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MONITORING OF THE ENVIRONMENTAL STATE OF OAK PLANTATIONS USING REMOTE SENSING

МОНІТОРИНГ ЕКОЛОГІЧНОГО СТАНУ ДУБОВИХ НАСАДЖЕНЬ ІЗ ЗАСТОСУВАННЯМ ДИСТАНЦІЙНОГО ЗОНДУВАННЯ

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Quercus robur L. plays an extremely important role in the formation, structure and functioning of forest and forest-steppe ecosystems (including parklands), supporting their biodiversity, vitality and sustainability. However, the deterioration of the environment quality as a result of numerous man-made impacts (the growth of industrial waste and transport load, military operations, radiation and toxic emissions) causes disruption of ecosystems, resulting in a significant weakening of oak plantations with a whole complex of phytopathogens, which causes their degradation

and leads to death. To assess and monitor the state of forest and forest park ecosystems in many countries, geographic information technologies and methods of remote sensing of the Earth are widely used. Among them, the spectrophotometric method for studying the reflective characteristics of vegetation cover, which was effectively used by the authors in previous studies, is basic [1, p. 38; 2, p. 116; 3, p. 421; 4, p. 1]. A number of studies have proved the existence of a relationship between the change in optical parameters and the physiological state of plants. In particular, it was found that the spectral reflection coefficients of green leaves correlate with the level of their photosynthetic activity. Since the process of photosynthesis is very sensitive to the influence of environmental factors, the change in its intensity can determine the reaction of plants to stressors, including air and soil pollution. A comprehensive analysis of changes in these parameters can serve as a basis for developing remote methods of diagnosis the state and monitoring park ecosystems.

The purpose of the studies was to evaluate the features and changes in the spectral reflection characteristics of oak leaves (*Q. robur*) in conditions of man-made pollution, recreational load and damage by phytopathogens. The object of our research was one of the oldest forests in Europe, located within the boundaries of modern Kyiv – the hornbeam oak grove, which is the basis of the park-monument of landscape art of national importance "Feofania." Here on an area of 107 hectares grows more than 4600 trees of *Q. robur*.

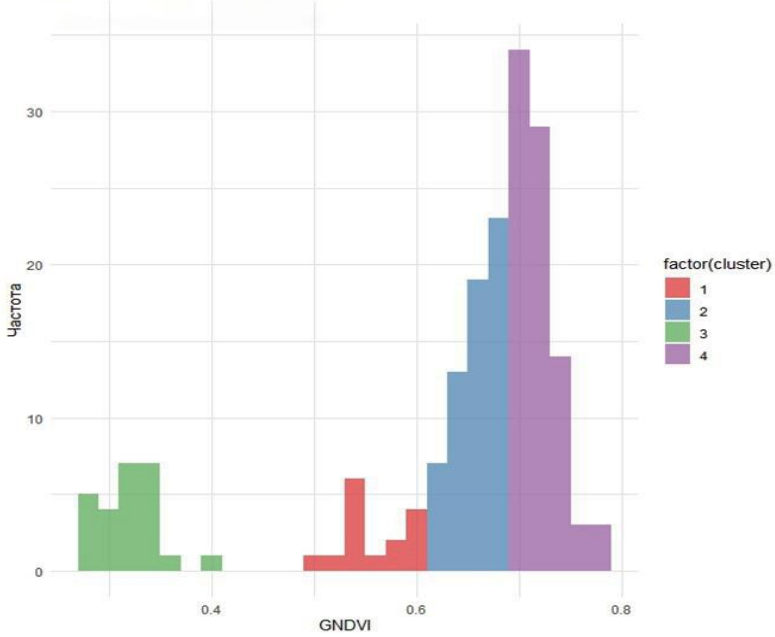
To assess the degree of damage by phytopathogens of leaves *Q. robur* during 2019–2023 spectrophotometric studies of their reflective characteristics were performed in the experimental areas of the Park “Feofania”. Model trees of different phenoforms were selected, along the profile from the main entrance towards the cascade of lakes in the lower part of the park. Measurements of spectral reflection coefficients (R)) of leaves were carried out with a spectroradiometer ASD FieldSpec® 3FR (USA), with an operating spectral range from 350 to 2500 nm. Remote studies of the central part of the Park are made by a multispectral camera installed on the DJI Phantom 4 Multispectral UAV in five spectral ranges: blue (B) – 450 nm ± 16 nm; green (G) – 560 nm ± 16 nm; red (R) – 650 nm ± 16 nm; red edge (RE) – 730 nm ± 16 nm; near-infrared (NIR) – 840 nm ± 26 nm and visible RGB. The study used five vegetation indices: *NDVI, GNDVI, LCI, NDRE and OSAVI*. Their choice is due to the fact that the multispectral camera installed on the DJI Phantom 4 Multispectral UAV conducts shooting in five reflection bands and automatically calculates these indices. Normal vegetation index $NDVI = (R_{840}-R_{650})/(R_{840}+R_{650})$ – a quantitative indicator of the photosynthetic activity of vegetation, minimizes the impact of lighting conditions, soil background, leaf orientation, meteorological factors. Green normal vegetation index $GNDVI = (R_{730}-R_{560})/(R_{730}+R_{560})$

is an indicator of the photosynthetic activity of the plant cover, which is most often used in assessing the moisture content and nitrogen concentration in plant leaves. The index of the red edge $NDRE = (R_{840}-R_{730})/(R_{840}+R_{730})$ is an indicator of the health and productivity of vegetation, allows more accurately to estimate the amount of chlorophyll in the vegetation cover in the red edge zone. The chlorophyll index $LCI = (R_{840}-R_{740})/(R_{840}+R_{665})$ is used to estimate the chlorophyll content in areas of complete leaves coverage. Optimized soil vegetation index $OSAVI=(1+Y)*((R_{840}-R_{665})/(R_{840}+R_{665}+Y))$, designed to examine young vegetation, taking into account the strong influence of the soil before the cover closes. Y=0.16 is a correction factor to account the influence of soil brightness on reflectivity measurements. Specified indexes are associated with characteristic wavelengths of absorption spectrum of basic plant pigments. They are most sensitive to any changes in the content of pigments in the leaves and form the basis of remote diagnosis of the ecological state of vegetation.

Analysis of changes in spectral reflection characteristics of leaves *Q. robur* model trees of different phenoforms, which was held in the first decade of June, the second decade of July and the first decade of October showed a clear trend in the change of these characteristics during the vegetation season both in the form of the reflection spectrum and in the values of the vegetation indexes. The highest level of correlation between vegetation indexes, the total leaf lesion area (from -0.74 to -0.84) and the area of the leaf miner lesion (from -0.68 to -0.91) was determined in June; in July, these figures are slightly lower: from -0.51 to -0.76 and from -0.41 to -0.66, respectively. In October, during the period of maximum lesion, the values of these links increase and represent: the total area of damage – -0.61 – -0.93; powdery mildew damage – -0.41 – -0.84; necrosis – -0.78 – -0.85. The nature of the lesion varies significantly during the growing season and, obviously, depends on the characteristics of meteorological factors. According to the results of cluster analysis by the k-means method, the structure and characteristics of the *Q. robur* distribution of Park "Feofania" in terms of vegetation indexes were investigated. An example of such a *GNDVI* index distribution is given in a graph where the X axis is the rank of the index values within each cluster, the Y axis shows which particular *GNDVI* values correspond to each rank in each cluster. Ranking is performed within each cluster, starting with the smallest value and ending with the largest. The analysis showed a clear distribution of index values into four clusters corresponding to the ecological state of *Q. robur*. The first includes dry, or almost dry – 25 trees; significantly damaged – 15; with damage up to 30% – 49; in satisfactory condition (up to 10% damage) – 95. Analysis and interpretation of the measurements results made by the ASD FieldSpec 3 FR ground-based

spectroradiometer and the DJI STS-VIS remote multi-spectral camera installed on the UAV showed a significant correlation between them. Combined application of remote sensing and ground-based spectrophotometric survey methods have shown high ficiency in determining factors, degree and area of phytopathogenic lesion of the *Q. robur* plantations.

The study revealed a clear trend in the change of spectrophotometric indicators of leaves *Q. robur*, depending on phytopathogenic lesion, man-made pollution and recreational load, and is an important component in assessing the state of park ecosystems.



Cluster analysis of remote sensing results Q. robur in Park "Feofania" according to the GNDVI vegetation index

It is determined that remote sensing methods for this assessment are very promising due to the high speed of the result, the breadth coverage of territories and low cost.

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