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QUANTITATIVE VEGETATION MAPPING OF URBAN AREA USING HIGH-RESOLUTION MULTISPECTRAL SATELLITE IMAGERY

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The geoinformation technology for evaluation the amount of vegetation in the green area of metropolis is described. This technology is based on multispectral satellite imagery and ground-truth data. Amount of vegetation is characterized by the leaf area index and related to satellite data through regression dependence between vegetation indices.

Keywords: geoinformation technology, satellite imagery, vegetation mapping, leaf area index.

Описано геоінформаційну технологію для визначення кількості рослинності лісопаркової зони мегаполісу. Дана технологія заснована на використанні багатоспектральних космічних знімків та наземних завіркових даних. Кількість рослинності характеризується значенням індексу листової поверхні та пов'язана з супутниковими даними через регресійну залежність між вегетаційними індексами.

Ключові слова: геоінформаційна технологія, супутникові зображення, картування рослинності, індекс листової поверхні.

Introduction

The urbanization of the territory is due to the needs of modern life. Currently, the city is transformed into a typical urban agglomeration. Maintenance of green spaces within the city is very important under current ecological conditions. In the present context, assessment of green spaces held by visually determining indicators plantations clarifying its instrumental measurements. The accuracy of this method largely depends on the qualifications and professional experience of the employee conducting an assessment. This process is expensive, time-consuming and non-operational. The sampling techniques are applied to reduce the complexity for mass measurements — getting together on the characteristics of its parts. But generalizing decreases objective assessment.

State-of-art

Investigations on remote study and mapping of vegetation in urban areas started in the 1980s. Miller R.W. studied urban vegetation and contributed to the field of urban ecosystem planning and management. «Urban Forestry» provides information on all aspects of the field, including the history and uses of urban vegetation, appraisal and inventories, the planning process, and management and maintenance [1].

Foreign scientists have been actively working on monitoring of urban forest canopy cover, green urban spaces and sealed surface areas using satellite imagery [2]. The urban forest is recognized for not only aesthetic benefits but for carbon storage, air filtration, noise reduction and wildlife habitat. Landsat satellite imagery (Thematic Mapper) proved effectiveness for mapping the density (crown closure) of non-urban forests [3].

The Russian scientist Bartalev S. A. made a significant contribution to the study of forest ecosystems. For example, in their use of the results of satellite imagery data ENVISAT MERIS and SPOT Vegetation for evaluation of vegetation in the area of influence of a source pollution by industrial emissions. Assessing the current state of the vegetation was carried out with the use of chlorophyll index MTCI (MERIS Terrestrial Chlorophyll Index). Temporal trends disturbance of vegetation have been identified by the analysis of time series of images SPOT Vegetation in the period 1998–2004 years. The results are the basis for spatial zoning of the degree of pollution emissions from industrial enterprises [4].

In Ukraine, the issue involved in such scholars as V. I. Lyalko, S. M. Kochubey, T. M. Shadchina, A. I. Sakhatsky, G. M. Zholobak, Z. M. Shportyuk other [5]. Vegetation assessment based on the use of the red-edge region of spectral reflectance of vegetation in the near infrared range of electromagnetic spectrum [6].

Traditionally assessment of vegetation made of medium-resolution imagery, such as, Landsat, Rapid Eye [7]. Currently, the trend of application of higher resolution images is observed not only for military tasks, but also for the problems of environmental management. Therefore the question of the application of high-resolution images to assess the vegetation needs to be elaborated.

Research objectives

High spatial and temporal resolution satellite systems provide information for operational monitoring of environmental conditions in the city and promote management decision making. Normalized Difference Vegetation Index (NDVI) –

index of plant "greenness" or photosynthetic activity — is widely used for vegetation studying. However, a more important phytometric parameter of vegetation is Leaf Area Index (LAI). Actually LAI is defined as the one sided green leaves area per unit of ground area in broadleaf canopies, or as the projected needle leaves area per unit of ground area in needle canopies [8].

Multispectral imagery processing to evaluate the NDVI and LAI provides informative and reliable indicators of vegetation quantity [9, 10]. Obtaining stable reproducible geoinformation technology for rapid assessment of large areas of vegetation is the primary objective of this study. The is-situ measurements of vegetation parameters are also necessary for this purpose.

Material and methods

High-resolution image from Pléiades-1A satellite was used in the study. This image was obtained at April 22, 2013. The data are characterized by a wide swath (20 km), and high geopositioning accuracy — less than 4.5 m (CE90) without additional ground control points.

The spatial resolution of image in panchromatic band is 0.7 m (0.5 m after preprocessing), and 2.8 m in all spectral bands (2.0 m after preprocessing).

Regulatory area of the "Goloseevsky" National Natural Park and M. Rilsky city park [11] was chosen to estimate the amount of vegetation using high-resolution satellite imagery. Image values in digital numbers (DN) were converted into at-sensor spectral radiance using each-band calibration factors extracted from image metadata. Next the atmospheric correction was performed and floating-point values of the ground reflectance were obtained (Fig. 1).

The satellite image was cut off using the mask, constructed on the basis of data on green plots within the research area to avoid large segments of industrial and residential urban development.

Mask data was calculated according to NDVI threshold using a decision-tree algorithm (Fig. 2).

Because of phenophases of major plant communities were different, the averaged nonlinear regression dependence between LAI and NDVI was constructed.

In-situ LAI estimation was conducted by photometric method [12]. Ground-based panoramic photographic survey of vegetation was carried out with a fisheye camera lens (Fig. 3).

Complete geoinformation technology for integrated quantitative assessment of vegetation in urbanized territory [13] provides a distribution of LAI within the study area. This technology can be explained by Fig. 4.

The first group of operations was used for preprocessing of multispectral satellite image. Output of these operations is a scene surface reflectance. The second group of operations comprises the steps of LAI calculations based on vegetation mask and LAI versus NDVI regression dependence. Final group of operations provides visualization and interpretation of the results.

Fig. 1. The original satellite image with a border (white lines) of city park green area

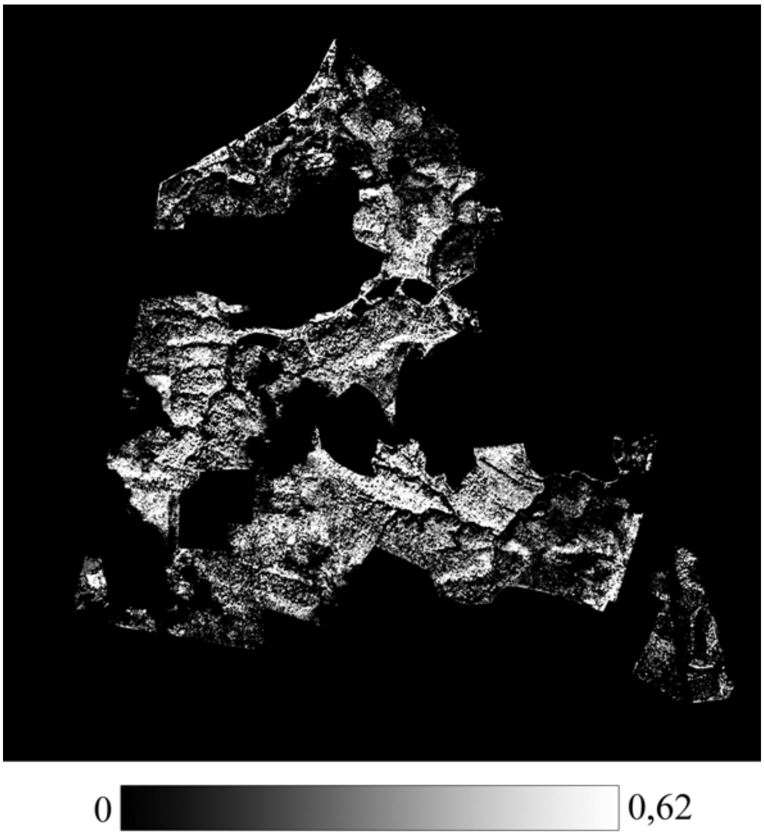

Fig. 2. Distribution of NDVI within the vegetation mask

Fig. 3. Fragment of vegetation panoramic photographic survey for LAI calculation

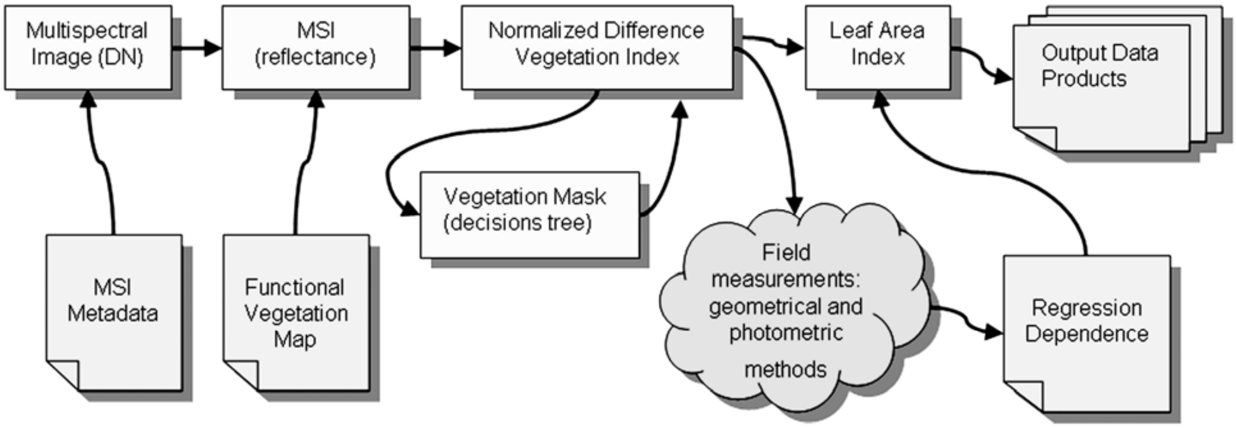

Fig. 4. Flowchart for vegetation amount assessment using multispectral satellite image

Results

Preliminary analysis of the LAI distribution which shown in Fig. 5 separates all vegetation area into specific plots of coniferous and evergreen plants. Strong growth of underbrush and its influence on increasing the total LAI value is also visible in this image.

Diagram from Fig. 6 illustrates a comparison of amounts of vegetation obtained by different methods. Area of green zone according to land registry includes roads and paths, as well as the area occupied by buildings and transportation infrastructure.

Common projective cover of vegetation was calculated using NDVI; one displays the area of the territory occupied by vegetation only.

The satellite-derived value corresponds to the total green LAI of all the canopy layers, including the understory which may represent a very significant contribution.

Practically, the LAI quantifies the thickness of the vegetation cover.

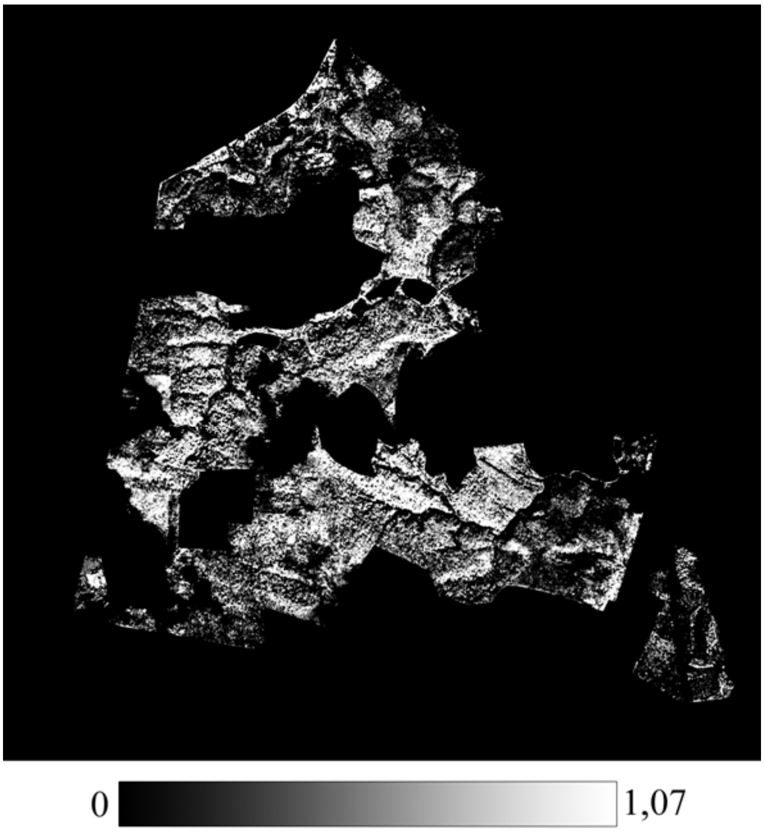

Fig. 5. The LAI spatial distribution within the study area

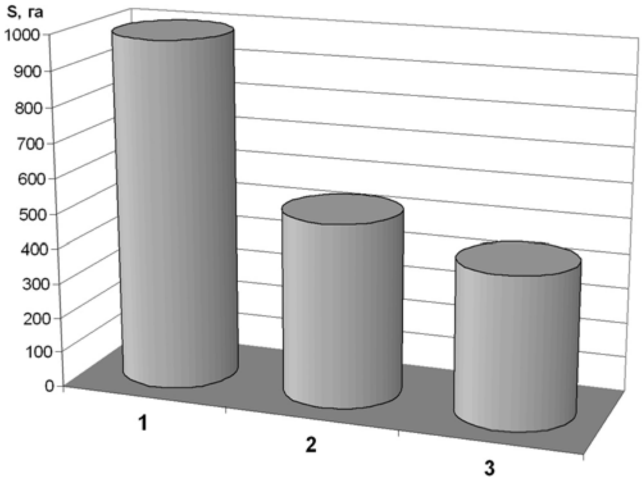

Fig. 6. Total area of vegetation within the territory of research:
1 — area of the green zone according to land registry;
2 —area of projective plant cover, calculated using NDVI;
3 — the area of vegetation, obtained by LAI evaluation

The methodology for calculating the vegetation area within the land registry boundaries gives biased values of green mass and its status. At the beginning of the growing season the regulatory area of green zone is much greater than the actual amount of vegetation.

It is possible to determine more accurately the boundaries and the total area of vegetation cover using the NDVI. Also the described LAI-based geoinformation technology provides tuning out the current phase of the phenological cycle. As a result, more accurate estimation of vegetation amount at moment and its changes over time are available too.

Conclusion

Thus, the paper presents a complete geoinformation technology for quick and objective assessment the amount of vegetation in view of phenological phases. Research based on LAI versus NDVI regression dependence. The distribution map of vegetation indices can be obtained.

Further studies aimed at assessing not only the quantity but also the quality of vegetation. The increase in number of ground control points and number of in-situ measurements are planned to clarify the regression confidence. There will also be studying the state of plant communities at different phases of the phenological cycle.

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