approach in conservation. To date, 5 editions of the RDB of Uzbekistan have been published since 1984. The number of red-listed species has gradually increased due to the discovery of new species and to an improvement in our knowledge of species' ranges and assessments of population sizes. The latest edition (Khasanov 2019) includes 314 endangered species; *Astragalus* (34 species), *Cousinia* (20 species), *Tulipa* (19 species), *Allium* (14 species) and *Eremurus* (12 species) are the most represented genera.

Threat categories in RDB of Uzbekistan (from 0 to 4) roughly correspond to the extinction risk categories of IUCN. According to analysis of distribution patterns and populations states of the species, we recommend the inclusion of 3 species (*T. borszczowii, T. hissarica, and T. korshinskyi*) in the forthcoming issue of RDB of Uzbekistan.

Privatization of hotspot zones

Identification of hotspot areas as priority areas for protection has been widely applied throughout the world (USA, Canada, Mexico, South Africa, some Latin and Caribbean Sea countries). For example, The Nature Conservancy (USA) and the Mexican Pronatura Noreste after identification of such areas purchased a 7,000-acre territory within the identified hotspot and conserved 77 endemic species successfully (Hunter & Heywood 2011).

The effectiveness of the privatization process depends on sustainability of the economy (Economist, 2013; Squires, 2013) and strong property of rights

(Norton-Griffith, 2007). Uzbekistan is a fast-developing country, and privatization of hotspot areas for protection in microreserves is promising, since microreserves require less conservation effort, minimized financial costs and high responsibility of the landowners. In 1992, the Legislative Assembly of Costa Rica approved the designation of private wildlife reserves which require landowners to develop and complete a government-approved management plan. A similar approach has been experienced in South Africa (The Cape Nature Stewardship Programme), and involves the conservation of biodiversity at long-term and mid-term levels, as well as within undefined periods (Hunter & Heywood 2011). Considering the absence of such an experience in Uzbekistan we recommend the implementation of the sequence represented in Fig. 9.

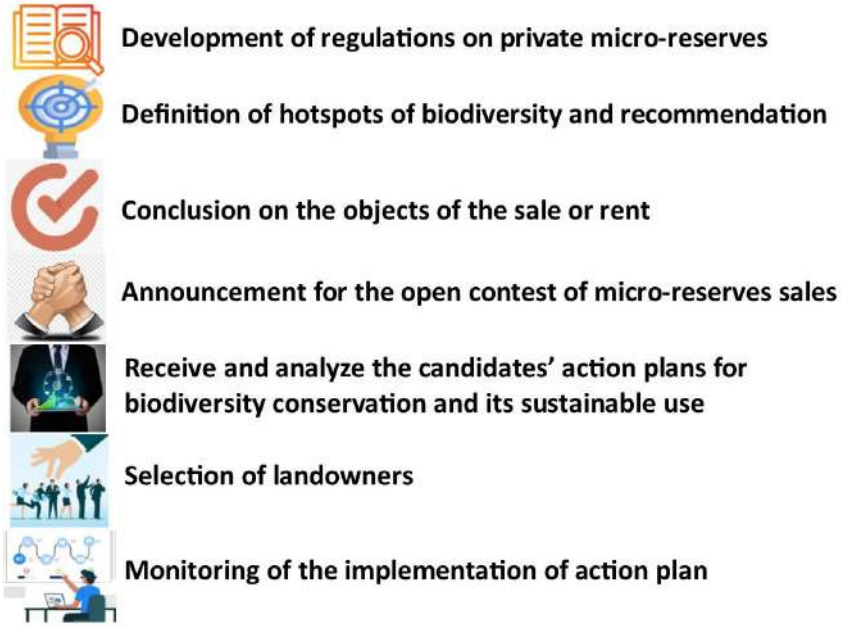

Fig. 9. Sequence of privatization process of hotspots

Such privatized zones should be established in the Chimgan mountains (*T. kaufmanniana, T. dubia, T. tschimganica, T. korolkowii, T. gregii, T. butkovii,* and *T. bifloriformis*) in the Tashkent region, Chaknak and Bakhcha villages (*T. lanata, T. ingens, T.carinata*) in the Surkhondaryo region, Imam-Ata mountains and the hills of the Bogishamol recreation areas (*T. ferganica*, *T. turkestanica*).

Home garden conservation

This approach can be implemented under both *in situ* and *ex situ* conditions (Suppl. Fig. 8): *in situ* home garden is a fenced and managed area established by an owner in the natural habitat of a species. In contrast, *ex situ* home garden is an area outside the natural habitat of a species with artificial conditions. During our field surveys and ethnobotanical investigations, we found that *in situ* home gardens exist for *T. tubergeniana* (Pashxurt village, Surkhondaryo region), *T. intermedia* and *T. bifloriformis*

(Gova village, Namangan region), *T. lehmaniana* (Navoi region, Kyzylkum, vicinity of the experimental field of the Institute of Botany); *ex situ* home gardens for *T. ingens* (Omonkuton, Samarkand region) and *T. tubergeniana* conserve around 1,000 individuals. Also *T. fosteriana* is grown both *in situ* and *ex situ* in home gardens in Ayakchi, Taragay, Langar, and Gaukhana villages (Kitab district, Kashakadaryo region), where over 50 home gardens provide protection for nearly 10,000 individuals.

Area-based conservation: Recommendation for micro-reserves

Small-scale plant protected areas were first proposed by Emilio Laguna (1995). The first micro-reserve was established in Spain in 1997. In the following 11 years, 273 micro-reserves for plants were established for conservation of 1,625 species (Laguna 2004). Micro-reserves are gaining in popularity worldwide (Saunders et al. 1991; Turner and Corlett 1996; Heywood 1999; Volis 2016). Studies to identify important plant areas where micro-reserves can be established was begun recently in Uzbekistan (Tojibaev et al. 2022b; 2023). The recommendations regarding such areas for species of *Tulipa* are presented below. The criteria for recommendations are from Recommendations for Expanding the System of Protected Natural Areas of Uzbekistan (2012).

1. Arbagish foothills

Location: the foothill is situated in the northeast of Chartak district (Namangan region). The area is located at the following coordination: northern part - 41.275009°, 71.875056° and 41.280410°, 71.903407°; the eastern part - 41.280410°, 71.903407° and 41.245315°, 71.902604°; the western part - 41.275009°, 71.875056° and 41.250845°, 71.876112°; 41.244529°, 71.881040° and 41.240570°, 71.890211°; the southern part - 41.240570°, 71.890211° and 41.243283°, 71.903479°.

Uniqueness. In the recommended area there are 8 taxa with the category Aii, 10 species with the category Aiii and 11 species with the category Aiv by IUCN. Such red-listed species of tulips as *T. scharipovii*, *T.intermedia* (Uzbekistan) and *T. bifloriformis* (Tajikistan) occur in these foothills.

Presence of endangered species. There are 4 RDB of Uzbekistan, 3 and 2 species included in RB of Kyrgyzstan and Tajikistan, respectively.

Naturality. The area is in a transboundary region with Kyrgyzstan and has low anthropogenic pressure. However, in the past 5 years the impact of land use and overgrazing has increased.

Threats. The main threat to the vegetation of this area is overgrazing. The degree of threat is low due to the protection of this areaa by military forces till 2020 as the boundary region.

2. Jiydalisay of the eastern Chap badlands

Location: the foothill is situated in the eastern part of Chap badlands (Chartak district, Namangan region) surrounding of Jiydalisay water reservoir. The area is located at the following coordinations: northern part - 40.915446°, 70.860274° and 40.911341°, 70.884798°; the eastern part - 40.911341°, 70.884798° and 40.872573°, 70.938081°; the western part - 40.859957°, 70.846946°; 40.885506°, 70.838723° and 40.892862°, 70.840619°; the southern part - 40.866930°, 70.935856°; 40.854685°, 70.879590° and 40.853228, 70.854554.

Uniqueness. In the recommended area there are 8 taxa with category Aii, 10 species with category Aiii and 11 species with category Aiv based on IUCN criteria. Red-listed species of tulips such as *T. scharipovii*, *T.intermedia* (Uzbekistan) and *T. bifloriformis* (Tajikistan) occur in these foothills.

Presence of endangered species. 7 red-listed species, 5 endemic and 12 sub-endemic species of Uzbekistan are recorded for this area.

Naturality. The area has a low pressure from anthropogenic factors.

Threats. The main threats to the vegetation of this area are overgrazing,

fragmentation, and land use, which have all increased in the last 5 years.

3. Dalverzin Steppe

Location: the area is situated in the central part of Bekabad district (Tashkent region). The area is located at the following coordinates: northern border - 40.4914°, 69.16825°; 40.49375°, 69.1862°; 40.49°, 69.1855°; 40.48976°, 69.193535°; 40.4859°, 69.1952°; 40.4845°, 69.20348°, and 40.4834°, 69.212763°; the eastern border - 40.481713°, 69.21294°; 40.48119°, 69.20826°, and 40.471678°, 69.210363°; the western border - 40.489814°, 69.16898°; 40.48967°, 69.1717°; 40.48474°, 69.175623°; 40.47796°, 69.176772°; 40.476839°, 69.176045°; 40.47463°, 69.18014°; 40.470157°, 69.18277° and 40.46377°, 69.181224°; the southern border - 40.4639°, 69.18387°; 40.46745°, 69.18329°; 40.46903°, 69.19194°; 40.467456°, 69.192624°and 40.4679°, 69.20556°.

Uniqueness. This is the last remaining undeveloped plot of natural ecosystem of relict sandy desert covered with typical psammophytic and halophytic vegetation in the Uzbek part of the middle reaches of the Syrdarya River. At present, almost the entire area of the Tashkent oasis and the so-called Dalverzin Steppe represent anthropogenic landscapes (irrigated croplands and settlements).

Presence of endangered species. One species is included in the RB of Kazakhstan, recommended for inclusion in RDB of Uzbekistan (*T. borszczowii*).

Naturality. The area is situated among irrigated croplands (rice, wheat and cotton), about 3–4 km of villages. The impact of anthropogenic factors is high.

Threats. The main threats to the vegetation of this area are overgrazing, collection of firewood and development of sand quarries. The degree of threat is high. If no protection measures are undertaken, the last plots of relict sands will be completely destroyed in the future.

We recommend some areas where red-listed species of *Tulipa* occur: the east and west part of Sangartak waterfall (*T. tubergeniana*, *T. ingens*, *T. lanata*), the foothills of Rabot village (Baysun, Surkhondaryo) (*T. korolkowii*, *T. tuberganiana*), and Tally Pass (Kashkadaryo region) where critically endangered *T. uzbekistanica*) grows.

Effective management

Monitoring and control of large-scale conservation zones requires a huge labor force and financial support. In addition, the development of animal husbandry and ecotourism in Uzbekistan are negatively influencing biodiversity within protected areas. One of the most effective solutions to the problem is to develop a management system for the Pas. Our suggestions for effective management are presented below:

Absence of fixed boundaries. The establishment of fixed boundaries is a tested experience for Uzbekistan. The pastures in the vicinity of Chatkal State Reserve had a remarkable destructive impact on the natural vegetation in 1948. The government completely prohibited pasture activity in 1956 and established boundaries between the reserve area and villages. After 30 years (in 1985) the difference in vegetation cover and species richness between the protected area and village became clearly visiable. Recovered populations of *T. greigii* and *T. tschimganica* were observed in the vicinity of Kukar village (Krasovskaya 1986). Thus, we suggest establishment of boundaries between the PAs and populated areas.

Training of specialists. The morphological appearance, especially in the variety of tepal colors, in *Tulipa* can confuse specialists as the result of hybridization. Hybridization can be easily observed in the Kurama mountains, which are a hotspot for tulip distribution. In the southern part of the Chap badlands, in the eastern part of the Kurama range located in the Kamchik pass and Betagalik mountains, there are different color forms of tulips that resulted from inter- and intra-specific hybridization. For example, there are 4 types of tepal colors of *T. intermedia*

(intraspecific) in the Chap badland (Suppl. Fig. 9), 3 colors of *T. vvedenskyi* and *T. talassica* (intraspecific) in Kamchik pass, and 3 colors of *T. dubia* and *T. vvedenskyi* (inter and intraspecific) in Betagalik mountains. Krasovskaya and Levichev (1986) observed interspecific hybridization in the middle belt of the Chatkal Range (Chimgan Mt.), where *T. kaufmanniana* with white or yellow tepals contacted *T. tschimganica* and became polychromic (Suppl. Fig. 10).

The correct identification of species/populations that are the result of hybridization is important for conservation decision-making. For example, white and yellow forms with a red blotch in *T. kaufmanniana* (Suppl. Fig. 10A and 10C) can be found in the Kurama range, where yellow forms of the species is intensively harvested (Fig. 6). Because the Red Data Book of Uzbekistan (Khasanov 2019) describes only the white form of *T. kaufmanniana*, this results in overexploitation of the yellow form. As a solution to the above problems, we recommend organizing workshops on plant morphology, distribution patterns and conservation issues for conservationists, and the inclusion of photos of both forms (white and yellow) of *T. kaufmanniana* and other similar cases.

Summarizing all the conservation actions presented above, a conservation strategy for species of *Tulipa in situ* was developed (Fig. 10).

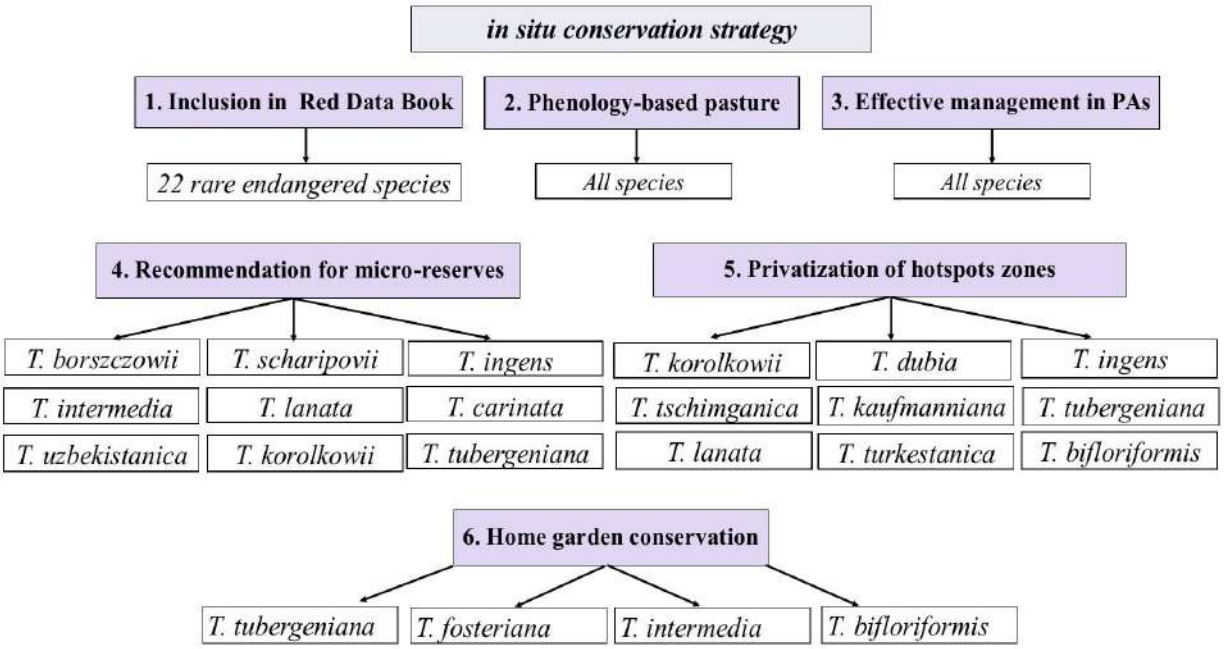

Fig. 10. *in-situ* conservation strategy of species of *Tulipa* in Uzbekistan.

Ex situ conservation: *Botanic garden conservation*

The Tashkent Botanical Garden has in its collection 2,394 plant species. Over 60 species of *Allium*, 16 species of *Eremerus* and 33 species of *Tulipa* of Central Asia are conserved in the recently created (2017) Global Monocot Center. It was a great challenge of recreation of Botschanzeva's garden (Suppl. Fig. 11). Nowadays the Center has more than 50 species of *Tulipa* (Suppl. Fig. 11B, C, D). It is important to note that the creation of BGs in different regions of Uzbekistan is more important than ever, because the number of threatened species is constantly growing and one BG cannot provide appropriate habitat for every endangered species. Thus, we

recommend the establishment of new BGs in several regions of the country. In this context, the Kokand BG has been a pioneering experience. It harbors 68 species (62 genera, 47 family) of decorative trees and shrubs. We recommend establishing a living collection of the species of *Tulipa* distributed in Ferghana valley.

Seed storage and DNA storage conservation

The Institute of Botany of the Academy of Sciences of Uzbekistan has in its seed bank 1232 plant species, including 23 species of *Tulipa* (Pechenitsyn 2020) from Uzbekistan. Additionally, DNA material of 19 species of tulips is barcoded in Barcode of Life Data System (2023) and cryopreserved.

In vitro conservation

Micropropagation can be indispensable means for cloning and multiplication of material through induction and multiplication of shoots. Currently, *in vitro* protocol has been developed for *T. fosteriana* and *T. ingens* from Samarkand region (Shukrullozoda et al. 2022).
Particular forms of ex situ conservation and number of species of *Tulipa* to which they were applied are shown in Fig. 11.

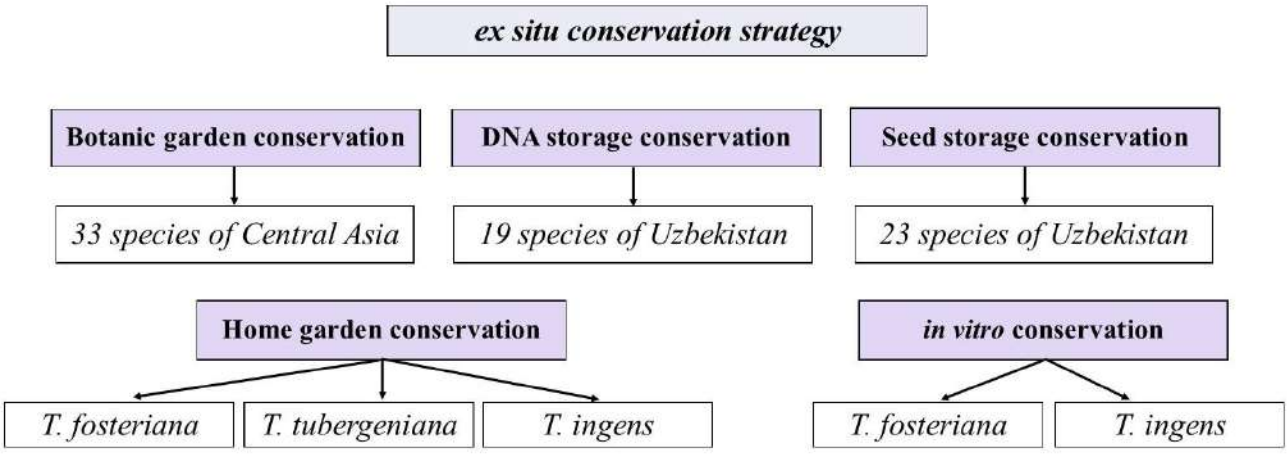

Fig. 11. *Ex situ* conservation of *Tulipa* in Uzbekistan

Civic awareness

Civic awareness is considered one of the most important conservation strategies (Ashraf 2012), given that all conservation actions depend on human will. The current state of civic awareness in the conservation of biodiversity in Uzbekistan is described below:

Legal-regulatory framework

The legal-regulatory system of the country can be divided into 2 parts: the 'Portal for the discussion of the projects of normative legal acts' (2022) and the 'National Database of Legislation of the Republic of Uzbekistan' (2023), which includes all approved documents. Biodiversity conservation and environmental protection require strict adherence to the rules of the normative documents. Criminal liability for the violation of regulatory documents is an effective measure in fighting illegal collection of endangered plants and habitat damage. For example, the relevant role of illegal collection (59.6%) and damage to habitats (22.8%) was identified during 2010-2018 (Environmental Performance Review, 2020). The Resolution of the Cabinet of Ministers (2014) provided a

legislative basis for the sustainable use of biodiversity in Uzbekistan. The regulation includes the use of resources of the flora and fauna, export of raw materials, licensing procedure, calculation of penalties and compensation for the results of illegal activities.

Environmental pedagogy

Environmental pedagogy includes education in the sphere of environmental protection, biodiversity conservation and the upbringing of youth from an early age in the spirit of nature conservation. These issues are an important part of civic awareness (Kassas 2002; Volis 2016).

The positive results of the environmental pedagogy can be seen in the experience of Israel which was launched in the 1960s (Volis 2016). Therefore, some regulatory documents were released by the Uzbek authorities for the development of an environmental culture among youth. We consider environmental pedagogy in Uzbekistan (Law of the Republic of Uzbekistan on Education 2020) to be an integral part of the proposed conservation strategy.

According to 'Law of the Republic of Uzbekistan on Education' (2020), the first stage of the education system is pre-school education through 36 to 108-hour of training aimed at appreciation of nature and protection of the environment by children. After realization of the educational program 'Ilk qadam – First step' (State Educational Program of the Pre-school Organizations 'Ilk qadam' 2018) ecological education is provided in some classes ('Introduction to the surrounding world,' 'Experiments - science' and 'Introduction to nature') using role-playing games, excursions etc. Also, every pre-school organization possesses 'Place of nature' where children take care of plants, animals and biodiversity habitats at a small scale.

The second step is ecological education that involves 6-7 to 9-10-year-old children provided by the classes 'Surrounding world,' 'Introduction to nature' and some encyclopedic knowledge for pupils. The next step is vocational education for the protection and caring for nature and its resources carried out through classes in botany, zoology ecology, geography, chemistry and biology. Climate change issues, observation and recognition of plants and animals are conducted in the frame of extracurricular activities.

By the initiative of the President of the Republic of Uzbekistan, faculties of Ecology were established in the countriy's universities. The leading higher education organization in environmental education is the National University of Uzbekistan with a special faculty (Faculty of Ecology) and all the state universities possess departments related to ecology, environmental protection and conservation of biodiversity. Advanced courses will be tought in the postgraduate education.

Environmental awareness

The experience of some plant conservation projects conducted in Uzbekistan and other countries can be adopted for *Tulipa* conservation, e.g. '100 Fields for Biodiversity' (2022) for the conservation of wild arable plants launched in Germany and 'Green land' afforestation project initiated in 2021 in Uzbekistan. Summarizing the above-mentioned experiences, we recommend to launch 'Tulip fields for conservation' programs in hotspot regions of *Tulipa*, such as Chap badland (Namangan), Kamchik pass (Namangan), southern part of Kurama range (Tashkent region), vicinity of Sangardak (Surkhondaryo region), Nurata relict mountains (Djizzakh region) using integrated *ex situ* and *in situ* approaches (Volis 2016). Summarizing conservation approaches for species of *Tulipa* in Uzbekistan, the following conservation strategy is proposed (Fig. 12).

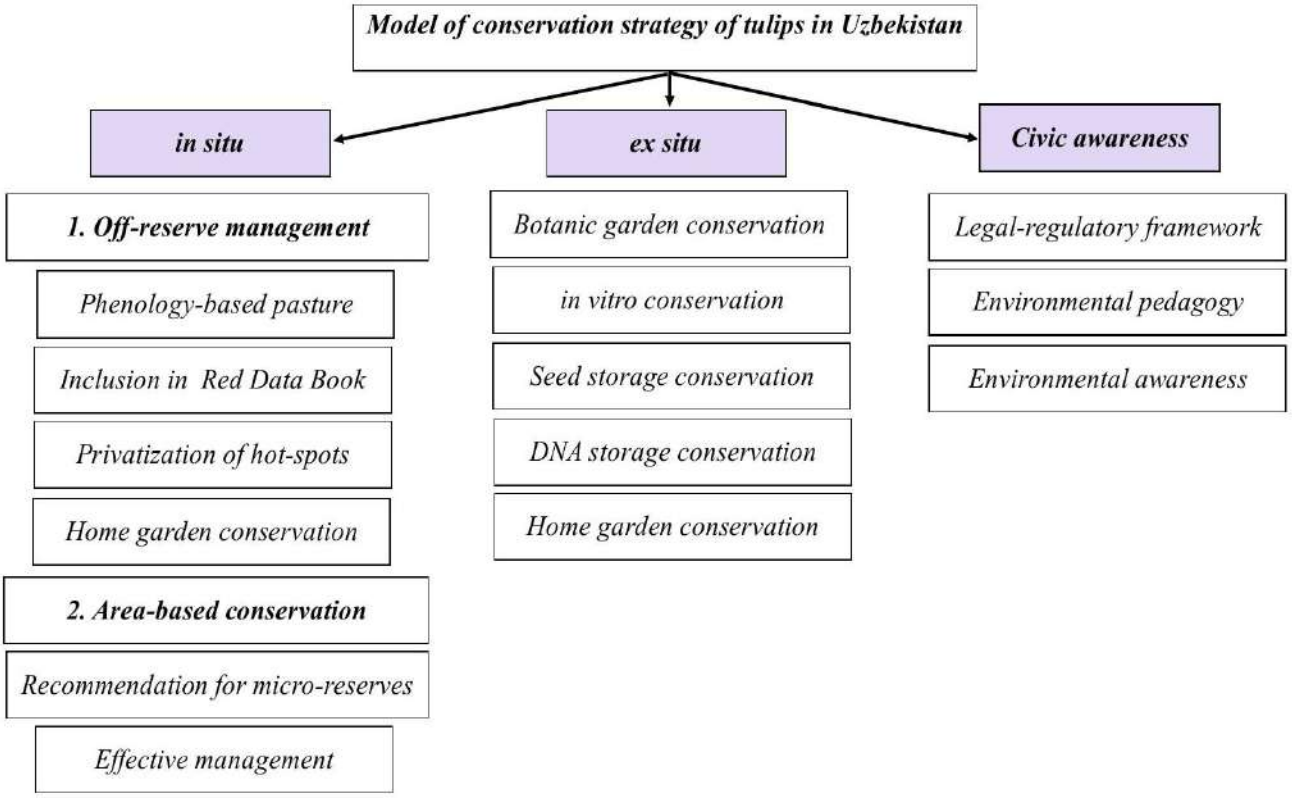

Fig. 12. Model of conservation strategy for *Tulipa* in Uzbekistan

Conclusions

1. According to field surveys and literature reviews, the impact of the anthropogenic factors on wild tulips in Uzbekistan is very high. Especially detrimental is overgrazing across all zones of the study area, but also urbanization and agriculture at lower elevations (Fergana valley, Tashkent, Surkhondaryo and Kashkadaryo regions).
2. The existence in Uzbekistan 48 protected areas protect only 27 species of tulips (82%) in 19 PAs, while 8 species, of which 5 are red-listed grow in unprotected areas.
3. The in situ and *ex situ* strategies involve six and five particular forms, respectively, applicable for Uzbekistan. Civic awareness is presented as an additional conservation strategy for the first time, which may become a crucial aspect for *Tulipa* protection. Another innovative conservation component is 'Phenology-based pasture' in different geographic ranges.
4. Three endangered and declining species (*T. borszczowii, T. hissarica, T. korshinskyi*) are recommended for inclusion in the new edition of RDB of Uzbekistan.
5. Six and five hotspot areas are recommended for micro-reserve establishment and privatization, respectively. The experience of China (Qiang 2015) can be applied in privatization processes in the Chimyon mountains (Tashkent region), the vicinity of Chaknak and Baxcha villages (Surkhondaryo region), Imam-Ata mountains and the hills of the Bogishamol recreation areas in the Andijan region which have no protected areas. Botanico-geographical characteristics of 3 hotspot areas for micro-reserve establishment are provided.
6. We recommend establishing sister botanical gardens in different regions. 'Home garden conservation' is a most perspective and effective tool for the conservation of *Tulipa*

both in situ and ex situ. Also, we recommend the declaration of a 'Tulips days' in Uzbekistan. 7. The civic awareness processes in Uzbekistan can be considered satisfactory. However, it is necessary to control the impact of anthropogenic factors and increase the responsibility of each citizen for biodiversity conservation.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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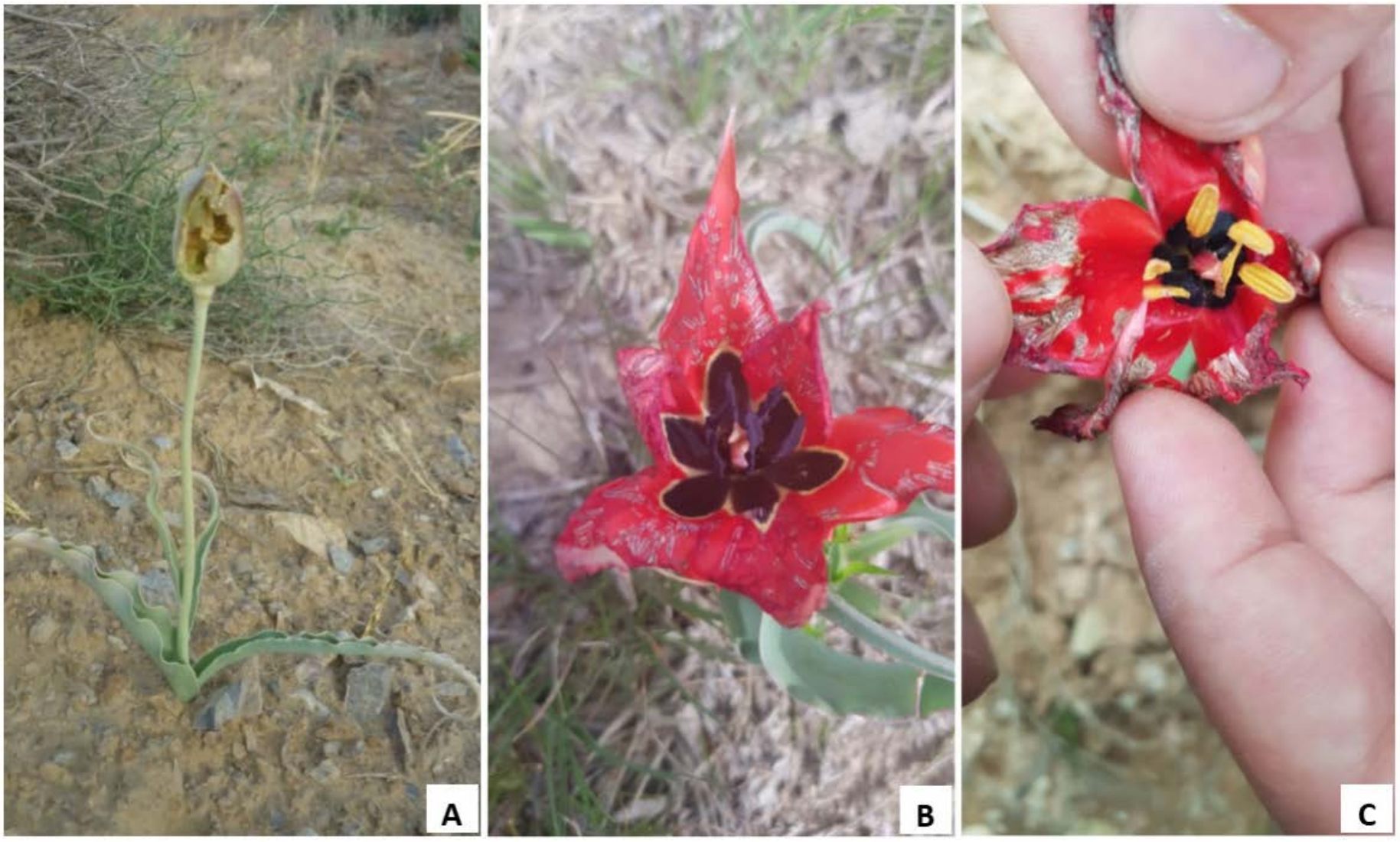
Supplementary files

Suppl. Fig. 1. Water deficient condition of *T. buhseana* (A) and floodwater habitat (B) of *T. borszczowii* (photos by Davron Dekhkonov 2021).



Suppl. Fig. 2. Impact of biotic factors on species of *Tulipa*: A – *T. lehmanniana*, B – *T. tubergeniana*, C – *T. ingens* (photos by Davron Dekhkonov 2021).

Suppl. Fig. 3. Agricultural activities in natural habitats of species of *Tulipa*. A. Natural habitat of *T. tubergeniana* and *T. korolkowii.* Vicinity of Rabot village, Baysun, Surkhondaryo region. B. Natural habitat of *T. ferganica* and *T. turkestanica*. Arbagish foothills, Chartak, Namangan region (photos by Davron Dekhkonov 2021).

Suppl. Fig. 4. Overexploitation of species of *Tulipa* (*T. vvedenskyi* and *T. kaumanniana*) in Kamchik pass (photo by Davron Dekhkonov 2022)

Suppl. Fig. 5. The impact of overgrazing on species of *Tulipa* (photos by Davron Dekhkonov 2023)

Suppl. Fig. 6. Habitat loss of *T. intermedia* in the vicinity of Gova village (photos by Davron Dekhkonov 2023)

Suppl. Fig. 7. The difference between irregular and pasture-limited areas during blooming period of species of Tulipa in the Chap badlands (photos by Davron Dekhkonov 2023).

Suppl. Fig. 8. Home garden conservation of species of *Tulipa* in situ (A, B) and ex situ (C) (integrated) conditions (photos by Davron Dekhkonov 2023).

Suppl. Fig. 9. Different colors of tepals (A - yellow, B polychromic, C - orange, D red) of *T. intermedia* from Chap badlands (photos by Davron Dekhkonov 2021)

Suppl. Fig. 10. Results of interspecific hydridization of *T. kaufmanniana* and *T. tschimganica*. A- *T. kaufmanniana*, B- *T. tschimganica* and C- *T. kaufmanniana* (photos by Komiljon Tojibaev and Dovron Dekhkonov)

Suppl. Fig. 11. View of Botschanzeva's tulip exposition (A) and newly established tulip garden (B, C, and D) in Tashkent Botanical Garden

Table 3. Phenology and distribution patterns of species of *Tulipa* in botanic-geographic regions of Uzbekistan

№	B-G districts	Species richness	RDB species	Foothill	Blooming Phenology	Middle mountain	Blooming Phenology	Alpine	Blooming Phenology
I. Central Asian Mountain Province									
	I-1 Western Tian-Shan region								
1.	Ugam-Pskem	6	4			*T. greigii* *T.kaufmanniana*	Flowering: last decade of III, fruiting: mid till IV	*T. dubia* *T.dasystemon*	Flowering: mid VII, fruiting: mid and end of VII
2.	Western Chatkal	9	5			*T. greigii* *T. vvedenskyi* *T.kaufmanniana*	Flowering: last decade of III, fruiting: till mid IV	*T.dubia* *T.dasystemon*	Flowering: mid VII, fruiting: mid and end of VII
3.	Arashan	2	2					*T.dubia* *T.dasystemon*	Flowering: mid VII, fruiting: mid and end of VII
4.	Kurama	9	6			*T. korolkowii* *T. greigii* *T. vvedenskyi* *T.kaufmanniana*	Flowering: mid III and IV, fruiting: V	*T.dubia* *T.dasystemon*	Flowering: till mid VI, fruiting: till the end of VI
5.	Chorkesar	6	5	*T. scharipovii* *T. intermedia*	Flowering: mid III, fruiting: 1st decade of VI	*T. korolkowii*	Flowering: till mid VI, fruiting: last decade of VI	*T.dubia* *T.dasystemon*	Flowering: till mid VI, fruiting: till the end of VI

6.	Tashkent	3	2			*T. korolkowii* *T. greigii*	Flowering: last decade of IV till mid V, fruiting: V		
I-2 Fergana region									
7.	South Chatkal	2	1			*T. ferganica*	Flowering III, fruiting VI		
I-3 Fergana-Alay region									
8.	Western Alay	1	1			*T. korolkowii*	Flowering: last decade of III till mid IV, fruiting: 1st decade of V		
9.	Eastern Alay	4	2			*T. ferganica*	Flowering: last decade of III till mid IV, fruiting: 1st decade of V	*T.dasystemon*	Flowering: till mid VI, fruiting: till the end of VI
I-4 Nuratau region									
10.	Nuratau	6	3			*T. affinis* *T. korolkowii* *T. micheliana*	Flowering: last decade of III, fruiting: till mid IV		
11.	Aktau	7	4			*T. affinis*	Flowering: last decade of III,		

						T. lehmanniana *T. korolkowii* *T. micheliana*	fruiting: till mid IV		
12.	Nuratau Relic Mountains	6	4			*T. affinis* *T. lehmanniana* *T. korolkowii* *T. micheliana*	Flowering: last decade of III, fruiting: till mid IV		
I-5 Kuhistan region									
13.	North Turkestan	6	4			*T. affinis* *T. korolkowii* *T. micheliana*	Flowering: last decade of III, fruiting: till mid IV	*T.dasystemon*	Flowering: till mid VI, fruiting: till the end of VI
14.	Malguzar	3	2			*T. affinis* *T. korolkowii*	Flowering: last decade of III, fruiting: till mid IV		
15.	Urgut	4	3			*T. ingens* *T. fosteriana* *T. korolkowii*	Flowering: last decade of III, fruiting: till mid IV		

16.	Ziadin-Zirabulak	3	2			*T. korolkowii* *T. micheliana*	Flowering: last decade of III, fruiting: till mid IV		
I-6 Western Hissar region									
17.	Kashkadaryo	6	4			*T. ingens* *T. korolkowii* *T. micheliana*	Flowering: last decade of III, fruiting: till mid IV	*T.dasystemon*	Flowering: till mid VI, fruiting: till the end of VI
18.	Tarkapchigay,	4	3			*T. korolkowii* *T. micheliana* *T. uzbekistanica*	Flowering: last decade of III, fruiting: till mid IV		
19.	Baysun	7	6	*T.tubergeniana*	Flowering: last decade of III, fruiting: till mid IV	*T. tubergeniana* *T. ingens* *T. carinata* *T. korolkowii* *T. micheliana*	Flowering: last decade of III, fruiting: till mid IV	*T.orithyioides*	Flowering: till mid VI, fruiting: till the end of VI
20.	Kuhitang	5	4	*T.tubergeniana*	Flowering: last decade of III,	*T. tubergeniana* *T. ingens*	Flowering: last decade of III,		

					fruiting: till mid IV	*T. korolkowii* *T. micheliana*	fruiting: till mid IV		
21.	Surkhan-Sherabad	4	2	*T. bactriana* *T.tubergeniana* *T. korolkowii*	Flowering: last decade of III, fruiting: till mid IV	*T. tubergeniana*	Flowering: last decade of III, fruiting: till mid IV		
I-7 Hissar-Darvaz region									
22.	Sangardak-Tupalang	7	5	*T.tubergeniana*	Flowering: last decade of III, fruiting: till mid IV	*T. tubergeniana* *T. ingens* *T. carinata* *T. korolkowii*	Flowering: last decade of III, fruiting: till mid IV	*T.orithyioides*	Flowering: till mid VI, fruiting: till the end of VI
I-8 Panj region									
23.	Babatag	4	3			*T. tubergeniana* *T. korolkowii* *T. lanata*	Flowering: last decade of III, fruiting: till mid IV		

II. Turan Province									
II-2 Middle Syrdarya region									
24.	Mirzachul	2	1	*T.borszczowii*	Flowering: mid III, fruiting: till mid IV				
II-3 Kyzylkum region									
25.	Kyzylkum	4	2	*T.lehmanniana* *T.korolkowii*	Flowering: mid III, fruiting: till mid IV				
26.	Kyzylkum Relic Mountains	4	2	*T.lehmanniana* *T.borszczowii*	Flowering: mid III, fruiting: till mid IV				
II-4 Bukhara region									
27.	Lower Zaravshan	2	1	*T.lehmanniana*	Flowering: mid III, fruiting: till mid IV				