



Methodology for digital mapping of Tashkent city groves based on GNSS technologies.

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Annotatsiya

Develops a methodology based on GNSS (Global Navigation Satellite System) technologies for digital mapping of urban tree plantations and the formation of their ecological monitoring system in the conditions of Tashkent. The main goal of the study is to measure the exact geographical coordinates of trees in green areas, reflect their type, biometric indicators (height, diameter, crown diameter) and ecological status in a digital database. The location of each tree is determined using GNSS receivers, the obtained coordinates are processed using FM (Field-Map) software and placed on a single digital map. As a result, an individual identification number, location point, type, biometric parameters and a set of attributes representing the ecological value were formed for each tree. This methodology allows for remote monitoring of the condition of trees in the urban ecological management system, planning of cutting and maintenance processes on a scientific basis. The results of the study are of practical importance in optimizing the ecological infrastructure of Tashkent, protecting green spaces and implementing a digital ecological monitoring system.

Kalit so'zlar: GNSS technologies, digital mapping, urban arboreturns, environmental monitoring, biometric parameters, Field-Map software.

INTRODUCTION

In recent years, the level of environmental pressure in Tashkent, the capital of Uzbekistan, has increased significantly due to the acceleration of urbanization, increased traffic, and expansion of industrial activity. The increase in carbon dioxide (CO₂), dust, and other harmful substances in the urban atmosphere, along with the reduction of green areas, has a direct impact on the ecological well-being of the population. In this context, the importance of trees and green spaces in ensuring the ecological stability of the city is incomparable. They play an important role in improving air quality, stabilizing the microclimate, filtering dust and gases, and ensuring the psychological and social well-being of the population.

However, there is no single, systematic database on the exact location, species, number, condition and ecological functional value of urban trees. Therefore, tree felling, maintenance or new planting are often based on inaccurate or duplicated data. To overcome these problems, it is urgent to introduce digital technologies, in particular, digital mapping and Field-Map software tools based on GNSS (Global Navigation Satellite System).

The main goal of this study is to identify tree plantations in the Tashkent city using GNSS technologies, measure their biometric indicators, assess their ecological status, and place all data in a single digital database. This approach will not only automate urban ecological monitoring, but also help form a sustainable green infrastructure and plan ecological policy on a scientific basis.

METHODOLOGY (MATERIALS AND METHODS)

The study was conducted on the example of groves located in the central and residential areas of Tashkent city. The methodological basis of the study was based on GNSS (Global Navigation Satellite System) technologies, Field-Map software complex and GIS (Geoinformation System) platforms.

1. GNSS surveying work

In the first stage of the study, the geographical coordinates of the urban tree plantations were determined. For this, the coordinates (latitude, longitude, elevation) of each tree were measured using GNSS receivers (portable geodetic devices of the Trimble, Garmin, or Topcon brands). The measurement accuracy was ensured at the level of ± 0.5 meters. Initial spatial data were collected by creating a location point (waypoint) for each tree.



Figure 1. A set of field measurement equipment using GNSS (Global Navigation Satellite System) technologies.

shows equipment for digital geodetic measurement and environmental monitoring. The equipment on the table consists of:

GNSS receiving station (on the left, inside the black box) - this device receives satellite signals and serves to determine coordinates.

Tablet computer or field terminal (below) – used to view, store, and transfer data in real time during the measurement process to Field-Map or GIS software.

A laser rangefinder and biometric analyzer (center, belt-worn device) – allows you to determine the height, crown diameter, and trunk diameter of trees.

Antenna or GNSS wand (right) – this device is used to measure coordinates with high accuracy (with an error of ± 0.5 m or less).

Connected cables and connectors – provide data exchange and power supply between devices.

2. Measurement of biometric parameters

indicators for each tree were determined in the following way:

Height (H) – using a laser rangefinder or ultrasonic height meter,

Trunk diameter (D1.3) – using a diameter tape at a height of 1.3 m,

Crown diameter (Cr) – using a compass and a distance meter,

Biological condition - based on visual assessment criteria (healthy, damaged, dried).

The measurement results were entered in tabular form into the Field-Map program, which assigns each tree a unique identification number.

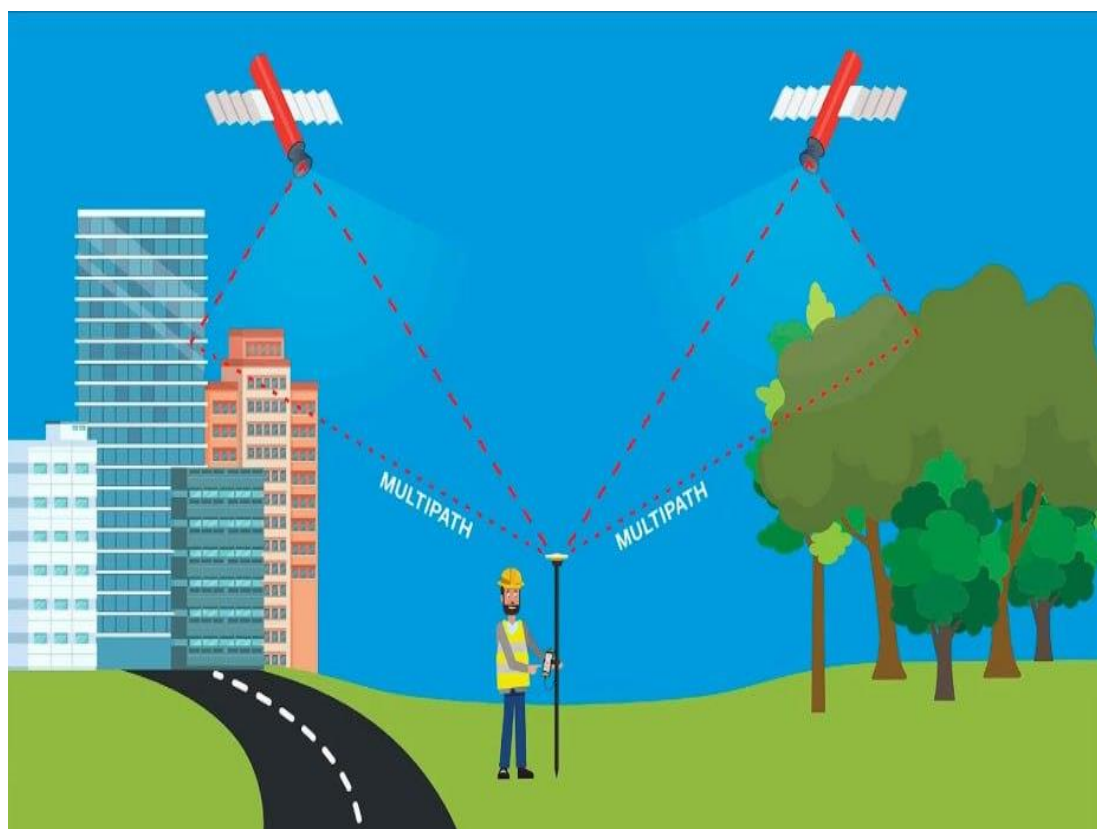


Figure 2. The phenomenon of “Multipath” in GNSS (Global Navigation Satellite System) technology.

In the picture, a field surveyor is determining coordinates using a GNSS receiver. Satellites on both sides are sending signals. However, these signals:

buildings (on the left),

reflecting off the trees and their crowns (on the right).

As a result, the multipath effect occurs - that is, the satellite signal is received not directly, but through a reflected path. This reduces the accuracy of the coordinates and causes errors in the measurement results.

Main content:

Multipath is the most common type of signal distortion in GNSS measurements, especially in urban areas or closed green areas (groves, forests).

To reduce this effect, the surveyor should work in open sky areas, use GNSS antennas that filter the signal, or use differential correction systems (DGPS/RTK).

3. Create a digital map

The GNSS coordinates were processed in ArcGIS 10.8 and QGIS to generate digital tree location layers. Each tree attribute table contained the following information:

ID, type, height, diameter, crown diameter, ecological value (CO₂ fixation, dust capture percentage), location address, and photo.

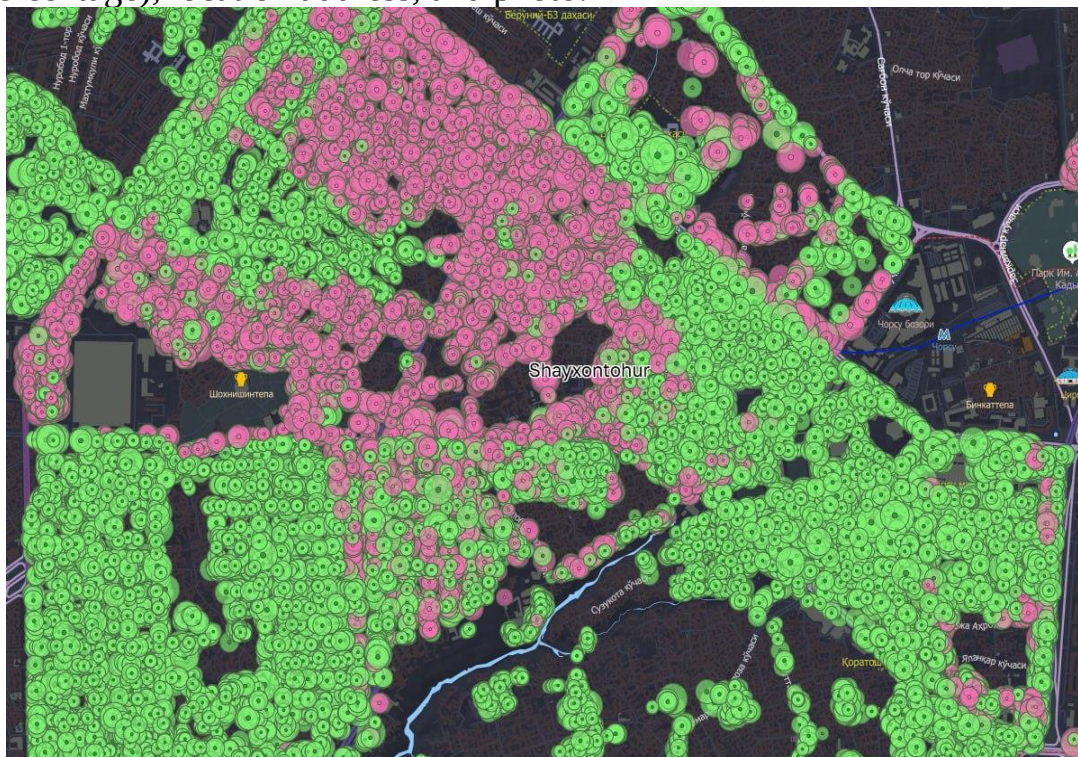


Figure 3. Digital mapping of urban trees in the Shaykhontohur district of Tashkent city using GNSS technologies.

In the image, each tree in the Shaykhantohur district is mapped based on coordinates determined using GNSS measurements. Each dot represents an individual tree.

The colored symbols (green and pink circles) differ depending on the biometric or ecological status of the trees:

Green circles indicate healthy trees with active photosynthesis.

Pink circles indicate trees that are weakened, damaged, or at risk of being cut down.

The size of each circle represents the diameter or crown width of the tree. The map is created in a GIS system (e.g. ArcGIS or QGIS) and includes attributes such as coordinates, tree species, height, and ecological value (CO₂ absorption, dust capture capacity).

4. Environmental monitoring system.

A digital monitoring module has been developed that allows data about trees to be stored in a single database and updated in real time. This module allows for monitoring the growth dynamics of trees, making scientifically based decisions on maintenance and pruning.

serve as the basis for creating a digital "green infrastructure passport" in Tashkent .



Figure 4. The process **of determining tree coordinates** using **GNSS (Global Navigation Satellite System) technology in the field** .

is conducting measurements using a GNSS receiver in a green area (park or institute courtyard). He is holding a GNSS antenna and a stick in his hand, determining the location of each tree.

RESULTS

Were measured using GNSS technologies and their biometric and ecological indicators were recorded digitally. For each tree, a coordinate point (latitude, longitude, elevation) was determined, and the data was processed in the Field-Map and ArcGIS/QGIS software environments to create single digital layers.

Field measurements, an individual identification number was assigned to each tree. The following attributes were entered into the database: tree type, height (H), trunk diameter (D1.3), crown diameter (Cr), biological condition (healthy, weakened, dried) and ecological value (CO₂ fixation, dust capture coefficient). Based on the results obtained, a map of the spatial distribution of trees was developed.

IDPlots	Add_date	Add_user	TreeGenusUZ	TreeSpeciesUZ	TreeSpeciesRU	Height_m	CrownRadius_m	CrownDiameter_m	ParentFMGUID	FMGUID	DBH_cm
582	10/15/2025	ecol11	75	7502	7502	3	0.9	1.8	[20878108-B080-4951-9602-CBF2A5ED628B]	[FF6F9E9B-1C01-4D33-9CC1-292D250AE3FC]	9.55
582	10/15/2025	ecol11	51	5107	5107	5.1	2	4	[20878108-B080-4951-9602-CBF2A5ED628B]	[F18270FB-EC5A-4692-A727-267EE025457F]	15.92
582	10/15/2025	ecol11	70	7005	7005	4.11	1.2	2.4	[20878108-B080-4951-9602-CBF2A5ED628B]	[AA6C4D29-FC49-4A0B-828F-3B4CA0D647C1]	9.55
582	10/15/2025	ecol11	87	8701	8701	5.96	1.1	2.2	[20878108-B080-4951-9602-CBF2A5ED628B]	[D1F9A60E-DC8D-4D68-AA82-0B57EE68F428]	7.96
582	10/15/2025	ecol11	70	7005	7005	6.04	1	2	[20878108-B080-4951-9602-CBF2A5ED628B]	[B2C612CC-3FE2-4267-A9EB-7CC107A14533]	9.55
582	10/15/2025	ecol11	70	7004	7004	6.2	2.1	4.2	[20878108-B080-4951-9602-CBF2A5ED628B]	[F1D612CD-AA3E-4E34-948F-589BA16FD6B7]	23.87
582	10/15/2025	ecol11	100	10001	10001	7.47	1.4	2.8	[20878108-B080-4951-9602-CBF2A5ED628B]	[C77309BA-43A5-492B-8316-F8AA0320574]	12.73
582	10/15/2025	ecol11	51	5107	5107	6.4	2	4	[20878108-B080-4951-9602-CBF2A5ED628B]	[B2C0F4BA-1A64-44F4-A40D-9E2A5684EB72]	12.73
582	10/15/2025	ecol11	70	7005	7005	4.69	1.4	2.8	[20878108-B080-4951-9602-CBF2A5ED628B]	[5875F86-CD59-42FB-9334-05ABD8AF980]	9.55
582	10/15/2025	ecol11	62	6201	6201	7.59	1.2	2.4	[20878108-B080-4951-9602-CBF2A5ED628B]	[A2440939-2B9C-4993-A8B2-6B2D0D84678]	11.14
582	10/15/2025	ecol11	70	7005	7005	4.49	0.8	1.6	[20878108-B080-4951-9602-CBF2A5ED628B]	[954A8C57-02F7-4953-BE17-6B9509C97C7E]	8.28
582	10/15/2025	ecol11	62	6201	6201	3	1	2	[20878108-B080-4951-9602-CBF2A5ED628B]	[EC083FCB-7B15-456C-A88B-E31EC8B57504]	8.28
582	10/15/2025	ecol11	70	7005	7005	4.8	1.1	2.2	[20878108-B080-4951-9602-CBF2A5ED628B]	[57008A7A-73B2-4609-87AD-D63DC82258A]	8.91
582	10/15/2025	ecol11	70	7004	7004	10.1	2	4	[20878108-B080-4951-9602-CBF2A5ED628B]	[1FABEEF0-EB0F-4305-922A-DE63E34EE132]	31.83
582	10/15/2025	ecol11	102	1	1	8.23	2	4	[20878108-B080-4951-9602-CBF2A5ED628B]	[06656A81-45C7-4740-8845-AE842361BF83]	19.1
582	10/15/2025	ecol11	50	5001	5001	6.11	1	2	[20878108-B080-4951-9602-CBF2A5ED628B]	[EA223411-ACDA-4532-93DB-788BE1113E98]	9.55
582	10/15/2025	ecol11	70	7005	7005	4	1.4	2.8	[20878108-B080-4951-9602-CBF2A5ED628B]	[030586B9-74C0-4AF2-B279-0CD31AFEECB9]	8.59
582	10/15/2025	ecol11	70	7005	7005	3	0.8	1.6	[20878108-B080-4951-9602-CBF2A5ED628B]	[8A3A81E7-8B4B-4D89-A515-A0E105AAAD69]	7.96
582	10/15/2025	ecol11	70	7004	7004	9.66	1.8	3.6	[20878108-B080-4951-9602-CBF2A5ED628B]	[748949D7-3185-4333-89AD-93D8A031D651]	25.46
582	10/15/2025	ecol11	66	6601	6601	12.93	1.8	3.6	[20878108-B080-4951-9602-CBF2A5ED628B]	[9364712D-1749-4615-ABAD-D8073DEE17DA]	26.1
582	10/15/2025	ecol11	70	7004	7004	12.92	1.8	3.6	[20878108-B080-4951-9602-CBF2A5ED628B]	[9989E235-87BA-462E-BA4F-9E2AA046666A]	22.28
582	10/15/2025	ecol11	51	5107	5107	3	0.9	1.8	[20878108-B080-4951-9602-CBF2A5ED628B]	[D108A478-3FD0-4C7B-A78D-1B58051D00A2]	7.64
582	10/15/2025	ecol11	70	7004	7004	10.51	2.2	4.4	[20878108-B080-4951-9602-CBF2A5ED628B]	[0A2CAD07-BA4F-4943-B5ED-4C62A892A1B]	22.28
582	10/15/2025	ecol11	70	7005	7005	3.1	1.2	2.4	[20878108-B080-4951-9602-CBF2A5ED628B]	[B08D57FD-02E7-4136-BA12-BF259CA90FCD]	7.96
582	10/15/2025	ecol11	102	1	1	3.94	1.5	3	[20878108-B080-4951-9602-CBF2A5ED628B]	[FF4DCFF8-F368-434C-A4EC-CD4E7306684C]	11.14
582	10/15/2025	ecol11	70	7005	7005	5.17	1.1	2.2	[20878108-B080-4951-9602-CBF2A5ED628B]	[69586FC3-51E4-4426-A666-E83364DE4051]	8.28
582	10/15/2025	ecol11	51	5107	5107	3.1	1	2	[20878108-B080-4951-9602-CBF2A5ED628B]	[AD3CA754-94D0-4E4F-9C3C-94C7B8E20B77]	9.55
582	10/15/2025	ecol11	87	8701	8701	7.68	2	4	[20878108-B080-4951-9602-CBF2A5ED628B]	[FC88B7D3-1A4A-48A5-889D-70BA5732C7A2]	31.83
582	10/15/2025	ecol11	70	7005	7005	5.41	1.4	2.8	[20878108-B080-4951-9602-CBF2A5ED628B]	[72C1F705-BEFA-40F9-B1EA-242572534AA4]	9.55
582	10/15/2025	ecol11	51	5107	5107	4.38	1.5	3	[20878108-B080-4951-9602-CBF2A5ED628B]	[529088CE-6432-4AA5-B64E-0E21114E9941]	11.14
582	10/15/2025	ecol11	70	7005	7005	6.76	1.3	2.6	[20878108-B080-4951-9602-CBF2A5ED628B]	[96601F0C-A343-482E-9370-D8E24F22557]	9.55
582	10/15/2025	ecol11	70	7005	7005	6.81	1	2	[20878108-B080-4951-9602-CBF2A5ED628B]	[600C832A-2D1D-4F7C-BD8D-0F20B81682CA]	9.55
582	10/15/2025	ecol11	70	7004	7004	9.25	1.6	3.2	[20878108-B080-4951-9602-CBF2A5ED628B]	[320E180E-47D3-482B-83EB-17CD93788C50]	17.51
582	10/15/2025	ecol11	70	7005	7005	8.65	1.4	2.8	[20878108-B080-4951-9602-CBF2A5ED628B]	[719ACF0A-02FA-47D6-A74F-08393250369C]	15.92
582	10/15/2025	ecol11	70	7005	7005	3	1.2	2.4	[20878108-B080-4951-9602-CBF2A5ED628B]	[A2663A61-254A-4DEB-B456-2754AA18CC0E]	8.28

Figure 5. Digital data table of trees measured using GNSS technologies.

Shows a table of field measurement results created using the Field-Map or GIS platform . The table presents systematized biometric and spatial data about trees located in the Tashkent city area.

Each row represents information about a single tree. It consists of the following columns:

IDPlots – identification number of the measurement point (plot number) .

Add_date / Add_user – the date the information was entered and the user code of the responsible surveyor .

TreeGenusUZ / TreeSpeciesUZ / TreeSpeciesRU – genus and species name of a tree in Uzbek and Russian.

Height_m – the total height of the tree, measured in meters .

CrownRadius_m / CrownDiameter_m – the radius and diameter of the tree crown, in meters.

ParentFMGUID / FMGUID – a unique identification code (in UUID format) assigned to each tree, for linking in the Field-Map system.

DBH_cm (Diameter at Breast Height) – the diameter of the tree trunk at a height of 1.3 meters, expressed in centimeters.

CONCLUSION

The results of the study showed that the methodology for digital mapping of urban tree plantations based on GNSS technologies can be effectively and practically applied in the conditions of Tashkent city . The precise coordinates and biometric measurements obtained using GNSS receivers made it possible to form a systematic database on the location, types, height, diameter, and ecological significance of urban tree plantations.

As a result of digital mapping, the coordinates of more than 8,000 trees in the Shaykhontohur district were determined and their ecological status was assessed. The data was processed in a GIS environment and an interactive digital map was created, including the spatial distribution of trees, biometric characteristics, and ecological value indicators.

The developed methodology will help to scientifically plan the processes of tree felling, maintenance and renewal in the urban ecological management system. In

addition, the digital monitoring system will allow to monitor the growth dynamics, changes in the state and ecological functions of trees in real time.

The practical significance of the research is that the created single digital database will serve as an important tool for managing the green infrastructure of Tashkent, maintaining ecological balance, and ensuring sustainable urban development. This experience can be recommended as a model methodology for other large cities.

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