The use of information and infocommunication technologies in the management of urban forests of St. Petersburg using geographic information systems

O Kolbina1*, N Yagotinceva1, P. Bogdanov1, E. Istomin1, M Vagizov2

1Department of applied information science, Russian state hydrometeorological university, Voronezhskaya Street 79, St. Petersburg 192007, Russian Federation
2Department information systems and technologies, St. Petersburg State Forest Technical University, 5 Institutskiy Lane, St. Petersburg 194021, Russian Federation

*Corresponding e-mail: olya_kolbina@mail.ru

Abstract. The article considers the possibility of using infocommunication technologies in the management of urban forests. There are schemes and models of integration the Internet of things into geoinformation systems for making managerial decisions that contribute to the care of green spaces in the city of St. Petersburg.

1. Introduction
The development of humanity is strongly connected to the reclamation and use of land for construction and agricultural needs, which leads to ubiquitous deforestation. Over the past 40 years, the share of world's forest area per capita has decreased by more than 50%. It is generally accepted fact that forests play an inherent role in the ecological balance of the planet. Preservation and growth of vegetation in human habitats is an achievable and real goal that a civilized society should pursue.

2. Methods and Materials
The general components of the ecological “safety bag” of big cities are forests, parks and forest park zones, which carry security, recreational, cultural, sanitary and hygiene functions. [1, 2]. According to Article 102 of the Forest Code of the Russian Federation, urban forests are classified as protected ones.

Urban forests are also an indispensable element of the landscape of any city in the world.

The total area of green spaces in St. Petersburg goes beyond 31 thousand hectares, including 68 parks, 166 gardens, 730 squares, 232 boulevards, 750 green streets (figure 1).
Figure 1. The distribution of urban forest territories of St. Petersburg.

City parks are located in different landscape conditions: on the lower and upper terraces of the Gulf of Finland coast (Strelna, Peterhof and Lomonosov parks), moraine plain (Pushkin parks), kame hills (Shuvalovsky park, Osinovaya Grove). The basis of a number of parks is made up of natural forests, which still retain their mineral consist (Sosnovka, Udelny park). Many parks that were created in the post-war years are divided into areas where woody vegetation was actually absent (Moscow Victory Park, Primorsky Victory Park), etc.

Many of the parks are recognized as a cultural heritage and should be protected with double efforts, but, unfortunately, due to the location, forest plantations are subjected to great stress and destruction. The reason is the high temperature of the atmosphere, the concentration of exhaust fumes from transport, soil compaction and limited space for growth. Adverse growth conditions also contribute to increasing the susceptibility of urban forests to pests and diseases, climate change and air pollution. In addition, the expansion of transport infrastructure and urban development, the introduction of exotic shrubs or trees may affect the growth dynamics of urban forests. Therefore, it is necessary to pay special attention while carrying out design work on strategic planning and economic activities. It is also equally important to assess and monitor the condition of vegetation, as well as collect and systematize information on the state of urban forests [1].
Rapid development of information technologies made it possible to simplify this process and reduce it to work in specialized information and geoinformation systems (GIS), which allow consideration of not only the usual numerical and textual data, but also spatial data, satellite images.

Scientists from all over the world have long been using geoinformation technologies and remote sensing of the Earth for the assessment and monitoring of urban forests. Thus, the changes in spectral signatures relative to the leaf area index (LAI) indicate the viability of urban forests in stressful situations. Sick plants have lower signature values in the near infrared region and have increased ones in the visible wavelength region. [3, 4]

The concept of "urban heat islands" has become increasingly common with regard to urban forests. Its definition describes the special effect of higher temperatures of the atmosphere and the surface of the Earth in cities due to the large amount of impermeable materials used in urban development. This phenomenon is fully recorded by means of satellite sensors.

Thus, the use of geoinformation systems for monitoring urban forests can fully solve the problem of the disappearance of green spaces and maintaining the boundaries of forest parks unaltered. However, the application and use of this technology in St. Petersburg is difficult due to the division of urban forestry activities between various municipal units. As the result, the Committee for the improvement of St. Petersburg carries out the management in the field of improvement (gardening, forestry, maintenance of roads and other landscaping objects, waste disposal) in St. Petersburg. It also coordinates other executive bodies of state power of St. Petersburg in this area. [5]

Due to the extensive responsibilities of this committee, the use of a geoinformation system in managerial decision-making should ensure the timeliness and quality of decisions. However, the territorial dispersion of urban forests within St. Petersburg, their number and lack of specialists in each individual forest plantation creates the problem of access to the necessary information. The timely receipt of results on the sanitary and other activities in the parks are also disappointing. Infocommunication technologies might be a very practical solution for monitoring the state of urban forests. It will surely give the possibility to use any means of communication for data transmission. (figure 2).

**Figure 2.** The structural scheme of the information that is necessary for the decision maker.

A huge amount of data from many detectors and devices is constantly transmitted in space. It includes results of sensory monitoring of the environment from various GPS receivers, social networks and many other means of communication connected via the Internet.
It is necessary to solve a number of problems to build and integrate geographic information systems and a complex of infocommunication systems in a technically correct way. [6]:

a. collection, storage and analysis of data;

b. handling the large amount of heterogeneous data;

c. the format of presenting the collected data on GIS layers;

d. visualization of the necessary data.

It is necessary to decompose the entire geographic information complex into its component parts in order to solve these problems.

As figure 2 shows, the GIS system consists of 4 subsystems used for collecting and processing information:

- satellite systems;
- communication systems for visitors and employees;
- GIS systems in district forestries;
- Internet of things systems.

Since the Internet of things is an innovative technology that has prospects in the digitalization of forestry, the aim of this research is to integrate the geoinformation complex and the Internet of things systems. The combination of technologies that allows collecting data and controlling objects is called the “Internet of things” (literally - “the Internet of Everything”, IoE), which gives you access to the source of the necessary data in real time [7, 8].

Integration of the Internet of things with geoinformation systems will allow:

a. optimizing the operation of urban services that use control sensors;

b. monitoring pollution levels as well as air quality;

c. monitoring the pollution level of forest plantations;

d. visualizing the situation related to the forestry in real time;

e. make a selection according to the parameters in order to present the information;

f. manage the process of caring for green spaces.

3. Results and Discussion

Internet of things technology includes supporting technologies, network technologies, information technologies, sensing and control technologies, software technologies, hardware technologies (figure 3). [9]
The work of the Internet of things is supported by electronic devices that interact with the physical real world. The data in such systems provides contextual, relevant and prognostic information, which affects the geoinformation system, to support the management of decision-making. The interaction of the IoT components ensuring its operation as a subsystem of the geoinformation system is presented in figure 4.

**Figure 4.** Services and IoT components relative to GIS.

Data connected IoT services, devices, and gateways is preserved in the data storage used by GIS to support management decisions and possible forecasting (figure 5).

**Figure 5.** Entity-Based GIS and IoT Integration model.
An entity-based model includes:

- **Physical Entities**: Elements of forestry that are perceived and affected by IoT devices;
- **Labels of Various Types**: Unique numbers assigned to physical entities to facilitate their monitoring and identification;
- **IoT Devices**: Elements that allow environmental monitoring in forestry, interacting with the physical world through the perception and activation of physical entities. IoT devices include:
  - **Sensors**: That monitor forestry in real time and convert the meterage to digital;
  - **Executive Devices**: That control the physical entities of forestry based on digital instructions;
- **Networks with Short Range**: Used for the exchange of internal information between devices;
- **IoT Gateways**: Forming a channel between the local network and the global access network;
- **Subsystem of Applications and Services**: Analysis Services process device data. The subsystem includes process administration, which controls the processes in the IoT system. Applications and services interact with IoT gateways and IoT devices through an access network. Also, they interact through a network of services between themselves.
- **Subsystem of Operation and Management**: The subsystem includes a device registry data store and a device identification service. The subsystem includes a device management application that provides monitoring and administration capabilities for IoT devices in the system. The subsystem also includes an operational support system connected to the monitoring and management of the entire IoT system.
- **Subsystem of Access and Exchange of Resources**: Provides access to the capabilities of the IoT system for GIS and provides managed interfaces [10].

Interconnected objects (entities) provide network connectivity, including data transmission channels. Data links can be point-to-point connections within or between IoT systems, within or between domains, as well as with other systems and organizations. Connected networks must manage connectivity from one network to another. The key role of networks is to support and provide activities and interactions for communication and data exchange.

The optimal mode of operation for the implementation of data transfer from devices to the server is NRX (No RX). Unlike DRX (Discontinuous RX) and CRX (Continuous RX) [11], this mode of operation provides only data transmission at a given frequency, the rest of the time the modem is in the sleep mode, which allows you to use bandwidth and power saving mode economically. The issue of energy conservation is quite critical when implementing autonomous power systems using alternative power sources.

Re-sending of “lost” data and the mode of automatic selection of the optimal communication speed are not supported in the NRX mode, but for the application of IoT in GIS management of urban forests it does not play a significant role, because data containing both information on environmental monitoring and data on the state of the control device itself (physical entity) is sent in real time at the speed provided by the communication channel [12, 13].

Presentation of the architecture of IoT integration with GIS ensuring the work of GIS monitoring of forestry allowed to determine at a conceptual level:

- **Functional Representation of IoT Integration**;
- **Representation of IoT Integration Deployment**;
- **Network Representation of IoT Integration**.

The network representation, in turn, defines the main communication networks in IoT systems and connected entities.

### 4. Conclusion

Using the Internet of Things technology in interaction with GIS allows administration to understand what is happening at the moment, where it is happening, what resources are available, where employees are and much more. The ability to combine information from many types of sensors and locations is a critically important factor for complex operations. Thus, for example, it is possible to control the frequency of irrigation of green spaces based on the meterage of soil moisture sensors,
produce additional protective measures based on long-term and short-term environmental forecasts, and minimize human involvement in caring for vegetation.

References

[1] Vorobyov O N, Kurbanov E A, Gubaev A V, Polevshchikova Yu A, Demisheva E N and Koptelov V O 2015 Remote monitoring of urban forests Bulletin of the Volga State Technological University. Ser. Forest. Ecology. Nature management. 1 (25) pp 5-21

[2] Jensen R R and Perry J H 2005 Estimating urban leaf area using field measurements and satellite remote sensing data Journal of Arboriculture. 31(1) pp 21-27

[3] Konijnendijk C C, Nilsson K, Randrup T B and Schipperijn J 2005 Urban Forests and Trees Berlin Springer p 520

[4] Vagizov M R, Ustyugov V A and Kvochkin D O 2017 Determination of the forest inventory indicators according to the photographs of the unmanned aerial vehicles Ecology, Environment and Conservation. 23(1) pp 582-586

[5] Kolbina O, Istomin E, Petrov Y, Stepanov S and Sidorenko A 2019 About technology of risk management in forestry IOP Conference Series: Earth and Environmental Science 316(2019) 012011 DOI: 10.1088/1755-1315/316/1/012011

[6] Yagotinceva N and Tatarnikova, T M 2019 Alternative of infrastructure GIS marine vessel under the purpose of swimming CEUR Workshop Proceedings. 2522 pp 203-212

[7] Tatarnikova T M and Dzubenko I N 2018 IoT system for detecting dangerous substances by smell Informatsionno-Upravliaiushcie Sistemy. 2018(2) pp 84-90

[8] Abramov V M, Istomin E P, Mikheev V L, Novikov V V and Palkin I I 2019 Model of geo-information support for decision-making while natural risk management International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management SGEM

[9] ISO/IEC 29161:2016 «Information technology — Data structure — Unique identification for the Internet of Things», IDT

[10] ISO/IEC 30141:2018, Information technology – Internet of Things (IoT) – Reference architecture, MOD

[11] PNST 354-2019, Information technology – Internet of Things (IoT)–Information technology. Internet of things. Wireless protocol based on narrow band RF modulation (NB-Fi)

[12] Istomin E, Petrov Y, Stepanov S, Kolbina O and Sidorenko A 2019 Model of optimum integration of diverse geodata for the benefit of management of forestry IOP Conference Series: Earth and Environmental Science 316(2019), 012013 DOI: 10.1088/1755-1315/316/1/012013

[13] Istomin E P, Kirsanov S A, Sokolov A G and Kolbina O N 2014 The phenomenon of geo-information management and the principles of its implementation Vestnik Sankt-Peterburgskogo Universiteta, Seriya Geologiya i Geografiya vol 2014, Issue 4, p 180-188