# Retrospective Analysis and Current State for *Pinus sylvestris* L. *var. cretacea* Kalen. in the "Kreidova Flora" Branch of Ukrainian Steppe Nature Reserve

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The "Kreidova Flora" (Cretaceous Flora) branch of Ukrainian Steppe Nature Reserve was created to protect unique cretaceous vegetation, including the tertiary relict – pine forests on chalk. In 2018, the Standing Committee of the Berne Convention added these forests to the list of endangered habitats. The main objective of our research was to assess the current state of *Pinus sylvestris* L. *var. cretacea* Kalen. habitat based on field observation and Landsat time series retrospective analysis. Satellite remote sensing data (Landsat archive) was used to analyze the distribution patterns and disturbances over a 40-year period. The obtained results show that the area covered with pine trees has doubled, but there are considerable threats of invasive plants, periodical fires and other losses as a result of military actions in the region since 2014. The assessment of the stability and risks in this habitat shows its rareness, narrow prevalence, poor reproduction, very high danger of destruction, and strong sensitivity to the environmental changes. A special set of monitoring and conservation measures are considered to provide successful protection of the habitat as a part of Emerald network.

**Keywords:** Scots pine, chalky outcrop, satellite remote sensing, endangered habitat, Emerald network, biodiversity conservation.

## Introduction

The studies of chalk outcrops in the floodplain of the Siversky Donets River within Donetsk region have been carried out by numerous researchers. As for *Pinus sylvestris L. var. cretacea* Kalen., for the first time, this unique forest attracted the naturalists' attention years ago (Güldenstädt, 1791). Such forests are very rare: in the entire Ukraine, they only occupy a small area within one administrative district of Donetsk region, and also a few areas within Don River basin.

Pine forests on chalk based on the justification of leading Ukrainian scientists (Kuzemko, 2017) were recognized by the Standing Committee of the Bern Convention as being endangered and, therefore, of particular value for conservation as "G3.4G *Pinus sylvestris* forest on chalk in the steppe zone" (Revised Annex I, 2018). Now the processes of getting closer national environmental legislation to European standards in Ukraine are intensifying due to European integration. Thus, an important task is to develop specific conservation measures for most endangered natural habitats and species.

According to previous botanical research, the pine forest area in this reserve has increased from 151.5 to 240.9 hectares for the first 10 years of protection (Tkachenko, 2004). A significant pace of natural regeneration of *Pinus sylvestris* L. *var. cretacea* Kalen. was also shown in the next decades (Lymansky, 2010). The steppe part of the reserve was overgrazed before but now there is another threat – a lack of disturbance led to invasion of broad-leaves trees, shrubs and weeds as a result (Polchaninova et al., 2017). Thus, in order to maintain biodiversity at the "Kreidova Flora" territory, additional measures have been proposed to improve the regime of protection according to the requirements of the environmental legislation (Lymansky, 2017).

Satellite remote sensing, Landsat time series particularly, proved to be an effective tool for long-term forest health monitoring (Banskota et al., 2014), disturbance detection (Huang et al., 2010), ecosystem stability, and habitat threat assessment (Radeloff et al., 2019), design and application of protected area management strategies (Pettorelli, 2019). It allows revealing the habitat threats, quantifying the ecosystem response intensity in terms of space and time, and selecting effective conservation measures.
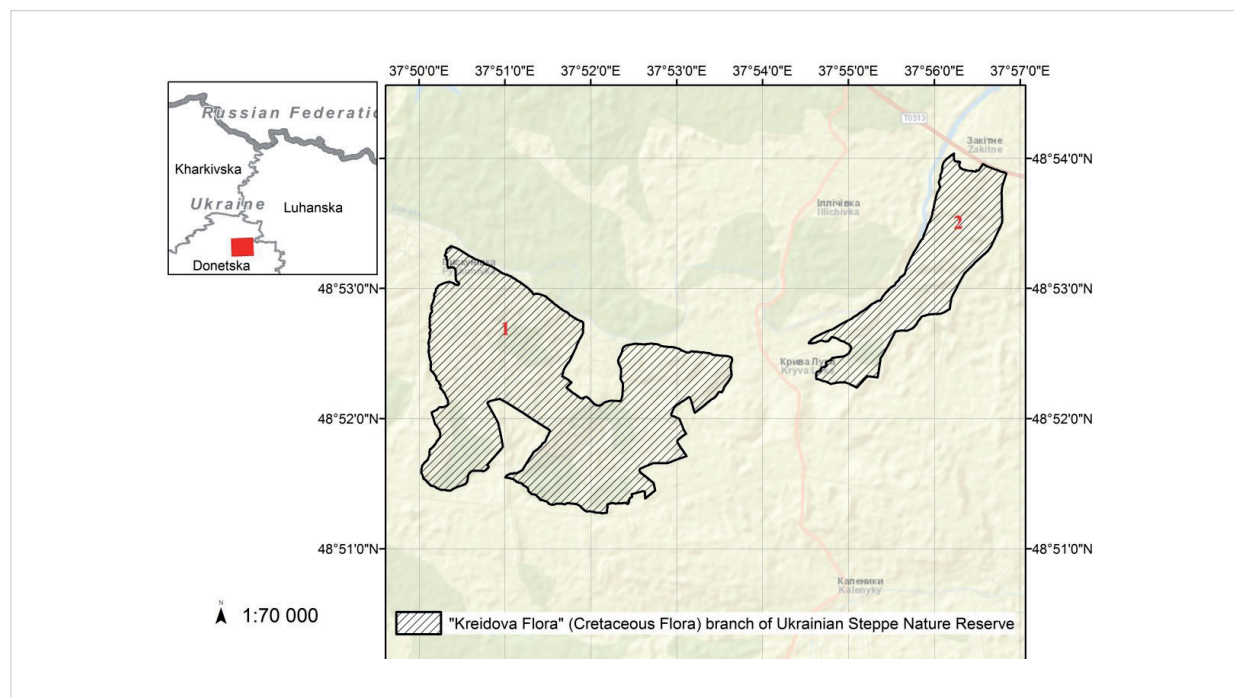
## Methods

The "Kreidova Flora" branch of Ukrainian nature steppe reserve was created in 1988 with the main purpose to protect unique cretaceous flora including pine forests on chalk. It is located in Donetsk region and consists of two parts. The eastern part is completely represented by grassland vegetation and the western one includes pine and ravine forests (Fig. 1). The Donetsk region area is coved mostly by grassland vegetation (Didukh et al., 2018) due to conditions of sub-continental (sub-arid) climate, characterised by large temperature amplitudes between summer and winter periods. The average annual temperature is 7–8°C, and it ranges from −4 to −6°C in January, and from +21 to +24°C in July. Annual precipitation is in the range of 420–500 mm in most parts of the territory.

The research area is located in the Slovianskyi district of Donetsk region, on the right bank of the Siverskyi Donets River.

The research methodology included the following tasks:
- satellite images selection and downloading to create the satellite time series (https://earthexplorer.usgs.gov);
- spectral bands synthesis for more effective determination of forest groups condition and species composition;
- normalized difference vegetation index (NDVI) calculation to develop the mask of woody vegetation;
- pine tree area calculation, based on pine tree mask, developed using maximum likelihood classification of satellite images;
- botanical descriptions *in situ* in expeditions of 2016–2017 and *in situ* data analysis;
- habitat sustainability and risk assessment by 12 parameters (including e.g., anthropogenic transformation impact, recoverability, regional representability, invasive species presence, sozological importance) on a four-point scale.

**Fig. 1.** *The territory of the "Kreidova Flora" Nature Reserve: 1 – western part with pine and ravine forests; 2 – eastern part with only grasslands..*



Retrospective analysis of the satellite images during the forty-year period (1977–2017) was performed to assess the state of the territory and detect the vegetation dynamics in the territory of the "Kreidova Flora" Reserve.

In order to ensure the unified satellite imagery data processing for the retrospective analysis, satellite data from Landsat, the longest earth observation satellite programme, was selected. All available images from Landsat 2, 4, 5, and 8 from the EarthExplorer archive were analyzed, and 32 images with a cloud coverage of less than 10% were selected during the vegetation season (mostly in June-September) with a spatial resolution of 30 meters.

Spectral bands synthesis was applied to develop a colour mosaics based on acquisition in the middle and near infrared and red parts of the spectrum (SWIR-NIR-R, or spectral bands 5, 4, 3 of the satellites Landsat 2–5, and bands 6, 5, 4 of the satellite Landsat 8). In this band combination, healthy vegetation is displayed in bright green, soils are light brown and pinkish-purple, urbanized areas are gray-blue, water objects are black and dark blue. This combination also allows emphasizing the difference in age and species structure of forest groups, in particular, coniferous vegetation is depicted in a dark green tint, and broadleaf trees are light green. Also, territories of new felling and fires are distinguished by a bright pink tint, in comparison with older areas of forest cover loss, which have a violet tint. Cartographic accompaniment of vegetation research was provided according to standard techniques while paying attention to chalk surface peculiarities (Sinna, 2014).

Semi-automatic classification plugin of QGIS software was used to detect the pine tree areas per each year. The vectorization classified raster was applied to assess the wood vegetation dynamics and area calculation. But with the automatic vectorization of the raster, the contours of the classes repeat the shape of the pixels of the raster matrix, which, depending on the resolution of the raster, makes an error in the calculations and complicates the visual perception of the results. Thus, it is necessary to perform generalization (post-classification) operations with the image in order to remove shallow contours. The next step was to simplify the boundaries of different classes of polygons (reducing the number of points of the fracture of the polygon boundaries).

The assessment of the sustainability and risk of ecosystem losses was carried out by assessment approach

(Didukh, 2014). According to this approach, every biotope refers to a certain grade of stability, which represents the 12 biotope's characteristics on a four-point scale.

Twelve biotope's characteristics include anthropogenic transformation's impact, recoverability, situation in the succession series (in relation to anthropogenic successions), regional representativity, distribution character, ecological amplitude, environmental conditions of distribution, invasive species presence, the hemeroby scale, the correlation between the types of live strategy, sozological importance, and synphyto-sozological status. The "value" of each feature was evaluated in points from 1 to 4. The degree of biotope's degradation risk (R) was estimated based on the sum of the all indicators. According to these estimates, all biotopes were divided into 5 classes according to their vulnerability: 1st grade – 48–42 points, R > 83%; 2nd grade – 41–35 points, R = 63–82%; 3rd grade – 34–28 points, R = 43–62%; 4th grade – 27–21 points, R = 23–42%; and 5th grade – 19–12 points, R < 23%.
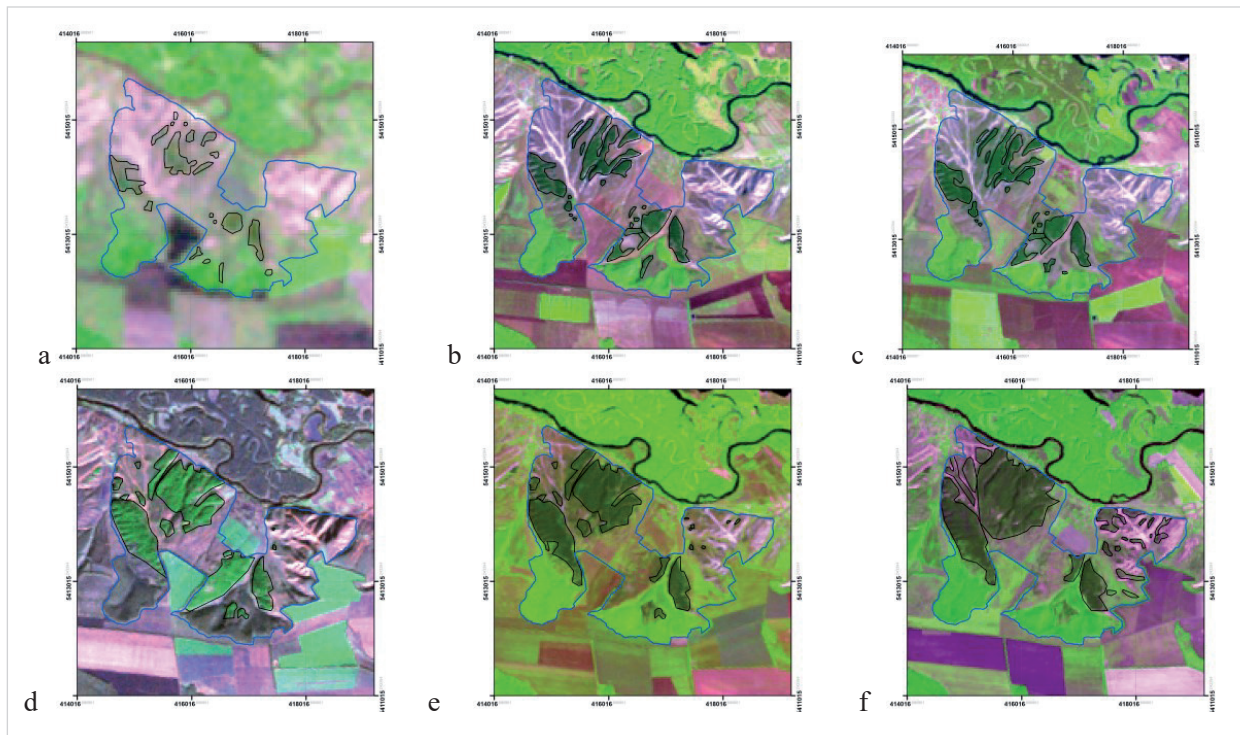
## Results and Discussion

Retrospective analysis of the satellite images during the forty-year period (1977–2017) showed the significant changes in dynamics of area covered by pine forests on the territory of the "Kreidova Flora" reserve. The results of cartographic analysis for 6 selected years are presented in Fig. 2 and Table 1.

As a result of the retrospective analysis, we found the following dynamics of pine propagation (Table 1).

**Table 1.** *Pine forest area on the territory of the "Kreidova Flora" reserve*

| Year | Pine forest area, ha |
|------|---------------------|
| 1977 | 78.69 |
| 1984 | 134.53 |
| 1992 | 136.88 |
| 2000 | 248.22 |
| 2009 | 198.9 |
| 2015 | 316.95 |

**Fig. 2.** *Dynamics of area covered by pine forests (dark green) on the territory of the "Kreidova Flora" reserve (blue contour) by years: a – 1977, b – 1984, c – 1992, d – 2000, e – 2009, f – 2015.*

It can be seen that the changes in forest area were rather uneven. The major factor was the major fires in 1996 and 2007, which damaged one-fifth of the habitat area. The obtained data indicate that after the first fire for the next 4 years there was a successful restoration of the pine population. In the 2 years after the 2007 fire, a full recovery did not take place. The pine plots in 2009 (Fig. 2, e) were smaller than such plots in 2000 (Fig. 2, d). It may be concluded that the two-year period was insufficient for full recovery. Another negative factor was distribution of deciduous woody vegetation, which wins the competition in the southern part of the "Kreidova Flora" reserve.

The assessment of the stability indicators for 12 main habitat characteristics is shown in Table 2.

Most of the 12 biotope's characteristics were rated at 4 points. The highest score was given to situation in the succession series (клімаксові стадія), regional representativity (distributed within one district), distribution character (only small localities were found), ecological amplitude (narrow amplitude of 5% for edaphic factors), correlation between the types of live strategy (the ratio of stress-tolerance to ruderal species is more than 1.7), sozological importance and synphytosozological status (the presence of species included in local and international conservation lists).

Indices of recoverability (full ecological restoration for decades), environmental conditions of distribution (rare), invasive species presence, and hemeroby scale (mesogemerob) were evaluated at 3 points.

Antropogenic transformation's impact was estimated at 2 points (biotope species composition changes). The obtained resulting sum in 42 points shows biotope's rareness, narrow prevalence, poor reproduction, and a very high risk of destruction (the degree of biotope's degradation risk R > 83%).

Fire prevention and measures for the species diversity conservation are major challenges at the present stage. In this case, permanent species monitoring should be implemented, regularly cutting the grass together with the pine seedlings on certain defined steppe areas, saturated with valuable grassy species, and the formation of swaths net up to 15 m in pine plots could limit the spread of fire. Implementation of technical measures for the prevention of fires,

limitation of invasive species, and regular monitoring of the pine population can be effective in reducing the degradation risk.

**Table 2.** *Stability indices for G3.4G Pinus sylvestris forest on chalk in the steppe zone*

| | Feature/characteristic | Stability indicator |
|---|---|---|
| 1 | Antropogenic transformation's impact | 2 |
| 2 | Recoverability | 3 |
| 3 | Situation in the succession series (in relation to anthropogenic successions) | 4 |
| 4 | Regional representativity | 4 |
| 5 | Distribution character | 4 |
| 6 | Ecological amplitude | 4 |
| 7 | Environmental conditions of distribution | 3 |
| 8 | Invasive species presence | 3 |
| 9 | The hemeroby scale | 3 |
| 10 | The correlation between the types of live strategy | 4 |
| 11 | Sozological importance | 4 |
| 12 | Synphytosozological status | 4 |
| | **Total** | 42 |

## Conclusions

For the last 40 years, including the protected status of the territory since 1988, the area covered with pine trees has doubled. Also, there are considerable threats of periodical fires, invasive plants, climate changes, and losses as a result of military actions in the region since 2014. Retrospective analysis of the satellite images confirms and clarifies long-term field observations of pine forest area dynamics. The obtained results prove the habitat's high value and a very high risk of its destruction. Strong sensitivity to the environmental changes, poor reproduction, and weak competitiveness require special complex measures of protection for the "*G3.4G Pinus sylvestris* forest on chalk in the steppe zone" habitat as a part of Emerald network.

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