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Using Landsat satellite time series for desertification processes mapping: case study for Oleshky sands, Ukraine

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SUMMARY

Desertification is a critical social, ecological and economic security problem in many countries around the globe. Southern Ukraine is also susceptible to desertification processes, especially concerning the large sandy areas generally called the Oleshky Sands – a landscape complex mainly formed from sandy soils and dunes. This complex is relatively dry and unstable, and uncontrolled wildfires often occur there. Another problem is expanding of sandy landscapes and desertification processes. To assess the dynamics of landscape changes within this area, several Landsat satellite images from the period between 1986 and 2020 were classified. The spatial and percentage distribution of the critical classes, which indicate desertification processes, were estimated using the supervised classification of obtained space imagery.

Introduction

The Oleshky Sands is the unique landscape complex of southern Ukraine. It includes dunes, semi-deserts, meadows, lakes and other landscape formations. The massif concentrates many species of flora and fauna listed in the Red Book. However, despite its cultural and ecological value, the massif carries a high threat associated with desertification. Vegetation losses provoked the expansion of the sandy landscapes due to droughts and the felling of protective forest strips. Climatic changes intensify the erosion processes, pollution of surrounding agricultural lands by sands and other negative consequences. An urgent task is the study of long-term landscape changes of the Oleshky sands to identify trends towards desertification and localization of territories with the most unfavorable changes and protect the unique landscapes.

Remote sensing satellites are an effective means of long-term monitoring of the Earth's surface. The series of Landsat satellites, starting with the Landsat-4 satellite launched in 1982, provides multispectral space data of most of the Earth's surface with a spatial resolution of 30 m (Wulder et al., 2019), which allows for studying landscape changes over large areas with sufficient detailization. Landsat satellite data is appropriate for studying desertification in many world regions (Rivera-Marin et al., 2022). For example, it used for studding desertification processes in Mongolia (Meng et al., 2021), vegetation loss in China due to desertification (Li et al., 2013), and long-term land use changes in Morocco (Moumane et al., 2022). Long-term landscape changes based on remote sensing data were also studied in Ukraine (Popov et al., 2021).

In this extended abstract, it is reported how a series of five Landsat data images were used to study the landscape changes of the Oleshky Sands by the method of supervised classification and to assess the spatial distribution of different classes over the research period. The approach to image selection and the logic of class selection are also described. Finally, it is provided with the percentage of land surface covered by each critical desertification indicator for all years to estimate their distribution dynamic.

Theory

Area of interest

Oleshky sands are one of the most immense natural sand masses in Europe. A wide variety of biotopes of semi-desert and desert areas is concentrated in this area: sandy steppe, fresh and saltwater bodies, deciduous groves, and coniferous forests. The uniqueness of these sands is that they are mobile. In the 20th century, the problem of the desert became very acute because sand masses began to spread close to the surrounding villages. To restrain the expansion of the sandy massif, the planting of buffer areas, the basis of which are pine forests, has been started.

The territory of the National Nature Park "Oleshky Sands" is one of the largest massifs of psammophyte steppes and dunes in Europe, as well as meadows, bogs and deciduous nuts in inter-Kuchugur depressions. This area is the habitat for 455 species of vascular plants (28 of which are included in various nature protection lists). In addition, the fauna of the Park contains 958 species of animals, 217 of which are under protection.

The park's territory is located within the northern slope of the Black Sea depression, with the depth of the Archean-Proterozoic crystalline basement from 1200 m at the park's north border to 1500 m within the Burkut areas. The geological basis of modern landscapes of the territory is sand deposits. Loess-like sandy loams and light loams of the middle and upper Pliocene and partly of the Miocene. The sandy-loam layer of alluvial deposits is underlain by highly eroded and lithologically diverse Neogene deposits (*The project for the organization of the territory of the national nature park*

"Oleshkivski Pisky", 2014). In the complete sections, loess-like loams, sandy loams, alluvial sand-clay formations, and brackish-water silt-clay and silt-sand deposits represent the delta-terrace stratum. In total, the Oleshki Sands cover seven arenas on the territory along the southern bank of the Dnieper estuary and the entire environment of the Kinburn Peninsula.

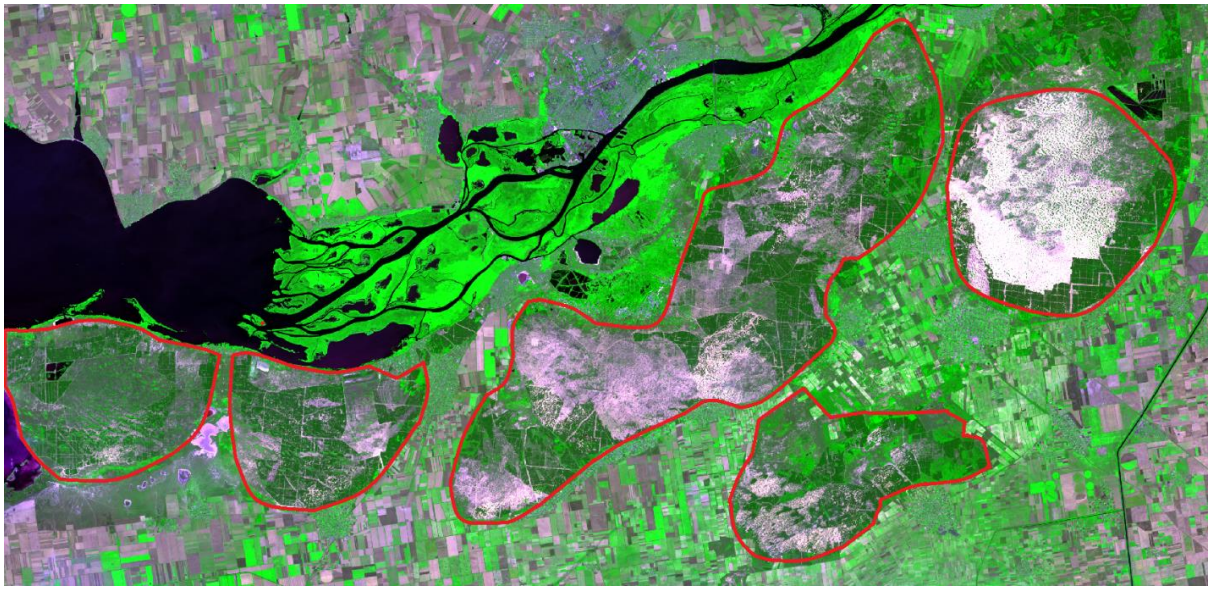

Figure 1 *Landsat-8 multispectral image (26 of July, 2020) in false colors (red, NIR, green) with sand arenas of the Oleshky sands region. Outlined areas were classified for landscape changes estimation*

Materials and methods

Five images obtained by Landsat satellites starting from 1986 were selected to determine landscape changes and identify desertification indicators within the study area. The data was downloaded from the USGS (United States Geological Survey) EarthExplorer service https://earthexplorer.usgs.gov/. The image acquisition dates and the corresponding satellites are listed in Table 1.

Table 1 *Landsat series satellite images, used for the landscape changes research*

Satellite	Acquisition date
Landsat-5	13 of July, 1986
Landsat-5	8 of July, 1996
Landsat-5	5 of August 2006
Landsat-8	26 of July, 2020

Data selection was carried out considering several criteria: data must be obtained during the highest vegetation activity period (June-August) for a clear distinction of plant classes and scenes without atmospheric obstacles (haze or clouds). In addition, the data from the first band of the Landsat-8 (Coastal aerosol) was removed since this band didn't exist in earlier satellites.

Remote sensing data classification is a method of automated image interpretation, which consists of transforming spectral reflectance data in each image pixel into a particular class of the Earth's surface, according to its actual spectral properties. For classifier "training", several samples from small reference areas on the input image are formed, reflecting the spectral properties of each class. The selection of classes was carried out in accordance with the capabilities of the scanning system and the general characteristics of the landscapes of the studied area. The following classes were chosen to assess landscape changes and identify trends toward desertification: sands, bare soils, grasslands, and coniferous forests.

Also, several vector shapes were created to delineate the areas of interest – the investigated sand arenas. After classifying all images, the percentage ratio of crucial classes, which are signed as desertification indicators within the vector shapes, was evaluated. Separately, the bare soils class should be noted, which indicates different types of soils other than open sands: sandy soils, areas covered with vegetation, sandy and loamy soils, etc. The coniferous forests have a critical role in sand distribution deterrence.

Results

According to the research results, the expansion of the sand arenas themselves was determined during the research period. Still, significant landscape changes, class transitions in many areas and changes in the percentage ratios were identified (Table 2). Examples of classification results for 1986 and 2020 are shown in Figures 2 and 3.

Table 2 *Percentage frequency distribution of the key classes for each classified image*

	Sands	Bare soils	Coniferous forests	Grasslands
1986	19.5	38.5	23.9	17.6
1996	11.9	45.6	26.8	15.2
2006	12.2	48.8	25.3	13.3
2020	13.9	44.4	18.4	23

The classification results analysis showed the active development of coniferous plantations around the Kozachelar sand arena (right) in the 1980s, which was necessary to contain the sand spread, leading to the clogging of the surrounding agricultural lands. In other areas, there is also a decrease in open sand massifs. At the same time, a significant decrease in the coniferous vegetation was found within the study area, despite its active growth in the 1980s. It is especially noticeable within the Kelegei arena (central) boundaries and the expansion of landscapes with bare soils and grasslands. Despite the apparent decrease in the area of the sand class, several classes corresponding to other types of bare soils are expanding. Also, the total area of coniferous forests decreased significantly, and the area covered by grass vegetation increased.

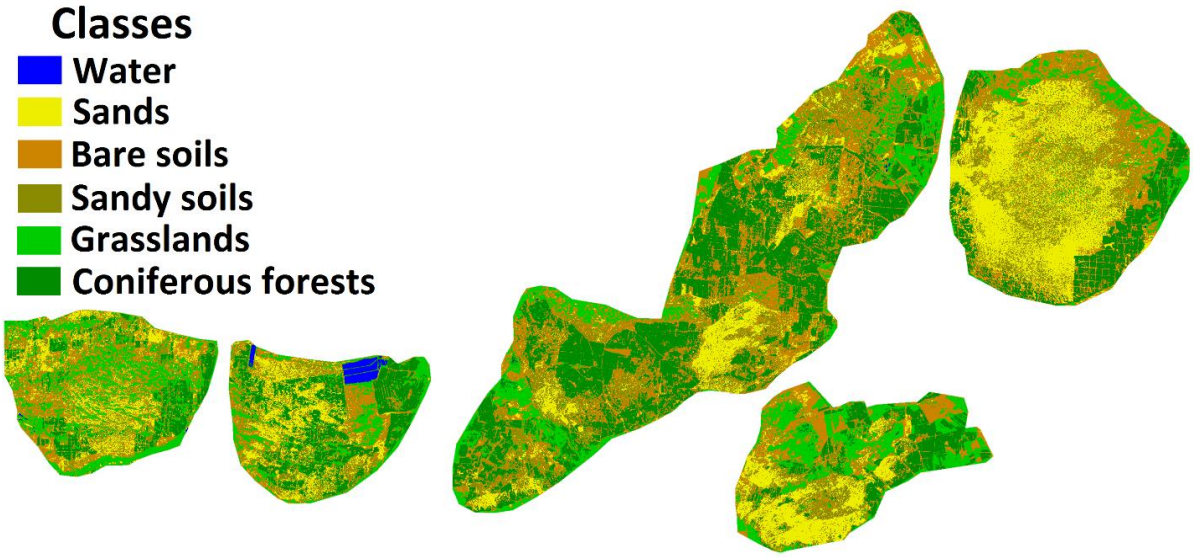

Figure 2 *Landsat-5 multispectral image (13 of July, 1986) classification results*

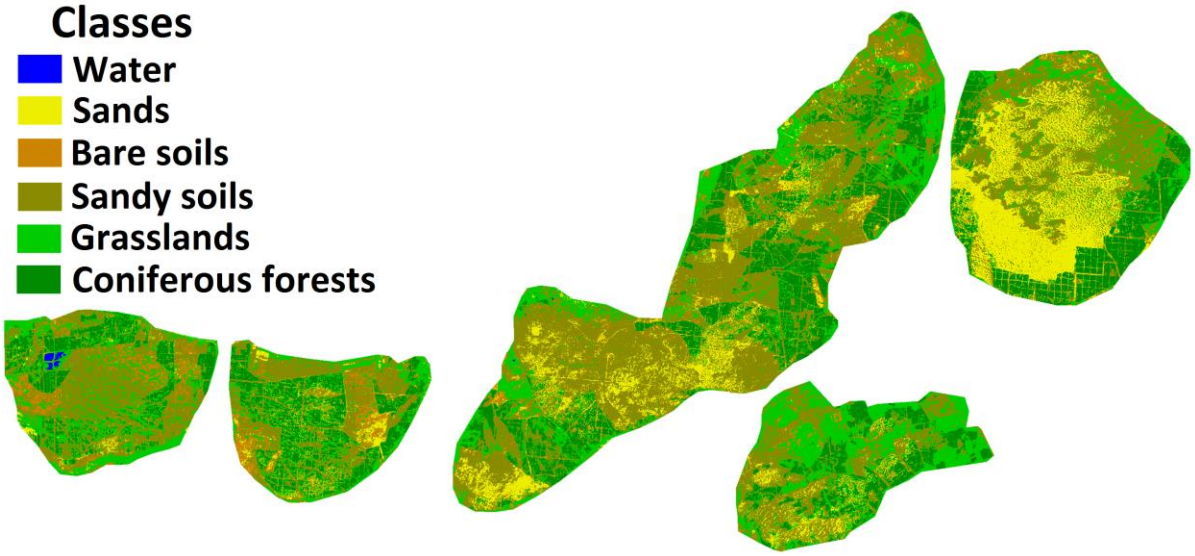

Figure 3 *Landsat-8 multispectral image (26 of July, 2020) classification results*

Conclusions

Oleshky sands are a unique and valuable region of Ukraine from an ecological and cultural point of view, which requires constant control and measures to prevent the expansion of sands. In the conditions of modern climatic changes, the vegetation cover is destroyed by droughts and exposed to anthropogenic influence. Coniferous protective strips are devastating due to droughts and spontaneous fires. In addition, the territories where the vegetation cover has been lost are transferred to the class of sands. The obtained results indicate a cumulative decrease in the density of woody vegetation and an increase in the area of bare soils. These consequences are very unfavorable degradation factors, which can exacerbate desertification processes in the future.

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