Mapping of Vegetation with the Geoinformation System and Determining of Carrying Capacity of the Pre-Urals Steppe area for a Newly Establishing Population of the Przewalski Horse Equus ferus przewalskii at the Orenburg State Nature Reserve

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Abstract. Mapping of the vegetation (1:25000) of the Pre-Urals Steppe area at the Orenburg State Nature Reserve was completed in 2016. A map created with the geoinformation system contains 1931 simple and complex polygons for 25 types of vegetation. In a drought year, the average stock of palatable vegetation of the whole area is estimated at 8380 tons dry weight. The estimation is based on the size of areas covered by different types of vegetation, their grass production, the correction coefficients for decreasing of pasture forage stocks in winter and decreasing of production of grass communities in dry years. Based on pasture forage stocks the area could tolerate the maximum population size of 1769 individuals of the Przewalski horse, their average density could be 0.11 horse per ha. Yet, as watering places for animals are limited in Pre-Urals Steppe, grazing pressures on the vegetation next to the water sources may increase in dry years. That is why the above-mentioned calculated maximum population size and density must be reduced at least by half until some additional watering places are established and monitoring of the grazing effect on the vegetation next to the places is carried out regularly. Thus, the maximum size of the population is estimated at 800 to 900 individuals, which is almost 1.5 times more than necessary to establish a self-sustained population of the Przewalski horse.

1. Introduction
At present, the number of living captive and reintroduced Przewalski horses Equus ferus przewalskii in the International Studbook is about 2000 individuals [1]. In 2015, the Government of the Russian Federation handed over to the Federal Government Funded Institution (FGFI) «Orenburg Reserves» the territory of the former military training ground of 16538 ha in size to establish a new strictly protected area called Pre-Urals Steppe as the 5th part of the Orenburg State Nature Reserve (hereinafter Orenburg Reserve). The FGFI «Orenburg Reserves» developed the Programme of Establishing of a
Semi-Free Population of the Przewalski Horse in Pre-Urals Steppe. Having been supported by The United Nations Development Programme / Global Environment Facility (GEF) / Ministry of Natural Resources and Eclogy of the Russian Federation within the frame of the Project «Improving the Coverage and Management Efficiency of Protected Areas in the Steppe Biome of Russia» FGFI «Orenburg Reserves» transported six Przewalski horse to Pre-Urals Steppe from France in 2015 and 30 horses from Hungary in 2016 and 2017. An evaluation of the carrying capacity of the area for the newly establishing population of the Przewalski horses was necessary for the successful development of the Programme.

The aim of the present study is to create a map of vegetation (1:25000) with the Geoinformation System (hereinafter GIS-map), to analyse the pasture forage stocks of the Pre-Urals Steppe area and to determine the maximum number of the horses the area can tolerate.

2. Materials and methods
A typology of the vegetation of Pre-Urals Steppe was developed by Sergey M. Yamalov, Maria V. Lebedeva, and Yaroslav M. Golovanov from Botanical Garden-Institute, Ufa Scientific Centre RAS in 2016 before the present study. The typology includes 26 types of plant communities with various degrees of anthropogenic disturbance. The analyses of the total productivity of grass available for horses and the production of palatable grass forage were carried out during the period of the maximum grass development. In each type of plant communities, vegetation was cut in 5 sample squares of 1m² each. The samples were sorted by 6 categories regarding their edibility and palatability for Przewalski horses. They are the following: 1) gramineous plants, 2) legumes, 3) well edible forbs, 4) reluctantly and non-edible forbs, 5) plants with unknown edibility, 6) standing dead plants from the last year. The data on preferred plant species for the Przewalski horse were obtained from an earlier study at the Biosphere Reserve “Askania Nova” [2]. Then the samples were air-dried and weighted to within 0.01 g.

During the main growing season in 2016, the Pre-Urals Steppe area experienced optimum vegetation-growing conditions. The field investigation for the GIS-mapping was carried out in Pre-Urals Steppe in June–August 2016. Geobotanical descriptions of 1354 sample plots of 100 m² each were fulfilled to classify them according to the above-mentioned typology of vegetation. Images obtained from Earth observation satellites Resurs-P, Landsat 7, and Landsat 8 were analysed with software NextGIS Mobile in an Android-based tablet and used as a cartographic base during the field period. Multispectral images obtained from the above-mentioned satellites and analysed with software QGIS were used for GIS-mapping during the desktop period. The resulting outlined polygons were simple and complex contours of vegetation. Simple contours demonstrated vegetation of a single type, complex contours included 2 to 3 types of vegetation. Each dominated type of vegetation was set in an individual layer of the GIS-map. Tables of attributes for each layer contained information about the ratio between the main type and associated types of vegetation of a given plot, bush encroachment, size of the plot, pasture forage stocks, etc.

Calculation of the pasture forage stocks and evaluation of the maximum size of the population of the Przewalski horse for Pre-Urals Steppe were made with the use of the methodological recommendations on optimisation of grazing pressure on natural steppe communities [3]. An estimation of maximum pressure of free-ranging domestic horses Equus caballus on lands of the Isle of Vodnyj in the Lake of Manych-Gudilo [4] was used. Data on the pasture food intake by Przewalski horses in winter and summer were used from the study by M K Pozdnyakova and co-authors [5].

3. Results and discussion
There were 1924 simple and complex polygons outlined in pursuing GIS-mapping of the Pre-Urals Steppe area. The most widespread vegetation type was Stipa capillata communities. 348 polygons of 2105.8 ha represented it. Recent fallow lands (Melilotus officinalis+Artemisia austriaca communities) occupied 288.1 ha. There was little woody vegetation; the size of steppe plots with bush encroachment of ≥10% of their total area were 154.6 ha. Yet, bush communities themselves occupied...
only 43.2 ha. Basing on the size of vegetation communities and their grass production the palatable grass forage stocks were calculated for the Pre-Urals Steppe area. Totally 30451.7 t of dry weight were estimated (table 1).

**Table 1.** Characteristics of types of plant communities in the Pre-Urals Steppe area at the Orenburg State Nature Reserve.

| Type of a plant community | Number of polygons in the GIS-map | Size, ha | Pasture forage stock, t Totally | Palatable plants |
|----------------------------|-----------------------------------|---------|--------------------------------|-----------------|
| *Stipa borysthenica* motley-grass species-poor | 76 | 632.7 | 14223.0 | 11145.5 |
| *Stipa borysthenica* motley-grass species-rich | 74 | 292.2 | 5653.8 | 3497.1 |
| *Agropyron pectinatum* | 48 | 1079.9 | 37830.5 | 34248.4 |
| *Alopecurus arundinaceus* | 4 | 35.2 | 1597.3 | 1464.5 |
| *Elytrigia repens*+*Poa transbaicalica* | 151 | 1049.0 | 35786.8 | 27609.0 |
| *Stipa zaleskii*+*Poa transbaicalica* | 84 | 927.2 | 32099.1 | 19387.4 |
| *Poa transbaicalica* motley-grass | 54 | 1310.0 | 55201.7 | 49265.4 |
| *Caragana frutex*+*Spiraea crenata* | 71 | 43.2 | 822.2 | 398.6 |
| *Stipa lessingiana*+*Festuca valesiaca* | 51 | 1410.4 | 45869.4 | 42676.9 |
| *Stipa lessingiana*+*Serratula cardunculus* | 9 | 384.3 | 13230.0 | 7609.2 |
| *Galatella villosa*+*Artemisia lercheana* | 188 | 1307.0 | 29806.2 | 3981.8 |
| *Poa crispa* | 138 | 1370.7 | 26015.3 | 15216.2 |
| *Festuca valesiaca*+*Artemisia austriaca* | 194 | 929.6 | 20944.1 | 6423.6 |
| *Ceratocarpus arenarius* | 1 | 18.2 | – | – |
| *Atriplex sagittata* | 23 | 144.6 | – | – |
| *Artemisia lerchiana* | 124 | 908.5 | 13647.3 | 7020.3 |
| *Serratula cardunculus* | 20 | 480.0 | 10348.8 | 7052.4 |
| *Festuca valesiaca*+*Falcaria vulgaris*+*Malabaila graveolens* | 17 | 1245.0 | 31472.0 | 26349.1 |
| *Festuca valesiaca*+*Artemisia lerchiana petrophytic* | 165 | 240.8 | 2898.3 | 1696.2 |
| *Festuca valesiaca*+*Artemisia lerchiana*+*Galatella villosa* | 96 | 154.6 | 2725.3 | 1414.0 |
| *Artemisia pauciflora* | 16 | 73.6 | 1215.5 | 542.2 |
| *Stipa capillata* | 291 | 2105.8 | 38118.7 | 35952.6 |
| *Puccinellia distans* | 6 | 6.4 | 123.4 | 84.3 |
| *Phragmites australis*+*Carex acuta* | 8.6 | – | – | – |
| *Melilotus officinalis*+*Artemisia austriaca* | 4 | 288.1 | 14758.0 | 1482.2 |
| Woody vegetation | 19 | 29.0 | – | – |
| Total: | 1924 | 16474.6 | 434386.6 | 304516.8 |

* Reluctantly and non-edible vegetation
The Przewalski horse has the same feeding preferences as the domestic horse [5]. Free-ranging domestic horses consumed 8 to 14 kg dry wt daily during snow-free grazing and 16 kg dry wt daily in winter [4]. The daily forage intake by the Przewalski horse was slightly less; depending on quality of the forage it fluctuated from 7 to 11 kg dry wt per horse [5]. Hence, our approach was based on daily forage intake of 10 kg per horse in summer. In winter, the Przewalski horse consumes gramineous plants preferentially (T L Zharkikh, pers. comm). As gramineous plants averaged 93.2% of the edible pasture forage in Pre-Urals Steppe, the daily food intake was estimated to be 17.2 kg per horse in winter. Consequently, the pasture forage consumption was estimated at 2.14 t per horse during snow-free period lasting 214 days from April 1 to October 30. The forage consumption was estimated at 2.6 t per horse in winter period lasting 151 days from November 1 to March 31. Totally, one Przewalski horse needs 4.74 t dry wt of pasture forage per year.

Figure 1. The productivity of palatable grass vegetation in plant communities in the Pre-Urals Steppe area.

Dry steppes are characterized by sharp fluctuations in vegetation production depending of rainfall. Grass productivity grows until the middle of June. In genuine steppe grasslands, half of vegetation dries out in August; petrophytic steppes dry out almost entirely at the same time. Meadow steppes mostly remain green in August. In autumn, the green plant weight of all types of steppe vegetation
increases as a result of colder weather and increasing in rainfall. Spring and autumn grazing results in grass regrowth increasing its productivity by 1.5 to 2 times. It compensates for the loss of forage in the second half of summer. [3, 6]

Thus, the productivity of the herb layer of plant communities in the period of their maximum growth could be used as a basis to calculate the maximum number of Przewalski horses the area can tolerate during the snow-free season. Correction coefficient 0.8 should be used to calculate winter edible forage stocks [6]. Extreme drought reduces steppe grass productivity by 2.5 to 3 times [3, 6], so, correction coefficient 0.3 should be used to calculate edible forage stocks. Taking into consideration the correction coefficients, we estimated the average total palatable forage stock at 8379.6 t dry wt in extreme years. Hence, the area could tolerate the maximum population size of 1769 individuals of the Przewalski horse, their average density could be 0.11 horse per ha. However, the estimation was carried out without regard to the shortage of constant sources of water in Pre-Urals Steppe. Grazing pressures on the vegetation next to watering places may be increased in dry years. In this connection, the establishment of additional water sources is essential given the variegated vegetation production in different parts of the area (figure 1). Once new water sources are established the constant monitoring of the state of vegetation in areas with most grazing pressure and its succession trends should be carried out.

Until some additional water sources are provided the above-mentioned calculation of the maximum size of the newly establishing population and the density of Przewalski horses should be halved at least. Thus, the maximum population size should not exceed 800 to 900 individuals. The density of the animals should be about 0.05 to 0.06 horse per ha or 16 to 20 ha per horse. Nevertheless, the estimated maximum number of Przewalski horses for the Pre-Urals Steppe area is 1.5 times more than the minimum required number of animals to establish a self-sustained population [7]. If some new species of large herbivorous are introduced in this area, the present estimation should be reviewed.

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