Monitoring city green zones using GIS technologies: An example of Tashkent city, Uzbekistan

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Abstract. Increasing green zones can be a suitable option to meet the challenges of growing cities. City authorities in developing countries face a lack of reliable data on the status of urban trees and forestry. The objective of this study was to carry out a spatio-temporal analysis of the dynamics of urban green zones of Tashkent City using Landsat satellite images taking into account climatic changes. For this, we used methods of laying test plots in assessing tree-shrubbery vegetation, a technique for expert interpretation of land cover objects from satellite images of medium spatial resolution, and mathematical statistics. The statistical analyses showed that the temperature regime has the greatest degree of influence on the dynamics of NDVI, i.e. the onset of the growing season corresponds to an increase in temperature. Precipitation, in view of its unstable and uneven distribution in the study area, has a weak negative relationship with the phytomass of green zones. Spatial analysis revealed an average degree of variability of NDVI in the green areas of the city for the studied period of 2000-2011.

1. Introduction

Many cities of the developing countries face challenges associated with their population growth and the urban development (Hens, 2010; Song, 2011; El Ghorab and Shalaby, 2016; Lo Storto, 2016; Alfaro-Navarro, 2017; Betman, 2017; Hegazy, 2017; Hovhannisyan and Nersisyan, 2017; Kamal, 2017; Mersal, 2017). Greening cities can be a suitable option to meet these challenges. Urban trees reduce the number of greenhouse gases by sequestering carbon dioxide and reducing the amount of energy needed to heat and cool buildings. Urban trees and forestry is the dominant natural element of the landscape of cities and at the same time provide important ecosystem services to the population, by maintaining clean air and mitigating temperature and humidity conditions. However, city authorities in developing countries face a lack of reliable data on the status of urban vegetation.

GIS applications can be used to fill the data gap. The study of green urban areas using GIS technology was the focus of research by Uy and Nakagoshi (2007), Kong (2006), Lahoti (2019), Wong (2019). For example, Uy and Nakagoshi (2007) monitored the status of green areas of Hanoi city, Vietnam, and concluded that the green areas have become more fragmented due to changes in land use, economic growth, demographic processes, urbanization, and poor development planning of the urban area. Kong (2006) studied changes in the spatial structure of urban land use and urban green spaces in Jinan, China in the period 1989–2004. He applied GIS and remote sensing data, and a green zone estimation technique using the “moving window” method (using the FRAGSTATS program). The study found changes in the green zone area as affected by urbanization (Kong F, 2006). Wong et al. (2019) carried out monitoring of urban areas in the Pearl River area using Sentinel satellite data to
assess land cover changes. For analysis, they used the normalized NDVI vegetation index and the fractional coefficient of vegetation. Due to the lack of field data in the target area, high-resolution satellite images (pixel size 0.59 m) have been used since 2016 to assess the reliability of the results. The authors concluded that global mapping of vegetation, taking into account local climatic changes, is very important for urban meteorological modeling (Wong et al. 2019). The objective of the study is to carry out a spatio-temporal analysis of the dynamics of urban green zones using Landsat satellite images taking into account climatic changes.

2. Methods
2.1 Study area
The study analyses satellite images for Tashkent city for 2000-2018.

![Location of the study area and Tashkent](image)

2.1. Research Methods
In this study, we used the method of laying test plots in assessing tree-shrubbery vegetation, a technique for expert interpretation of land cover objects from satellite images of medium spatial resolution, and mathematical statistics. The steps applied in this study were as follows: (1) selection of high-resolution satellite imagery Landsat-8 and MODIS in the study area; (2) correction of images; (3) classification of images; (4) assessment of the accuracy of thematic mapping; (4) determining raster index indicators according to MODIS data to the study area over an 18 year period; (5) identification of patterns of spatial and temporal relationships of raster data of urban green areas with climatic parameters; (6) analysis of satellite images using ArcGIS 10.3.

3. Results and Discussion
3.1 Selection of Landsat-8 and MODIS high-resolution satellite imagery for the research area
To identify the green areas, Landsat-8 satellite images were used for summer periods and MODIS Terra to analyze climatic data for 2000-2018. The interpretation of satellite images was carried out using the software packages ENVI 5.0 and ArcGIS 10.3.
3.2 Image correction
The image has been pre-processed (radiometric, atmospheric and geometric correction).

3.3 Image classification
The classification was carried out in two stages - primary for 25 classes and secondary, with the classification of complex classes of the land cover into 10 subclasses (Fig. 3).

3.4 Assessment of the accuracy of thematic mapping.
The accuracy of thematic mapping was determined by the method of statistical evaluation using a cross-analysis of test and thematic data. Based on the results of mapping and expert analysis, several raster classes evaluated as sections of the green zone of Tashkent city.

Table 1. Accuracy of classification of thematic mapping for Tashkent city

| Coefficient | Value |
|-------------|-------|
| AAM         | 0.81  |
| Kappa       | 0.74  |

Then based on the results of the secondary classification, vector layers were obtained for the study area. Then, from them using expert decryption and field research data, a final vector layer of urban “green zones” in urban areas was obtained (Fig. 4).
To analyze the relationship between tree and shrubbery vegetation and obtain the values of climatic parameters only for areas of "green zones" according to satellite data, vector layers were converted to a point format.

3.5 Definition of index and climate indicators

Thus, according to MODIS data, the values of the NDVI index indicator were obtained, as well as the values of climatic parameters: precipitation and temperature from a series of thematic maps of different times from 2000 to 2018.

The indicators of the selected parameters were extracted according to the principle of one point, one value. Values were taken for each month during the year for the entire estimated period. As a result, databases were compiled for three indicators for subsequent assessment of their relationship.

Because there were meteorological observations on the territory of Tashkent over a long period, it was decided to compare MODIS data with ground-based data to determine the possibility of using satellite data to analyze the response of urban green zones to climate change.

To identify the accuracy of the spatial data of climatic indicators obtained using raster maps, a comparative correlation analysis was carried out with the data of meteorological observations (weather station in the suburbs of Tashkent) over an 18-year period (Table 2). According to the results of the assessment, the value of the correlation coefficient was $R = 0.72$, which indicates a high degree of compliance of satellite monitoring data and ground-based observation data.

3.6 Identification of patterns of spatial and temporal relationships of raster data of urban green areas with climatic parameters.

To identify the patterns of spatial and temporal relationships of raster data of urban green areas with climatic parameters, a selection of ready-made thematic maps was carried out, including NDVI spatial data sets, maps of the underlying surface temperature and precipitation for the studied period from 2000 to 2018 (Fig. 5).

| Year | NDVI | MODIS T °C | Precipitation mm | Weather station T °C | Precipitation mm |
|------|------|------------|------------------|----------------------|-----------------|
| 2000 | 0.1  | 4          | 69               | 3.32                 | 52.2            |
| 2000 | 0.21 | 3.5        | 24               | 3.47                 | 34              |
| 2000 | 0.3  | 9.8        | 42               | 5.52                 | 20              |
| 2000 | 0.45 | 18.4       | 35               | 16.54                | 23              |
| 2000 | 0.45 | 22.3       | 3                | 20.58                | 6.6             |
| 2000 | 0.42 | 25.9       | 15               | 21.57                | 14.1            |
The relationships between the dependent parameter NDVI characterizing the dynamics of phytomass and the general condition of the vegetation cover of the western area and independent parameters in the form of climate data, temperature and precipitation in the study area were estimated using the method of two-factor regression analysis in the Excel software environment. The analysis was carried out both according to the averaged data covering the estimated urban areas and separately for each of the objects. Analysis of statistics showed that both key climatic factors, temperature, and precipitation have a significant impact on the vegetation cover of urban areas, regardless of location. The general equation of dependence is presented below:

\[ Y = 0.109 + 0.012X_1 + 0.001X_2, \quad R^2 = 0.71(1) \]

The relationship of climatic parameters and NDVI values amounted to for Tashkent received \( R^2 = 0.71 \). This is determined by the coefficient of determination equal to 0.71. Those more than 70% of changes and dynamics of phytomass throughout the year and the entire 18 year period can be explained by the influence of both temperatures and precipitation.
3.7 Dynamics of NDVI values of the vegetation cover of the “green zones” in Tashkent over an 18-year period.

An analysis of changes in the vegetation cover of green areas of urban areas can be traced using the method of raster analysis of spatial data of different images at the same time. As an example of such opportunities, a comparison of spatially distributed values of NDVI data is given for 2000-2010-2018 in Figure 7.

The changes themselves are determined by the method of analysis of thematic maps of raster spatial changes of the NDVI index (Fig. 8).
A comparative analysis of the changes that took place based on thematic maps of different times revealed spatial changes in the NDVI index indicators over the past 18 years. If from 2000 to 2010 there were no significant changes in index values in the city (the color of “stability” is brown), the next 8 years there is an increase in these changes, which is associated with a significant increase in construction work in certain sections of the city territory (color change from blue to blue). What is important, the dynamics of NDVI in the area of the city park has remained practically stable since 2010. Climate indicators also affect the level of changes in index indicators. An analysis of this fact was given in the section above. Thus, spatial analysis of raster data for the urban area can significantly enhance the ability to monitor the urban environment according to satellite observations.

4. Conclusions
The study applied the methodology of assessing the relationship of index indicators of vegetation cover of urban green areas with climatic parameters based on satellite data. The study proved the efficiency of the applied method by a high degree of correlation of climate data obtained from satellite images and ground control data. The application of the method allowed reconstructing the status and volume of phytomass (using NDVI data) over the studied period of 18 years. The temperature regime had the greatest degree of influence on the dynamics of NDVI, i.e., the onset of the growing season corresponds to an increase in temperature. Precipitation, in view of their unstable and uneven precipitation into the study area, had a weak negative relationship with the phytomass of green zones. Spatial analysis revealed an average degree of variability in the dynamics of NDVI in the green areas of the city for the estimated time cycle of 2000, 2010, and 2018. The use of satellite data for monitoring green areas was proved to be highly effective for multilevel assessment and analysis of urban green zones.

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