Structural changes of the three-segment desert and steppe complex in Saratov Priuzenie area (based on Earth remote sensing data and ground-based observations)

V Z Makarov ORCID 0000-0003-0505-5257*, N V Pichugina ORCID 0000-0003-4738-9933, A N Chumachenko ORCID 0000-0002-9482-1496, V A Gusev ORCID 0000-0001-9223-2447*, V A Danilov ORCID 0000-0002-6971-9860, A V Fedorov ORCID 0000-0002-8999-6398*, A M Nevryuev ORCID 0000-0002-7985-8629

Faculty of geography, Saratov State University, Saratov, Russia

E-mail: makarovvz@rambler.ru, pichuginan@mail.ru, rector@sgu.ru, geografnauka@yandex.ru, kohavi@yandex.ru, alexievf@gmail.com, nevruev5@yandex.ru

Abstract. Northern semi-desert with zapadiny microrelief area is located in the south of Saratov Oblast. Microrelief contributes to moisture redistribution and its accumulation in micro-depressions (swales, or Russian name “zapadines”) under conditions of extremely low precipitation (312 mm per year). This allows to form a specific surface, where micro-slopes with light chestnut soils (44.1%), micro-hills with solonetz (37.5%) and micro-depressions with meadow chestnut soils (18.4%) coexist. Studies of the microcomplex semi-desert were carried out in Aleksandrovo-Gaysky district at the key site (100×100 m) in 2010 and 2020. The morphological structure of the landscape is preserved, but the quality of soil and vegetation cover has changed significantly. The projective cover of the herbaceous layer has decreased by 20-30%, the species diversity has significantly decreased as well. Herbaceous vegetation has almost disappeared in the micro-depressions, and the height of the spirea shrub has decreased from 1-1.4 m (2010) to 0.5-0.7 m (2020). Semi-desert landscapes are used for grazing cattle, sheep, goats and horses. The density of pasture trails on the key site was 0.11 m/square m in 2010, and 0.17 m/square m in 2020. The landscape area disturbed by livestock trails increased from 3% (2010) to 4.7% (2020) of the site area. The upper soil layer on trails is in a loose state to a depth of 4-6 cm. It is necessary to reduce pasture load, limit grazing time and take measures to organize the Priuzen semi-desert reserve to preserve microcomplex semi-desert landscapes.

1. Introduction

Saratov Oblast is part of the Volga federal district of Russia. The region is located in the south-east of the East European Plain. The Volga River flows along the territory of the region from the north to the south, south-west. The area, which is located to the west from the river Volga is called “Saratov Right Bank”, while the territory located to the east from the river Volga is called “Saratov Left Bank” or “Saratov Trans-Volga region”.

Typical steppe, southern steppe and northern semi-desert alternate in the direction from the north to the south in Saratov Trans-Volga district. According to A.G. Isachenko, semi-deserts are environmentally unfavourable landscapes with the significant lack of moisture [2]. Semi-deserts of the Caspian region have long been cultivated by people due to the presence of pasture lands and transit
rivers. At the same time, these landscapes require rational use of natural resources, and need monitoring and protection.

2. Models and Methods
The area under study is located in the Alexandrovo-Gaysky municipal district in the south of Saratov Trans-Volga region. The district belongs to the northern part of the Caspian marginal depression located in the south-east of the East European platform [8]. The Saratov Trans-Volga region was in the zone of transgressions of the Caspian Sea, as well as in the zone of the spread of permafrost processes during the Quaternary period.

The Bolshoy Uzen River and Maly Uzen River flow from the north-west to the south-east through Alexandrovo-Gaysky district. The territory adjoining to the rivers is called the Priuzenie plain. The northern part of the Priuzenie plain with altitudes of 25-40 m is an accumulative early Khvalynian surface. [3]. The southern part of the Priuzenie plain with altitudes of less than 25 m belongs to the accumulative middle Khvalynian surface [3].

The Priuzenie plain is characterized by diverse swale (zapadinn) microrelief. Micro-Depressions have the depth of less than 50 cm and the diameter of less than 30 m [3]. A.G. Ryabukha points out that there are various hypotheses (erosional, karst, suffusion, salt leaching) in the scientific sources regarding the origin of the zapadinn microrelief on the loamy plain of the Caspian lowland, but recently, emphasis has been placed on the paleocryogenic genesis hypothesis [6].

The ancient marine loamy plain in the north of the Caspian lowland existed under periglacial conditions in the Late Pleistocene [6, 4]. Poor drainage of the territory, increased water-cut of sediments and periglacial conditions contributed to the formation of polygonal cavern-locate ice [6, 4]. A block-depression morphosculptural complex was formed after the ice melting [6, 4]. According to A.G. Ryabukha, formation of micro-depressions occurred before the Holocene under conditions of severe cooling, when permafrost no longer existed, although there was deep seasonal freezing and complete summer thawing of soils [6].

The Priuzenie plain is in an extreme continental climate. The average duration of the period with air temperatures above 0°C is 229 days, with air temperature above +10°C – 164 days [5]. The sum average of air temperatures with values above +10°C varies from 3,096°C [5] to 3,300°C [3]. The average monthly temperature in July is +24°C [5], average monthly temperatures in January and February range from -10°C to -15°C [3]. Maximum air temperatures may exceed +40°C, for example, a temperature of +44°C was observed at the Aleksandrov Gay meteorological station in August 1982 [3].

About 312 mm of precipitation falls annually, and the moisture coefficient corresponds to 0.13 [5]. In some years, the amount of precipitation drops to 185 mm and very rarely increases to 499 mm [3]. The value of evaporation in the Priuzenie plain varies from 906 mm [3] to 970 mm per year [5]. Snow cover appears in late November or early December, in some years it is formed only in January [3]. Snow cover melts at the end of March [3]. The average thickness of the snow cover is 9-11 cm, but it can increase to 52 cm or decrease to 7 cm in some years [3]. About 40% of the winds blowing in the semi-desert are characterized by the speed of 10-15 m/s or even more [3].

The primary paleocryogenic morphosculptural relief became the basis for the development of microcomplexity of the soil and vegetation cover in the clayey semi-desert in the north of the Caspian lowland [4]. In the northern semi-desert, light chestnut soils are present on the micro-slopes to micro-depressions. There are xerophytic herb-fine-legged fescue-feather grass, white wormwood-desert fescue-fescue, wormwood-fescue and other associations on them [4, 3]. The herbaceous layer of micro-slopes includes Festuca valesiaca, Stipa lessingiana, Stipa cappilata, Koeleria crispata, Agropyron desertorum, Artemisia lerchiana, Artemisia austriaca and other spices [4, 3, 1].

Micro-Depressions are characterized by soil leaching and suffusion-subsidence processes, as well as the formation of a small lens of fresh water. Meadow-chestnut soils are common for the depressions. They are associated with thickets of Spiraea hypericifolia, rich herb-thin-legged wheatgrass-breast-feather grass, rich herb-feather grass, wheatgrass and other communities [4, 3].

Prepared by Zaiyev S.к.

9th International Symposium "Steppes of Northern Eurasia", Vol. 817 (2021) 012063
IOP Publishing
DOI: 10.1088/1755-1315/817/1/012063
Depressions grow in the grassy layer: Stipa capillata, Stipa zalesskii, Koeleria cristata, Elytrigia repens, Galatella villosa, Veronica spicata, Phlomis tuberose and other spices [4, 3, 1].

Micro-highs are 25-50 cm above micro-depressions [3]. Salts are pulled up to the surface and salt licks are formed on micro-highs. Here, the ostrich-prutnyak-bluegrass-wormwood, wormwood-fescue-bluegrass, bluegrass-black wormwood-camphorosm-prutny, bluegrass-black wormwood and other communities [4, 3]. Artemisia pauciflora, Artemisia austriaca, Festuca vallesiaca, Leymus ramosus, Poa bulbosa, Kochia prostrata, Camphorosma monspeliaca and other species can be observed in alkali soil [4, 3, 1].

In 2010 we studied the desert-steppe complex in the Bagyrdaysko-Bolsheuzensky landscape on the Priuzenie Plain, using high-resolution satellite image interpretation method (QuickBird) [3]. In 2020 field studies were carried out in the same landscape at a key site. DJI Mavik 2 Pro unmanned aerial vehicle (UAV) survey was used at altitudes of 10, 25 and 50 m to study the soil and vegetation cover. We carried out laboratory processing of photographs and GPS data when constructing a high-precision orthophotomap and digital elevation model using Agisoft PhotoScan and ArcGIS software. We used the MapInfo program to calculate areas, lengths and to create a landscape map of the area under study.

3. Results and Discussion

Based on the satellite image (2010) and the orthophotomap (2020), we compiled a map that reflects the landscape structure of the key site located on the accumulative flat surface of the Priuzenskaya plain with absolute heights of about 23 m (figure 1). According to calculations, micro-slopes occupy 4,404.8 square m (or 44.1% of the total area of the site), micro-highs – 3,751.5 square m (37.5%), micro-depressions with motley grass-grasses communities – 1,415.1 square m (14.1%), micro-depressions with Spiraea hypericifolia overgrowth – 428.6 square m (4.3%). It should be noted that the facies boundaries were preserved in 2020, but there were qualitative changes. The projective cover of vegetation cover on micro-slopes in 2010 reached 60-80%, and in 2020 it was at 40-50%. The projective cover on micro-highs in 2010 was 45-75%, while in 2020 it was less than 45%. The vegetation of the micro-depressions was especially badly damaged. In 2010, the projective cover in the micro-depressions was at the level of 80-100%, while in 2020 it was at 50-60%. Spirea overgrowth in the micro-depressions occupied 213.1 square m in 2020, which is 49.7% of the area of depressions with shrubs. The height of the shrubs in 2010 reached 1.4 m, while in 2020 it was at 0.5-0.7 m. The herbaceous layer was practically destroyed in the micro-depressions.

The territory under study is used as pastures for cattle, horses and sheep. According to the Federal State Statistics Service for Saratov Oblast data [7], the total number of cattle livestock units in Aleksandrovo-Gaysky District at all its farms was 24,095.4 in 2009, and 26,395.4 cattle livestock units in 2019. The number of livestock units of farm animals increased by 9.6% over 10 years. In 2009, cattle accounted for 73.7% of the total number of animals, sheep and goats – 18.9%, horses – 7.4% [7]. In 2019, cattle accounted for 81.9% of the total number of animals, sheep and goats accounted for 10.1%, horses accounted for 8.0% [7]. In many farms the preference is given to breeding cows belonging to the Kazakh white-headed beef breed.

A significant part of farm animals graze on pastures in the course of 7-8 months. In 2010, the length of the herding paths in the area under study was 1,125.7 m, in 2020 it was 1,723.0 m. The average width of the herding paths reaches 27 cm. The upper part of the soil on the trails is in a loose state to a depth of 4-6 cm. According to calculations, pasture trails occupied 303.9 square m in 2010 (3.0% of the total area of the site), while in 2020 they covered 465.2 square m (4.7%).
Figure 1. The desert-steppe complex in the Bagyrdaysko-Bolsheuzensky landscape on a site (100×100 m) located 1.7 km north-east of the Baiguzha farm, Aleksandrovo-Gaysky district, Saratov region.

4. Conclusion
The study that was carried out on the key site (100×100 m) in the northern semi-desert in the south of Saratov trans-Volga region brought us to the following conclusions.
1. Over the period of time from 2010 until 2020 the morphological structure of the microcomplex semidesert landscape remained preserved, i.e. micro-slopes with light chestnut soils accounted for 44.1%, micro-hills with alkoli soils – 37.5%, micro-depressions with meadow chestnut soils – 18.4% of the site area.

2. Over the period of 10 years, the projective cover of the herbaceous cover decreased by 20-30%, species diversity decreased significantly as well. The communities of micro-depressions, where the herbaceous layer almost disappeared and only individual grasses and spirea were preserved, were especially badly affected. The height of spirea overgrowth decreased from 1-1.4 m (in the year 2010) to 0.5-0.7 m (in the year 2020).

3. Within 10 years, the soil cover surface underwent changes. The increase in grazing time and the number of farm animals contributed to pasture trail growth. In 2010, the density of pasture trails on the area under study was 0.11 m/square m, in 2020 it was 0.17 m/square m. The area occupied by livestock trails increased from 3% (2010) to 4.7% (2020) of the site area. The upper soil layer on the trails has been damaged by the cattle hooves, it is in a loose state, and can be moved outside the site by the wind.

4. To prevent degradation of the semi-desert landscapes, it is necessary to reduce the pasture load and control grazing time.

5. To preserve microcomplex semi-desert landscapes as one of the feature elements of the northern semi-desert, it is recommended to provide for the organization of the Priuzen semi-desert reserve. Unfortunately, the status of the monument of regional significance does not always effectively fulfill the protective function.

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