Important characteristics and features of steppes within the Trans-Asian mountain belt (Pamir - Anadyr)

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Abstract. The steppes occupy an important place in the vegetation of Eurasia. The steppe biome of the continent, along with zonal types on the plains of Europe and Asia, is diverse and richly represented in the vegetation of the mountains of Asia. Among the latter, the most significant are the mountain systems of the Trans-Asian mountain belt (TAMB), stretched from the southwest to the northeast over a vast area from the greatest Pamir – Tien Shan mountain range to the Chukotka-Anadyr plateau in the zone of the Arctic tundra of Asia. The article provides a brief analysis of typological diversity, an overview and reflections on the steppes of boreal Eurasia, elongated in the mountainous zone of Asia in a wide geographical range both in latitudinal (37-67° N) and in longitudinal dimensions (72-163° E). They differ significantly in the mountains of various climatic sectors; they are especially pronounced in the floristic composition and phytocenotic structure of extrazonal steppe phenomena and in longitudinal vicariates – from the mountains of Central Asia to the subarctic of North Asia.

1. Introductions

The steppes occupy an important place in the vegetation cover and the structure of the zonation in the mountains of the Trans-Asian mountain belt (TAMB). This is due, on the one hand, to the confinement of many ridges and highlands of the mountain belt to the steppe zone, on the other, to the extrazonal position of the steppes both in the more southern (desert zone) and significantly northern territories (from the boreal forest zone to the subarctic) of the temperate zone of Asia.

Revealing the floristic and phytocenotic diversity of vegetation of the mountain steppes of the Palaearctic is a fundamental geobotanical problem. Steppe ecosystems of the mountain belt are surprisingly diverse, including both typical zonal and distinctive mountain types of steppes, phylogenetically related to real steppes. These are such types as tragacanth formations, friganoids, shibliak, ephemeral semi-savanna steppes. Their diversity shows the richness of the steppes of Asia as a whole.

The positions of the steppes in the systems of zonation and contrasting in structure landscape complexes differ significantly in the mountain ranges of Central Asia, Altai and Sayan, Transbaikalia and the Baikal region, Verkhoyan-Anadyr (table 1).
Table 1. Distribution features of the types of steppes within the Great Trans-Asian Mountain Belt (TAMB) : from the Pamir to the Anadyr highlands.

| Mountain systems | Sectors | Geographic coordinates, degrees north latitude and east longitude | H (m.) above sea level | Climatic modes |
|------------------|---------|---------------------------------------------------------------|----------------------|---------------|
| Types of steppes (florocenotypes) | Pamir - Tien Shan | Dzungaria - Altai | Sayan - Baikal region | Verkhoyan - Anadyr | | Mesothermal | Meso-microthermal | Microthermal | Hekistothermal |
| | | | | | | | 35 / 72 | 40 / 83 | 50 / 110 | 63 / 165 |
| 1. Tragacanth formations | | | | | | | 2500 | | |
| 2. Cryophytic steppes | | | | | | | 2000 | | |
| 3. Herbage Turf | | | | | | | 1000 | | |
| 4. Stepoids | | | | | | | 500 | | |
| 5. Meadow steppe | | | | | | | | | |
| 6. Shibliak | | | | | | | | | |
| 7. Friganoids | | | | | | | | | |
| 8. True steppes | | | | | | | | | |
| 9. Deserted steppes | | | | | | | | | |
| 10. Desert steppes | | | | | | | | | |
| 11. Ephemeral steppes | | | | | | | | | |

Notes. Climates: mesothermal (total heat / T / 3000-4800 degrees. Average annual temperature / t / + 17-25 degrees. Average annual precipitation / Precipitations / 180-760 mm.); meso-microthermal (T 1800-3200, t + 7-10 / - 5.1, Precs 180-450); microthermal (T 1200-1800, t - 2.5, Precs 300-500); hekistothermal (T 800-1200, t – 5-7, Precs 250-340).

Types of steppes: 1. – Tragacanth formations; 2. – Cryophytic steppes; 3. – Herbage turf (without feather grass); 4. – Stepoids; 5. – Meadow steppes; 6. – Shibliak (xerophyte shrubs); 7. – Friganoids (subshrubs of Lamiaceae); 8. – True steppes (with feather grass); 9. – Deserted steppes; 10. – Desert steppes (mountain, intermontane); 11. – Ephemeral steppes (half-savanna).
To a large extent, they depend on the location of ridges, uplands and intermontane basins in different geographical loci of TAMB, which can be subdivided, following Alphonse Decandole, into the following integral climatypes: mesothermal, meso-microthermal, microthermal and hekisto thermal [1], supplemented by the latest data on the mountains of Southern Siberia [2]. In all four geographical enclaves-onmords, the steppes are characteristic as a landscape-geographical and phytocenotic phenomenon, but in each of the 4 sector strips, the steppes occupy a certain place in the structure of the vegetation cover. Differences in the positions of the steppes in the climatic sectors are especially pronounced in the phytocenotic structure of extrazonal (latitudinal-longitudinal) steppe formations.

The aim of our study is to analyze the positions of typical steppes and distinctive types of mountain steppes and extrazonal steppe phenomena along the TAMB.

2. Materials and Methods
This study is based on the results of geobotanical and floristic studies of outstanding experts in the flora of the steppes of mountainous Central Asia and ultracontinental – North Asia, and the author's studies of the steppes of South Siberia, from Altai to the Baikal region, from 1975 to the present. Geobotanical studies of steppe vegetation were carried out in the mountains of Tuva, Southeastern Altai, the Baikal region and Transbaikalia. The volume of initial materials amounted to more than 2300 geobotanical descriptions, the number of landscape profiles and 12 medium and large-scale maps of vegetation of key areas. The studies covered all regional types of steppes characteristic of the Altai mountains, the Sayan-Baikal sector of the mountain belt of Southern Siberia (SS). They are predominantly characteristic in mountain massives of the semi-humid climatic facies of the SS; steppe vegetation dominates in intermontane basins, and along their periphery as part of the mountainous forest-steppe exposure. On insolated slopes, steppe communities penetrate into the forest belt and up to high mountains in the mountains with a semi-arid climate, where steppes constitute a background type in the landscapes of the mountains of South-Eastern Altai and South Tuva.

The names of vascular plants are given according to the Flora of Siberia [3].

3. Results and Discussion
First of all, it should be noted about our broad interpretation of the types of steppes. The concept "type of steppes" I include not only communities of herbal perennial microthermal xerophytic plants (turf grasses, sedges, onions), herb species – short-rhizome rosette polycarpics in the interpretation of E. M. Lavrenko et al. [4], and phyllocoenogenetic related types – distinctive florocoenotypes of mountain steppes. The latter widely and variably replace the sod-grasses (both feather-grass and non-feather-grass) steppes in the conditions of contrasting landscapes of the mountain systems of the Great orographic belt of Asia. They are especially well expressed in more southern latitudes from the strip of zonal steppes. So, in the Tien Shan and Pamir mountains, they are represented by cryoardid thorns (tragacanths), communities of xeromorphic deciduous shrubs on the breakdowns of bedrocks (shibliak), half-shrub xeropetrophytic groups (friganoids), and also half-savannah ephemera. Their relationship is so clearly and convincingly given by R.V. Kamelin [5]. So, when characterizing the vegetation of the Syrdarya Karatau, he noted that “in most of Karatau, there is essentially a single complex of vegetation, a characteristic element of which is the Iranian-Turanian friganoid vegetation of rocky slopes and plateaus, mountain steppes and partly mountain semi-savannas (ephemeral steppes) on fine earth and upper parts of sais, groupings of steppe shrubs (interspersed with shibliak elements), and belt forests of large gorges...”.

Depleted tragacanth formations are found in Southeastern Altai and fragmentarily in Tuva (Sailyugem, Chikhacheva, Yuzhno-Chuisky, Mongun-Taiga, and Tannu-Ola ridges), belonging to the group of semiarid vegetation types in Altai [6]. Here, they are represented by only one formation from Oxytropis tragacanthoides, with the inclusion of a number of cushion-shaped and often spiny biomorphs of the aciphylla, O. hystrix, and the curtain spreading hermit – Eremogone mongholica. In general, tragacanths in the vegetation of the Pamir-Alai belonged to the type of upland xerophytes [7], in the communities of which thorny cushion shrubs and dwarf shrubs dominated - oligo- and
mesothermal on skeletal and drained substrates, forming an independent belt. Species of the genera Acantholimon, Astragalus, Oxytropis, Ephedra, Scorzonera, etc. play a significant role in the coenocomplex of tragacanth steppes at altitudes over 3000.0 m.

Shibliak is peculiar as a type of steppes. Genetically, and structurally ecological-phytocenotic, it fits well into the subgynecosthermal-euxerophilic series of evolution of steppe florocenotypes [8]. The phylocenogenesis of the shibliak is associated with the mountain petrophytic arid vegetation of the Ancient Mediterranean [9]. In the dry woodlands of Tajikistan and the Dzhungarskii Alatau, in combination with petrophytic shrub groups, complexes of species from the genera Pistachio, Almond, Honeysuckle and Spirea are characteristic, forming communities of the shibliak. They are characteristic in the vegetation of the Pamirs and Tien Shan, where they are presented in the classical form [10, 11]. These coenocomplexes belong to the most ancient representatives of the vegetation of mountainous Central Asia, their ancestral types are known from the Oligocene fossil flora [12]. In the modern vegetation of the Pamir – Tien Shan mountain cluster, it is expressed in a wide range of heights – from the foothills (500-600 m) to the lower tier of high mountains, typical at heights of more than 2000.0 m (Table 1). Above, they are replaced by communities of cryophyte formations, forb-sod steppes at levels of 2500 m and more. Returning to the Shibliaks, it is necessary to note their physiognomic similarity with the thickets of petrophytic shrubs and shrub steppes in the Dzhungar-Alai sector of the TAMB [13], which were not considered Shibliaks because boreal elements predominated in the cenoflora of the communities. However, according to our studies in recent years, the specificity of shrub groups (drought-resistant, petrophytic and deciduous) of Altai – Tuva – Transbaikalia has been revealed [14]. In the Altai-Sayan-Pribaikalsky sectors of the TAMB, original shrub communities with the participation of tree species (in Transbaikalia with Ulmus pumila, in Tuva with Larix sibirica) are noted, which belong to the Shibliak Daurian or Kharganats, and the Tuva shibliak [15]. In the vegetation of the communities of the Tuva shibliak, marked within the boundaries of the belt of the mountain exposure forest-steppe in the spurs of the southern macroslope of the ridge. In Tannu-Ola, a series of specific shrub species such as Lonicera mycrophylla, Cotoneaster megalocarpus, Spiraea hypericifolia, which phyloecogenetically enter into a single complex of shibliak cenoflora in mountainous Central Asia, have been identified. Similarly, in the Daurian Shibliak coenocomplex, the original fraction consists of species of the genera Armeniaca, Rhamnus, Amygdalys, Ribes, and others belonging to the original hemeral complex of East Asia. Shibliak in the conditions of Tuva and Transbaikalia (Baikal region) are relic formations, distributed in fragments and in small areas at heights from 1100 to 1700 m on the Tannu-Ola and Sangilen ridges; in Transbaikalia at altitudes from 700 to 1200 m above sea level.

The type of Friganoid is original, which, like the shibliak, has mountainous Central Asia with its genetic center. We mentioned earlier about this type of steppes, which is of ancient Mediterranean origin [16] and their role in the diversity of the TAMB steppes. One thing is certain, that Friganoids have the greatest development in the mountains of Dzungaria and Tien Shan, rising to 2700 m and more in the Pamirs (table 1). At the same time, they as a type of vegetation were not unknown in the Altai, Sayan and Baikal mountains, except for insignificant fragments with a predominance of Ziziphora clinopodioides, Lagopsis marrabiastrum in the vegetation of the mountain-steppe belt in Southeastern Altai and the Mongun-Taiga mountain knot in southwestern Tuva. Species of the genera Thymus and Dracocophalum, phylloecogenetically related taxa in the floristic complex of the friganoid steppes of Asia, are characteristic of these peculiar groups of Altai-Tuvanian phryganoids (table 1).

Ephemeral steppes, which are also referred to as semi-savannas by Central Asian phytogeographers, stand out somewhat apart in the composition of the vegetation of TAMB [17, 7]. The type of ephemeral steppes is the lowest, basic level in the vertical differentiation of the steppe vegetation of the Pamir-Alai-Dzungaria from 600-700 m to 1000 m and more. These are steppes on sandy massifs of foothill plains and foothill-ridge landscapes, low and middle mountains. The coenotic complex of these steppes is composed of the distinctive types of psammophytic ecology – long-rhizome and sod-grass biomorphs, endjuveniles. In the composition of polycarpic cereals, original
forms stand out, such as the viviparous bluegrass *Poa bulbosa* [18], an amazing example of adaptation to the extremely dry and sandy substrate of the semi-savanna. In the Altai-Sayan sector of the mountain belt, they are extremely poorly represented, except for isolated finds of ephemeral steppe communities in the foothill parts of Western Altai at the transition to the belt forests of the West Siberian Plain [19]. Ephemeral steppes are similar in nature to the psammophyte or psammophytic variants of the true steppes [20]. However, the latter are genetically little related to the ephemeral steppes in both floristic and landscape-ecological relations. However, the latter are genetically little related to the ephemeral steppes in both floristic and landscape-ecological relations.

Further analysis of the diversity of the types of steppes in TrAzGP show different relationships in the distribution of classical types of mountain steppes, genetically related to their zonal analogues. These are real steppes (grass - feather-grass) and their mountain variants - herb-turf, often petrophytic (in the interpretation of P. N Ovchinnikov [12] – feather-free). This group is composed of original formations dominated by small sod grasses from the genera Festuca, Koeleria, Poa and especially species of the genus Helictotrichon (*H. altaicum, H. tianshanicum, H. mongolicum, H. krylovii*). The role of sheep steppes in the mountains of the Asian belt is especially great, with the greatest diversity traced in the southwestern largest orographic nodes - the Pamir and Tien Shan, further to the north-east it is noticeably weakening. So, in the mountains of the Altai sector, the coenocomplex of oat plants is composed of three species – *H. altaicum, H. mongolicum* and *H. sangilense* Krasnob. On the extreme northeastern fringing of TAMB – in the highlands of Anadyr and Chukotka, the genus is represented by only one endemic oat – *Helictotrichon krylovii*.

In the typology of the TAMB steppes, a peculiar place is occupied by the type of steppes - Stepoids (table 1). Stepoids as a type of vegetation are a boreal phenomenon, characteristic at the contact of forest and steppe vegetation types, and at the same time are characteristic of semi-humid climatic facies in the Altai-Sayan-Baikal region. It should be noted that in the diagram in the Altai sector of the mountain belt, the stepoids are not indicated, since the ridges of the South-Eastern Altai, belonging to the semi-arid climatic facies, are taken as standards. The zonal manifestations of the steppe cenogenesis also include Meadow steppes as a component of the forest-steppe. In the mountains of the Trans-Asian chain, the FCT of meadow steppes is most fully and diversely represented in the Sayan-Baikal (including Central and partly Northern Altai) sector within the geographical coordinates - 100-110 degrees. E and 50-52 degrees. N. In the presented scheme, the Dzhungar-Altaisk sector includes the ridges of the Southeastern Altai, in particular the South Chuisky, genetically and climatically the same with the Mongolian Altai, belonging to the semi-arid climatic facies [21, 2]. Therefore, there are no conditions for the development of communities of formations of the meadow-steppe complex, which cannot be said about the ridges of the Sayano-Baikal sector with a rich variety of meadow steppes at altitudes from 900-1500 m [22].

Special mention should be made of the type of Cryophytic steppes, which are composed of two geographical vicariates, on the one hand high-mountainous (Pamir-Altaisk-Sayan), on the other - subarctic Chukotst-Anadyr analogs. The latter are relict, genetically close to the tundra-steppes [23, 24, 25]. In contrast to them, the cryophyte-steppe FCT is rich and diverse, while the proportion of endemic formations such as *Festuca kryloviana* Re verd., *Poa litvinoviana* Ovcz., *H. tianschanicum, F. ganeschini* Drob., *Kobresia capilliformis, K. humilis, K. filifolia* in the composition of the type is quite high [17, 7, 18]. The altitude limits of the distribution of communities of cryophyte steppes are very significant up to 3000-3500 m absolute height in the Pamir-Tien Shan, decreasing to 1900 m in the Sayan and Baikal mountains. The northernmost variants of subarctic cold steppes on the Anadyr plateau are recorded at altitudes of 500-700 m, occupying the most insolated slopes in the foothills. However, their latitudinal position is striking – on a parallel above 60-65 degrees and at the longitudinal boundary being more than 160 degrees. Such high indicators of geographic coordinates, causing extreme climatic conditions, do not contribute to the development of the steppes, they occupy very local positions in landscapes, are relict in nature and their coenotic diversity is poor; are represented by only two types - herb-turf and cryophyte.
And finally, in the diversity of steppes, differing in adaptation to the conditions of the highest dryness and heat supply (mesothermal climatic regime) in comparison with cryophytic ones, there are types of desert and desertified steppes (table 1). In the nature of the geographical distribution of these steppes, which are most adapted to hot and extremely dry conditions, two points should be noted. Firstly, mountain analogs of desert steppes, depending on the insolation of macro-slopes, can be observed at significant altitudes, up to 3000.0 and more meters (Pamir-Alai) and, on the contrary, significantly decreasing in hypsometric indicators, for example, on the bottoms of the Chuya depression in Altai - up to 900 -1000.0 meters, which essentially corresponds to the zonal position of the desert steppes of Central Asia [26, 15]. Secondly, the type of desertified steppes is characteristic of the Altai-Sayan-Baikal sector of the TAMB and is exclusively characteristic of territories with semi-arid climatic regimes. The species composition and structure of communities of desertified steppes are a kind of ecotone on the mutual influence of arid and semi-arid ecosystems in the mountains of southern Siberia - the result of the historical stage of their cenogenesis, the floristic composition of which combines species as typically desert (Stipa glareosa, Gypsophila desertorum, Artemisia caespitaria, Ancathia ignathia) and real dry sod grass steppes (Cleistogenes squarrosa, Carex duriuscula, Potentilla acaulis, Artemisia frigida). Quite often they have the character of secondary desertified steppes as a result of pasture digestion.

4. Conclusion
Thus, as a result of considering the features of the distribution of steppes and steppe phenomena over a vast extent in the belt of mountains of Eurasia, crossing parallels and meridians from the very south (35°) to 65° – 67° in latitude, covering longitudinal sectors between 72° and 163° east longitude, the vegetation of the steppes is widely and diversely represented, its typological diversity is rich and contrasting, the floristic composition of communities and formations with the participation of many endemic and relict species is heterogeneous. The migration potential of the territory is enormous, which is, in fact, a route for mixing and subsequent transformation of flora. When considering the steppes from the standpoint of its coenotic diversity, the most important are the issues of phylocenogenesis – its historical development. The revealing of this aspect becomes key and presupposes a deep consideration of the entire diversity of species in the cenocomplexes of the steppes - the predominant ecobiomorphs, dominants and edificators of communities.

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