UAV survey of sand knolls in the Tsasucheysky Bor Nature Reserve

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Abstract. The paper examines development of sand knolls under the influence of climatic and anthropogenic factors in Southern Zabaykalye within the territory of Tsasucheysky Bor nature reserve. The sand knolls were studied on-site with instruments and aerial surveying. Grain size distribution of the soil cover was studied. The floristic composition of the sand knolls represented by motley grass-grasses and herbs-grasses steppe communities with varying degrees of projective cover was investigated. The analysis of the field survey data from an unmanned aerial vehicle (UAV) made it possible to obtain the main morphometric parameters of the sand knolls, and overlaying aerial photographs on historic satellite images allowed to trace how they changed in time. The studies showed that the movement of the studied sand knolls with time as Aeolian formations under the influence of wind erosion is unlikely, as the sand knolls are currently mostly covered by steppe vegetation, and only about 20% of the areas are bare. The analysis of satellite images and aerial photographs showed that over the last twenty years the sand knolls had not moved or changed their size.

1. Introduction

The formation of sand knolls on the land surface under the influence of climatic and anthropogenic factors has long been of interest to many researchers [1–3]. Numerous scientific works studying sand knolls located in the Nature Reserve of Federal Significance "Tsasucheysky Bor" were carried out in Southern Zabaykalye [4]. Most scientists call these sand knolls "Baer knolls" because their first description was given by the academician K.M. Baer in 1856 [5–9].

The present work is a partial continuation of previous studies using modern technology. The aim of the study was to examine sand knolls using an unmanned aerial vehicle (UAV) and dynamics of their development under the Aeolian processes. The objectives were to study the morphological appearance of the sand knolls and the state of their vegetation cover.

To achieve this goal, the following was carried out: study of meteorological data affecting the movement of Aeolian landforms; field surveys of sand knolls at the key areas using UAV aerial photography; study of the dynamics of changes that occurred over the past 20 years by overlaying aerial photographs and satellite images.

Recently, UAV studies have been of great importance; they are also used abroad by specialists during field studies, for environmental monitoring. They provide data and reduce costs of the necessary studies by traditional field methods while increasing efficiency of the work. Undoubtedly, the use of UAVs will give an innovative character to the ongoing research work [10–12].
The object of the research has unusual landforms representing parallel, sandy and sandy loam ridges of latitudinal and sub-latitudinal direction located in the Pre-Caspian lowland between the mouths of the Kuma and Emba rivers. Baer knolls are also located throughout the Northern Caspian Sea region unevenly, and differ from each other in shape and size [13].

2. Data and Methods
Long-time wind direction and speed observation data were received from Nizhny Tsasuchey meteorological station and processed in Microsoft Excel. Granulometric composition was investigated by screening [14]. Plant communities were studied with traditional phytocenotic methods.

During field studies geobotanical descriptions were made on sample plots of standard size 10×10 m for herbal phytocenoses [15] located on the knolls: the descriptions were performed according to the generally accepted procedure using a dominant approach, taking into account the complete floristic composition, coverage and abundance of species belonging to the plant community [16]. Projective species coverage was estimated by sight [17].

Digital model of the knolls and their orthophotomap was created with "Phantom 4 Pro+" with 20 MP camera, ensuring greater clarity and less grain noise with the new 1 CMOS sensor. Support of 2.4 GHz and 5.8 GHz ensures a more reliable connection in environments with more interference.

The flight was carried out in clear sky in the open area. In order to obtain basic morphometric parameters of the knolls aerial photographs were taken from various altitudes (max 200 m) followed by orthophotomaps in Agisoft PhotoScan. The images were compared using Google satellite images taken in 2004. The satellite images of this area obtained from available public sources (Google EarthPro 7.3) allow to identify large habitats of modified and natural objects (sand knolls). The main requirement to satellite images was the absence of clouds.

3. Results and Discussion
In 2019 INREC staff of Siberian Branch of the Russian Academy of Sciences examined 4 sand knolls with UAV (figure 1). The obtained images were processed using Agisoft PhotoScan. Agisoft PhotoScan is a universal tool for generation of 3-D surface models of the objects on the basis of their photographic images.

![Figure 1. Sand knolls in Tsasucheisky Bor (UAV image): a – flight altitude 30 m; b – flight altitude 50 m.](image)

The development and georeferencing of the terrain model in the software consists of several stages. During the first stage one uploads photographic images taken by the UAV. After proper positioning of a sparse point cloud (from the common points of the images) a dense point cloud is built. On the basis of the dense point cloud a three-dimensional polygonal mesh is built (figure 2a). The next step is
texture building; the polygonal model is "painted" with textures taken from the photographs (figure 2b).

![Figure 2. Digital terrain model: a – wireframe model; b – textured model.](image)

In the texture mapping mode, the object surface is split into the flat part and vertical regions. The flat part of the surface is textured using the orthographic projection, while vertical regions are textured separately to maintain accurate texture representation in such regions. This mode allows to produce more compact texture representation for nearly planar scenes, while maintaining good texture quality for vertical surfaces. The next step is to build a digital terrain model, create an orthomosaic; the final step is to export the results.

It is convenient to make a KMZ file (usually of smaller resolution and size) to review the results of the survey. Review of this file in Google Earth clearly shows the position of the digital terrain model of the object, in our case the sand knoll, on the satellite image (figure 3).

Digital contours (of the satellite image and aerial photographs) of the knoll in different periods of satellite images (Google Earth) are overlaid. In addition, translucency of the overlaid raster layers was set in the raster layer properties using Transparent tool to allow additional analysis and control.

![Figure 3. Digital terrain model of the sand knolls: a – knoll No. 3 (height 200 m); b – digital terrain model in the satellite image.](image)

The main morphometric parameters were also obtained in Agisoft PhotoScan (table 1). The studied objects are drop-shaped (oval) and U-shaped. All the knolls have south-eastern direction, which is due
to the predominance of constant north-western winds in this area. The height of the knolls reaches 10 m.

**Table 1.** The main morphometric parameters of the knolls.

| Knolls | Coordinates | Shape, direction | Area, km² | Morphometry, height/length/width, m | Slope, % |
|--------|-------------|------------------|-----------|-------------------------------------|--------|
| 1      | N 50°29'7.0" E 115°29'5.6" Altitude 636 m | U-shaped, south-eastern direction | 0.06 | 8/381/230 | 0.5 |
| 2      | E 114°53'44.3" Altitude 660 m | U-shaped, south-eastern direction | 0.08 | 9/317/238 | 1.7 |
| 3      | N 50°26'46.2" Altitude 656 m | U-shaped, south-eastern direction | 0.09 | 10/284/270 | 1.7 |
| 4      | E 114°59'18.7" Altitude 665 m | Oval-shaped, south-eastern direction | 0.01 | 5/241/65 | 0.1 |

Grain size composition of the sand knolls is 100% sand with particle diameters ranging from 0.05 to 1.0 mm (table 2). With this composition the movement of soil particles is irregular and with the wind speed of 5–7 m/s light particles, especially those up to 0.25 mm in size, are lifted and moved over long distances. Given the fact that there is less and less forest within the study area (caused by forest fires), the movement of sand grains in the upper horizons of the sand knolls will be facilitated by constant winds.

**Table 2.** Granulometric composition.

| Particle content (% by weight) and diameter, mm |
|-----------------------------------------------|
| 2–1     | 1–0.5 | 0.5–0.2 | 0.2–0.1 | 0.1–0.05 | 0.05–0.01 |
|        | 47.6 | 45.0 | 4.9 | 2.5 | 0 |

Due to the fact that the main cause in the spreading of Aeolian landforms is wind, analysis of long time observations of wind direction and speed was carried out on the basis of information from Nizhny Tsasuchey meteorological station. Predominant winds at the study area are of north-western and western direction (22–25%)

The average wind speed over a year is 3 m/s, the maximum wind gust reaches 34 m/s (June). The maximum wind speed during the year vary from 20 to 34 m/s with squally wind occurring in May, June and November.

It is impossible to completely reject further spreading of sand knolls in Tsasuchesky bor under the influence of wind erosion, since there are prerequisites for its manifestation: light sandy soils exposed by fire with particles up to 1 mm, squalls and gusty winds in spring - all this can lead to activation of erosion in this area.

During the field studies, it was noted that the sand knolls are mostly covered by herbaceous-grass and mixed-grass-grass steppe communities with varying degrees of projective coverage (the total projective coverage is 60–70%).

The floristic composition of grass and shrub vegetation in the key areas of the studied sand knolls has the following characteristics. The grass stand can be divided into three layers:

- *upper* layer, dominated by the following species – *Aconogonon divaricatum* (L.) Nakai ex Mori, *Artemisia dracunculus* L., *Potentilla anserina* L., *Saussurea pulchella* Fisch. etc., with an average height of 60 cm;
medium layer – *Heteropappus altaicus* subsp. altaicus, *Potentilla tanacetifolia* Willd. ex Schlecht., *Lespedeza juncea* (L. fil.) Pers., *Artemisia scoparia* Waldst. et Kit., *Saussurea salicifolia* (L.) DC etc., with an average height of 45 cm;
- lower layer – *Potentilla acaulis* L., *Saussurea davurica* Adams, *Carex korshinskyi* Kom. and *Carex pediformis* C. A. Meyer, with an average height of 20 cm.

The most common families are Asteraceae, Poaceae, Rosaceae, Fabaceae.

As of the study period (August 2019) the total projective cover of the grass stand was 80%; projective cover of the greenery was 60%, dead grass 5%, and underlayer 15%.

The study showed that belt-zonal groups of the steppe complex prevail on the sand knolls both in terms of the number of groups and the number of species in the group. There are also representatives of other groups (figure 4).

**Figure 4.** Ecological groups of plant species growing on sand hills.

4. Conclusion
The overlay of the digital terrain models of the sand knolls created on the basis of UAV aerial photography and the satellite image of 2000 showed that the sand knolls in the coordinate system of 2019 aerial survey coincide with the coordinates of the satellite image made in 2000. Therefore, it is concluded that the movement of the knolls as Aeolian formations under the influence of wind erosion in time is unlikely, as the biggest part of their area is now covered by predominantly steppe vegetation. Only about 20% of areas are bare, and before the extensive fires of 2012 they were covered with forest vegetation.

The analysis of satellite images and aerial photographs showed that over the last twenty years there had been no movement of knolls or change of their size. Nowadays the location of the knolls is fixed in the coordinate system and their digital model is created. Subsequent study of the sand knolls will give a more detailed picture of their change over time.

The use of UAVs is a promising, low-cost and efficient method of remote sensing, a good alternative to satellite images for small territories. The use of remote data for early identification of the territories subjected to degradation processes allows to take appropriate measures and will help to eliminate spots of desertification at the initial stage.
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