IV. SPACE TECHNOLOGY AND ENVIRONMENTAL MONITORING

DURANKULAK LAKE ACTUAL STATE AND MONITORING USING SENTINEL 2 SATELLITE DATA

Iva Ivanova, Iliyana Gigova, Temenuzhka Spassova, Nataliya Stankova

Abstract: Durankulak Lake is one of the most important wetlands in Bulgaria and Europe. It is included in the Ramsar Convention and is recognized as an important bird area of world importance. The subject of protection within the protected zone is the condition of the natural habitats and the habitats of the species, including the natural species composition, the typical species and the conditions of the environment. Remote sensing methods provide opportunities for characterization and monitoring of the wetland on various scales that have not been done so far. In the present study satellite multispectral images from the European Union Copernicus Satellite Program, Sentinel 2 are used for assessment and monitoring of the actual state of the lake. Based on these satellite images, the boundaries of the protected wetland are derived. An index classification of the wetland was made. Normalized Difference Vegetation Index (NDVI) is used to classify sites within the protected area. Sentinel-2 satellite data to implement the orthogonal transformation model called Tasseled Cap Transformation (TCT) has also been used. The model is an effective method for classifying and analyzing of the processes related to the dynamics of changes, affecting the main components of the earth's surface: soil, water and vegetation. The spring survey of 2019 was selected for the present study. The results will show successful mapping and monitoring of the wetland, which will give a real idea of the state of the Durankulak Lake and the need to take conservation measures to protect it.

Key words: monitoring, satellite data, wetlands, habitats

INTRODUCTION

Wetlands are among the most biologically productive natural ecosystems in the world. A wetland is a land area that is saturated with water, either permanently or seasonally, such that it takes on the characteristics of a distinct ecosystem [1]. Wetlands play critical parts in maintaining and improving water quality, mitigating floods, reaching aquifers, and providing habitat for fish and wildlife. The loss of wetlands has gained considerable attention over the past few decades, more than 50 % since 1900 [1, 2].

The present study develops a methodology for monitoring of a typical example of a wetland such as Durankulak Lake using remote aerospace methods. Aerospace monitoring so far has not been carried out on this area.

Study Area

Protected area "Durankulak Lake" (4465.4 ha) is situated in the northeastern part of Bulgaria, about 6 km from the Bulgarian-Romanian border and 15 km north of the town of Shabla. It was announced by Order No. 123/21.02.1980 of the Committee for the Protection of the Natural Environment. It has a management plan developed by the Ministry of Environment and Water in 2002. The lake is included in the Ramsar Convention as a habitat for waterbirds of international importance. The whole territory is included in the list of BirdLife International – Important Bird Areas in Europe, under the name

"Durankulak Lake". The site is part of the Corine site according to the European program CORINE Biotopes. The Protected Site, together with adjacent agricultural lands and marine aquatory, is the subject of the European Ecological Network NATURA 2000 under the name "Durankulak Lake" (under Directive 79/409/EEC on the conservation of wild birds and Durankulak Lake and under Directive 92/43/EES for the Conservation of Natural Habitats and Wild Fauna and Flora) [3].

The Durankulak Lake is a shallow, indoor liman, occupying the coastal low parts of the deep drylands (Vaklinska River, the village of Bilo – the village of Smin and the village of Granichar – Durankulak village). It was formed at the beginning of the Holocene (about 10 000 years ago) when a period of epheroidal decline and invasion of seawater into the river valleys occurred. As a result, bays are cut off later by the sea through sand spit and turned into a lake. In the pruning parts of the drylands there have been formed radial cuts of the lake in the land.

The largest extension of the lake is in the north. It is called the Karteli /Eagle/ Marsh and is naturally separated from the lake with a narrow, almost entirely overgrown with water vegetation shallow. Another characteristic extension of the lake is the Southeast Marsh. It is separated from the lake with narrow sand spit, part of which is flooded at high water levels. In the southwestern part of the lake there are two islands: "Goliamata ada" at an altitude of 12.4 m and "Malkata ada" at an altitude of 4.3 m. Durankulak

Lake is one of the most significant and best preserved coastal wetlands in Bulgaria with an international importance for the conservation of more than 260 species of endemic, rare and endangered plants and animals. It is a representative model of the natural coastal lakes in the western Black Sea coastline [3].

There are 244 bird species in Durankulak Lake and its adjacent territories, of which 67 are included in the Red Data Book of Bulgaria (1985). Of the birds that are present 123 are species of European nature conservation significance.

Fig. 1. Location of Durankulak Lake, Sentinel 2, 19/03/2019

Since the lake is located on the Via Pontica migration route and close to the Danube delta, it is one of the most important stations for the birds on the Bulgarian Black Sea coast. Durankulak Lake is a place of global importance for waterbirds in the winter, mainly due to the large geese clusters. Together with

the great White-fronted Goose, the Red-breasted Goose is here in considerable quantities, with almost all of its population in January and February living in Durankulak and Shabla Lakes, making them one of the most important wetlands in the world.

Fig. 2. NATURA 2000 protected area

Fig. 3. Durankulak Lake

One of the main threats in the lake is disturbing the natural balance and an accelerated eutrophication process. Increased eutrophication results in the channeling and fouling of channels and open water

areas, and the drop in water level leads to a lack of spills. On the territory of the complex there are 3 unique and representative ecosystems, included in the National Strategy for the Conservation of

Biodiversity, 1995, which are threatened. Therefore, a regular monitoring is needed.

Natural succession has accelerated significantly over the past 30 years from anthropogenic activities. The waters in both basins have been enriched in nutrients in recent years due to the infiltration of contaminated underground and surface waters from surrounding fertilized lands. Renovation of lake and marsh water is reduced due to the construction of dikes and the intensive water abstraction in the area. The two ponds have become traps for nutrients and organic matter. High concentrations of nutrients shift the balance of the ecosystem to primary production. Aquatic blossoms are registered in both ponds. Most of the primary production remains unprocessed in the food chains and accumulates at the bottom as sludge [4].

Therefore, the necessary to carry out of monitoring surveys on the lake is imperative in future management activities of the protected area.

METHODOLOGY

Input data

For the purpose of the study satellite data from Copernicus, Sintinel 2 was used. The study period for establishing the actual state of the lake is the spring of 2019. Two images were used to perform a precise monitoring of the lake:

Sentinel 2A 19/03/2019 and

Sentinel 2A 03/04/2019.

The Copernicus Sentinel-2 mission comprises a constellation of two polar-orbiting satellites placed in the same sun-synchronous orbit, phased at 180° to each other. It aims at monitoring variability in land surface conditions, and its wide swath width (290 km) and high revisit time (10 days at the equator with one satellite, and 5 days with 2 satellites under cloud-free conditions which results in 2-3 days at mid-latitudes) will support monitoring of Earth's surface changes. The coverage limits are from between latitudes 56° south and 84° north. Sentinel 2A was also launched in June 2015. The satellite has 13 spectral bands in the visible, NIR, and SWIR spectral range. The spatial resolution of the bands varies from 10 to 60 meters [5, 6]. The satellite images can be downloaded free from the Copernicus Open Access Hub (<https://scihub.copernicus.eu/>).

Input data processing

Mapping of the site of research was made, the boundaries of the Natura 2000 site and the Durankulak Lake has been done.

A composite images of all 13 channels and an extraction of the areas with Durankulak Lake Ecosystem were made. After Sentinel data acquisition,

on the base of the input composite images Tasseled Cap Transformation and NDVI index was applied [6].

For a precise assessment of the dynamics of the actual state of Durankulak Lake, a model of TCT (Tasseled Cap Transformation) images were obtained as results for implementation of the proposed approach. After the TCT the decomposition of each of the Tasseled Cap components – Brightness (BR), Greenness (GR) and Wetness (W) was made, based on which the spatial distribution graphs for each of the components are plotted [7]. On the base of the input composite images from Sentinel 2, vegetation index – NDVI was calculated [7, 8, 9]. The NDVI index in addition to the vegetation assessment and for the accurate identification of reed massive in the Durankulak Lake was used. Using the NDVI is for quantitative quantifies assessments of vegetation in the lake by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs):

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}} \quad (1)$$

- ρ_{NIR} = the spectral reflectance measurements acquired in the near infrared band;
- ρ_{RED} = the spectral reflectance measurements acquired in the red band.

RESULTS

Spatial distribution of the tested components (Greenness, Brightness and Wetness)

The decomposition of each of the Tasseled Cap components – Brightness (BR), Greenness (GR) and Wetness (W) was made, based on which the spatial distribution graphs for each of the components are obtained. In the following figures the graphs are shown:

Fig. 4 a) Spatial distribution of Greenness, 19/03/2019-03/04/2019

b) Spatial distribution of Wetness, 19/03/2019-03/04/2019

c) Spatial distribution of Brightness, 19/03/2019-03/04/2019

The scattering diagram for the spatial distribution of the Greenness (Fig. 4a) shows that in the end of March the vegetation is very poorly developed, which corresponds to the early spring season in the lake. At the second date in early April, the vegetation begins to grow, which corresponds to an initial stage of the beginning of the growing season. The vegetation in the lake is represented mainly by the reed, and its expansion is the reason for the gradual swamping of the lake. Therefore, regular monitoring is important for assessing ecological equilibrium and making the

right decisions for the management of reedbeds in the lake.

In Fig. 4b the spatial distribution of Wetness in Durankulak Lake is shown. It shows that the humidity in the spring season is high, due to a higher water level in the lake. In April, the water level in the lake is higher. The distribution of the soil component is shown in Fig. 4c. It shows that the Brightness is more pronounced in March, and in April, due to the strong vegetation development, the soil decreases, which is normal for this season.

Spatial distributions of the tested components (Greenness, Brightness and Wetness) compared together

Fig. 5 a) Spatial distribution of Greenness/Wetness, 19/03/2019

b) Spatial distribution of Greenness/Wetness, 03/04/2019

c) Spatial distribution of Brightness/Wetness, 19/03/2019

d) Spatial distribution of Brightness /Wetness, 03/04/2019

The spatial distribution between Greenness and Wetness for March is shown in Fig. 5a. This shows that for this month of the year, vegetation has not yet captured the lake. During this season, the water

component dominates. In Fig. 5b is shown how the vegetation gradually descends the open water areas of the lake, but the humidity is still high for the season.

Correlation between NDVI and Greenness

Fig. 6 a) Correlation between NDVI and Greenness, 19/03/2019

b) Correlation between Greenness, 19/03/2019-03/04/2019

c) Correlation between NDVI and Greenness, 03/04/2019

b) Correlation between NDVI, 19/03/2019-03/04/2019

From Fig. 6a it can be seen that the correlation between the NDVI and the Greenness is low – 0.522, which is the result of the poorly developed vegetation in the lake. In Fig. 6c The correlation between the two indices rises slightly – 0.591, indicating that the vegetation is starting to develop.

CONCLUSION

From the obtained results can be seen that in March – vegetation is still poorly developed, the water level is high. In April there is a strong development of the vegetation in the lake (the reed beds are growing), the water level still remains high. The correlation between NDVI and Greenness is low, which is typical for the season.

The monitoring from this study shows the actual state of Lake Durankulak, in spring, 2019. The early stage of vegetation development in the lake can be seen, when the reed does not drastically capture the open water areas. When and what measures are needed to stop the massive development of vegetation in the lake, which gradually leads to its swamping and loss of valuable habitats was shown from these results.

The present study shows a methodology for monitoring the actual state of Durankulak Lake, which can help to better management the territory and preserve vulnerable habitats. However, in order to establish the development of the lake over the years and the beginning of the processes of strong eutrophication, more research and a collection of satellite imagery database are needed, which will be the target of future research.

Urgent restoration measures are needed to restore stability of the aquatic ecosystem and avoid its rapid degradation. Restoring and preserving the natural water regime of the lake and the natural equilibrium of the lake ecosystem should be a priority in the preparation of the new management plan for the protected area.

Assoc. Prof. Iva Ivanova, PhD

Space Research and Technology Institute
at the Bulgarian Academy of Sciences
Acad. G. Bonchev str, Bl. 1, 315
Sofia 1113, Bulgaria
E-mail: ivaivanova@space.bas.bg

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