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ORIGINAL PAPER
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LAND ADMINISTRATION SYSTEM AND GEOPORTAL SERVICE FOR THE NEED OF A FIT-FOR-PURPOSE NATIONAL URBAN GREENERY MANAGEMENT SYSTEM (UGMS). THE CONCEPT FOR THE EU MEMBER STATE OF POLAND

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ABSTRACT

Motives: IT is nowadays an effective tool supporting management in many fields, including management of urban greenery. Only a few cities in Poland have launched a dedicated urban greenery management system (UGMS). The need to provide all cities in the country with such a possibility gave birth to the idea of developing a concept using existing Land Administration System (LAS) infrastructure connected with INSPIRE Geoportal which can provide more than 75% of the information for urban greenery management.
Aim: The main aim of this study was to propose the functional and database concept of a fit-for-purpose urban greenery management system (UGMS) in Poland as a universal tool for different types of urban greenery management bodies (UGMB) and a consistent information platform covering the entire country based on LAS referred to as the Integrated Real Estate Information System (IREIS), and the INSPIRE Geoportal service. The UGMS concept can be implemented in the other Member States of the European Union and other countries that have LAS and SDI like INSPIRE.
Results: This approach develops a cost-effective information system that contains comprehensive information from the existing SDI in Poland and can be used by all Polish cities. The system will provide UGMB with access to data that is required for the performance of their statutory duties. Previous accomplishments, EU recommendations, and national experiences in spatial planning have been taken into account in the design process. In line with the fit-for-purpose concept, the relevant needs were determined during a survey of selected public administration authorities responsible for urban greenery. As a result, the scope of data required to create the UGMS was defined in the context of system functionalities. In addition, potential sources of data for the UMGS and their location in the NSDI were identified.

Keywords: urban greenery, green infrastructure, green information system, urban greenery management system, land administration system, INSPIRE

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INTRODUCTION

Urban greenery should be maintained to protect biodiversity and help cities adapt to a changing climate (Makinde et al., 2021). In Europe, the development of Urban Greenery was particularly influenced by European Commission guidelines and standards (EC, 2012a; 2016) recommending the implementation of consistent green policies and the development of Green Infrastructure (GI). Green information systems should play an important role in the sustainable management of green infrastructure (Pauleit et al., 2017; Nowak et al., 2020). They should be purposefully designed to meet the information needs of all actors who are responsible for urban greenery (UG). However, an analysis of good practices relating to the implementation of GI systems as part of the European GREEN SURGE (GS) project (Pauleit et al., 2019) indicates that despite European Commission guidelines concerning GI systems and the implementation of the European Spatial Data Infrastructure (INSPIRE, 2007), a uniform approach to developing such systems has not been proposed in the European Union or the individual EU Member States. The existing approaches do not cover the territory of entire countries, and the proposed solutions are implemented only locally. In the EU Member States tree risk management is not being regulated at the state level, and instead depends on the decisions made by local municipalities. In consequence, the applied approach to green infrastructure varies between different cities. The above also applies to Poland, where local regulations have been drafted and implemented by selected Polish cities (Biejat, 2017). The existing local information systems contain fragmented databases (Feltynowski et al., 2018; Ślązak, 2017), mainly due to a shortage of funds, insufficient experience in implementing different stages of GI projects, and the lack of economic incentives because the benefits of GI are difficult to assess in financial terms (Kabisch et al., 2016). Since there are no key, nationally standardized regulations for urban greenery maintenance, it is difficult to expect the creation of a nationwide information infrastructure for common use in greenery management.

Therefore, the main aim of this study was to propose the concept of a fit-for-purpose urban greenery management system (UGMS) in Poland as a universal tool for different types of urban greenery management bodies (UGMB) and a consistent information platform with a database and functionalities covering the entire country using information technology (IT) of Land administration system (LAS) integrated with INSPIRE Geoportal service (INSPIRE, 2007) as components of National Spatial Data Infrastructure (NSDI). The UGMS concept can be implemented in the other Member States of the European Union and other countries that have LAS and SDI after adaptation to national information needs. Spatial Data Infrastructure is a global framework of policies and institutional arrangements; therefore, the developed concept can also be used as a reference in non-EU countries. The Polish land administration system (LAS) is referred to as the Integrated Real Estate Information System (IREIS). This approach was adopted to develop a cost-effective system that contains comprehensive information about the existing spatial data infrastructure in Poland and can be used by all Polish cities. The system will provide all users, in particular UGMB, with access to data that is required for the performance of their statutory duties. The UGMS infrastructure should span the entire country to address the lack of cohesive IT tools for urban greenery management, the absence of valid data, and different methods of data collection, and to enable less affluent cities to benefit from the accumulated resources. These goals can be achieved by localizing the UGMS in the LAS environment and using INSPIRE data. The LAS constitutes integrated information infrastructure which is a part of the national spatial data infrastructure (NSDI) and which enables the public administration to perform tasks related to land management. The LAS plays a very important role as a source of reference data for spatial planning, tax assessment, real estate registration in the land register, statistical reports, and real estate management (Williamson et al., 2010). In turn, the Geoportal service constitutes spatial data infrastructure that is open to the public and has been developed under the provisions of the

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INSPIRE Directive (INSPIRE, 2007). The LAS and the INSPIRE Geoportal service are described in detail in subsection *National Spatial Data Infrastructure…* The NSDI comprises public registers and is kept by public administration bodies. Urban greenery constitutes a public resource, and it is also managed by public administration authorities; therefore, the UGMS should be a part of the NSDI. The resulting system could become a national platform for managing UG as well as green spaces outside urban areas. This is a logical approach that will deliver economic (the use of shared infrastructure will decrease development and maintenance costs) as well as environmental benefits (less affluent cities will have access to a greenery management system). A UGMS that is developed based on the LAS and the Geoportal service as a part of the Polish NSDI will create access to large amounts of integrated spatial data.

Literature study covering the last 20 years involving the following keywords – urban greenery/green infrastructure/green spaces information/management systems, urban green spaces maps has shown that there are a lot of studies developing greenery managing systems with new functionalities, including GIS tools e.g. for planning UG (Kulkarni et al., 2017), for mapping urban green spaces (Vatseva et al., 2016), for environmental monitoring (Trubina et al., 2019), and their functions in the absence of spatial data (Łaszkiewicz et al., 2020). However, solutions are lacking for creating a single country UGMS. Hansen et al. (2016) conclude that currently developed greenery management systems in the EU member states are limited in scope and profiled towards solving particular issues at a local scale. They use their own software using publicly available spatial data from selected public records and create their own databases. This is an inefficient approach as it requires significant financial investments and is time-consuming. Furthermore, searching the literature on LAS for urban greenery management or smart urban greenery management also did not identify any scientific proposals for using LAS infrastructure connecting with INSPIRE SDI for UGMS. The most common concepts in current studies are the use of cloud computing, the internet of things (IoT), and artificial intelligence (AI) for smart UGM (Anh, 2021) using GIS and nationally available land use maps. Some smart GIS for UGM uses databases from sensors e.g., for measuring soil moisture for irrigation (Nguyen et al., 2020). So far there is no approach to implement a standardized information technology available to all cities in the country, such as cadastral systems, for the information service of urban greenery management. The proposed concept is innovative not only because it provides a solution for launching the UGMS at a national level, but also because it offers a standardized approach to create fit-for-purpose UGMS. It integrates various types of thematic data for UG management in one access window based on the information technology of the LAS and the provisions of the INSPIRE Directive. The innovative character of the proposed approach to developing a national UGMS was emphasized in subsection Lessons learned… in the context of the European debate on good practices in the process of implementing such systems. The local dimension of such measures and the absence of standard approaches at the national level has also been accentuated by the European GREEN SURGE (GS) project (Pauleit et al., 2019) that aims to develop and evaluate the best practices in urban green infrastructure management.

The proposed concept UMGS will support the management of urban greenery at every stage, from policy-making, through design, material procurement, and implementation, to monitoring, protection, and maintenance. It will enable the development of a uniform system covering all cities in the country, and it will create equal opportunities for developing green infrastructure in all urban areas. This novel approach towards creating a comprehensive national system can support the development of national-level regulations for establishing and operating a UGMS.

The UGMS should not rely on individual information systems because most of the data for UG management is supplied by national spatial databases that are integrated with the LAS and the Geoportal service. Therefore, the following research hypothesis

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was formulated: the Polish NSDI integrating the land administration system, referred to as the Real Estate Information System (IREIS), and the INSPIRE Geoportal service is capable of supplying more than 75% of the data required for UG management in Poland. The proposed approach marks a new direction in the process of developing the UGMS.

MATERIALS AND METHODS

Research organization and methods

An empirical study involving qualitative methods was carried out to achieve the research objective, namely to identify the types of data and the functionalities that are essential in the proposed UGMS. The study relied on an in-depth analysis of the literature, policy documents, legislation, and good practices in the implementation of urban greenery management systems in Europe. Due to considerable differences in the terminology describing urban green spaces in domestic and international literature, the existing definitions were analyzed, and consistent terminology was proposed. Strategic European and domestic documents were reviewed to identify the key EU recommendations on urban planning and the promotion and implementation of green infrastructure and to describe the existing information systems as the sources of the best practices in UG management. In addition, the theoretical concepts relating to spatial data infrastructure (SDI) in Europe and Poland were analyzed to determine the applicability of integrated spatial data in the Geoportal service and the Polish LAS for the needs of the proposed UGMS.

The resulting knowledge was used to describe the main functionalities and features of the proposed UGMS based on general trends in green infrastructure development, the implementation of various information systems in the EU, and the possibilities offered by NSDI. The formulated assumptions were then validated by surveying the employees of public agencies responsible for urban greenery management in five Polish cities (Warszawa, Kraków, Poznań, Gdańsk, and Olsztyn). The selected cities are large urban agglomerations that are situated in different Polish regions, are more affluent than other Polish cities, and have made different progress in the implementation of systems supporting green infrastructure management. In Poland, urban greenery is managed by various entities at different levels of the administrative hierarchy. For the needs of this study, these entities were described collectively as urban greenery management bodies (UGMB). The respondents were UGMB employees (sectoral experts) who were asked to indicate the types of data, tools, and functionalities that would be useful in daily practice. The results of the survey were used to identify the types of spatial data and system functionalities that would most effectively support the operations of UGMB in three general areas of competence: planning, administration, and field operations. In addition, these results were used to select the main (urban greenery) and supplementary (other spatial objects) types of data and essential system functionalities that are best suited for sustainable UG management (detailed information is presented in subsection *Field research*…).

Databases were analyzed in thematic groups to verify the research hypothesis stating the Polish NSDI integrating the land administration system, referred to as the Real Estate Information System (IREIS), and the INSPIRE Geoportal service is capable of supplying more than 75% of the data required for UG management in Poland. The research hypothesis was verified by analyzing the extent to which NSDI resources can cater to the need for spatial data in the proposed UGMS.

The present study did not set out to offer detailed technological or organizational solutions. The study aimed to localize the UGMS database within the Polish land administration system integrated with the INSPIRE Geoportal. The architecture and organization of the UGMS will be described in a future publication.

Research area – survey research

Public administration inspectors (experts) responsible for UG management were surveyed in five Polish cities: Warszawa (3 departments), Kraków, Wrocław, Gdańsk, and Olsztyn (Fig. 1). The survey involved

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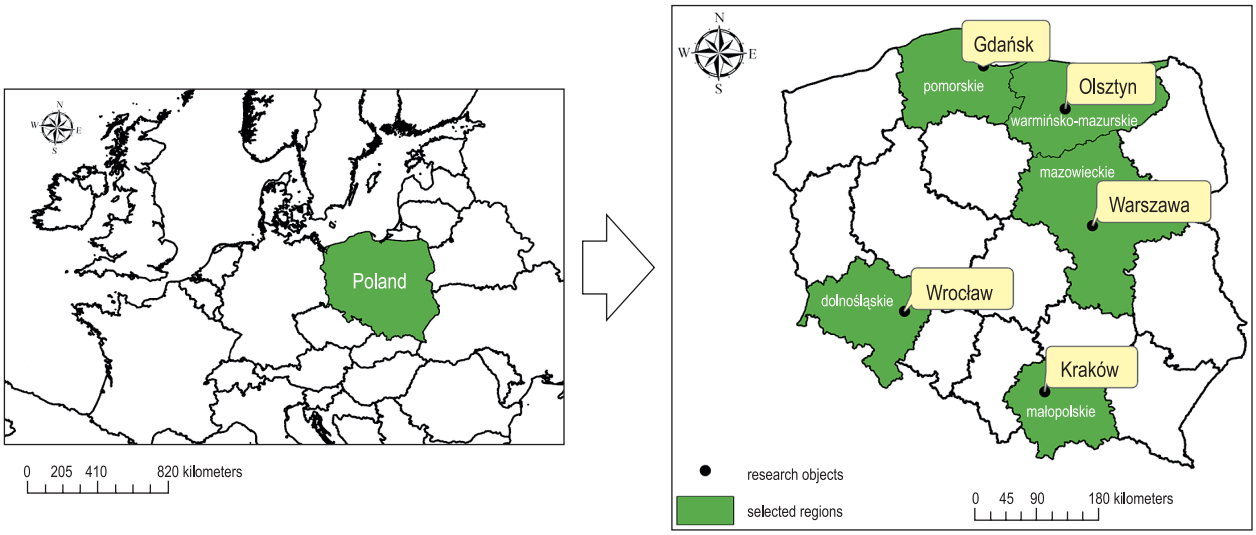

Fig. 1. Polish regions and regional capitals with marked research objects
Source: own elaboration.

the employees of environmental protection departments, urban greenery departments, and city offices in Olsztyn (Olsztyn Road, Greenery and Transport Authority; Department of Urban Planning and Architecture of the Olsztyn City Office; Chief Landscape Architect), Wrocław (Municipal Greenery Authority; Chief Urban Landscape Architect; Department of Urban Greenery; Department of Land Resources; Technical Documentation Department; Investment Department), Kraków (Municipal Greenery Authority), Warszawa (Warszawa Greenery Authority, including three Garden Zone departments; Real Estate Management Department; Green Landscaping Department; Green Infrastructure Department; Water Department; Participatory Budget Department) and Gdańsk (Gdańsk Road and Greenery Authority).

The survey aimed to elicit comprehensive information about urban greenery management at different levels of public administration. The interviews were conducted in public institutions responsible for planning, administering, and managing urban greenery. The cities selected for the study are regional capitals that represent the geographic regions of Poland, and they differ considerably in the implemented solutions and systems for UG management. The selection of research objects was preceded by a detailed analysis of information systems for UG management in these cities.

Survey questionnaires were forwarded by email and post to 50 sectoral experts, 10 in each analyzed city, and completed questionnaires were returned by 34 respondents. The results of the study are presented in subsection *Field research…*

RESULTS

Desk research – Overview of existing studies and documents

The first stage of the study involved a review of the literature, strategic documents, acts of Polish and EU law, and reports from the implementation of modern information systems for urban greenery management. The results were analyzed to create a comprehensive list of data for UMGS and its functionalities. These findings were verified during the expert survey.

Terminology

The present research was undertaken to define the concept of UG management and determine the scope of information required for the effective

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implementation of UMGS. For this purpose, the term "urban greenery" was selected as the main keyword, and "urban green areas" and "green infrastructure" were regarded as related terms that are frequently encountered in the literature and Polish legal acts. In the literature, the term "urban greenery" is often used interchangeably with "urban green areas" (Shashua-Bar & Hoffman, 2000; Morancho, 2003; Ernstson et al., 2008) to denote *urban* land covered by all types of vegetation, including vegetation on private and public grounds, regardless of their size and function, as well as small water bodies such as ponds, lakes or streams ("blue spaces"). The Nature Conservation Act of 16 April 2004 (Article 5.21) (Act, 2004) states that green areas include developed areas with technical infrastructure and functionally related buildings, areas that are covered with greenery and serve public functions, in particular parks, gardens, promenades, boulevards, botanical gardens, zoological gardens, game parks, historical parks, cemeteries, roadside greenery in developed areas, squares, historical fortifications, buildings, storage sites, airports, railway stations and industrial facilities. Green areas also include green walls and municipal forests, as well as tourist and leisure areas. Urban greenery is often incorrectly regarded as synonymous with public areas because Polish urban planning documents focus on the formal and most frequently identified categories of urban greenery (formal urban greenery, FUG) that are managed by the local authorities. In turn, many forms of urban greenery that are found on private land are not formally classified as green spaces (e.g. arable land, grassland, pastures, orchards, brownfields / undeveloped land located within city limits) (Feltynowski et al., 2018). These areas can be referred to as informal urban greenery (IGS). In this study, both formal and informal UG were regarded as components of urban greenery. In the literature, the term "urban greenery" is used synonymously with "urban green areas" (UGA), and both terms will be used interchangeably in this study.

Urban greenery is undoubtedly a fundamental element of urban green infrastructure (GI). Green infrastructure is defined as "a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services" (EC, 2016). This concept incorporates green spaces (or blue spaces if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. In other words, GI denotes successfully tested tools that provide ecological, economic, and social benefits through natural solutions (Benedict & McMahon, 2002). Green infrastructure is a concept that is broadly understood, and it is expected to evolve into a comprehensive approach to fulfilling many integrated functions, from greenery management to the preservation of wild flora and fauna species, recreational areas, ecosystem services such as flood prevention and microclimate control (Pauleit et al., 2017). In Poland, GI is still under development, especially about the division of competencies and responsibilities; therefore, the most urgent task at present is to develop the assumptions for urban greenery management and expand the existing databases to support all GI.

Legal regulations and recommendations in Poland and the EU

European Union documents

The management of green spaces is addressed by numerous policy areas at the European level, and the three most relevant areas are natural resource management, sustainable urban development, and spatial development. Urban greenery is a part of GI, and the following policy documents concerning GI have been adopted by the EU in the context of UG: the Roadmap to a Resource Efficient Europe (EC, 2011a), EU Biodiversity Strategy to 2020 (EC, 2011b), Urban Agenda for the EU – Pact of Amsterdam (Agenda, 2016), Blueprint to Safeguard Europe's Water Resources (EC, 2012b), and Adapting to climate change: towards a European framework for action (EC, 2009). Green infrastructure also refers to the Natura 2000 ecological network of protected areas Directive on the conservation of natural habitats

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and wild fauna and flora (Directive, 1992) and the Directive on the conservation of wild birds (Directive, 2009). The above documents were analyzed, and the following types of data were selected as relevant for UG management: land cover, soil and water conditions, existing infrastructure, land use, protected species and habitats, environmental pollution, and meteorological data. The analyzed documents emphasize the need to collect and exchange information at the level of the EU Member States. Many other documents have been adopted to standardize the approach to improving urban green infrastructure or urban greenery. International conventions, EU regulations, and programs focus on selected elements of green infrastructure. Green infrastructure can deliver numerous benefits and serve different functions, including environmental (biodiversity conservation, climate change adaptation), social (green space planning), and economic (job creation and increased property value). All policy documents recognize the importance of reliable data in GI management. The above documents were examined to identify datasets that are essential for achieving green policy objectives, including land cover (especially green objects), land use, protected areas, valuable species and habitats, the conservation status of natural habitats, and species of European importance, climate, and environmental pollution. These datasets were then verified in an expert survey involving the employees of Polish UGMB.

Polish legal acts and strategies

The concept of Green Infrastructure (GI) is not yet present in Polish legislation, especially in its integrated-strategic approach. However, Polish legal regulations contain references to specific elements of UG. The fragmentation of the relevant regulations and the absence of a clear definition of green infrastructure undoubtedly hinders GI protection. However, specific GI components are protected under other acts and strategic documents; therefore, green infrastructure is not absent from Polish legislation (Neubert et al., 2019).

The most important national strategic document relating to urban greenery and blue spaces are Resolution of the Council of Ministers of 13 December 2011 on the adoption of the National Spatial Development Concept 2030 (Resolution, 2012), Environmental Protection Act of 27 April 2001 (Act, 2001), Nature Conservation Act of 16 April 2004 (Act, 2004), Act on forests of 28 September 1991 (Act, 1991), and the Water Law of 20 July 2017 (Act, 2017). These laws emphasize the importance of land use planning in biodiversity conservation and the protection of valuable natural resources. The following documents were also analyzed in the study: Resolution of the Council of Ministers of 5 February 2013 on the adoption of a Long-Term National Development Strategy – Poland 2030. The Third Wave of Modernity (Resolution, 2013); Resolution of the Council of Ministers of 16 July 2019 on the adoption of the State Environmental Policy 2030 – Development Strategy for the Environment and Water Management (Resolution, 2019); Strategic Adaptation Plan for sectors and areas vulnerable to climate change by 2020 with an outlook to 2030 (Ministry of the Environment, 2013); Resolution of the Council of Ministers of 6 November 2015 adopting the Program for Biodiversity Conservation and Sustainable Use of Its Components and the Action Plan for 2015–2020 (Resolution, 2015). These documents emphasize the importance of protecting and improving the environment, monitoring biodiversity, and working to prevent climate change.

The maintenance and restoration of ecosystem services play an important role in UG establishment. This task requires a system for the valuation and integration of ecosystem services into development strategies, the planning system, and national accounting and reporting systems. Such a system will enable reliable assessment of biodiversity loss, and it will improve communication between different levels of government. The performance of the Polish nature conservation system can be considerably improved through the integration of green infrastructure (Resolution, 2015). The tasks to be performed by the responsible institutions under the Program for Biodiversity Conservation and Sustainable Use of Its

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Components and the Action Plan for 2015–2020 (Resolution, 2015) are presented in Table 1.

An analysis of the above documents indicates that Poland is on the right track towards developing GI and that plans are being made to develop national standards based on EU guidelines, organizational solutions, and divide the relevant responsibilities. To summarize, the above documents indicate that effective GI management requires analyses of long-term climatic and hydrological data (thermal indicators, precipitation, extreme phenomena, air pollution), land use planning studies, flood hazard maps, various nature conservation schemes, ecological corridor maps, and nature monitoring data. The recommendations concerning data collection for planning and managing green areas were taken into account in subsequent stages of the study to identify the types of data that are essential for the development of the UGMS.

Table 1. Key tasks and objectives for the development of Green Infrastructure in Poland

Responsible institution	Tasks
Ministry of Environment	Development of a national catalog of ecosystems and their services with a map of ecosystem distribution
Ministry of Environment	Development of national principles for valuing ecosystem services
Ministry of Environment Ministry of Finance Central Statistical Office	Development of national principles for integrating ecosystem service valuation with accounting and reporting systems
Ministry of Infrastructure and Development	Development of national guidelines to make green infrastructure a standard element of spatial planning and territorial development
Local government entities	Integration of green infrastructure into planning efforts at the local level

Source: own elaboration based on the Program for Biodiversity Conservation and Sustainable Use of Its Components and the Action Plan for 2015–2020 (Resolution, 2015).

Lessons learned – experience from the implementation of the best information systems for urban greenery management in EU member states

Information technology such as databases and Geographic Information Systems (GIS) for comprehensive urban greenery management is still a relatively new phenomenon in Europe. This observation was confirmed by the GREEN SURGE (GS) project (Pauleit et al., 2019) which examined the progress made in GI implementation in 20 European urban areas and identified good practices for GI planning (Davies et al., 2015). The results indicate that all urban areas had defined green space strategies and had developed various tools for their implementation, including the relevant spatial information systems. The key provisions of the strategies introduced by the analyzed cities focused on planning green spaces, most often recreational spaces, and climate change mitigation standards, including adaptation to new climate conditions in future planning of urban GI. The differences in the analyzed green strategies and the relevant information systems resulted mainly from environmental conditions and the funds allocated to the implementation of these policies, which are described below in the example of Barcelona, Berlin, and Kraków. In all surveyed cities, SDI was developed in line with the provisions of the INSPIRE Directive which lays down a general framework for GI development. However, none of the examined European cities had implemented an urban greenery management system that is integrated with the land administration system.

In post-transition EU countries such as Poland, Lithuania, and Slovakia, many cities are struggling with various economic, organizational, and legal problems that are delaying GI development (Davies et al., 2015). However, in some UE cities, considerable progress has been made in urban greenery management, and advanced information technologies have been

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introduced to support the developed management standards. The examples of Barcelona, Berlin, and Kraków point to a strong link between the quality of GI management and information technology. One of the most promising examples that focus strictly on GI development is the Green Infrastructure and Biodiversity Plan 2020 implemented by Barcelona (Spain). Barcelona has developed an information system dedicated to green infrastructure, green spaces, and biodiversity conservation that is consistent with the provisions of the Green Infrastructure Development Program (Barcelona, 2017) whose priory goal is to increase green space per capita. This system called GAVI uses software that interacts with the community through the website (Barcelona City Council, 2011). It integrates a variety of information layers to facilitate urban greenery management e.g. pruning, maintenance, and removal management as well as replacement and risk management. Green spaces in Barcelona were first identified based on the available spatial data, including topographic maps, orthophotos, thematic maps, the normalized differential vegetation index (NDVI), and local plans. Barcelona's GAVI measures and monitors the continuity and accessibility of green areas, their functional complementarity, and their ability to provide social and environmental services, including the planning of green infrastructure as a network of green corridors; assessment of areas identified as recreational spaces with the potential to increase biologically active and permeable surfaces; provision of ecosystem services in green areas on a city-wide scale, and the development of an information system dedicated to green infrastructure, green areas and biodiversity. Unfortunately, Barcelona's Green Information System remains a local initiative, and it has not been implemented in other Spanish cities. The scope of data in Barcelona's GI system was taken into consideration in the process of developing the UGMS database concept.

Berlin has implemented the Green-Space Information System (GRIS). The GRIS has been designed to improve the effectiveness of green space maintenance from the economic point of view and to facilitate data processing for planning and communication with the local authorities and the public. The Biotope Area Factor (BAF) was introduced to determine the proportion of urban areas to be left as green space. This indicator was developed to limit environmental degradation in the inner city and suburban areas and to ensure that sufficient green space exists to provide recreational functions and maintain ecological functions (BGMR & HCU, 2017). The databases in Berlin's system contain information on land cover, including green and blue infrastructure (with particular emphasis on areas that provide ecosystem services, such as forests, parks, vegetable gardens, green roofs), native plant and animal species, and protected areas of high environmental value. Both systems operate independently of the national SDI, and they import and update cadastral reference data within the specified time intervals. The systems cater to the needs of public administration bodies responsible for UG management. They cannot be accessed by other users under a limited license. The databases in Berlin's system should be regarded as a set of good practices for designing the Polish UGMS.

Urban greenery information systems in Poland

Polish cities face many barriers in the process of planning and managing green areas (limited funding, shortage of complete data, reluctance to cooperate) (Feltynowski et al., 2018; Kronenberg et al., 2016). Greenery inventories are usually fragmented and do not cover the entire city (Biejat, 2017). As a result, UG information systems cannot be effectively implemented. However, some progress has been made in recent years, and several large Polish cities have implemented GIS.

The analysis demonstrated that Kraków and Warszawa had implemented two specialist systems each, Gdańsk and Wrocław – one specialist system each, whereas no such systems were available in Olsztyn. In the analyzed group of cities, Kraków had the most advanced green information system (R3Trees) with a detailed and regularly updated inventory of urban greenery data. The system features

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thematic maps illustrating the location of new trees and felling decisions for development projects. This project was largely facilitated by Kraków's UG strategy referred to as Directions for the Development and Management of Green Areas for 2017–2030. Kraków is the only Polish city to have implemented such a strategy. The strategy aims to create new green areas, combine the existing areas into a coherent system, raise UG maintenance standards and improve the management of green areas in Kraków. To establish R3Trees, green areas were identified based on cadastral data for various land use types, information about green areas maintained by the Municipal Greenery Authority, an orthophoto map of Kraków, and field surveys. The system has been designed to perform the following functions: manage and maintain green areas, acquire land for GI development, obtain information about the provisions of the local zoning plan, plan investments, establish nature conservation sites, as well as specific functions such as determining sites where compensation planting is needed. R3Trees is a multifunctional system; however, it is not connected to the IREIS rail service. The system operates in internal mode, and cadastral data are imported periodically, which compromises the timeliness of the gathered information. In addition to cadastral data, R3Trees also relies on orthophoto maps and own data inventory; therefore, only a small percentage of the data available in Poland is used. The main advantage of R3Trees is that it contains an extensive database of inventoried UG data.

Gdańsk has implemented the BAND Tree Planting Bank application (BAND Gdańsk, 2020). Olsztyn has a well-organized spatial information system (MSIPMO Olsztyn, 2020), but it has not introduced any applications that are dedicated exclusively to urban greenery. In Warszawa, efforts are currently being made to develop a tree crown mapping application with detailed information about tree species, their location, and health status. The application will enhance cooperation between public agencies responsible for urban greenery management and green infrastructure development. A tree-felling map has also been developed in a local geoportal as part of the NSDI. The "Greenery" tab in the geoportal contains data layers from the Warszawa Urban Greenery Database developed by the Environmental Protection Department of the City of Warszawa (Warszawa City Hall, 2020). The website of the Warszawa Greenery Authority contains information about trees, new plantings, replacement plantings, tree felling requests, and the relevant approvals (Greenery Board of the City of Warszawa, 2019). This database is an inventory of urban green spaces, in particular roadside greenery, parks, squares, pocket parks, playgrounds, and schools. The ArcZieleń application was created in Warszawa to support the collection and processing of multi-layered information about green areas, and the generation of thematic maps, tabular lists, and graphic lists. The ArcZieleń database contains information about trees (species, dimensions, health status, growing conditions), shrubs, flowerbeds, and lawns. The application contains detailed information about every identified green object. In the future, the application will be expanded to include information about the planned maintenance operations, plant age, and species (Supreme Audit Office, 2017). In Wrocław, the local land administration system features a nature map with information about urban greenery management, greening plans, community initiatives, and environmental protection programs (WSIS, 2019). All green information systems in the surveyed cities rely on data from local information systems. Local systems are not connected to the IREIS rail service.

Other UG information systems in Poland support only selected management tasks, such as the identification of trees and canopies, or public participation (reporting problems in public green spaces) (Czepkiewicz, 2013; Biejat, 2017). Many of these systems cover only selected parts of urban greenery, such as urban and peri-urban forests. Electronic databases of urban trees that are linked to GIS and complete tree inventories facilitate UG planning and management (Tsitsoni et al., 2015).

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National Spatial Data Infrastructure: INSPIRE Geoportal and the Land Administration System in the Polish Integrated Real Estate Information System

A uniform information system for UG management should be confronted with the existing public information systems, in particular with the National Spatial Data Infrastructure (NSDI) which integrates various spatial databases to prevent data duplication and minimize implementation costs. The Polish NSDI conforms to the provisions of the Spatial Information Infrastructure Act (Act, 2010), and it is a part of the Infrastructure for Spatial Information in the European Community (INSPIRE) that had been called into existence by the INSPIRE Directive of the European Parliament and the Council (INSPIRE, 2007). The regulations concerning the development and use of spatial data infrastructure, including spatial data and metadata, services, interoperability of spatial data sets and spatial data services, spatial data sharing, cooperation, and coordination in the field of spatial data infrastructure, have enabled the creation of useful information infrastructure that integrates various databases in Poland and other EU countries. The progress made by Poland in the integration of the databases listed in the annexes to the INSPIRE Direction is presented in Table 2.

Table 2. Implementation of databases in the Polish Geoportal as of 31 December 2020

Annex	No	Theme	Polish Geoportal
1	2	3	4
Annex I	1	Coordinate reference systems	+
	2	Geographical grid systems	+
	3	Geographical names	+
	4	Administrative units	+
	5	Addresses	+
	6	Cadastral parcels	+
	7	Transport networks	+
	8	Hydrography (complex)	+
	9	Protected sites(complex)	+
Annex II	1	Elevation	+
	2	Land cover	+
	3	Orthoimagery	+
	4	Geology	+
Annex III	1	Statistical units	+
	2	Buildings	+
	3	Soil	+
	4	Land use	+
	5	Human health and safety	-
	6	Utility and governmental services	+
	7	Environmental monitoring facilities	+
	8	Production and industrial facilities	-
	9	Agricultural and aquaculture facilities	+
	10	Population distribution – demography	-
	11	Area management/ restriction/regulation zones and reporting units	-
	12	Natural risk zones	-
	13	Atmospheric conditions	+
	14	Meteorological geographical features	-
	15	Oceanographic geographical features	-
	16	Sea regions	+
	17	Bio-geographical regions	-
	18	Habitats and biotopes	-
	19	Species distribution	-
	20	Energy resources	-
	21	Mineral resources	-
Annex I		Sum	9
Annex II			4
Annex III			9
Total			22

Source: own elaboration.

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As shown in Table 2, the Polish Geoportal is a source of spatial data detailed in Annexes 1 and 2 to the INSPIRE Directive (INSPIRE, 2007). The preparation and implementation of Annex 3 data are still in progress. However, even when all data indicated by the INSPIRE Directive have been incorporated, the Geoportal will not guarantee full access to information that is required for UG management. The Geoportal does not contain protected data, including personal data and property rights data, which are kept in the cadaster and the land and mortgage register integrated with the LAS. Protected data are released only for public administration tasks and to persons who have a legal interest in such data. To guarantee effective UG management, access to protected data should be granted based on a license to perform public tasks.

At the national level, protected data can be accessed via the LAS, which is referred to as the Integrated Real Estate Information System (IREIS). The IREIS is the backbone of the NSDI for the

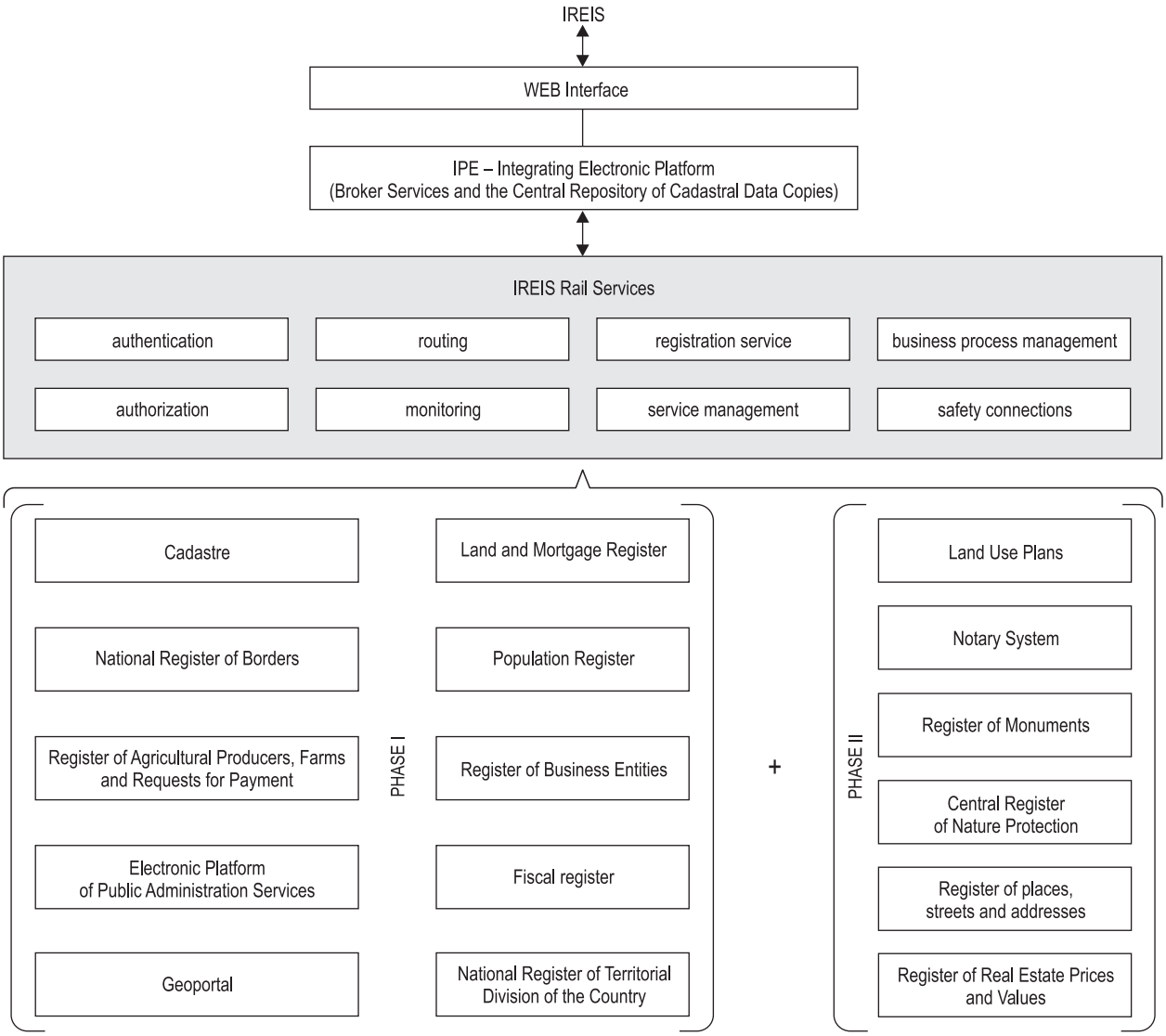

Fig. 2. Functional architecture of the IREIS
Source: own elaboration based on Regulation (2013).

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implementation of sustainable land policies and land management strategies, and it provides comprehensive access to information about spatial objects, land tenure rights, restrictions, and responsibilities (Dawidowicz & Źróbek, 2018). The LAS as a part of the NSDI, and includes institutional arrangements, a legal framework, processes, standards, land information, management and dissemination systems, as well as technologies that support land allocation, land markets, valuation, control of land use, and the creation of equitable interests in land (Williamson et al., 2010). The LAS facilitates the implementation of land policies to fulfill political and social objectives and achieve sustainable development goals (UN-GGIM, 2015). Land administration systems are implemented in different countries to guarantee the harmonization of global data in line with the Land Administration Domain Model (LADM) and ISO standard 19152 (ISO 19152, 2012; Lemmen et al., 2015; Bydłosz, 2015).

The Polish IREIS was introduced under the provisions of the Regulation of the Council of Ministers of 17 January 2013 on the Integrated Real Estate Information System (Regulation, 2013). Successive functionalities are being implemented in stages (Fig. 2). The IREIS aims to integrate the databases of many public registers, including the cadaster, land and mortgage register, fiscal register, land-use plans, population register, central register of nature protection, and others. These registers are integrated to improve data exchange and provide effective information support for other systems, land administration, and economic processes. The IREIS relies on the functional specification of the Integrating Electronic Platform (IPE) for viewing and transferring data between public registers. The functional architecture of the IREIS and IPE is presented in Figure 2. The IREIS is a multi-functional system that can be accessed by the authorities and the public (with limited functionality).

The IREIS is integrated with the Geoportal, and it is the most complete source of data for the UGMS. It contains reference data for address locators as well as the rights, responsibilities, and restrictions (RRR) associated with the use of the property. Public registers have been incorporated into the IREIS via the IPE, and the same approach can be used to integrate the UGMS as a sub-module containing basic data about urban greenery.

Development of a conceptual framework of a fit-for-purpose urban greenery management system (UGMS) in Poland in the context of the database and system functionalities

Initial assumptions regarding the functionalities of the UGMS were developed based on a review of the EU recommendations, Polish legal acts and strategies addressing green infrastructure, including urban greenery, and an analysis of good practices for developing UG management systems in Polish and European cities. A preliminary set of spatial data was identified, and the functionalities of the designed UGMS were described on the assumption that a universal UGMS covering the entire country should meet the following threshold conditions:

1) it should be fit-for-purpose (it should be a comprehensive source of data for UG management) (Dawidowicz et al., 2020);
2) it should reconcile the interests of various entities responsible for urban greenery (the departments responsible for UG management (Planning, Administration, Field Operations) should be able to exchange and view the relevant data and processes);
3) it should account for EU recommendations, local SDI solutions, and the local environment;
4) it should contain data from the existing public registers and information systems in Poland to eliminate redundancy, save time and minimize costs.

The system should cater to the needs of diverse users (public authorities and residents) because participatory management of urban greenery can deliver various benefits, including local needs assessment, identity building, and ecosystem services (Kronenberg et al., 2016). The functional architecture of the UGMS should enable members of the public to report current problems and needs under a local license. The following four principles of green infrastructure

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planning and implementation (Davies et al., 2015) should be taken into account when designing the UGMS database concept:

1) integration – urban greenery should be regarded as a type of infrastructure that is physically and functionally integrated with other urban systems;
2) connectivity – the functional and physical integration of green areas should generate added value;
3) multifunctionality – integrated green infrastructure should deliver ecological, social, and economic benefits;
4) multiscale – different spatial scales within and across city regions should be taken into consideration in urban greenery planning.

Based on the above principles, the proposed system should integrate and process multiple data for the needs of various tasks and functions. The system should be accessible to all interested users under a license, and it should cover all cities in the country. In the future, the system could be expanded to cover rural areas. The only potential limitation is the shortage of funds for inventorying and mapping green areas. The UGMS will constitute a sub-module of the NSDI, and it is economically justified because additional funds will not be required to develop separate infrastructure. The proposed system will contain timely and cohesive data because IREIS resources, in particular cadastral data for all Polish regions, are regularly updated. Therefore, attempts were made to determine the extent to which the technical infrastructure of the Polish LAS (IREIS), which functionally integrates public registers such as the cadaster, land and mortgage register, land use plans, Register of Places, Streets and Addresses, Central Register of Nature Protection, and the Register of Monuments, can be used for UG management. The integration of the INSPIRE Geoportal with the UGMS as a sector-specific sub-module will facilitate the creation of a standardized data model based on ISO 19152 standards for the Land Administration Domain Model (LADM), (ISO 19152, 2012; Bydłosz, 2015). This innovative approach will contribute to the development of a comprehensive information system for UG management as part of the NSDI, and it offers a technological perspective on the evolution of SDI and LAS. This solution closely contributes to the following Sustainable Development Goals (UN-GGIM, 2015): (11) Sustainable Cities and Communities, (13) Climate Action, (15) Life on Land.

A fit-for-purpose UGMS should support UGMB in the process of implementing international standards on the quality and organization of ecosystem services (including ISO 9001 (2015) and ISO 14001 (2015)) as well as the Eco-Management and Audit Scheme (GDOS, 2021) developed by the European Commission to evaluate the environmental performance of businesses and other organizations. The above implies that the UGMS should be consistent with legal regulation and the needs of UGMB.

Based on an analysis of the existing information system, a list of 15 thematic data groups that should be included in the UGMS was identified: urban greenery (basic and supplementary data, including maintenance and management of urban greenery), address data, physical attributes of land parcels, legal status (RRR), land and planning, infrastructure, soil and water conditions, nature conservation sites, protected monuments, climate, environmental pollution and threats, habitats and protected species, technology/machines, market, cooperation, and support. The extent to which the identified thematic data groups cater to the needs of UGMB was determined during an expert survey.

Field research – expert survey to determine data requirements for UG management

The expert survey demonstrated that Polish municipal authorities generally manage urban greenery based on the data published by Statistics Poland, cadastral data, and orthophoto maps from the geodetic and cartographic resources of Polish counties, and, less frequently, the Database of Topographic Objects and the Urban Atlas of 2012. The Urban Atlas is a pan-European repository of land cover data that is coordinated by the European Environment Agency (EEA). It provides extensive information on various

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land use types, including orchards, fallow land, farmland, and private land. The Urban Atlas is not widely used in Poland (Feltynowski et al., 2018), which further accentuates the need for cohesive standards for the development of a fit-for-purpose (FFP) UGMS. The present study was conducted to fill the existing knowledge gap.

Survey questionnaires were forwarded by email and post to 50 sectoral experts, 10 in each analyzed city, and completed questionnaires were returned by 34 respondents. The questionnaire contained open-ended and closed-ended questions relating to daily problems and information needs in urban greenery management. The first four questions were designed to elicit personal data, including the respondents' official titles, competencies, education, and training. The survey revealed differences in the organizational structure of the surveyed institutions and the types of personnel involved in greenery management. Two types of management regimes were identified: centralized management, where the responsible personnel report to a single authority (such as the municipal landscape architect), and distributed management, where urban greenery is managed by numerous civil officers in various organizational units. The relevant posts are determined by the organizational structure of the surveyed institutions and the characteristic features of urban greenery in the analyzed cities. In the surveyed population, 68% of the respondents had a university education and 32% had secondary school education. All respondents were keen on expanding their knowledge and skills by participating in training courses, attending conferences, and enrolling in post-graduate courses. This is a highly satisfactory result which indicates that the surveyed employees are professionals in their respective fields. However, the competencies of the surveyed employees and departments were significantly fragmented. For this reason, the UMGS should integrate all operations relating to UG management by enabling all users to enter data and view the information contributed by other users. Therefore, the UGMS should flexibly adapt to the organizational structure of the responsible authorities, and it should be accessible to suitably authorized personnel.

The fifth question in the survey contained a list of 15 groups of data that were selected based on an analysis of the literature, legal acts, and reports on the implementation of green information systems. The respondents were asked to choose data that would be useful for daily operations relating to UG management. They were also encouraged to add other types of data that were not listed in the questionnaire. The respondents selected groups of data by marking them with an "x". None of the experts proposed additional groups of data, which confirms that the presented information was exhaustive. However, six respondents remarked that UGMB employees would benefit from information relating to tree-based ecosystem services, the responsible (managing) authority, and detailed physical parameters of green objects. These inputs were taken into consideration in the analysis, and they were classified as basic UG data. Due to the fragmentation of competencies and responsibilities relating to UG maintenance, uneven progress in UG development in Polish cities, and a small number of respondents, all responses (regardless of their frequency) were included in the analysis. Therefore, each response was considered relevant in the process of developing the standard database. Regardless of the occupied post and responsibilities, all respondents selected the following groups of data as essential for UG management: urban greenery (basic green object data), address data, physical attributes of land parcels, infrastructure, soil and water conditions, nature conservation sites, protected monuments, climate, environmental pollution and threats, habitats and protected species. The selected data groups are presented in Table 4. The surveyed experts recognized the need for aggregating the data generated by inventories of trees and other green objects, including their location and the accompanying technical infrastructure. Employees responsible for planning operations additionally selected the following types of data: supplementary urban greenery data (maintenance and management of UG), legal status (RRR), land planning, cooperation, and support. Data relating to technology/machines and the market were selected mainly by respondents

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responsible for field operations. As a result, all of the 15 proposed data groups were used in the process of developing the UGMS. The scope of data in each thematic group was determined based on an analysis of public registers, good practices, and the respondents' answers.

The results of the survey were used to define a list of core data for the UGMS (Table 3), including a specification of different types of UG. Supplementary data (Table 4) were compiled with reference data (shown in bold) to validate the research hypothesis stating that the Polish NSDI (IREIS Geoportal) contains sufficient resources to meet the data requirements of an FFP UGMS. Urban greenery management bodies will collect basic UG data and contribute supplementary data for the UGMS.

Table 3. Basic urban greenery data for the UGMS

Trees	
Location / ID	
Tree number (on the map)	
Type of urban green space (park, roadside greenery, residential greenery, green squares, pocket parks, informal urban greenspace)	
Responsible authority (managing authority)	
Species (variety)	
Planting date	
Height (in meters)	
Diameter at breast height (1.30 m)	
Crown width (in meters)	
Tree health (crown damage in %, bark cracking, hurricane damage, broken branches)	
Habitats and protected species (species, types, abundance, hatching time)	
Completed maintenance works (wooden supports for trees, pruning, removal of broken and damaged branches, crown reduced by 20%, replanted trees)	
Maintenance costs (based on the service price list)	
Additional information (breeding sites, follow-up inspections after 1 or 3 years)	
Ecosystem services:	Energy benefits
	Esthetic value and social benefits
	Stormwater benefits
	Air quality control

cont. Table 3

Shrubs
Location / ID
Shrub number (on the map)
Type of urban green space (park, roadside greenery, residential greenery, green squares, pocket parks, informal urban greenspace)
Responsible authority (managing authority)
Species (variety)
Height (in meters)
Habitats and protected species (species, types, abundance, hatching time)
Form: a cluster of shrubs, hedge (length), individual shrubs
Recommendations (replacement of dried shrubs, pruning)
Completed maintenance works (hedge trimming,…)
Maintenance costs (based on the service price list)
Other types of plants (dwarf shrubs, perennial plants)
Location / ID
Plant number (on the map)
Type of urban green space (park, roadside greenery, residential greenery, green squares, pocket parks, informal urban greenspace)
Responsible authority (managing authority)
Species (variety)
Area (m^2)
Habitats and protected species (species, types, abundance, hatching time)
Recommendations (watering, weeding, replacement)
Completed maintenance works (mowing, mulching, watering…)
Grass lawns
Location / ID
Number (on the map)
Type of urban green space (park, roadside greenery, residential greenery, green squares, pocket parks, informal urban greenspace)
Responsible authority (managing authority)
Area (m^2)
Habitats and protected species (species, types, abundance, hatching time)
Recommendations (mowing, repairs)
Completed maintenance works (mowing, repairs)

Source: own elaboration.

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Public registers that can be a potential source of data in each identified group were analyzed in Table 4. Registers integrated with the NSDI are presented in columns, and they are linked with IREIS and INSPIRE infrastructure according to the specification. The IREIS and INSPIRE are a part of the NSDI, but they are operated separately. In the future, dedicated solutions could be developed to link both infrastructures, protect data and create client access licenses. Public registers that are not integrated with the IREIS or INSPIRE are also presented in Table 4. In the future, these registers could be merged with the UGMS by incorporating additional databases into NSDI.

The list in Table 4 indicates that NSDI can be a source of 12 to 14 supplementary data groups for an FFP UGMS. These results validate the research hypothesis and shed new light on future directions for the development of green information systems that can be incorporated into the NSDI rail service, especially the IREIS.

The final two questions in the survey addressed the respondents' current responsibilities, information needs, and expectations concerning UGMS functionalities. The questions were closed-ended, the respondents marked the selected items with an "x", and they could provide additional information. The list of potential UGMB responsibilities was created based on the statutory tasks of selected greenery management units in Warszawa and Kraków (Poland's largest and most highly developed cities) described on their respective websites (ZZW, 2020; ZZM, 2020). The respondents were asked to indicate their professional duties and responsibilities. The relevant information was used to compile a list of UGMB tasks (Table 5. Duties/Tasks). The respondents added the following additional information to the list of duties: planning replacements for the most expensive services, acquisition of funds from other sources, surveying local residents' expectations regarding urban greenery, recommending changes in the existing procedures to eliminate planting defects, analyses of energy benefits, stormwater benefits, esthetic value, and social benefits, air quality control. Based on the identified scope of UGMB duties, UGMS functionalities were developed given the good practices from Barcelona, Berlin, and Kraków. UGMS functionalities and UGMB duties are presented in Table 5. The proposed functionalities were divided into groups of tasks supervised by planning, administration, and field operations bodies (Table 5). System functionalities should be identified separately for different types of management tasks to facilitate access control.

According to the respondents, an urban greenery management system should support tree inventorying at all stages of planning, administration, and management. The designed system should also incorporate analytical, calculation, and prognostic tools that facilitate daily operations. The study revealed that the required UGMS functionalities frequently overlapped. All experts, regardless of their post and scope of duties, thought that the UGMS should support:

- collection and analysis of data concerning green areas;
- monitoring of changes in green areas in the context of adaptation to climate change;
- introduction of green-blue infrastructure solutions to cities;
- identification of ecosystem services provided by trees;
- cooperation between administration units in the management of green areas;
- social participation in the process of creating green areas;
- data analysis for adapting different tree species to changing urban conditions;
- analyses of the benefits provided by trees;
- improvements in the operations and performance of UGMB.

The respondents responsible for planning thought that local citizens' needs should be taken into account in the process of planning urban green spaces and that cohesive standards for urban greenery management should be implemented. They recognized the need for consistent regulations relating to replacement planting in cities. According to the subjects responsible for urban greenery management, unambiguous standards are also needed for handling trees in crises.

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Table 4. Main and supplementary sources of data for the UGMS

No.	Group of supplementary data (data layers)	NSDI		Other registers and information systems (Source/data)	Urban greenery management bodies (UGMB) data
		IREIS (Integrated Real Estate Information System) (Source/data)	**INSPIRE (Source/data)**		
1	2	3	4	5	6
1	**Address data**	**Cadaster:** Number of cadastral plot, **Register of Places, Streets, and Addresses:** Street name and number, building number **National Official Register of the Territorial Division of the Country:** Statistical numbers and unique identifiers of spatial objects in the country: number of cadastral districts, number of the municipality, type of municipality	**Cadaster:** Number of cadastral plot, **Register of Places, Streets, and Addresses:** Street name and number, building number **National Official Register of the Territorial Division of the Country:** Statistical numbers and unique identifiers of spatial objects in the country: number of cadastral districts, number of the municipality, type of municipality	-	Green objects identification number
2	**Physical attributes of land parcels**	**Cadaster:** Area, boundaries	**Basic map/ Situation-height map:** Slope	-	-
3	**Legal status / Rights, Responsibilities, Restrictions**	**Land Register:** Owner, tenant/administrator, documents granting legal title, restrictions in rights **Cadaster:** Distribution of plots **Population Register:** Personal identification number	**Cadaster:** Distribution of plots	-	-
4	**Land Planning**	**Land Use Plans:** Permissible types of land use and management, site functions, restrictions on use	**Land Use Plans:** Permissible types of land use and management, site functions, restrictions on use	**Decisions on the conditions of development and land use:** In the absence of land-use plans, the decisions issued shall specify the conditions of land use and permits	Planting plans, green regeneration plans, green protection, and maintenance plans

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cont. Table 4

1	2	3	4	5	6
5	**Infrastructure**	**Cadaster:** Buildings **Land Use Plans:** Planned infrastructure and public utilities	**Cadaster:** Buildings **Land Use Plans:** Planned infrastructure and public utilities **Geodetic Register of Utility Networks:** Existing infrastructure and public utilities, location of infrastructure networks	-	Small architecture (park benches, arbors, fountains, rubbish bins, statues).
6	**Soil and water conditions**	**Cadaster:** Soil quality class, land use including still and running waters, drainage ditches	**Water cadaster:** water table, watercourses and water bodies, hydrographic classification of Poland, indirectly protected zones, protected water intake zones, **Geology Cadaster** soil and agricultural maps, Soil type, geology **Geodetic Register of Utilities Networks** Existing infrastructure and public utilities, location of infrastructure networks	-	Small ponds
7	**Nature conservation sites**	**Central Register of Nature Conservation Sites:** Nature reserve, protected ecosystem, Nature 2000 area, nature, and landscape conservation site	**Central Register of Nature Conservation Sites:** Nature reserve, protected ecosystem, Nature 2000 area, nature, and landscape conservation site	-	-
8	**Protected monuments**	**Central Register of Monuments, culture park, protected urban area:** Type of monument, Historical small architecture objects such as chapels	**Central Register of Monuments, culture park, protected urban area:** Type of monument, Historical small architecture objects such as chapels	-	-

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cont. Table 4

1	2	3	4	5	6
9	**Climate**	-	**Institute of Meteorology and Water Management – National Research Institute (IMWM) – climate maps:** Average annual temperature, average annual precipitation, humidity, insolation (agricultural climate model – application), extreme weather events (drought, floods, hurricanes)	**Solar atlas:** Sunshine time per day **European Severe Weather Database**	-
10	**Environmental pollution and threats**	-	**State Environmental Monitoring – pollution maps:** Air pollution (e.g. CO_2); soil pollution (e.g. nitrates and Nitrate Vulnerable Zones); radioactive and microbiological threats; artificial water deficit; landscape degradation; air, underground water, surface water, and seawater pollution; water cycle disruptions; changes in land relief; soil erosion; degradation of flora; industrial and municipal waste; noise pollution; pests	-	-
11	**Habitats and protected species**	**Central Register of Nature Conservation Sites:** list of protected species (data from the species lists and monitoring of protected objects)	**Central Register of Nature Conservation Sites:** list of protected species (data from the species lists and monitoring of protected objects) **State Environmental Monitoring (nature monitoring reports):** natural habitats (status and changes occurring within their range, area covered, structure and function); species (status and changes occurring within their range, population size and structure and area and quality of the habitats to which they are associated).	-	Location of occurrence of protected plant and animal species in green areas (in. urban greenery basic data)

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cont. Table 4

1	2	3	4	5	6
12	**Technology/ machines**	-	-	-	Equipment with fixed assets (all available machines and tools for automation of greenery care and protection, year of purchase and production, value, consumption, fuel type.
13	**Market**	**Electronic Platform for Public Administration Services, ePUAP:** Unit prices from public tenders	-	**Price comparison applications:** Prices of plants, prices of plant protection products, prices of small architectural objects, and prices of building materials	Wholesale marketing, retail marketing (prices of seedlings and seeds). Assessment of market situation, trends, forecasts, tenders, etc.
14	**Cooperation and support**	–	–	**Institutions supporting development projects (Marshal's Offices):** Information on open financial or material support programs and training courses, workshops. **A public participation gateway to report problems and comments:** Information on risks and new proposals for solutions in public green space	Social participation (location and type of participation)

Source: own elaboration.

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Table 5. List of UGMS functionalities assigned to different types of tasks urban greenery management bodies (UGMB)

Responsible entity	Duties / tasks	UGMS Functionality
Planning (expert body)	Expenditure planning	Generation of lists of urgent maintenance works
	Expenditure monitoring, planning replacements for the most expensive services	Generation of reports on greenery maintenance costs
	Acquisition of funds from other sources	Generation of reports on the sources of financing for urban greenery
	Monitoring public tenders	Reminders on upcoming public tenders, financial settlements for greenery maintenance services
	Surveying local residents' expectations regarding urban greenery	Generation of reports on participatory greening
	Modifying the list of recommended tree species for urban areas	Generation of reports on tree species damaged by hurricanes
	Modifying the list of recommended tree species for urban areas	Generation of reports on tree species that are most resistant to climate change
	Environmental monitoring/environmental protection plans	Systematic analyses for monitoring urban green areas
	Evaluations of maintenance services and their future consequences	Analyses of tree maintenance services
	Planning replacement plantings	Coordination of replacement plantings
	Expenditure planning, analysis of tree species that require maintenance	Analyses of street tree inventories (range of tasks)
	Recommending changes in municipal regulations	Observance of tree protection laws in urban areas
Administration (regulatory body)	Selection of tree species for planting	Analyses of the number of removed tree species and reasons for removal
	Selection of tree species for replacement plantings	Generation of reports on tree species for replacement plantings
	Monitoring replacement plantings, recommending changes in the existing procedures to eliminate planting defects	Generation of reports on the feasibility of replacement plantings
	Assessment of replacement plantings	Generation of reports on service teams performing replacement plantings
	Analyses of energy benefits, stormwater benefits, esthetic value, and social benefits, air quality control	Generation of reports on ecosystem services
Field operations (executive body)	Planning field operations	Tree safety alerts
		Alerts on upcoming maintenance and planting operations
		Alerts on upcoming greenery development projects
	Coordination of field operations	Inspections of tree and shrub maintenance in a given district

Source: own elaboration.

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DISCUSSION

The study demonstrated that the UGMS should be an integrated system that compiles information about urban greenery, the accompanying facilities, and local policies from various sources in line with the infrastructure planning principles of the GREEN SURGE project, including integration, connectivity, multifunctionality, and multiscale. The UGMS database should be standardized and based on the results of urban greenery inventories. Inventories can be automated by deploying drones. Selected types of data can also be collected by municipal employees responsible for UG maintenance. The relevant information would be collected with the use of a dedicated inventory form (Table 3), and it would be entered into the database as a UGMS sub-module in the IREIS environment. The data collection process should entail minimal effort, and it should rely primarily on the existing sources of information from NSDI. The UGMS should cover urban green spaces that are owned, co-owned, or administered by the city.

The UGMS should contain basic information about the location and requirements of different plant species. The employees should be notified about problems that require urgent intervention as well as upcoming maintenance works. The system should also register the boundaries of different types of urban green areas, such as roadside vegetation, residential, ornamental, and monumental greenery. The information relating to individual UG objects will be gathered within cadastral plots. The objects in each plot will be assigned a unique identifier.

The developed list of UG data (Table 3) includes ecosystem services for trees only, as indicated by the experts. The above could be attributed to the fact that this functionality is easy to implement in the start-up phase. The development of ecosystem services for other UG types requires further research and recommendations. However, the proposed system is flexible, and the database can be easily expanded when the standards for calculating ecosystem services delivered by other UG types are developed. In Poland and other countries, municipal authorities rarely identify and assess ecosystem services as part of standard planning operations. Therefore, workshops and training courses should be organized to raise the employees' and the public's awareness about the ecosystem potential of UG and the impact of climate change on urban green spaces.

The list of supplementary UGMS data (Table 4) is extensive. These data are needed for various tasks, including:

- to determine the demand for public green areas with recreational functions, which is directly related to the urban population and population density, and changes in these parameters over time;
- to determine whether the existing and predicted demand for green areas can be met through the existing municipal resources by analyzing the legal status of land zoned for public green areas;
- to identify areas that should be zoned as green urban areas to protect valuable natural sites, minimizing development pressure, and securing land for future UG development through access to information on the spatial policy. Development projects that encroach on green areas in an uncontrolled manner pose a threat to the continuity and accessibility of urban green spaces;
- to verify the boundaries of plots where new green objects are planted, the plots' legal status, location of underground utilities, soil and water conditions, existing environmental hazards, public procurement of plants in previous years;
- to plan remediation works and select resistant plant species for planting in contaminated areas;
- to plan and perform lawn mowing operations by analyzing the number and parameters of lawn-mowers in stock;
- to determine the local community's needs and expectations regarding urban green spaces by analyzing the results of public consultations.

In terms of functionality, the system should feature tools for spatial and descriptive analyses, statistical tools for reporting, IT tools, and it should generate descriptive (guidelines and recommendations for fieldwork) and cartographic (maps) documents. The proposed UMGS should feature the above

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functionalities to analyze data, generate various reports, including reports on plant tolerance to various urban pressures. The UMGS should support the monitoring of trees in urban green spaces and identify the reasons for tree removal (safety concerns, encroachment upon utility networks, tree decline, tree diseases). By analyzing the collected data, the system would automatically identify potential locations for replacement plantings. The UMGS would also plan and control the expenditures relating to urban greenery maintenance, and it would calculate the value of ecosystem services (such as oxygen production). The proposed system would notify the responsible employees of upcoming maintenance works, and it would generate alerts on hurricanes and other risks that necessitate tree control.

The UGMS will be integrated with the IREIS rail service to guarantee the continuous exchange of data and access to valid reference data stored in the land administration systems, including the cadaster, land registers, land use plans, population register, and other public registers listed in subsection *National Spatial Data Infrastructure…* This solution will compromise the timeliness of data in the INSPIRE Geoportal, but this limitation can be overcome by improving data update frequency standards. The Geoportal does not contain sensitive personal data, and it will not adversely affect the informational capacity of the UGMS.

The UGMS database was designed to support urban greenery, but it can be expanded to include the entire Green Infrastructure. The system will be integrated with IREIS infrastructure; therefore, data can be exchanged between multiple bases that are connected to the IREIS rail service. The integration of the UGMS with the IREIS environment will guarantee the system's structural flexibility.

SUMMARY AND CONCLUSIONS

The proposed system for urban greenery management can support the development of green infrastructure and improve the quality of municipal vegetation. Numerous publications and reports have demonstrated that friendly urban policies can facilitate access to green infrastructure and significantly improve the quality of life in cities (Bieda & Telega, 2021). The present study demonstrated that most of the relevant initiatives in Poland, including comprehensive green information systems, have been undertaken locally, whereas the handful of measures implemented at the national level are limited to a single functionality. This study identified the key functionalities and the scope of data for designing a universal for the entire country and cohesive urban greenery management system that meets the needs and expectations of urban greenery management bodies. The relevant functions and data were identified in detailed analyses based on previous research findings, EU recommendations, national experiences in spatial planning, and current needs. The proposed UGMS contributes to the body of knowledge on urban greenery management. The developed functionalities and categories of essential data can be used to develop a theoretical framework for designing technological solutions in the future.

The results of this study confirmed that urban greenery management bodies need an information system that contains comprehensive information about green and blue infrastructure and is integrated with other public registers and sources of data, including the register of protected areas and monuments, local policies, the cadaster, land registers, address database, and climate services. It is demonstrated in the text that this is possible, thanks to the technological location of the UGMS in the IREIS and INSPIRE infrastructure. The research hypothesis postulates that the Polish land administration system, referred to as the Real Estate Information System (IREIS), and the INSPIRE Geoportal service that are integrated as parts of the NSDI are capable of supplying more than 75% of the data required for UG management in Poland was positively validated.

A universal for the entire country UGMS can be created by relying on IREIS and INSPIRE infrastructure. This approach is consistent with the needs of the Polish UGMB and the infrastructure planning principles of the GREEN SURGE project, including integration, connectivity, multifunctionality,

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and multiscale. The proposed approach is valid from an economic and practical point of view because the IREIS contains complementary and reference spatial data. The UGMS will be connected to the IREIS rail service to create access to regularly updated data and enable efficient data exchange. The UGMS database concept follows the latest trends in green information systems development. The UGMS will be consistent with the fit-for-purpose approach to land administration. Therefore, the research hypothesis was confirmed.

Experts and professionals responsible for urban greenery management were surveyed to ensure that the proposed UGMS reconciles the interests of different decision-makers and accounts for EU recommendations as well as local and climatic factors. The UGMS should address the needs of different users, and it should facilitate communication between the relevant authorities to build local identity and promote ecosystem services. The key functionalities and the required scope of data for the designed system were identified given the allocated responsibilities. The proposed UGMS will provide a cohesive and nation-wide framework for:

- inventorying urban greenery;
- identifying plant species, their requirements, and susceptibility to disease;
- automating field operations by alerting users of upcoming maintenance tasks;
- calculating ecosystem services;
- monitoring changes in urban greenery and improving response times in problematic situations and emergencies;
- generating reports on the planted species, the longevity of different tree species, location of public safety threats.

The proposed database and UGMS functionalities were designed based on an analysis of local (Polish) needs, but the presented solutions can be modified and expanded. In the future, the needs and expectations of UGMB should be surveyed in other countries to develop a universal UGMS that can be applied around the world.

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