Phytoecological mapping of the North-West Pre-Caspian area

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Abstract. The aim of the research is to identify the patterns of spatial distribution of the vegetation in the North-West Pre-Caspian area and to develop its cartographic model. The work is based on long-term material (1983-2016). Geobotanical and cartographic studies have been carried out in accordance with generally accepted methods. Observations were conducted on three quaternary terraces using key sections (test sites) and environmental-dynamic profiling. The field material has been processed by the GIS program Mapinfo 6.0, the space images were decrypted with the help of ArcGIS 9.3. In total, about 1,600 geobotanical descriptions were provided. The cartographic vegetation model of the North-West Pre-Caspian area is based on the area-type principle. It reflects zonal and subzonal subdivision, the edaphic variations. This cartographic model of indigenous vegetation allowed: 1. to reflect its horizontal structure; 2. to confirm the southern zonal boundary between steppes and deserts (still disputed) identified by I.N. Safronova. Basing on the field studies results, the patterns of vegetation formation in the region have been identified and its spatial distribution, and the succession direction within the north-western part of the Caspian Sea region.

1. Introduction
The aim of research is the northwestern part of the Caspian Plain, which is the bottom of the ancient Caspian Sea. A distinctive vegetation cover at the junction of two latitude zones - steppe and desert had been created due to geography and geological history of the region [1-6]. In 1907 B.A. Keller and N.A. Dimo defined the Caspian Sea as an independent zone, naming it a “semi-desert” [7] to point out the transitional nature of the vegetation in the region. The principal of new zone indication was based not on the dominant feature of vegetation type, but on an integrated approach that reflected the horizontal heterogeneity of vegetation and soil cover. Despite the fact the term “semi-desert” has become a fairly solid scientific term, most geobotanists believe that the semi-desert zone does not exist naturally. In 1940, the semi-deserts that were previously identified by B.A. Keller were divided into two zones by A.V. Prosorovsky - a zone of northern semi-deserts with the predominance of deserted steppes and a zone of southern semi-deserts with the predominance of semi-shrub communities [7]. Analyzing the works of A.V. Prozovsky, academician E.M. Lavrenko [2, 8] named the northern semi-deserts “steppes” and considered the area of their spread as the southern subzone of steppe zone. The southern semi-deserts were defined as the northern sub-zone of desert zone and this approach was supported by many scientists: [3, 4, 9, 10], and by the authors of this article [11-13].

2. Statement of the problem
In the Caspian Sea region, B.A. Keller drew the zonal boundary between steppes and deserts between 50°- 48°N (1923, 1938). Later, based on new expeditionary data, the values were modified and marked out between 47,030°S in the northeast and 46,035°S in the south-west [4, 14, 15]. In the southwest, the boundary of the desert zone runs in the south along the foot of the Yergeni upland [14, 15]. An analysis of the published works on the region allowed the authors of the article to determine that...
the boundary between steppes and deserts roughly coincides with the northern boundary of the late Khvalyn transgression of the Caspian Sea [1, 14, 15].

Currently, the North-West Caspian Sea is a part of the Republic of Kalmykia, laying on the entire eastern part of its area. The economy of Kalmykia is based on pastoral livestock, and its development is determined by the productivity of natural forage land and phytosanitary diversity. Therefore, the aim of this work is to identify the spatial patterns of the vegetation of the region and to develop its cartographic model.

3. Methods of research

The vegetation was studied on the field. Detailed route studies were conducted across the region. The key sections (test sites) of the size between 180 and 300 hectares each were put in place. The geographical values of their positions were determined by satellite localization device GPS-Garmin 76. From 1983 to 2016 more than 1,600 geobotanical descriptions were delivered with the help of the method of semi-stationary research [13, 14, 16]. The received data were entered into the database (GIS project in MapInfo 6.0). They were processed using synthetic cluster analysis algorithms and the floristic commonality index by P. Jacquard. Phyto-centric diversity was characterized by the formation of quaternary terrace communities. The relationship of vegetation and natural habitat factors was determined by three indicators: soil salinity, groundwater abundance and presence of indicator plants [16, 17]. Land cover mapping was carried out using topographic and thematic maps and space imagery. Their interpretation was done by Arcgis 9.3 [18]. The diversity of plant communities was considered at the typological level using the ecological-phytocoenotic classification [9].

4. Results of research

Phytoecenotic diversity is reflected in cartographic materials revealing the diversity of the natural environment. We have classified and mapped the vegetation of the North-West Pre-Caspian area based on geobotanical descriptions. Its structure is hierarchical. The higher units correspond to the steppe and desert zones; at the same level, the nitrogen vegetation is identified, the sub-zone categories reflect the formative diversity and the subdivision of the formations into the edaphic variants. The lowest cartographic unit is complex and corresponds to phytocoenochoras: complexes and combinations. The analysis of obtained material confirmed that the natural conditions of the northern part of region, the Sarpinsk lowland, corresponds to the steppe zone and the Tchernozemelsk lowland – to the desert zone. In each zone, depending on its granulometric composition, and soil salinity degree, we have identified edaphic variants: on the loamy – pelitophyte, on the suppository – hemipsamomophyte, on the sandy – psimmophyte, on the saline – halophytophyte, etc. [13, 16, 19]. The indicator role in this case is played by the half-shrubs: Artemisia lerchiana, which grows on the middle straw; Artemisia pauciflora is on the cork; Artemisia taurica can be found on the straw-like light-chestnut soils. The alkaline soles are also characterised by Tanacetum achileifolium, and chestnut soils by Artemisia austriaca. The salinized soils are represented by Artemisia santonica, and sandy soils – by Artemisia arenaria (figure 1).

The space images were used during the mapping, which featured following relief: the macro-clone of Yergeni upland, lakes, canals, villages, ploughshares, etc. However, it is almost impossible to determine the nature of vegetation neither its structure according to space images. In regards with this, the presented cartographic model is mostly based on the historical expeditions of 1983-2016. (figure 1).

4.1. Steppe zone. South subzone. Pre-Caspian desert steppes on light-chestnut soils

As known, steppe vegetation type is characterized by «domination of more or less microthermal xerophilic sod grasses from genus: Stipa, Agropyron, Helototrichicton, Festuca, Koeleria, Poa, Cleistogenes, rarely - Sedge (Carex spp.) or wild grasses (from genus Allium, Galatella) [1, 2]. In the desertified steppe, depending on the degree of alkalinity of the background light-chestnut soils, one type from listed gramineous is predominant. In this case, semi-scrubbers (species of the genus Artemisia from the subgenus Seriphidium, as well as Kochia prostrata, Tanacetum achilleifolium, etc.) are subdominant as in the vegetation structure their role depends on the presence of the corresponding habitat types [5, 19]. The habitat of Artemisia pauciflora and Camphorosma monspeliaca is mainly in the steppe zone. On the contrary, phytocentric optimum of Artemisia lerchiana is noticed in the desert
zone. However, mentioned worms are the part of species diversity in both zones. The Black wormwood and camphor-fume are often presented in the desert zone, but they are mostly associated with the northern part. In the steppes, *Artemisia lerchiana*, *Kochia prostrata* are indicators of soil salinity.

![Figure 1. Vegetation cover of the North-West Pre-Caspian area.](image)

The Caspian Sea is represented by zonal deserted *Stipa sareptana*, *Festuca valesiaca*, *Agropyron desertorum*, *Artemisia lerchiana* steppes which form the most xerophytic subzone in the steppe zone. They are characterized by poor species composition, extremely heterogeneous horizontal structure, and widespread complex vegetation. This is related to the salinity of the soil and to the irregular distribution of precipitation by micro- and nano-relief elements. In addition, in the upland, we found edaphic variants: pelitophyte, halophyte-pelitophyte, hemipsamomophyte (figure 1). In the Sarpinsk lowland, various complexes and combinations have formed around the saline lakes, with the domination of hyperhalophytic, less often halophytic half-bushes: *Halocnemum strobilaceum*, *Suaeda physophora*, *Limonium suffruticosum*, *Artemisia pauciflora*, *A. santonica*, or *Salsola acutifolia*, *Salicornia perennans*, *Climacoptera lanata* and others.

4.2. Desert zone. Northern subzone. Caspian deserts in brown soils

Desert vegetation forms communities of xerophytes and hyperxerophytes plants, most often microthermal plants of different life forms. However, the dominant species are the semi-shrub plant formations of the Asteraceae family, of the *Artemisia* genus and *Seriphidium* subgenus, the less common are from goosefoot family (Chenopodiaceae) of *Anabasis*, *Nanophyton*, *Salsola*, and other genuses.

The Caspian deserts take part of the temperate deserts and form the northern sub-zone of the desert zone. They are timed to the Late Khvalyn and New Caspian terraces, starting at the southern edge of the Sarpinsk lowland and reaching the Kuma river-valley in the south. Semi-scrubland deserts are found in a wide variety of environmental conditions. The sagebrushes form complexes with the black sagebrushes in the salinized soils of the Khvalyn planes, while in the south and south-east the hemipsammophyte and psammophyte variants predominate (figure 1). Communities of *Artemisia lerchiana* – *Stipa sareptana* – *S. lessingiana* and *A. lerchiana* – *Agropyron fragile* as well as *A. lerchiana* – *Ephedra distachya* can be found on sandy plains and hilly fixed sands, *Artemisia arenaria* – on hilly, ridgy semi-fixed sands, *Calligonum aphyllum* – *Tamarix* spp. shrub deserts – on hilly unfixed sands. The zonality is observed in alkaline soils and in salt lakes that dry out in summer [15].

Vegetation of quaternary terraces. As mentioned earlier, as a result of transgressions of the Caspian Sea, three quaternary terraces with different ecological conditions have appeared in the area of the sea, which was proved by vegetation and species composition [20, 21].

Novocaspian terrace is located along the Caspian coast. The Baer knolls, hilly sands, estuaries and saltworts are situated on its undulating sandy plain [20, 23]. In the vegetation of the coastal area, according to humidity level, following communities are spread zonally: *Phragmites australis* – *Typha
alkali soils, they form cenosis with haloxerophytic communities: variants are dominant and represented mainly by *Camphorosma monspeliaca*, *Artemisia lerchiana*, *Stipa sareptana*.

However, in the eastern part (figure 1; II/3), the sandy loams are taken over by hemipsamophytic desert communities. On sandy soils, grass is homogeneous, often in combination with vegetation of scattered desert communities. In some places, on shallow and cortical lighter loamy soils (figure 1; I/3) are taken over by *Poa bulbosa*, *Petrosimonia oppositifolia*.

On quaternary terraces in the North-West Pre-Caspian area, the regional patterns of vegetation spatial distribution were identified. This distribution is due to environmental factors on these terraces in direction from the sea, lower groundwater levels and soil salinity: 1. Hydrogenic complexes with reed swamps (flood plains) and meadows are dispersing on the New Caspian terrace, in the coastal zone under the influence of sea-level rise, salinity of soils and...
groundwater. Halophytic desert communities of *Artemisia santonica* have developed on flat brown saline soils among with halosere around alkali flats and psammosere on the sands.

2. Due to decrease of salinity and the moisture regime on sabulous, sandy and clay sediments on the Late Khvalyn terrace, expansion of ecological sequences till normal site was noticed. The vegetation cover is more differentiated: pelitophyte of *Artemisia lerchiana* form communities on salkali soils, psammosere – on sands, halosere – around salt flats.

3. On the sediments of the salty chocolate clay and loam, the early Khvalyn terrace is characterized by the pelitophyte *Stipa sareptana* – *Artemisia lerchiana* steppes, which have a complex structure on the salt flats and zonation of communities around large water bodies and salt flats.

4. The identified regional features reflect the regularities of centuries-old successions from initial stages on the coast of the New Caspian terrace to zonal communities on the Early Khvalyn terrace.

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