UDC: 528.854.4: 57.081.1

VEGETATION QUALITY REMOTE ASSESSMENT IN URBAN AREA: GOLOSIIVSKY NNP CASE STUDY

S.A. STANKEVICH, I.A. PIESTOVA, O.O. GODYNA, R.S. FILOZOF

In the paper the technique for estimation of vegetation quality using multispectral satellite imagery and ground truth data is described. This technique is an important component of an integrated geoinformation technology for remote assessment of vegetation condition within urban area. The developed technique application for the vegetation condition assessment within the "Golosiivsky" Kiev National Nature Park is demonstrated.

Keywords*: vegetation quality, satellite imagery, spectral reflectance, red-edge tangent, spline interpolation, "Golosiivsky" NNP*

Introduction. Particular urban environment is the result of relentless urban development. Urban environmental status affects the quality of the living conditions of its residents. To improve the quality of urban life, the continuous operational monitoring and forecasting of urban area environmental condition is required.

Because a significant role of greenery in environmental conditions improving, a special attention should be paid to research the vegetation state using modern remote and field data and GIS technologies.

Problem. Nowadays the vegetation assessment is a hard challenge. It needs the analysis of a large amount of heterogeneous, poorly formalized, and sometimes even contradictory indicators. It also requires expert's knowledge and thus is subjective and under human issues. Wide area investigation is consuming and costly, then data updating is very longtime. One way to mitigate these difficulties is to involve remote sensing data such as medium spatial resolution satellite imagery [7].

Objective. Purpose of current research is to ensure operational objective quantitative remote evaluation and mapping of urban vegetation by applicable models

and algorithms development as well as by appropriate geoinformation services implementation.

State-of-the-art. The vegetation state is characterized by quantitative and qualitative indicators, which are determined in different ways. For example, the methods for vegetation amount evaluation are known, which are based on the leaf area index (LAI) [18]. We tested the method for vegetation amount evaluation within urban area using multispectral satellite imagery [12] and we estimated LAI(NDVI) regression inside Kiev city for the first time [20]. We also examined vegetation cover changes within the Kiev metropolitan agglomeration for long-term series of satellite images [13].

Modern methods for vegetation quality assessment can be classified as ground-based and satellite. Ground-based methods use vegetation inventory and landscape analysis. They provide a vegetation quality averages, verbal mainly. Satellite-based methods involve a vegetation quality attributes such as the chlorophyll content, gaseous metabolism rate, etc. [14]. We attempted to adopt vegetation quality assessment methods for GIS platform.

Study area. The study area was “Golosiivsky” National Nature Park (NNP), which was established by the 794/2007 Decree of the President of Ukraine of August 27, 2007 within “Golosiivsky” district of Kiev city. The 446/2014 Decree of the President of Ukraine of May 1, 2014 extends up the “Golosiivsky” NNP area for 6462.62 hectares of Sviatoshynsky forest park.

“Golosiivsky” Park is a multirole nature reserve of the following activity domains: environmental, research, recreational, cultural and ecology-educational. According to the Law of Ukraine “On Nature Reserve Fund of Ukraine”, the differential zoning was established in “Golosiivsky” NNP. This one includes four functional zones: conservation, regulated recreation, stationary recreation and service. Naturally Park consists of five separate forests. Forest ecosystems occupy more than 90% of the park territory. “Golosiivsky” NNP is the exclusive highest rank wildlife institution in Ukraine, which is located within the metropolis.

“Golosiivsky” Park is located in the right-bank part of Kiev city, in the far north of forest-steppe zone. Associated territory with mixed forests belongs to the Kiev Polesie geographical region. The southern part of the Park is a Dnieper sandy terrace, mostly covered with pine and pine-oak forests. There are lots of forest swamps inside valley of Vita small river. There are broad-leaved forests inside Bychok small stow at Dnieper northern floodplain.

The central part of the Park includes the protected broad-leaved forests within the Kiev plateau – “Golosiivsky” forest reserve (with the nearby Maksym Rylski “Golosiivsky” city-park) and “Teremki” forest. Just “Golosiivsky” forest was chosen for current research as the most visited and built-up surroundings.

Source data. The study used the “Sich-2”/MSU medium spatial resolution multispectral satellite image fragment, which was acquired at September 1, 2011 in four spectral bands: green, red, near infrared and short-wave infrared.

There are following auxiliary in-situ data were processed: the “Golosiivsky” NNP territory protection, maintenance and management plan [9], and the “Koncha Zaspa” municipal enterprise activities and management plan [8]. These documents contain forest taxation data, forest units’ statements, etc.

Methods. The common dataflow for vegetation state assessment using satellite data, which is implemented as integrated geoinformation technology has been developed previously. The technology provides a cut-through data processing from calibrated satellite imagery up to vegetation thematic map with recommendations [11]. This study focuses on most complicated subsystem intended for vegetation quality assessment (Fig.1).

The vegetation quality on multispectral satellite imagery is characterized by life- important pigments content. They are chlorophyll mainly as well as carotenoids, anthocyanins and flavonoids [2, 6]. The vegetation spectral reflectance in visible and near infrared spectral bands is a source data for remote evaluation of pigments content [3]. The accuracy depends on the accuracy of vegetation reflectance spectral curve and its derivatives restorations [5]. The vegetation water content is determined by reflectance in short-wave infrared band and temperature [10]. Photosynthetic

activity and stress are investigated using specialized vegetation indices [15, 17, 19] and orthogonal transformations [16].

During the research it was found that better correlation with ground-based urban vegetation quality provides no red edge position (REP), which is most often used for such assessment, but the first derivative in red-edge wavelengths – red-edge tangent (RET). RET is somewhat like a well-known normalized difference vegetation index (NDVI), but as against NDVI it more accurately estimates the vegetation spectral reflectance in red-edge range.

The modern methods for RET estimation were considered such as polynomial interpolation, expansion into series of orthogonal functions, NDVI regression, etc. As the most suitable and noise-resistant the optimal spline interpolation method was chosen for further research [1]. Optimal interpolation takes into account the derivative values at boundaries of red-edge range. This method is based on determining the optimal nodal points, which are connected by spline curve with continuous first and second derivative. The algorithm for optimal spline interpolation and RET calculation considering the multispectral sensor spectral band specifications (in this study – the “Sich-2”/MSU sensor) is implemented using SciLab open-source software. So, for “Sich-2”/MSU the spectral curve derivative values outside red-edge range was estimated using reflectance in additional working spectral bands: green one leftward and short-wave infrared one rightward.

Data processing. The data processing flowchart is presented in Fig.1.

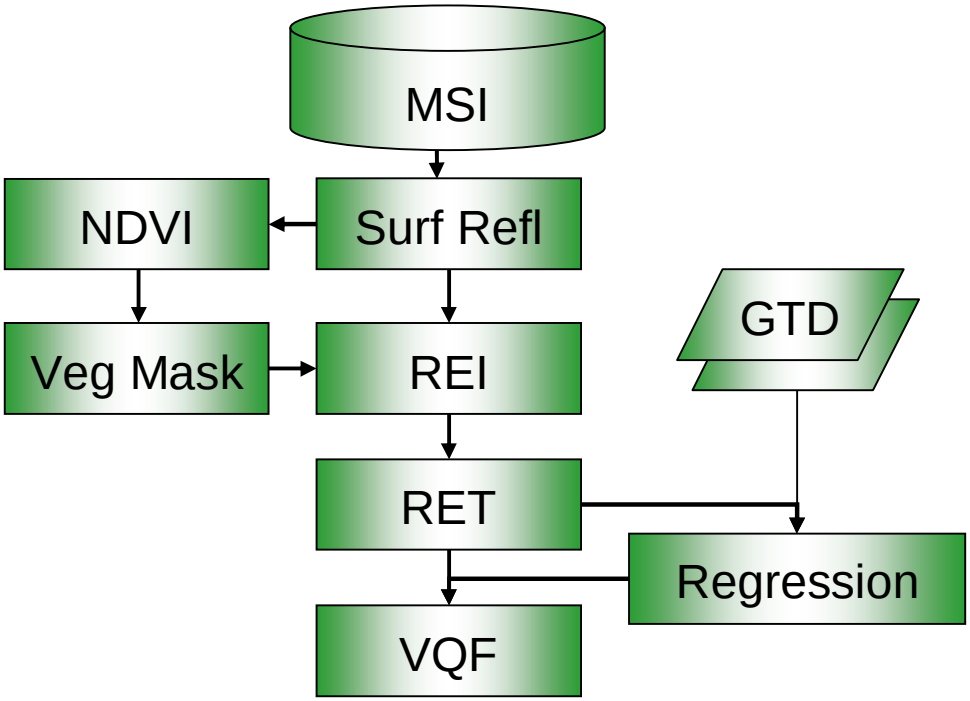

Fig.1. Vegetation quality assessment using multispectral imagery dataflow diagram

First the “Sich-2”/MSU calibrated satellite image (MSI) fragment was cut-out for study area. The atmospheric correction of image was carried out and at-sensor spectral radiance was recalculated into land surface reflectance (Surf Refl). Next the vegetation mask (Veg Mask) was created by NDVI threshold and elementary plots of plant communities (forest units) with available ground-truth data (GTD) were mapped. The RET pixel values within the vegetation mask were calculated using red-edge optimal spline interpolation (REI) algorithm. The average value of RET was determined for each forest unit.

Normalization of statistical samples was conducted and robust regression (Regression) was restored by known classes of vegetation quality. Regression diagram is shown in Fig.2. The vegetation quality was described by dimensionless percentage-based score VQF (vegetation quality factor). The restored regression was used to calculate the VQF values for area where ground-truth data are missing.

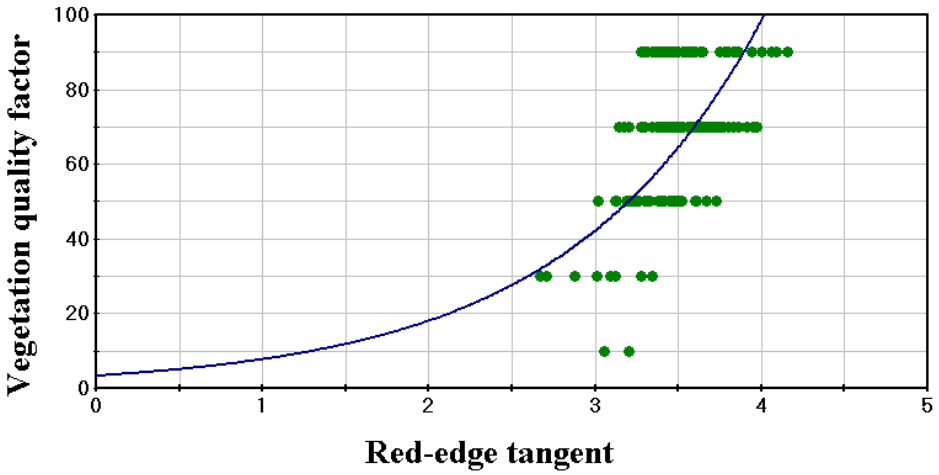

Fig.*2. VQF(RET) regression diagram*

Results. The VQF distribution map of study area was retrieved using satellite data. To improve visual acceptability VQF scale is subdivided into 5 classes (Fig.3 left) and compared with the distribution of recreational digression index (Fig.3 right) because this landscape assessment index depends significantly on the vegetation state [4].

Analysis of Fig.3 distributions shows that the average RET values of small units (I) quite clearly coincide with ground-truth data. This is due to compliance of image and map spatial resolution, as well as due to low variability of RET within a few pixels area.

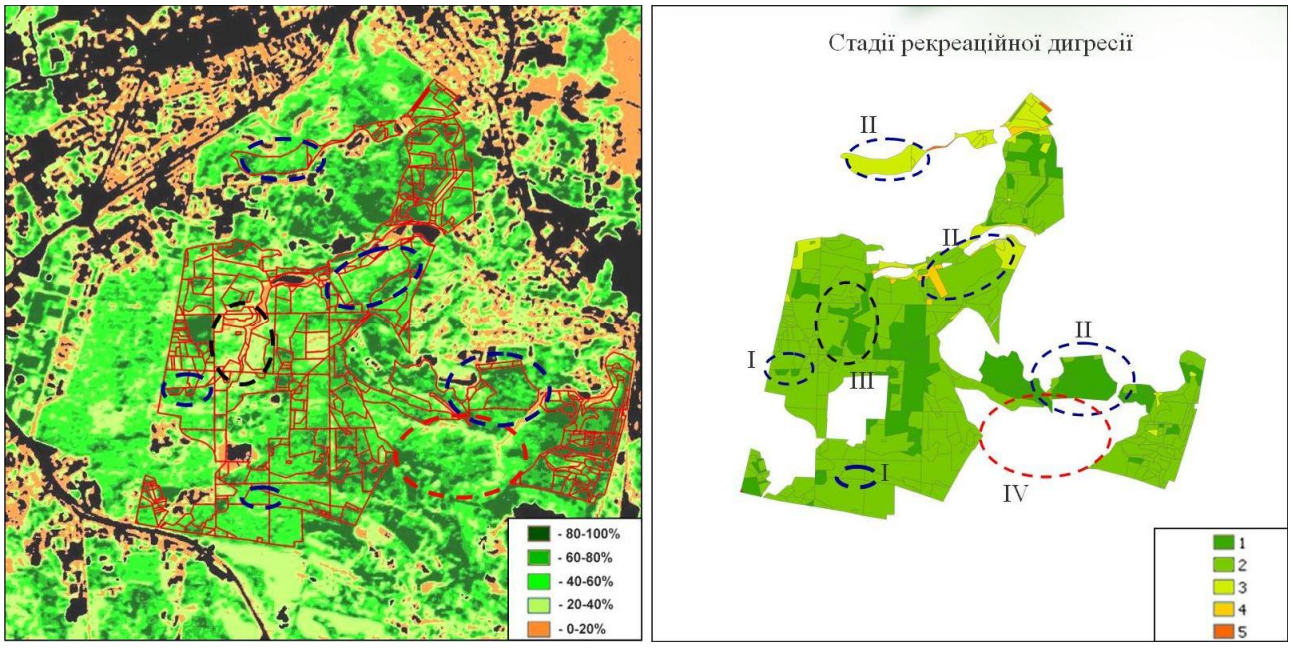

Fig.3. Vegetation quality distribution map by satellite data and in-situ inspections

In other areas (II) the VQF values are well-matched with ground-truth data. However, the obvious advantage of the results obtained by the satellite data is possibility to detect the some heterogeneity in comparison with generalized landscape assessment index. This is caused by both the species diversity within the forest unit and the small-size troubled units' presence that are detected difficultly by ground survey and/or not considered in expert inspection.

The third area type (III) there is a significant mismatch between the results of satellite and in-situ assessments. This case is the reason for additional ground survey of troubled units and understanding the nature of mismatches.

Finally the satellite data advantage is the ability to assess vegetation quality within areas (IV) where in-situ observations are not performed. For example, in current research this is a territory of protected area in "Golosiivsky" NNP where natural plant communities inhabited, as well as plants and animals listed in the Red Book of Ukraine.

Generalized estimation of accuracy was performed by comparing the ground-truth recreational digression classes and remotely sensed VQF values, which was sampled into corresponding landscape assessment unified classes. Quantitative results of comparison are given in table.

Table. Overall coincidence of vegetation quality assessments by in-situ inspections and by remote sensing data among forest units

Total units fraction, %	Mismatch, %
52,2	0
42,4	20
4,6	40
0,5	60
0,3	80

Averaged over whole units accuracy is 89.14%, which is quite satisfactory for remote assessment of vegetation quality in urban area.

Conclusions

1. A technique for vegetation quality assessment by remote sensing data is developed. This technique is important and most complicated subsystem of integrated geoinformation technology for vegetation state assessment. The technique was tested on ground-truth data within the “Golosiivsky” Park. The results obtained are satisfactory.

2. The reliability of estimates obtained was characterized by the determination coefficients of restored regressions that are in the range 0.36-0.68 for different types of plant communities. Incomplete correspondence and some inconsistence in results are due to ambiguous expertise. So, the appropriate step in further studies should be proposals to clarify and unify the vegetation quality assessment rules. Nevertheless, the technique provides 89% accuracy of results matching with ground-truth data. This fact permits the technique application in practice of urban green space monitoring.

3. The estimates obtained are one-time and are not described the overall vegetation quality in full extent, so the more valid estimates can be collected using long-term time series of satellite images to smooth out statistical outliers and to exclude phenological phases effect within the study area.

4. It is necessary to assess the different classes or species of vegetation separately for more exact results. It can be achieved through the engagement of hyperspectral imagery with ground spectrometry data, as well as high resolution satellite imagery.

References

1. Bakirov N.K. An asymptotically optimal cubic spline (in Russian) / N.K. Bakirov // Russian Mathematics.– 2011.– Vol.55.– No.4.– P.8-14.

2. Brand A.B. Optical Parameters of Vegetative Organisms (in Russian) / A.B. Brand, S.V. Tageeva.– M.: Nauka, 1967.– 302 p.

3. Vygodakaya N.N. Theory and Experiment in Vegetation Remote Sensing (in Russian) / N.N. Vygodakaya, I.I. Gorshkova.– Leningrad: Gidrometizdat, 1987.– 248 p.

4. Datsyuk V.V. Study of forest ecosystems changes under recreational impact in the “Golosiivsky” National Nature Park territory (in Ukrainian) / V.V. Datsyuk, O.O. Godyna.– Proceedings of International Conference “Aims of Stable Development of Ukraine”.– Kiev: Center for Ecological Education and Information, 2013.– P.197-200.

5. Kochubey S.N. Spectral Properties of Plants as a Base of Remote Diagnostic Methods (in Russian) / S.N. Kochubey, N.I. Kobets, T.M. Shadchina.– Kiev: Naukova Dumka, 1990.– 136 p.

6. Movchan J.I. Phytoindication in Remote Sensing (in Russian) / J.I. Movchan, V.A. Kanevsky, V.D. Semichaevsky, E.I. Levchik, A.E. Turuta.– Kiev: Naukova Dumka, 1993.– 306 p.

7. Popov M.A. Towards rapid evaluation of the urban green space capacity using multispectral satellite imagery (in Ukrainian) / M.A. Popov, S.A. Stankevich, A.A. Kozlova, I.A. Markova // Scientific Bulletin of the National Agricultural University.– Vol.128.– Kiev: NAU, 2008.– P.299-301.

8. Kiev “Koncha Zaspa” municipal enterprise activities and management plan. Golosiivsky Forestry: Forest Taxation Data, Forest Units’ Statements (in Ukrainian).– Irpen: “Koncha Zaspa” municipal enterprise, 2010.– 202 p.

9. “Golosiivsky” NNP territory protection, maintenance, recreation and management plan (in Ukrainian).– Kiev: “Golosiivsky” NNP, 2013.– 303 p.

10. Sakhatsky A.I. About possibilities of soil moisture estimation using space imagery optical bands for Ukraine territory (in Ukrainian) / A.I. Sakhatsky, S.A. Stankevich // Reports of the NAS of Ukraine.– 2007.– No.11.– P.122-128.

11. Stankevich S.A. Geoinformation processing technique for vegetation assessment in urban area (in Ukrainian) / S.A. Stankevich, I.A. Piestova // Bulletin of Geodesy and Cartography.– 2014.– No.3.– P.23-26.

12. Stankevich S.A. Remote estimation of vegetation quantity in metropolitan agglomerations (in Ukrainian) / S.A. Stankevich, I.A. Piestova // Proceedings of II Conference “Scientific Aspects of Geodesy, Land Management and Information Technologies”.– Kiev: UNT NAU, 2013.– P.75-80.

13. Stankevich S.A. Vegetation cover changes mapping within Kiev metropolis agglomeration using long-term time series of Landsat multispectral satellite imagery (in Russian) / S.A. Stankevich, I.A. Piestova // Actual Problems in Remote Sensing of the Earth from Space.– 2014.– Vol.11.– No.2.– P.187-196.

14. Strochinsky A.A. Greenery Taxation within the Kiev City Territory: Theory and Practice (in Ukrainian) / A.A. Strochinsky, V.V. Mironyuk.– Korsun-Shevchenkovsky: Gavrishenko, 2013.– 179 p.

15. Apan A. Detecting sugarcane ‘orange rust’ disease using EO-1 Hyperion hyperspectral imagery / A. Apan, A. Held, S.R. Phinn, J. Markley // International Journal of Remote Sensing.– 2004.– Vol.25.– No.2.– P.489-498.

16. Crist E.P. The tasseled cap de-mystified / E.P. Crist, R.J. Kauth // Photogrammetric Engineering and Remote Sensing.– 1986.– Vol.52.– No.1.– P.81-86.

17. Merzlyak M.N. Nondestructive optical detection of pigment changes during leaf senescence and fruit ripening / M.N. Merzlyak, A.A. Gitelson, O.B. Chivkunova, V.Y. Rakitin // Physiologia Plantarum.– 1999.– Vol.106.– No.1.– P.135-141.

18. Myneni R.B., Nemani R.R., Running S.W. Estimation of global leaf area index and absorbed PAR using radiative transfer model // IEEE Transactions on Geoscience and Remote Sensing.– 1997.– Vol.35.– No.6.– P.1380-1393.

19. Peňuelas J. Semi-empirical indices to assess carotenoids/chlorophyll a ratio from leaf spectral reflectance / J. Peňuelas, F. Baret, I. Filella // Photosynthetica.– 1995.– Vol.31.– No.2.– P.221-230.

20. Piestova I. Vegetation state quantitative estimation within urban area / I. Piestova // Proceedings of Fourth International Conference on Earth Observations for sustainable Development and Security (GEO-UA 2014).– Kiev: Naukova Dumka, 2014.– P.90-93.

ДИСТАНЦІЙНА ОЦІНКА ЯКІСНОГО СТАНУ РОСЛИННОСТІ НА МІСЬКИХ ТЕРИТОРІЯХ НА ПРИКЛАДІ НПП «ГОЛОСІЇВСЬКИЙ»

д.т.н. С. А. СТАНКЕВИЧ, доктор технічних наук,
І. О. ПЄСТОВА, О. О. ГОДИНА,
Р. С. ФІЛОЗОФ, кандидат географічних наук

Описано методику оцінки якісного стану рослинності за багатоспектральними супутниковими знімками та наземними завірковими даними. Ця методика є важливою складовою цілісної геоінформаційної технології дистанційного оцінювання стану рослинності урбанізованих територій. Продемонстровано застосування розробленої методики до оцінювання стану рослинності в межах території національного природного парку «Голосіївський» міста Києва.

Ключові слова: *якість рослинності, космічні знімки, спектральне відбиття, Red-Edge Tangent, сплайн-інтерполяція, НПП «Голосіївський»*

ДИСТАНЦИОННАЯ ОЦЕНКА КАЧЕСТВЕННОГО СОСТОЯНИЯ РАСТИТЕЛЬНОСТИ НА ГОРОДСКИХ ТЕРРИТОРИЯХ НА ПРИМЕРЕ НПП «ГОЛОСЕЕВСКИЙ»

С.А. Станкевич, И.А. Пестова, О.О. Годына, Р.С. Филозоф

Описана методика оценки качественного состояния растительности по многоспектральным спутниковым снимкам и наземным заверочным данным. Эта методика является важной составляющей целостной геоинформационной технологии дистанционного оценивания состояния растительности урбанизированных территорий. Продемонстрировано применение разработанной методики к оценке состояния растительности в

пределах территории национального природного парка «Голосеевский» города Киева.

Ключевые слова: *качество растительности, космические снимки, спектральное отражение, Red-Edge Tangent, сплайн-интерполяция, НПП «Голосеевский»*