Application of the Field-Map software and hardware complex for creating GIS of urban green spaces and Botanical gardens collections

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Abstract. The possibilities of the use of geoinformation systems (GIS) for green areas managing were discussed. The features of the use of the Field-Map software and hardware complex on landscape architecture objects are given. Field-Map allows you to perform mapping of any object in real time, estimate distances and areas, create thematic maps, perform dendrometric measurements, i.e. use all the features of a full-featured GIS directly when working in the field. The GIS of urban garden and park objects on the example of the city of Simferopol (the Republic of Crimea) were demonstrated. It seems promising to perform a planned inventory of urban green spaces of municipalities with mandatory GIS of plants collections of introduction points can contain an unlimited number of attributes, which allows to enter into a single database information on the time, origin and sources of receipt of the plant sample, the type of planting material, estimation of frost resistance, drought resistance, disease and pest infestation, the beginning and duration of flowering or fruiting, the period of greatest decorative effect, and other features. The work on creation of GIS arboretum and scientific exhibitions were conducted in N V Bagrov Botanical garden of the V I Vernadsky Crimean Federal University.

1. Introduction
Radically improving the comfort of the urban environment is one of the priorities of the modern social-oriented development of the Russian Federation and the target indicator of the national project "Housing and urban environment". The objectives for increasing the urban environment quality index were outlined in the Decree of the President of the Russian Federation "On national goals and strategic objectives for the development of the Russian Federation for the period up to 2024" [1]. Green areas are an integral part of urban space. The Decree of the President noted the need for effective use of land for mass housing construction, provided that the green planting is preserved and developed.

In the XXI century, urban management and the green space system as a component cannot be based on outdated approaches and technologies. The national project "Digital economy of the Russian
Federation" is aimed at "...transformation of priority sectors of the economy and social sphere, including ... urban economy... through the introduction of digital technologies and platform solutions" [1]. GIS (geographical information system) is a reliable tool for monitoring and making economically and socially effective decisions in urban management, but it is used in Russian regions with varying degrees of efficiency. Taking into account the active development of domestic hardware and software tools for creating urban geoinformation systems [2], we should expect a general transition to unified repositories of basic information resources of municipalities in the near future.

The use of geographical information systems in the study of the spatial location of green spaces has been actively developed during the past 20 years. This is primarily due to the comprehensive penetration of computer systems in all areas of human activity and the formation of the so-called "geoinformation paradigm" of scientific research. During such a short stage of development, geoinformation technologies have made a significant contribution to the development of landscape and territorial planning, landscape architecture, etc. The works of the following authors should be noted among the basic works. Lahoti and co-authors [3] developed a mapping methodology for creating a map of urban green areas of Nagpur city in India. Germann-Chiari and Seeland [4] studied green spaces and green zones of Swiss cities. Bijker and Sijtsma [5] used GIS to assess green spaces of urban areas in the Netherlands, Germany, and Denmark on four spatial levels: district, regional, national and global. Pietrzyk-Kaszyńska and co-authors [6] used GIS to identify green spaces in Poland. Senanayake and co-authors [7] studied green spaces in Colombo city, Sri Lanka using GIS and high-resolution satellite images. Agus and co-authors [8] used GIS to study green spaces of Bontang City (Indonesia). Among domestic works the following works worth highlighting: Trubina and co-authors [9, 10] used GIS technologies for monitoring and managing green areas in Novosibirsk city; Kuznetsov and Markelov [11] conducted a study of green spaces in Khabarovsk city; Morozova and co-authors [12] developed the geoinformation system "Green spaces of Khabarovsk city"; Olkhin and Kabonen [13] developed the geoinformation system of the Yamka Park in Petrozavodsk city. The general analysis shows that studies on determination of the proportion of green spaces within a locality or a certain territory prevail, and only a few works include tree survey in the GIS. This is connected in most cases with significant labor costs for field survey of individual tree units and lack of special technologies.

GIS technologies are used even less frequently in specialized landscape architecture sites (Botanical gardens and arboreta) than in urban areas. There is a small amount of work indicating the development and application of GIS in domestic Botanical gardens [14, 15]. At the same time, the prospects of geoinformation technologies for managing collection funds are obvious. Until recently, the only possible way to maintain a collection was to save information in the form of a list of available taxons and their placement schemes within the collection area or flower bed. Data is often presented only on paper and is available to curators only. This collection management entails a number of difficulties: possibility of duplication or loss of information, complexity of evaluating and analyzing the entire collection, difficulties in determining the exact location of plants and their biomorphological characteristics, losses in transmitting information when changing the curator, etc.

The existence of a correct and up-to-date GIS of green spaces at the level of municipalities facilitates both territorial planning processes and simplifies a number of issues during the current operation of garden and park facilities. Major cities around the world, including Russian ones, have portals containing thematic maps with localization of trees and shrubs (sometimes flowerbeds and lawns) and related databases [16-19]. The Republic of Crimea and the city of Sevastopol are seriously lagging behind other Russian regions in this direction.

The purpose of this work is to discuss the methodology and features of GIS of urban green zones and territories of scientific and educational institutions using the Field-Map software and hardware complex.
2. Methods and Materials

In 2019, we developed a GIS of green spaces in a number of streets in the city of Simferopol and started work on creating a GIS of the arboretum and expositions of the N V Bagrov Botanical garden of the V I Vernadsky Crimean Federal University. To create them, we used the Field-Map software and hardware complex. It is a technological platform that combines a geographic information system (GIS) and measuring instruments for mapping and dendrometric measurements, working and synchronizing in real time. Field-Map is a classic geographic information system consisting of four subsystems: data entry subsystem, data storage and management subsystem, data processing and analysis subsystem, and data output subsystem.

The entry subsystem is a set of tools for obtaining and converting spatial (geographical) information about an object into computer memory or into an attribute table. Digitized cartographic materials, satellite images, statistical data, field measurements and surveys materials, etc can be used as input information. Input is performed by digitizing (manually digitizing of objects and contours in vector form), adding images in raster form, using the keyboard. The data storage and management subsystem organizes the storage, updating and editing of information and allows to perform quickly queries to databases. The processing and analysis subsystem allows to perform statistical analysis, mass data analysis, decrypt satellite images and aerial photographs, to perform classifications, modeling, and to solve various spatial and managerial tasks, depending on the goals set. The data output subsystem visualizes cartographic and statistical data in the form of maps, tables, images, charts, etc.

In Field-Map, the data entry system is implemented in real time using the Getac T800 field computer and connected measuring systems: TruPulse 360R laser combined height and rangefinder, GPS SX Blue II+ GNSS, electronic measuring fork Caliper Masser, as well as a number of other devices. As noted earlier [20], Field-Map allows real-time mapping of any objects by changing their scale on the screen, measuring distances and areas, creating thematic maps, i.e. using all the features of full-function GIS directly when working in the field. Field-Map works with various spatial data formats, such as ESRI shape-files for spatial objects (points, lines, polygons), Paradox databases, or MS Access for attribute data. Using the Field-Map Project Manager export utility, you can easily convert attribute tables to dBase, Excel, and other formats, which allows to work also with the resulting formats in other software products. Now Field-Map is actively used by researchers from different parts of the world [21-23].

3. Results and Discussion

Both linear and areal landscape architecture objects were selected for development and testing of the geoinformation system of green areas in Simferopol city. Vernadsky Avenue is a main street of citywide significance, Trenev, Dekabristov and Shpolyanskaya Streets are main streets of district significance. Green spaces within the red lines of streets are located mainly on the side dividing lines, as well as small grassed and landscaped areas adjacent to the streer axis. They are represented by group and row plantings laid down in the period from 1960 to 1970, as well as by overgrown and self-seeding groups formed in a later period.

For these objects of landscape architecture on the Field-Map technology platform, real-time mapping of landscaping areas and plantings of various types (row and group planting of trees and shrubs, hedges and arrays, areas of lawns and flower decoration) were carried out. The main dendrometric characteristics (diameter of the tree body and crown, height of trees, area of arrays) were determined. The obtained data are combined with estimates of the phytosanitary and vital state of plants (figure 1, table 1, 2). A detailed inventory of plantings was performed in accordance with current regulations [24, 25].

When assessing the state of plantings in disputed cases, the tree body and skeletal branches of trees were diagnosed using a resistograph (RESISTOGRAPH RINNTECH). RESISTOGRAPH equipment made it possible to identify the location and volume of hidden rot, decay zones, and internal trunk
cracks, and to identify trees that are potentially dangerous and affected by rot. Data of resistograms was also included in the database developed in the GIS (figure 2).

![Figure 1. Fragment of the map of tree survey of green spaces on Vernadsky Avenue (Simferopol).](image)

Table 1. Fragment of the attribute table with data from the inventory of green spaces on Vernadsky Avenue (Simferopol).

| Plan ts No. | Life form | Type   | Specific name                  | Age (years) | Height (m) | Tree body diameter at a height of 1.3 m (cm) | Shrub diameter, m | Quality |
|-------------|-----------|--------|--------------------------------|-------------|------------|---------------------------------------------|-------------------|---------|
| 12          | tree group| Platanus acerifolia (Aiton) Willd. | 45           | 23         | 64                                      |                   | good    |
| 13          | tree group| Picea pungens f. glauca (Regel) Beissn. | 45           | 16         | 28                                      |                   | good    |
| 14          | tree group| Juglans regia L. | 45           | 21         | 47/46/44/26                              |                   | good    |
| 15          | tree group| Juglans regia L. | 45           | 20         | 41/37/36/35                              |                   | satisf. |
| 16          | tree group| Fraxinus ornus L. | 45           | 6          | 21                                      |                   | good    |
| 17          | shrub group| Buxus sempervirens L. | 10           | 1.5        | 0.75                                    |                   | satisf. |
### Table 2. Fragment of the attribute table with data from the inventory of green spaces on Vernadsky Avenue (Simferopol)

| Plants No. | Life form | Type    | Specific name                          | Note                                | Recommendation on care | POINTX  | POINTY  |
|-----------|-----------|---------|---------------------------------------|-------------------------------------|------------------------|---------|---------|
| 12        | tree group| tree    | *Platanus acerifolia* (Aiton) Willd.  | Arched-cane pruning                  |                        | 5191747.995 | 4970510.722 |
| 13        | tree group| tree    | *Picea pungens f. glauca* (Regel) Beissn. |                                      |                        | 5191752.877 | 4970513.58  |
| 14        | tree group| tree    | *Juglans regia* L.                     | Dry branches in the crown           | Dry branches cutting   | 5191752.004 | 4970505.404 |
| 15        | tree group| tree    | *Juglans regia* L.                     | Breakups of branches, damage by polypore, small hollows | Dry branches cutting, treatment of hollows | 5191759.386 | 4970509.69  |
| 16        | tree group| tree    | *Fraxinus ornus* L.                    |                                      |                        | 5191761.687 | 4970500.308 |
| 17        | shrub group| shrub  | *Buxus sempervirens* L.               | Affected by *Cydalima perspectalis*, sooty fungus, depressed |                        | 5191765.696 | 4970483.858 |

**Figure 2.** Resistogram of tree No. 244 on Shpolyanskaya Street (Simferopol).

The system allows you to sort by any attribute with the corresponding reflection on the maps. For example, in practice, it is very convenient to sort all the plants in poor condition and provide the operating organization with felling permits with maps of trees location. A similar algorithm is possible
when planning work on treatment, pruning, inspection of trees and shrubs of specific species or based on the recommendations of specialists.

In the N V Bagrov Botanical garden the work is performed to create a GIS of collections of the arboretum and scientific exhibitions (Rosarium, Syringarium, Labyrinth, Alley of Scientists). The Field-Map software and hardware complex allows to create GIS of collections with an unlimited number of attributes. For the introduction point, information about the time, origin and sources of receipt of the plant sample, the type of planting material, data of the phytosanitary certificate, etc. are important. Over time, it becomes possible to assess the prospects of the plant in terms of acclimatization and use in the area of introduction. Estimates of frost resistance, drought resistance, disease and pest infestation, and other economically valuable features, as well as the beginning and duration of flowering or fruiting, the period of greatest decorative effect, and the results of other scientific tests and studies are recorded in a single GIS. Transferring of all data about the collection funds of the Botanical garden into a single database eliminates the problems associated with curator quitting, allows long-term scientific observations without losing the reliability of information, which is of particular importance when studying dendrological collections.

4. Conclusion
The development of a GIS for green spaces using Field-Map hardware and software has a number of undeniable advantages over traditional approaches.

At the data collection stage:
- Combining and automating mapping processes and creating a comprehensive database of qualitative and quantitative characteristics of green spaces within the landscape architecture object;
- The open nature of the database allows to add new attributes in the form of numeric data, text notes, photo fixation materials, etc., adapting it to the needs of managing green areas, forming a green city frame, using it in landscape design, maintaining research collections, etc.
- The ability to clearly map dendrological objects simultaneously with the determination of taxonomic affiliation and life status allows to avoid mistakes in the future when implementing measures for planting maintenance;
- Possibility of selective registration, systematization and accounting of individual rare species, age, historical, plus trees or plants with special properties.
- Simplicity, visibility, and multi-variant graphical representation of results;
- Possibility to sort the database by various classifiers - species, life form, life condition, disease affection, etc.
- When monitoring the nature of research, GIS allows to track the dynamics of the development of green spaces, determine the most stable species, identify the core of diseases or pests distribution, etc.

At the stage of practical use of GIS:
- Displaying the crown projection on the plan and possibility of three-dimensional modeling of storied structure of plantings greatly facilitate the formation of the planning and spatial structure of park objects in landscape design. Modeling is of particular importance in the design of protective plantings;
- The possibility to calculate quickly and objectively the cost of labor and materials in the preparation of technological maps and estimates at green municipal services enterprises.
- Convenience in the formation of technical specifications for workers in the appointment of typical agricultural activities.

Acknowledgments
The work is partially supported by an Intra-University Grant to Young Scientist of the Development Program of the V I Vernadsky Crimean Federal University for the period 2015-2024 on the theme: "Creating a geoinformation system (GIS) of the N V Bagrov Botanical garden of the V I Vernadsky Crimean Federal University".
The work presented in this paper was carried out in the framework of RF state task according to plan of scientific research of the A.O. Kovalevsky Institute of Biology of the Southern Seas of RAS (“Studying the spatio-temporal organization of water and land ecosystems with the aim of developing an operational monitoring system based on remote sensing data and GIS technologies”. Registration number АААА-А19-119061190081-9).

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