Application of Field-Map technology for vegetation assessment in Saint Petersburg

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Annotation. This paper discusses the use of Field-Map technology. It has been established that the use of Field-Map technology requires significant changes in the structure of work: first of all, it is necessary to change the structure and content of such documents as the object's passport, registry of green spaces, etc. Inventory of objects using the Field-Map technology will expand the number of indicators in the passport objects and registers of green spaces, which will affect the cadastral valuation and damage assessment from the demolition of vegetation.

1. Introduction

Green spaces of any locality can fulfill their functions only if their condition allows it. Maintaining the proper functional state of the greenery is possible in an aggressive urban environment with regular maintenance. To do this, it is necessary to have up-to-date and accurate information about their availability, quality, condition, presented in the form of electronic cartographic materials, databases, the use and modification of which is available to the green building specialist, without which it is impossible to improve the quality of the information received and create an object management system.

Currently, in the practice of technical inventory of green spaces in cities, telling of the trees should be carried out once every 5 years, and in fact, is performed every 10-15 years. Moreover, the inventory consists in updating the data on the acts of felling, planting shrubs and trees. In this case, only the total values are changed, without affecting the planning and cartographic materials on a paper basis. A system of monitoring of green spaces in St. Petersburg exists, but does not fall to the level of inventory of a concerning every single tree. As a result, this most important tool for managing the urban environment, even in a separate facility, becomes obsolete in 1-3 years after reconstruction (creation, inventory), due to the accumulation of changes.

The inventory of green spaces in parks and forest parks in Saint Petersburg was conducted more than 20 years ago. After that, the work is still carried out unsystematically by various executors using various technologies, without the use of GIS and other technologies. There is no single approach, and
as a result, the planning and management of landscape gardening does not meet the challenges and technical capabilities of the 21st century.

In accordance with Article 4 of the Law of St. Petersburg “On the Protection of Green Spaces” [1], the local self-government authorities must organize the registration of local green spaces. However, ground inventory is not provided. Work on compiling the register of woody and shrubby vegetation is performed by ground visual (eye-measuring) method using topographic plans of scale 1: 500, on which elements of green space are mapped: trees indicating the species, groups of large shrubs, as well as lawns. The use of Field-Map technology will reduce the cost of telling of the trees of green spaces, the time for work and will improve the quality of data collection.

The experience of telling of the trees of green spaces of the Svetlanovskoye municipal district of St. Petersburg is given in [2]. The method of telling of the trees of green spaces combined a field survey (ground inventory) of parts of green spaces, analysis of topographic plans and high-resolution space images. In 2010, the new administration of the Svetlanovskoye municipal district decided to re-take the inventory. The problem is insufficient accuracy and incomplete data.

The updating work included the following operations: based on satellite images, the authors evaluated the safety of specific trees shown on the topographic plan (1: 500); the diameter of the surviving trees was determined according to the growth progress tables or correlation equations of the relationship between the diameter of the crown and the diameter of the trunk; according to the plan and satellite images, the areas of shrubs and lawns were calculated; the state of green spaces, the inventory of which was carried out according to topographic plans and satellite imagery, was estimated on the basis of extrapolation of field survey data.

Comparison of the results with a scanner image from Google showed that the data from topographic images have a number of significant differences with the ground inventory. The use of satellite images made it possible to partially avoid errors in determining the total number of trees, but did not solve the problem of determining the type of tree and assessing its condition (except for shrinking and dead trees) [3]. In addition, topographic plans lack information on the state of trees; the topographic plans of 20 years ago show less than 50% of woody plants that exist in nature; the number of trees for which species on the topographic plans are erroneously determined is 16% of those mapped. The use of satellite images does not facilitate the task, since it is impossible to determine the type of tree, taxation indicators and its condition from the image. In order to obtain accurate and reliable data, it is necessary to conduct a field survey of green spaces, which requires more substantial funding.

In recent years, a new technology has been introduced in the Russian Federation that can facilitate the work on telling of the trees of green spaces since it allows you to transfer measurement data from electronic and laser measuring instruments directly to the field computer database and display them on the GIS screen [4-6]. Databases and electronic maps generated in the field can then be transferred to a central GIS without additional preparation and processing. Field-Map technology developed by the Czech Institute for Forest Ecosystem Research (IFER) is a flexible system that allows you to change the structure of the database. Special Field-Map functions allow you to: measure tree heights, map projections and measure crown shape; calculate surface area and crown volume; measure and calculate all the necessary taxation parameters; verify the accuracy of the information collected and control the completeness of the database during field work; visualize measured objects in three-dimensional graphic space; create digital terrain models, as well as solve many other tasks in the field related to processing databases and GIS [3].

It turned out that Field-Map is more economical and effective for telling of the trees of green spaces when comparing the time spent on data collection and mapping of this technology because it excludes geodetic work on surveying the territory and mapping trees [7].

A problem that can arise with any traditional method: if an error is detected in the measurements, it is necessary to make repeated measurements with a time shift, when the parameters and state of the object are completely different. With Field-Map, a map is created directly on the work field, so that errors are detected and corrected on the spot [7].
Field-Map is suitable for any kind of tasks related to the compilation of forest maps or measurements in the field. Field-Map projects can be quickly developed and easily adjusted during implementation [4]. The authors of this technology indicate that their method of instrumental field measurements allows the use of the obtained data to calculate the parameters of mathematical models (tables) of the growth of trees and plantings. The effectiveness of the use of technology increases with increasing complexity of the terrain conditions, the structure of the plantings and the methodology for observing [7].

The law “On the Protection of Green Spaces”, adopted on May 12, 2004 [1], has undergone a number of changes in recent years, which related to issues of administrative offenses (2007, 2010), land use and development rules in St. Petersburg (2008, 2009). Issues of protecting green spaces are regulated by article 3 of the Law, according to which all green spaces located in the territory of St. Petersburg are subject to protection, regardless of the form of ownership of the land plots on which these plantings are located. The registration of green spaces is regulated in accordance with Article 4 of the Law the decree of the Government of Saint Petersburg of November 17, 2005 “On the Procedure for the Registration of Green Spaces”.

In May 2010, the Legislative Assembly on first reading adopted as a basis the draft law "On Green Spaces in St. Petersburg" introduced by the Commission on Urban Management, Urban Planning and Land Issues [8]. The developers indicate that the project takes into account the requirements of ensuring the right of citizens to a favorable environment, the protection of the St. Petersburg green fund. Compared with the current law, the procedure for the use and protection of green areas of each of the established species (green areas for general use, limited use, special purposes, local landscaping, green areas of land plots, urban forests and parks) has been changed.

In order to protect and improve the green fund of the city, it was proposed to introduce a system of standards, including indicators of the population’s availability of green areas of public use and their accessibility, as well as the responsibilities of state authorities and local self-government to keep records, inventory and environmental monitoring of green areas.

At the same time, it is planned to carry out measures for the evolvement of the St. Petersburg green fund on the basis of the Sectoral scheme for the development and placement of objects of landscape gardening developed in accordance with the General Plan of the city [9].

2. Methods and Materials
1) Study the set of devices, software and database structure of Field-Map technology;
2) To work out the issues of cartography and ecological-taxation assessment of urban vegetation on the example of various green construction objects;
3) Based on an analysis of the results of the work, give suggestions for improving Field-Map technology, taking into account the current state and prospects for the development of an inventory of parks and forest parks in St. Petersburg.

The application of Field-Map technology in St. Petersburg began in 2007. This is a search work in which it is necessary to develop a rational combination of measuring taxation methods and Field-Map technology. This can be done after checking on real objects.

The purpose of the research was to develop methodological issues in the inventory of forest park objects and forestry tasks: determining the volume of trunks of growing trees; assessment of the relationship between taxation indicators; selection from the database of threat trees, dead wood, etc; formation of lists by species; evaluating the dynamics of objects, etc.

Brief description of the dashboard and software Field-Map
The basic set of Field-Map equipment is a complex set of modern devices, which consists of: a Toughnote DI-5 field computer; Impulse 200 Laser Rangefinder; electronic compass; electronic goniometer MapStar CM; GPS device; electronic plugs; command device and power supply.

Field-Map software makes it possible to carry out the following types of research while working in the forest [8]: measurement of single trees and plantings, as well as calculation of parameters of trunks and crowns; various kinds of field surveys (measurements, data reliability control, mapping,
preliminary analysis of the data obtained in the field); database design for any measurements in the forest (creating a project in the database format); subsequent processing of data in a computer and their transport to GIS of any level.

A special application for Field-Map – DENDRO is used for processing the received data. You can also export data from Field-Map (maps and databases) to other programs. Since Field-Map uses the ESRIshapefile format as a data format, data can therefore be processed by many GIS programs.

Work on the inventory of green spaces is carried out in accordance with the instructions for the technical inventory of green spaces.

The work is carried out in two stages:
- first - preparatory work and mapping of the territory: lawns, paths, objects, as well as an inventory of green spaces - mapping of tree and shrub vegetation, measuring horizontal projections of tree crowns, the diameters of their trunks and heights, assessing the state of vegetation.
- second - processing the results.

For woody vegetation in the park, the following indicators are measured and evaluated: the species, the coordinates of each tree, the trunk diameter at a height of 1.3 m, the height of the tree, the height of the start of the living crown, the horizontal projection of the crown, the state of the tree and the trunk profile.

Statistical processing of the results is performed by computer processing of the Field-Map in the normal mode. This information can be used later in assessing the volumetric indicators of a population of trees in solving many applied problems up to calculating the amount of damage.

3. Results and Discussion

The main advantage of Field-Map is its modular structure. Within the standard user interface, a large number of modules can be used to fulfill specific needs. It is possible to connect external user modules in the form of dynamic libraries (DLL), for example, tables of trunk volumes, equations for estimating biomass, growth of stands and stock, their assortment tables and other extensions can be used as applications [7].

The internal structure of the Field-Map database is based on tables for storing geographic objects. At the same time, attribute tables can be converted to MS Access or dBase format using the export function of the Field-Map Project Manager.

The Field-Map database is completely relative. The project structure (identification layer) is used as the root of the database which can be associated with many other layers. Each of these layers can in turn be the beginning of an additional chain of related data layers. The relations between the layers can be “one to many” or “one to one.” For polygons, you can use the many-to-one relationship (for example, the line of a section of one type of vegetation with a general description) [10].

Each layer can have several attributes. Search lists are stored in separate data tables and it is possible to use them again in various Field-Map projects. Certain attribute types are available for remote measurement of height and diameter.

Field-Map Project Manager provides quick and easy database development. The database structure is based on the use of visual tools and features including search lists can be easily identified. As soon as the project is completed, the Field-Map database is compiled and ready for work. The database can be modified by users at any time without losing the data already collected.

Any Field-Map project can contain an unlimited number of different layers. All layers in the project share the same database structure but they may differ in shape, size and location. Field-Map provides a link between the Project Manager and Data Collection. The pages of the laptop are created exactly according to user-defined layers and tables, making data collection on the field computer easy and transparent.

Field-Map includes virtually all types of tasks related to the construction of field maps or field measurements. For example, starting with a simple mapping of the terrain to an inventory of the national forest with hundreds of features stored in a large number of related tables. Field-Map projects can be quickly supplemented and easily adapted during project implementation [7].
Field-Map allows you to perform three-dimensional mapping of plantings using a number of devices: a laser rangefinder combined with an electronic goniometer and a compass for measuring distance and determine vertical and horizontal angles.

Information about trees is specially processed in the Field-Map environment. The trees defined as points are supplemented by the diameters at the height of the chest directly using an electronic measuring fork and visualized as a polygon of trees in the main area. Special tools are available for measuring overlapping polygons of horizontal projections of tree crowns. Thanks to the laser equipment, you can measure the height of the trees and the heights of the crowns. Additionally, this technology allows you to measure the vertical profiles of the crowns of trees and trunks.

Field-Map provides a convenient and multi-functional tool for building and editing maps. It uses the latest ESRI ArcGIS which is a map design software product that works with hundreds of different designed maps.

For repeated measurements, Field-Map provides components to copy database structures where old data can be transferred.

The data collected using the Field-Map is in a ready-to-use GIS (ESRI shape files) format. Compared to the usual digitalization of maps, Field-Map transfers accurate and up-to-date information with no errors, ready for further processing after returning from field measurements. Field-Map itself is not intended as a GIS-system for evaluating data, but can be used as a complex and multifunctional tool for receiving and accumulating data.

MS Access or dBase formats of tables with features allow you to use Field-Map data with many desktop applications for statistical processing, data visualization, etc. ArcViewshapefile is a geographic layer format that makes it possible to use Field-Map data with other GIS software (ArcView, Arc / Info, MapInfo, SPANS, etc.) without further conversion. In Field-Map, you can use bitmap images as background maps and collect data for different layers. PDA tables include many field data collection tasks.

As a result of the development of Field-Map technology, the need for thorough training of performers at test sites has been identified. In addition, it is necessary to introduce simplifications into the methodology for mapping garden and park, forest and park objects, individual allelic plantings, and other objects within the Field-Map, as current regulations do not require accurate measurement of objects. All activities can be divided into organizational measures to improve the Field-Map and legal measures to create new legal documents and bills. Some of them are given in table 1.

| Table 1. Project of measures for implementation of organizational and other activities and rationalization of Field-Map technology. |
| --- |
| **Measures** | **Volume** | **Notes** |
| **1. Legal Support of Field-Map Technology** | **Existing technology** | **Field-Map** | **Notes** |
| 1.1. Changing the form of object passports | - | + | no changes since the middle of the XX century |
| 1.2. Introduction of legislative proposals to regulatory legal acts | - | + | |
| **2. Organizational measure** | **2.1. Training of performers on the materials of test objects** | - | 72 hour course | qualification text |
2.2. Training at demonstration training facilities - 2-3 days at 3 sites

2.3. Working with inventory materials no up to 36 hours per user

3. Technology improvement

3.1. Creating a network of reference points temporary picketing long-term brands (benchmarks) prevention of daily loss and repetition of measurements of necessity

3.2. Creating a supporting vicious circle closed traverse transects

3.3. Mapping of landscape and vegetation elements survey of the internal situation by geodetic methods GPS use -

3.4. Stable power supply of a set of equipment - 2 sets of batteries ensuring continuous operation for 10 hours

3.5. Creating and transferring electronic data office work, cartographic process receiving information via the Internet step-by-step daily replenishment of the database of remote objects

3.6. Replacing measurements of tree indicators with taxation methods + + increasing productivity at forest park sites

The created database in the field computer is transferred to other GIS for further processing and evaluation. Since not every computer user is able to work in GIS, it is necessary to conduct overview training.

The bottleneck in improving technology is the energy supply to field work. The battery included in the kit allows you to work continuously for only 3-4 hours, which is not enough for large and remote areas. For successful operation, a backup set of equipment must be available.

Determination of the possible economic effect of applying Field-Map technology

To analyze the effectiveness of technology application, the main factor of labor costs was analyzed. A comparison of two technologies - the basic and design options. For the base case, a plane-table method was taken with the telling of the trees (table 2).

Table 2. Comparison of the basic and design work options.

| Basic option | Design option |
|--------------|---------------|
| 1. Plane-table method | 1. Field-Map technology with tree mapping |
| Scope of work: Obtaining assignments and materials. Preparation of tools for work. Reconnaissance of the area. Survey of the contours, situations and terrain. Measurement of buildings and structures. Field tracing of contours and relief. Drawing | Scope of work: Obtaining assignments and materials. Preparation of tools for work. Reconnaissance of the area. Survey of the contours, situations and terrain. Measurement of buildings and structures. Mapping of tree and shrub vegetation and flower beds. Drawing |
tracing of heights and contours. Making copies on the frames (north and west). Summary of the framework (southern and eastern), the design of magazines, filling out the form. Submission of work. Transitions and relocations at the site of work.

Scale 1: 500.
Category of work difficulty - IV-4 (city squares, parks. Concerning every single tree survey).
Performers: 
- Topographer of the 4th category
- Measurer of the 3rd category
Production rate - 0.86 ha / day

Scale 1: 500.
The category of work difficulty is the same as in the basic version.
Performers: 
- Operator - engineer of the 6th category
- Assistant of the 4th category
The production rate (based on the results of a pilot check of Field-Map technology) is 2 ha / day (varies from 1.5 to 2.5 depending on the scope of work and category of difficulty)

2. Telling of the trees
Performers: 
- Engineer of the 4th category
- Assistant of the 3th category
Production rate - 3.74 ha / day

2. Dendrological survey (preparation of an inventory plan - telling of the trees, determination of the status category, measurement of diameters, heights, etc.)
Performers: 
- Engineer of the 4th category
- Assistant of the 3th category
Production rate (based on the results of a pilot test of Field-Map technology) – 4 ha/day

As an example, the cost of the work was calculated for the object "Lunet Litke", the area of which is 2.6 hectares (table 3-4).

Table 3. The cost of the work.

| Options | Work | Production rate, ha/day | Volume of work, ha | Need for standard days | Tariff rate, rub./day | Wages, rub. |
|---------|------|-------------------------|--------------------|------------------------|----------------------|-------------|
| Basic   | 1    | 0.86                    | 2.6                | 3.02                   | 440                  | 1328.8      |
|         | 2    | 3.74                    | 2.6                | 0.70                   | 440                  | 308         |
| Design  | 1    | 2                       | 2.6                | 1.3                    | 543.6                | 706.68      |
|         | 2    | 4                       | 2.6                | 0.65                   | 440                  | 286         |

Table 4. Field-Map Technology Efficiency.

| Options | Labor costs Person/days | Wages, rub. | Deviation |
|---------|-------------------------|-------------|-----------|
| Basic   | 3.72                    | 1636.8      | 1.95      |
| Design  | 992.68                  | -1.77       | -644.12   |

As a result of applying Field-Map technology, wages are reduced by 2.5 times, and labor costs are reduced by almost 2 times, which proves the effectiveness of this technology.
4. Conclusion
Currently, for many green construction projects in St. Petersburg there are no accurate inventory data updated at least at the beginning of 2010. Previously available data have different reliability but even accurate data are not suitable, because since 1996, the situation has changed due to tree growth, economic activity, land grabbing, etc.

The project considered the possibility of using Field-Map technology for an inventory of urban landscaping objects. Field-Map technology may well become the basis of GIS, therefore, a training system for practitioners to work with Field-Map technology and GIS is needed.

Inventory of objects using Field-Map technology will expand the number of indicators in the passport of objects and registers of green spaces, which will affect the cadastral valuation and damage assessment from the demolition of vegetation, etc. This technology is ideal for compiling inventory documents of not only small and medium-sized objects due to the speed of work, but also suitable for large objects. The cost of 1 ha of inventory varies within very large limits due to differences in the area of plots, structure of work, required accuracy and timing of work.

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