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Developing a concept to define green spaces suitable for spatially concentrated forms of physical activity

Green spaces play an important role in promoting physical activity and public health, and so it is vital they be equally accessible to all residents. Nonetheless, Slovenia has insufficient high-quality spatial data to assess the provision of urban green spaces for physical activity. This article develops the concept of green space provision in Slovenian towns and other settlements. It defines the concept of provision and presents a new method for identifying green spaces suitable for concentrated forms of physical activity. The method is based on a combination of spatial data on the occurrence and function of green spaces, allowing a sufficiently reliable identification of green spaces suitable for concentrated forms of physical activity that can also form the basis for assessing the provision of such spaces to develop relevant indicators. The discussion section highlights the lack of comprehensive and high-quality spatial data to make such assessments in Slovenia, and the need for cross-sector collaboration to improve the management and planning of urban areas. The article concludes by emphasizing the need for a harmonized expert approach to collecting these data and establishing long-term stakeholder collaboration to improve the accessibility and quality of green spaces to promote physical activity in Slovenia.

Keywords: green spaces, physical activity, indicator, GIS, spatial aspects, spatial data

1 Introduction

As in many developed countries across the globe, people in Slovenia do not engage in sufficient physical activity (Pustivšek et al., 2018; Remec & Pustivšek, 2023). Physical activity is defined as any body movement produced by skeletal muscles that requires more energy than resting. This includes walking, cycling, dancing, various games and other forms of entertainment, gardening, work around the house, lifting and carrying things, sports, and targeted exercises (Šuklje Erjavec et al., 2019). Green spaces are an important factor in encouraging physical activity and, hence, promoting public health. In addition, they have a significant impact on reducing stress and improving people's psychological wellbeing. At the same time, many people find them more attractive than other venues, and they motivate them to engage in physical activity, which has been proven in various studies (e.g., Lee & Maheswaran, 2011; Roe et al., 2013). In addition to parks, playgrounds, and recreational areas, an important role in providing environments suitable for physical activity is played by green and other spaces in residential areas and around preschools, schools, and retirement homes, by those provided as part of other tertiary and quaternary activities and jobs, as well as by forests, waterfronts, bodies of water, and agricultural landscapes near towns and villages that provide important ecosystem services (Žlender, 2024). These green areas must be equally accessible to all and suitably distributed across settlements, so that their residents can engage in physical activity and are in contact with the natural environment without the need to travel long distances to reach them.

In Slovenia, urbanization and urban sprawl challenge the preservation of green spaces and their accessibility for all residents. Slovenia's Spatial Development Strategy 2050 (Sln. *Resolucija o Strategiji prostorskega razvoja Slovenije 2050* or *ReSPR50*, Ur. L. RS, no. 72/2023; Resolucija, 2023) specifies the country's spatial development goals and emphasizes the importance of green infrastructure and systems at the local level, with a vision of achieving a high share of green urban areas for socializing and recreation. A uniform distribution of publicly accessible urban green spaces that promote physical activity is vital. This is a key element in planning a high-quality living environment that takes into account people's needs and current issues, such as climate change mitigation and active mobility. The proposals presented by the European Commission within this context include a just and inclusive transition to carbon neutrality and prioritizing public health and wellbeing (Resolucija, 2021).

The term *preskrbljenost z zelenimi površinami* 'green space provision' is relatively new in Slovenian and is adopted from English (e.g., Kabisch & Haase, 2014; Wüstemann et al., 2016; Grunewald et al., 2017). The Spatial Planning Act (Sln. *Zakon o urejanju prostora*, Ur. l. RS, no. 199/21) introduced the principle of equal green space provision and accessibility, which, on the one hand, includes diverse users and, on the other, available activities suited to their needs. However, research shows that spatial conditions vary greatly across Slovenian municipalities and they do not provide equal opportunities to Slovenians, which became especially clear during the COVID-19 pandemic (Martinko et al., 2023).

To appropriately determine, assess, and monitor the state of green space provision, it is vital that high-quality spatial data be available on all the relevant publicly accessible green spaces and their quality-specific spatial characteristics (Šuklje Erjavec et al., 2020b). However, as established by Vertelj Nared and Simoneti (2011) for Ljubljana, in reality there are no universal data on green spaces available, and there are great differences between individual databases arising from the purpose and method of collecting data and the interpretation of concepts and features, which prevents comprehensive insight into the state of public green spaces in terms of their size, location, type, and equipment. Šifkovič Vrbica and Simoneti (2021) argue that the legal framework for regulating public green spaces is deficient. The municipalities do not maintain all the spaces that are accessible to the public, and they do not have suitable tools to monitor their state. The data on spaces that are in public use but not owned by the local community are especially problematic because they are usually not included in the records or databases of maintained urban green space (Vertelj Nared & Simoneti, 2011).

Slovenia is thus dealing with a lack of familiarity with the provision of green spaces suitable for physical activity at all levels, which makes it difficult to adopt appropriate measures to improve the situation. The hypothesis presented in this article is that Slovenia has suitable bases for defining and monitoring urban green space provision and several public registers with sufficiently useful data for developing the method and aggregating data for identifying relevant green spaces to assess green space provision and develop an indicator of green space provision for physical activity at the local level.

This article presents a new method for collecting data that makes it possible to determine the provision of green spaces in Slovenian settlements suitable for spatially concentrated forms of physical activity – that is, activity performed in a specific, complete spatial unit or green space, whose spatial characteristics facilitate and encourage physical activity such as various types of games, skills, workouts, dance, gardening, and so on (Šuklje Erjavec et al., 2019).

This method focuses on Slovenia, but it can also be adapted for and applied to other countries. This article presents a special approach to selecting data to identify green spaces suitable for spatially concentrated forms of physical activity. Its main goals are the following: to define the provision of green spaces suitable for all types of physical activity and an active lifestyle; to analyse current data collection options to identify green spaces suitable for concentrated forms of physical activity; to assess options for updating and aggregating data to identify such green spaces; to define the type and level of spatial data to be used in identifying such spaces; and to prepare a protocol for selecting and assessing data for identifying these spaces.

The following research questions were formulated to achieve these goals: How is green space provision defined in Slovenian and international official documents and research literature? Are there data that can be directly used to identify greens spaces suitable for physical activity? Can current data be combined to identify such spaces in a town?

The work presented in this article is part of broader research conducted as part of the targeted research project Development of indicators for the assessment of the provision of settlements with green spaces for outdoor physical activity (referred to in Slovenian with the acronym PREZENCA), whose aim is to define an indicator of the provision of green spaces suitable for physical activity or an active lifestyle, which will complement the green space accessibility indicators at the local level. For several years now, these indicators have been in preparation by the Ministry of Natural Resources and Spatial Planning to monitor the situation and make reports within the framework of the 2030 Agenda for Sustainable Development (UN, 2015).

2 The concept of green space provision in literature and legislation

Urban green space provision is becoming an increasingly important topic in urban planning and development. Nonetheless, there is a great deal of variability in understanding and defining this concept, which makes it difficult to effectively plan and manage urban spaces. To improve the understanding and later provide their own definition of this concept (Section 3), the authors analysed the Slovenian legislative framework and specific sectoral acts and documents (Section 2.1) and reviewed the current approaches to defining green space provision (Section 2.2). The main findings are presented below.

2.1 Understanding green space provision within various sectors

In Slovenia, various terms connected with green space provision are used in practice and in various studies, including *zagotavljanje zadostnih količin zelenih površin* 'provision of sufficient green spaces', *zagotavljanje ustreznega ali uravnoteženega razmerja med grajenimi in zelenimi površinami* 'providing a suitable or balanced ratio between built-up and green spaces', *enakovredna oskrba* 'equal supply', *uravnotežena oskrba* 'balanced supply', *delež zelenih površin* 'share of green spaces', *delež javnih površin* 'share of public areas', *delež javnega prostora* 'share of public space', and so on (Žlender et al., 2023b). These expressions appear in various contexts, not only in connection with publicly accessible spaces. In conducting a content review of various documents, the authors took into account all aspects of provision that refer to green spaces as well as other related terms and synonyms.

A review of relevant spatial planning legislation showed that issues related to green space provision are addressed in various ways and often not comprehensively. The concept is only mentioned in the Spatial Planning Act (ZUreP-3) and Slovenia's Spatial Development Strategy 2050 (Resolucija, 2023). According to this strategy, suitable accessibility of public green spaces is an important goal for all residents. Based on the accessibility indicators, public green spaces must be within a five-minute walk or 300 m if they are larger than 0.5 hectares, and within a fifteen-minute walk or 900 m if they are larger than one hectare.

Documents related to public health highlight the importance of green spaces for people's health and, within this context, the importance of improving and including spatial factors, especially green spaces, to promote physical activity. They emphasize cross-sector collaboration to support forming links and connections with spatial planning (e.g., European Commission, 2008; WHO, 2020), which is an important step to a more comprehensive approach to this issue.

The reviewed documents related to sports tend to use the terms *telesna dejavnost* and *gibalna aktivnost* 'physical activity' less often than, for example, *športna rekreacija* 'sports recreation' or *telesna vadba* 'workout'. Public health specialists define sports and workouts as targeted exercises structured and aimed to improve one's fitness. Sports usually also include a type of competition, whereas workouts are primarily aimed at improving one's health. Health-promoting physical activities are defined as any type of physical activity that is beneficial for one's health and functional ability without causing unnecessary harm or risk (Šuklje Erjavec et al., 2020b). Hence, Article 3 of the Slo-

venian Sports Act (Sln. *Zakon o športu* or *ZŠpo-1,* Ur. l. RS, št. 29/17; ZŠpo-1, 2017) specify the principles of providing opportunities for every Slovenian citizen to engage in sports. This also refers to the physical environment, which should be safe and healthy. The act highlights the importance of outdoor sports facilities and areas for people's health, but the options for cross-sector collaboration are limited and insufficiently articulated, especially in relation to spatial planning.

2.2 Review of current approaches to defining green space provision at the international level

Urban green space provision is a complex approach, which is defined in research based on diverse aspects. Individual aspects are studied with various methods. Proximity to green spaces is an especially important aspect connected with people's physical activity (Kaczynski & Henderson, 2007). GIS tools are usually used to calculate the distance between one's home and the nearest green space (Talen, 1997; Sister et al., 2010); for example, by employing distance radiuses, with a 300 m walking distance being the one most frequently used (Coles & Bussey, 2000; Giles-Corti & Donovan, 2002; Nielsen &Hansen, 2007). Accessibility of green spaces can also be measured based on networks of existing routes, such as with the Network Analyst tool (Oh & Jeong, 2007). The accessibility aspect also includes the temporal component and quality of access (Šuklje Erjavec et al., 2019). In addition to measurements, methods of collecting data with surveys are also common, such as for assessing perceived access to parks (Koohsari idr., 2015). For example, Lundh (2017) reports that the aesthetic experience of open space is the most important factor in selecting places for recreation and visiting green spaces to engage in physical activity. Despite the complex aspect of achieving spatial attractiveness, the quantity of natural resources is the parameter most frequently used in research in this regard. Based on satellite data, the presence of vegetation has previously been measured in selected areas using aerial colour infrared photography (Sripada et al., 2006), and methods incorporating measurements from the user perspective have been used, such as the Green View Index (Ki & Lee, 2021). Other aspects include the ecological characteristics of the environment, such as air, water, and soil quality, as well as soundscape quality and the absence of negative factors, such as stench, dust, overheating, and glare (Koohsari et al., 2015). In addition, the quality of open spaces, their utility, and experiential appeal are also very important (Francis et al., 2012; Pazhouhanfar, 2018).

The WHO recommends a minimum 9 to 11 m^2 of green space per capita, without specifying the exact distance from one's place of residence used for calculating this indicator (WHO, 2020). Already in 2012, Gupta et al. (2012) questioned the suitability of information on the required size of green space per capita in cities because it is inaccurate and insufficient to determine the distribution, accessibility, and quality of green space. An epidemiological medical study (Mitchell et al., 2011) showed that larger green spaces may be more important for people's health than smaller spaces, depending on the type of users. In terms of impact on health, it is not only the quantity, but also the diversity of green space that is important. For example, a comparison of urban green space and forest showed that forest was associated with fewer days of mental health complaints (Akpinar et al., 2016). The use of open public space is also affected by its equipment, safety, and maintenance. Different spaces require different levels of equipment and maintenance, depending on their purpose and natural processes. These aspects are usually studied by qualitative methods reflecting user satisfaction and by using objective data, such as public utility records. Based on a review of relevant studies, especially the review of indicators for the provision of green spaces to promote physical activity (Kozamernik et al., 2023), the following are the most important aspects for this study, along with some indicators for assessing the provision of green spaces suitable for concentrated forms of physical activity:

- Public accessibility, with the basic criterion that a universally accessible public green space larger than 500 m^2 should be within a 300 m or five-minute walking distance, and an urban park should be within a 900 m or fifteen-minute walking distance;
- Urban parks should cover at least one hectare and be within a 900 m walking distance from residential areas;
- Green spaces should be evenly distributed and connected into networks combining various types of green space or activity that can be practiced there;
- Attractiveness and quality of green space.

3 Provision of urban green spaces suitable for physical activities: concept definition

The literature review showed that the concept of green space provision is often used in various contexts and hence it is necessary to provide an expert rationale for its use. Green space provision requires a systemic approach that includes collaboration between spatial planning, public health, and sports. Green space provision is evaluated from the ecological and social perspectives, whereby green spaces that do not meet the conditions for being publicly accessible are excluded from assessments of suitability for daily use by residents (Šuklje Erjavec et al., 2020a).

A variety of terms related to green space provision appear in Slovenian documents. The expression *načelo enakovredne preskrbljenosti z zelenimi prostori* 'principle of equal green space provision' encompasses the aspects of public accessibility and balanced distribution, capacity, and quality of green spaces. Sufficient provision facilitates equal access to green spaces for all residents (Kozamernik & Šuklje Erjavec, 2021) and strengthens public health equality and urban justice (Sister et al., 2010; Ward Thompson et al., 2012; Kabisch & Haase, 2014). Pursuing this principle is key to ensuring a good quality of life and choice for all residents, which is also the central goal of green system planning, an approach established in Slovenia and similar to the approach of green infrastructure planning established at the international level (European Commission, 2013, 2023; EEA, 2014).

Based on a review by Žlender et al. (2023b), the key aspects referring to the adequate provision of green spaces suitable for physical activity and an active lifestyle are presented below. The key aspects to defining green spaces suitable for concentrated forms of physical activity include the following:

- According to the definition provided by ZUreP-3 (Ur. l RS, no. 199/21, p. 6), a green space is "a space in a settlement area with a certain degree of naturalness (e.g., parks, urban forests, greenery next to bodies of water, lawns, tree-lined avenues, greenery along streets and roads, recreational areas, playgrounds, cemeteries, gardens, and so on) and specific natural physical structures in this area (e.g., trees and other vegetation), regardless of its ownership, function or location";
- Capacity, size, and scope of all suitable green spaces in a town or settlement, as well as individual green spaces: This means sufficiently large and complete green spaces that residents can use daily to achieve the recommended levels of physical activity to maintain their good health. This is directly related to the accessibility of green spaces and the population or user density in a specific area;
- (Universal) public accessibility: This means that a green space is accessible to everyone, including functionally impaired people, regardless of its ownership and without a required financial investment, in which the quality of access should also not be neglected (this is further defined through specific evaluation attributes).

Aspects to be taken into account in evaluating the suitability of green spaces for concentrated forms of physical activity (not the subject of this study) are the following: suitable distribution, connectivity and continuity of green spaces, equipment, diversity (typology), attractiveness, and safety. Proximity to green spaces is key to their accessibility because it affects the time that pedestrians and cyclists need to travel to reach a green space, taking into account their varied ability to travel the distance. In addition, the quality of connections between the green spaces suitable for physical activity is also important. Green spaces can be multipurpose (for various uses and groups), single-purpose (for single use), or without a designated purpose (without a special design but making it possible to engage in physical activity).

4 Method for defining the criteria for identifying green spaces suitable for spatially concentrated forms of physical activity

In developing this method, the focus is on the following questions: What green spaces are relevant for assessing green space provision? Which data are available for identifying green spaces suitable for concentrated forms of physical activity? What is their quality in relevance in terms of content? Are they publicly accessible and sufficiently detailed in spatial terms?

The bases for collecting suitable data for identifying green spaces suitable for concentrated forms of physical activity included the following:

1. Aspects used to identify these spaces, including their capacity, size, scope, and public accessibility. Based on conceptual aspects, the selection of data to identify suitable green spaces can be expanded from databases of public green spaces to databases that define the characteristics of green spaces. This includes land uses outside settled areas (e.g., farmland, forests, and waters) and the register of current land use, where green spaces are included in the building land register (MNVP, 2021). This expansion makes sense when the data on public green spaces are too inaccurate or deficient in spatial terms to identify green spaces in settlements or small municipalities;
2. Information on the databases that municipalities or the ministry of spatial planning will be required to provide in the near future. This issue is addressed by Part 6 of ZUreP-3 (Ur. l. RS, no. 199/21, p. 140), titled "Spatial information system, monitoring the spatial development status, and spatial planning information". Specific provisions in the sections "Spatial information system" (Section 1, Articles 263, 267, 270, and 275), "Spatial development status monitoring system" (Section 2, Article 277), and "Information on public infrastructure networks" (Section 4, Article 281) are especially relevant for this study. Green spaces relevant for this study are part of both natural public goods as defined in the Environmental Protection Act (Sln. *Zakon o varstvu okolja* or *ZVO-2*, Ur. l. RS, nos. 44/22, 18/23 – ZDU-1O, and 78/23 – ZUNPEOVE, 2022) and built public goods as defined in ZUreP-3; data and records are required to be

kept for both;
3. Spatially accurate data, which make it possible to identify green spaces, both small and large. Based on the recommended sizes of green spaces (Šuklje Erjavec et al., 2020), a contiguous green space with a minimum size of 200 m² was selected for the purposes of this study. The data should make it possible to determine the typology of green spaces and assess the realistic public accessibility of these areas (a 300 m distance to smaller multipurpose green spaces and 900 m to larger ones).

4.1 Review of databases

Taking into account that there are no data on green spaces suitable for physical activity purposefully collected at the national level, databases set up for other purposes, which might help identify such spaces, were reviewed. The review took into account the usefulness of the data sources, their accessibility, spatial resolution, and currency, and whether they incorporate official records to allow comparison between municipalities. International, Slovenian, and municipal databases were reviewed, focusing on areas classified as green spaces in terms of their current use, and areas that could potentially be considered green spaces (forests, waterfronts, and farmland). In addition, data on the pedestrian and cycling accessibility of green spaces were examined, along with their potential users (i.e., population, population density, house numbers, and building type classification). The selected data layers were then professionally evaluated.

4.2 Testing various options of identifying green spaces suitable for spatially concentrated forms of physical activity

To identify green spaces suitable for spatially concentrated forms of physical activity, several variants of combining data layers were examined. The data sets applied included Copernicus remote sensing data (EEA, MNVP, 2022a), data from the building land register (MNVP, 2021) and the agricultural and forestry land-use database (MKGP, 2023), ground plans from the real estate cadastre (GURS, 2023), and selected OpenStreetMap data (OpenStreetMap, 2023). Analyses were conducted in PostgreSQL and its extension PostGIS, where the data were stored, and in QGIS Desktop, which was used to visualize and review the data and edit them manually.

Based on the conceptual definition of the provision of green spaces suitable for spatially concentrated forms of physical activity, the following operational criteria were specified:

- Defining the wider area of analysis. The area studied included an urban area with a 900 m distance from all housing. To be able to manipulate the data, a 10 × 10 m vector grid was created (across the study area), which was estimated as sufficiently detailed to collect minimal green spaces suitable for spatially concentrated forms of physical activity;
- Identifying green spaces within the area analysed. To make a green space suitable for physical activity, its minimum size was set at 200 m², in which the area had to include at least two adjacent 10 × 10 m cells;
- Defining the proximity of green spaces. The following distances were defined quantitatively for accessing green spaces suitable for spatially concentrated forms of physical activity: a walking distance of up to 300 m (a five-minute walk) and 900 m (accessible by bicycle or within a fifteen-minute walk).

A part of Kočevje was selected to test these variants. To identify green spaces suitable for physical activity, an area 900 m from the ground plans of the houses and apartment buildings in Kočevje was specified (900 m is the maximum distance suitable for the daily use of green spaces). A 10 × 10 m vector grid was created, and several data merging models were run to identify green spaces with precision. The results of modelling are described in Section 5.2.

As a preventive method to ensure the suitability of the approach applied, various public green spaces across a small area were also manually entered into QGIS. This was made based on an expert evaluation, along with the use of a satellite orthophoto and verification by a spatial planner from the municipal office. Public spaces were identified by type: parks, public playgrounds, school and preschool playgrounds, community gardens, public sports fields, other sports fields, sports and recreational areas, specialized parks, setups in forests, green spaces in residential neighbourhoods, and green spaces next to public buildings.

4.3 Creating a merged layer of green spaces suitable for spatially concentrated forms of physical activity

Using remote sensing data and a 10 × 10 m vector grid for larger areas resulted in a large number of cells, which made data processing difficult. In the following stage, a different method was tested, in which the basic data were not gridded. A layer of data from the building land register (MNVP, 2021) was used, with a graphic part and a relational table with current land uses and areas (layers 3171, 3181-3184, 3243, 3111, 3112, 3131-3136, 3141, 3142, and 3151). After merging all the data, the predominant use was identified for every polygon. Forest

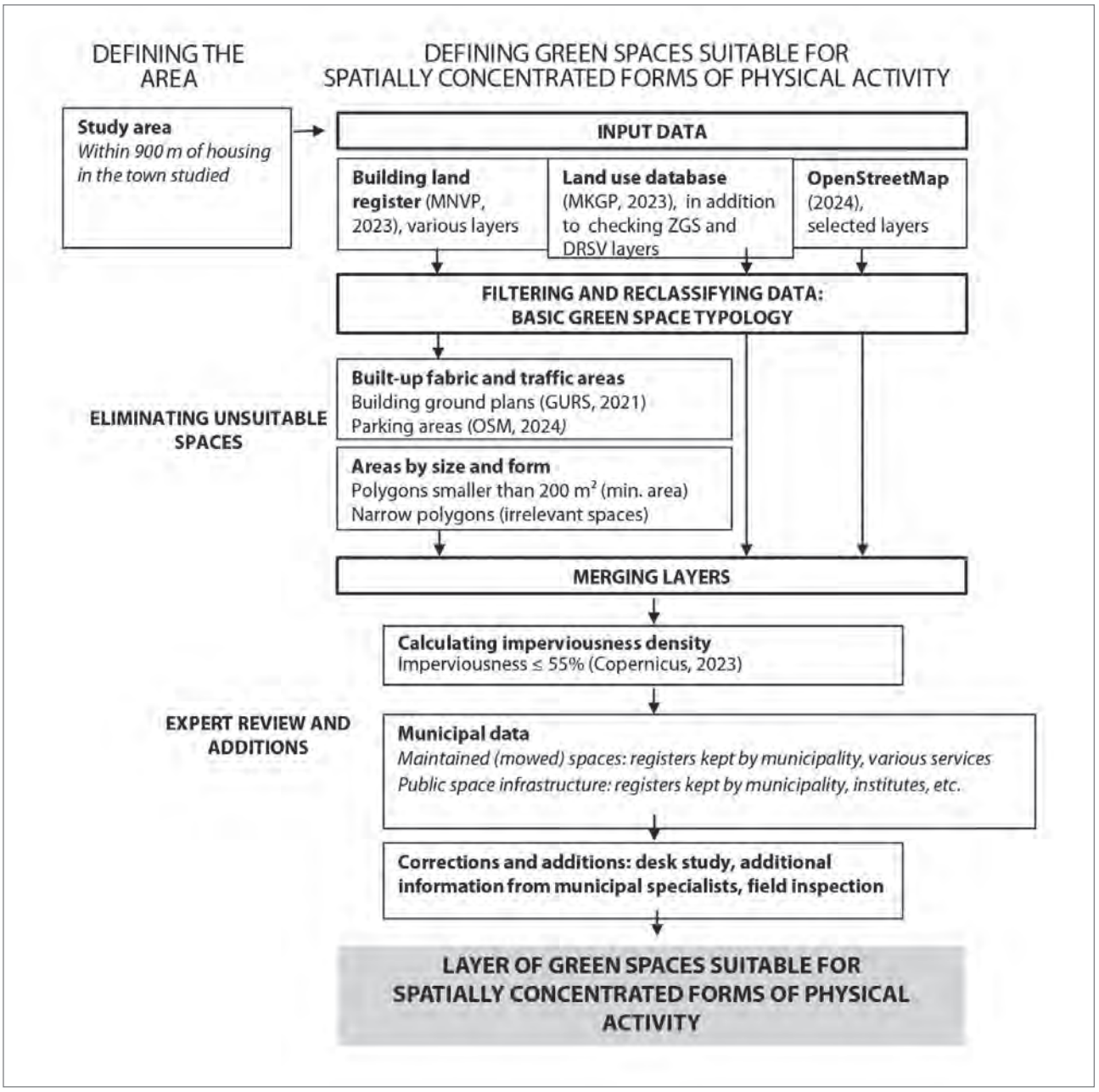

Figure 1: Steps used in merging data or creating the final layer of green spaces suitable for spatially concentrated forms of physical activity (illustration: Jana Kozamernik).

areas were identified from the agricultural and forestry land-use database (MKGP, 2023; layers 1800 and 2000) because this layer was more consistent with the building land register. Additional data sources included Open Street Map (OSM) data for Slovenia, which were downloaded from the Geofabrik website (Geofabrik, 2024) in PBF format. Various categories related to recreational and leisure activities and the outdoor space studied were used, especially "leisure", "land use", and "access". Raw OSM data were first imported into a PostgreSQL database, including all the attribute values saved in hstore format. This made it possible to use the entire range of attribute values in filtering data.

Based on the criteria specified for the provision of green spaces suitable for spatially concentrated forms of physical activity, data were merged to create a layer for the pilot area covering the ten districts of Celje. Green spaces were reclassified into eleven basic types, such as parks, playgrounds, sports and recreation, specialized parks, water recreation areas, green areas around public buildings, common green areas around apartment buildings, lawns, cemeteries, community gardens, forest areas informally used for physical activity, and so on. Public

accessibility of green spaces was specified by type of access: universal, public, unlimited public, time-limited, and entrance- or fee-based access. The typology and access filters were used to create a layer of green spaces suitable for spatially concentrated forms of physical activity. Automated classification accelerated the manual review and made it possible to enter the attribute values correctly.

The recategorized layer of building land register data was additionally processed by eliminating built-up areas and parking areas obtained from the OSM layer. After inappropriate areas from the building land register were eliminated, adjacent polygons of the same type were merged. After the layers were graphically overlayed, narrow parts of polygons were left in some places, and so the narrowest parts were removed by creating a 20 cm negative buffer distance and then a positive buffer distance of the same size. This eliminated the narrowest parts of the polygons with a width of no more than 40 cm. A longer buffer distance was not selected because that would have somewhat distorted the geometry on the vertices and increased the error.

In addition, the share of impervious surfaces was calculated by overlaying the merged layer of the three data registers with the Copernicus raster data (EEA, 2022a). In the next step, data were reviewed and complemented. Major errors were rectified by examining the digital orthophotos and through detailed reviews carried out in collaboration with specialists from the municipal office and in the form of field inspections.

5 Results

5.1 Comparing and selecting data at various spatial levels

In reviewing international databases, Corine Land Cover (EEA, 2022b, 2022c), Urban Atlas (change) (EEA, 2022d, 2022e), and the Global Human Settlement Layer (Copernicus Services, no date) proved to be inappropriate due to their insufficient spatial resolution or incomplete coverage of Slovenia. The European Settlement Map data (EEA, 2019) are useful to present built-up areas with sufficiently high spatial resolution, but they are not up to date (the most recent data are from 2019). Green spaces can be identified relatively accurately based on imperviousness density data. Due to potential errors (e.g., inaccurate identification of green spaces with a high share of paved surfaces), however, these need to be combined with other data. In this regard, two data layers are vital: tree cover density (EEA, 2022f) and grassland (EEA, 2022g). They are especially useful to identify green spaces that are not officially designated as green spaces in terms of their actual or intended use. The European Digital Elevation Model (EEA, 2016) can be used to assess the terrain and, for example, to define slopes that affect various types of physical activity, the courses of recreational trails, and so on. To determine the equipment and facilities provided in green spaces, OpenStreetMap (OSM) data (OpenStreetMap, 2023) may prove useful. These data also contain information on road networks, including pedestrian and cycling infrastructure. A disadvantage of the OSM database, which prevents its broader application, is that the data are gathered and updated through open collaboration, which means that it may contain errors. The review of international data on open-access portals showed that these data were not sufficiently precise to analyse local areas. The imperviousness density provides useful information, but a more up-to-date system is required. An advantage of international data is their comparability.

The review of national data included all urban planning databases kept at the national level. Green spaces in built-up areas are recorded in the building land register (MNVP, 2021). The data in this register are linked to parcels, and so an individual parcel may include several land uses, which are recorded in a relational table based on which the share of each use can be calculated. These data are thus only partially useful because small green spaces are not captured and shown separately. Information on planned land use refers to the planned use of spaces and does not convey the current situation. Even though this information is relatively detailed, it only includes large green spaces (designated as such in terms of planned use), but it does not take into account green spaces within areas with a designated planned use other than green space. Moreover, the real estate cadastre (GURS, 2023) may prove useful for a detailed identification of undeveloped open space. This layer includes all occupied land, building ground plans, and unfertile land next to buildings, such as outdoor spaces, parking areas, squares, small parks, and other small and fragmented undeveloped areas without a specific function. In identifying green spaces, it makes sense to combine these data with satellite images, but a challenge that may arise in this regard is the size of the error in combining raster (10 × 10 m) data with vector data. Based on the highlighted aspects of identifying the quality of green spaces, the information on tree canopies is also important. A detailed vegetation layer is provided through laser scanning (ARSO, 2014). Because these are high-resolution data, they are very difficult to process. In identifying green spaces that are not part of populated areas or building land, the data provided by the Slovenian Forestry Institute are vital (Zavod za gozdove Slovenije, 2023); among other things, these specify wooded areas with a recreational and cultural function, as well as other social functions that may potentially (based on their location and accessibility) constitute important green spaces for physical activity. The agricultural and forestry land-

use database (MKGP, 2023) is useful for identifying non-cultivated farmland that is required to be publicly accessible by law. Also useful for identifying the attractiveness of areas, and partly green spaces, may be the information on cultural heritage protection, such as the cultural heritage protection regimes (Ministrstvo za kulturo, 2021), and information related to nature protection regimes, such as the Natura 2000 sites (ARSO, 2018), valuable natural features (ARSO, 2015), and protected areas (ARSO, 2010). To identify the use of water and waterfront areas suitable for physical activity, data from the water cadastre (DRSV, 2020) may be useful; for example, information on surface water, including various types of surface streams. The information on bathing waters and their spheres of influence is less useful because it is not kept up to date.

Demographic data is important for defining the locations of users of green spaces suitable for concentrated forms of physical activity. Information on the population provided by the Slovenian Statistical Office (Statistični urad RS, 2022) includes data on the number of population by age group, and the number of households and their size, with a spatial resolution of 100 m. Information from the central population register (Ministrstvo za notranje zadeve, 2024) is linked to house numbers, and, due to personal data protection requirements, it is difficult to obtain. Also important is the information on the persons that use a specific area during the day (e.g., students, shoppers, etc.), which can be obtained from various sources, but their accessibility is limited. The review of national data on open access portals showed that these data do not meet the needs of green space identification in this study and that, hence, it is necessary to combine various data. An advantage of national data is that they are regularly updated, which makes it possible to compare them across several years.

The review of municipal data focused on open-access data on web portals, such as iObčina, PISO, Prostor Celje, q3MAP (Koper), Prostor Kranj, UrbInfo (Ljubljana), and Prostor Maribor, as well as bike rental websites. The data were very diverse, ranging from information on street furniture, playgrounds, sports fields, sites and monuments, public green spaces, trees, and hedges to data on various uses (overlapping uses, public domain, etc.). In terms of type, mobility data predominate (nineteen data layers), followed by data on public utilities and services (eleven), and land use (eight; green, sports, recreational, and tourist areas). The review of municipal data on open access portals showed that these data are inconsistent and that they are often too incomplete to be used directly, and they cannot be compared to one another. Nonetheless, in certain cases they can complement other data layers to identify green spaces suitable for concentrated forms of physical activity. Based on the database review conducted, it can be established that, to identify the green spaces in question or their sizes, it makes sense and is currently also vital to combine various data sources and layers.

5.2 Testing various options of combining data sources and layers

Data merging models were used to test various combinations of data layers. Model A was based on various data from the Copernicus database (EEA, 2018), Model B was based on national data, and Model C combined the Copernicus and national data. These were further divided into:

- Model A1, which used three data layers from the Copernicus programme (EEA, 2018): small woody features, tree cover density, and grassland;
- Model A2, which used four Copernicus data layers (EEA, 2018): small woody features, tree cover density, grassland, and imperviousness density;
- Model B1, which used four official data layers: data from the agricultural and forestry land-use database (selected uses: wooded farmland – code 1800, trees and shrubs – code 1500; MKGP, 2023), land-use data from the building land register (selected uses: sports and recreation areas – code 3171, parks – code 3181, community gardens – code 3182, public green areas – code 3183, other public open spaces – code 3184; MNVP, 2021), data on surface bodies of water from the water cadastre (DRSV, 2020), and data on forest functions from the online forest data viewer (selected functions: recreational and cultural forest functions; ZGS, 2023);
- Model B2: in this model, areas that do not constitute green spaces suitable for concentrated forms of physical activity according to the definition used in this study were subtracted from the areas identified in Model B1; the subtracted areas included residential building ground plans from the real estate cadastre (GURS, 2023), selected uses from the agricultural and forestry land-use database (i.e., fields and gardens – code 1100, hop yards – code 1160, perennial crops – code 1180, permanent pastures – code 1300, greenhouses – code 1190, vineyards – code 1211, nurseries – code 1212, intensive orchards – code 1221, extensive or meadow orchards – code 1222, olive groves – code 1230, and other perennial crops – code 1240; MKGP, 2023), and traffic areas or the road and rail network from the public infrastructure cadastre (GURS, 2022), taking into account a 6 m distance from the railroad and road axes within the first five categories (i.e., motorway, expressways, first- and second-category regional roads, and main roads) and a 2.5 m distance from other roads, except mountain trails and cycle paths;
- Model C1, which combined all areas obtained in Models A2 and B2;

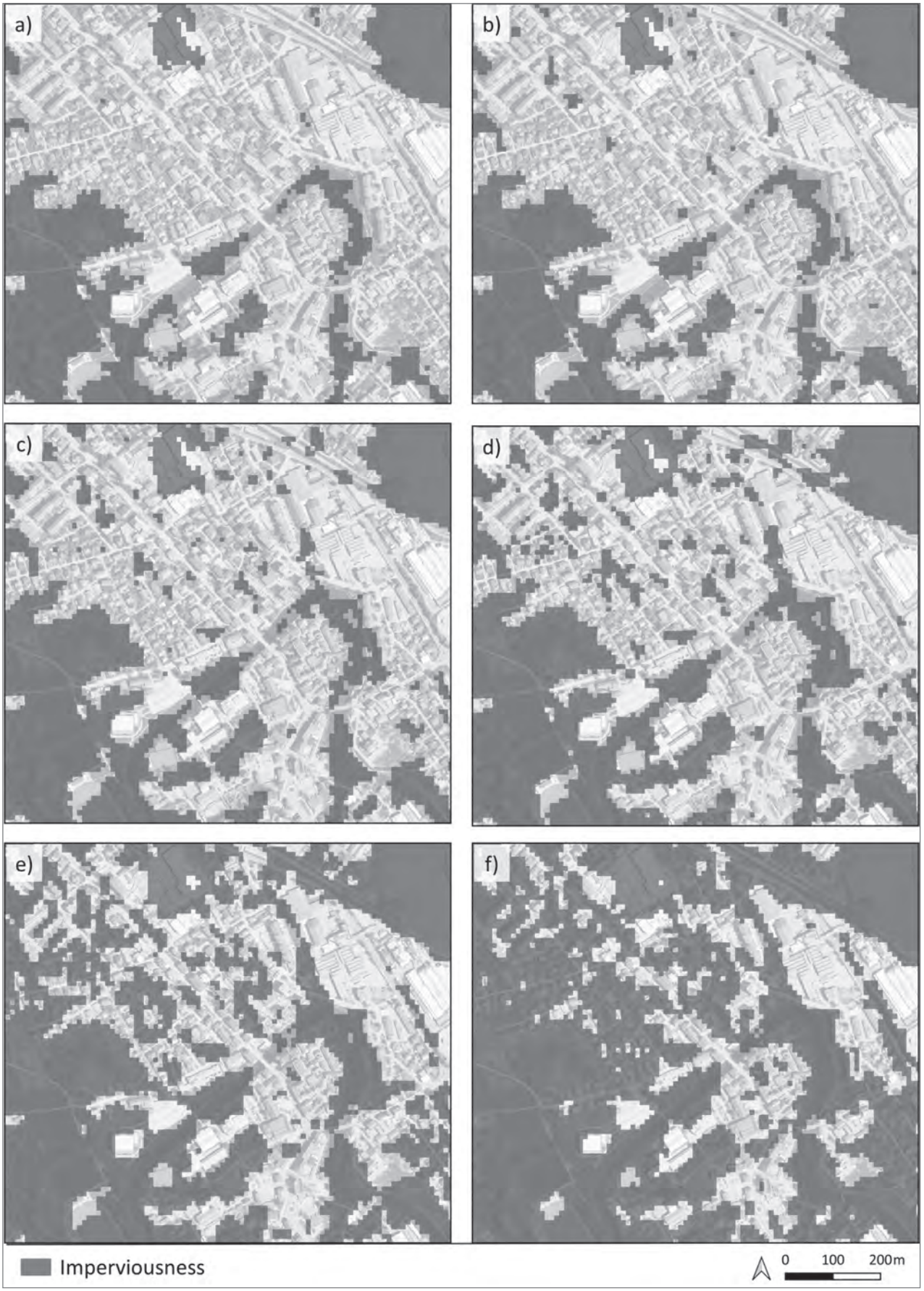

Figure 2: Identifying the degree of imperviousness using a test case from the Copernicus database (100% refers to complete imperviousness and 0% to complete perviousness): a) imperviousness ≤ 5%; b) ≤ 15%; c) ≤ 25%; d) ≤ 35%; e) ≤ 55%; f) ≤ 75% (illustration: Rok Brišnik).

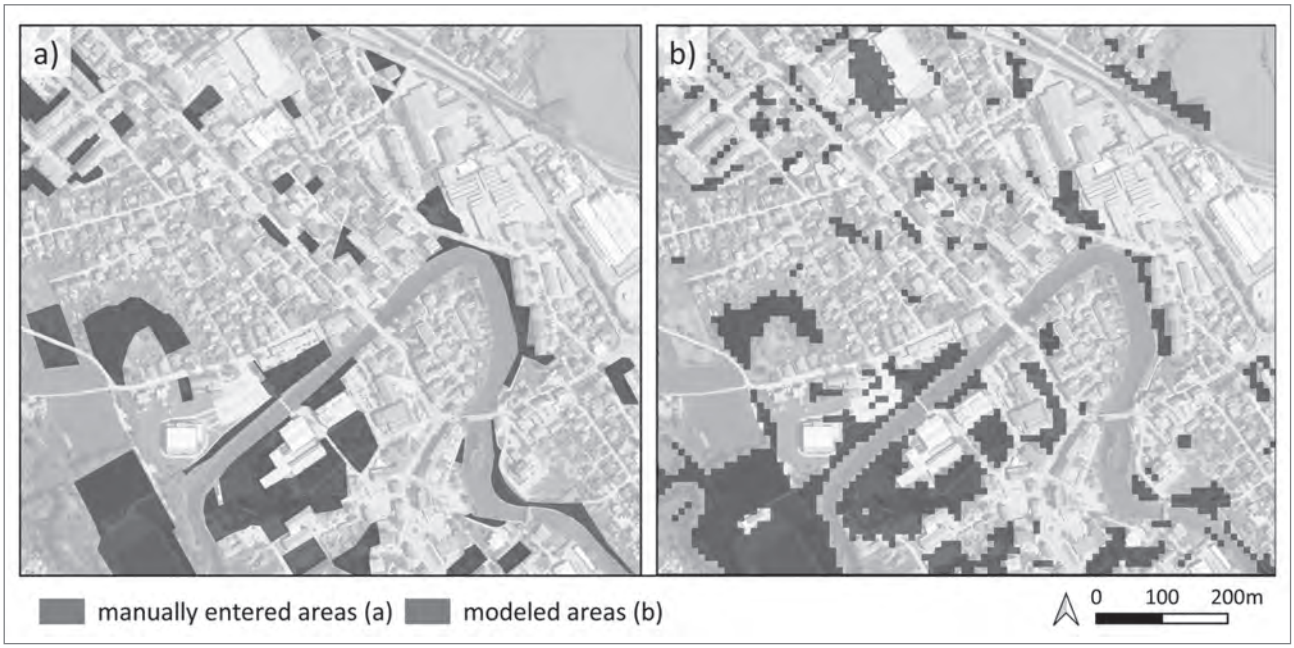

Figure 3: a) Comparing areas identified manually and b) areas identified through modelling (illustration: Rok Brišnik).

- Model C2, which combined areas obtained in Models A2 and B1, and then removed the areas subtracted in Model B2.

In each model, after merging the input data with the 10 × 10 m grid, four different filters were used to calculate the data layer share in each cell: ≥ 5%, ≥ 1%, ≥ 0.5%, and no filter. Filters help reduce anomalies that form when converting the input layers into a grid. The authors also tested the most suitable imperviousness percentage for identifying green spaces (Figure 2). The threshold imperviousness values tested were set at ≤ 5%, ≤ 15%, ≤ 25%, ≤ 35%, ≤ 45%, and ≤ 75%. The variants were tested to obtain the best possible approximation of the status quo.

The suitability of the modelling approach was tested through manual identification of green spaces in a small area of Kočevje. By comparing both methods of identifying green spaces suitable for physical activity in GIS (Figure 3), it was established that areas identified through modelling largely agreed with those identified manually. Certain discrepancies were determined; for example, in marking community gardens and urban grasslands (e.g., the computer model eliminated all meadows, whereas some were entered manually). The best approximation to the manually entered data was achieved with the final variant, Model C2, with a 5% filter (for all data) and an imperviousness degree ≤ 55%. This type of modelling proved effective because the authors were able to eliminate a large portion of areas that do not constitute green spaces suitable for concentrated forms of physical activity.

Based on the results, it can be concluded that the model proved to be a sufficiently good basis for processing data in pilot cases to improve the model. To achieve this, in parallel to using the model in pilot areas, it also makes sense to manually test the results in a smaller area. In doing this, various data sources can be combined, such as a digital orthophoto and final verification by an expert at the municipal office. Despite the suitability of the result, the method proved too complex to make calculations for entire towns and municipalities (too complex for the current software capacity).

5.3 The final merged layer of green spaces suitable for spatially concentrated forms of physical activity

The method that combines only vector data and uses remote sensing data as a verification step proved better suited for processing data for larger areas (towns and municipalities). Based on a review of available data and testing the data merging models, a layer of green spaces suitable for spatially concentrated forms of physical activity can be produced. The procedure is largely automated through SQL scripts, which allows reproducibility, but automation alone does not yield sufficiently reliable results, and so a final review and manual update of data are required.

A merged layer of green spaces suitable for spatially concentrated forms of physical activity was produced for the ten districts of Celje, which included all green spaces within 900 m of housing. This method identifies green spaces as a whole,

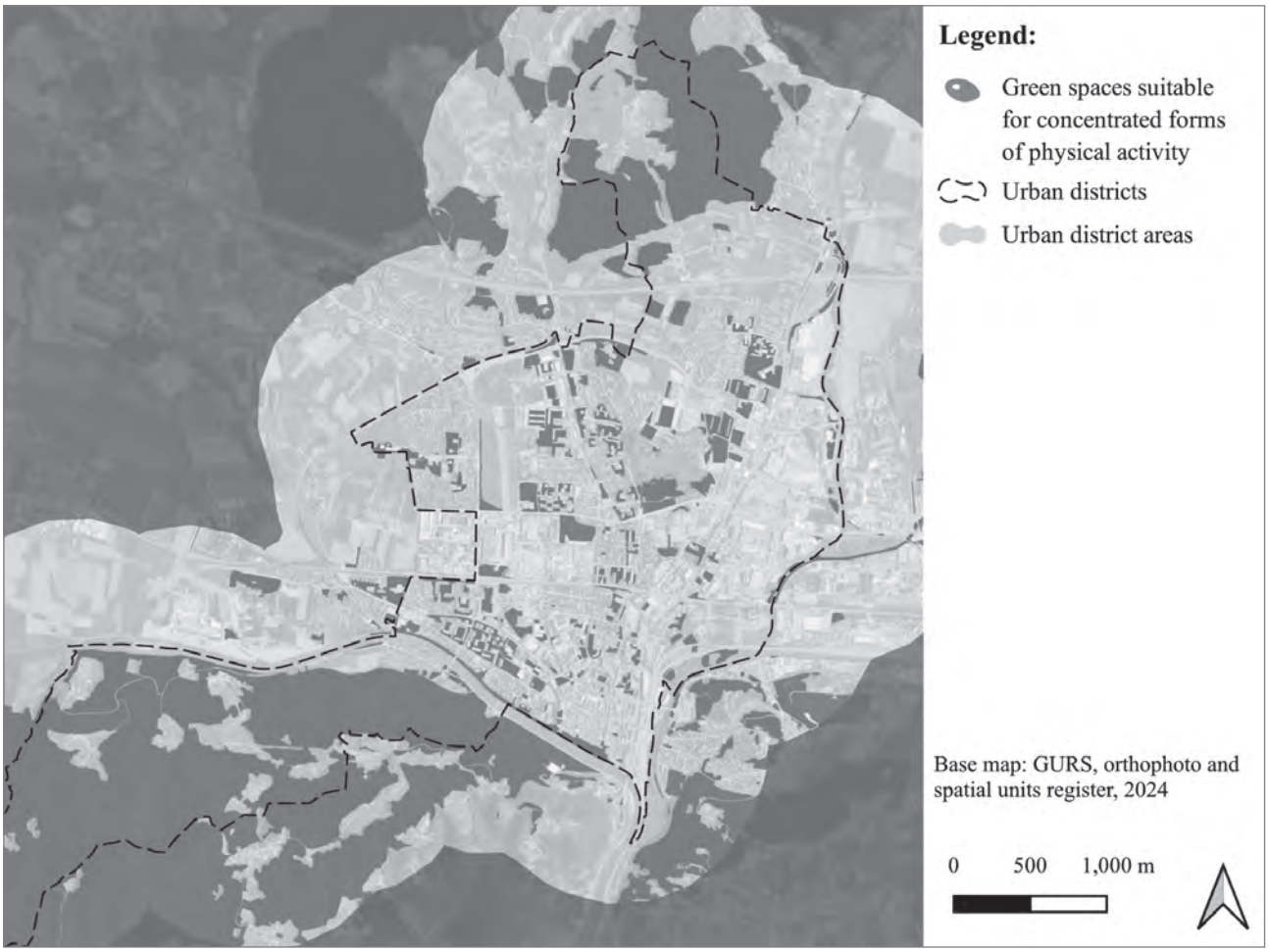

Figure 4: Green spaces suitable for concentrated forms of physical activity identified in the ten districts of Celje (illustration: Simon Koblar).

and so the results must be appropriately interpreted. One such example is the identification of the green space type "forest area used informally for physical activity", which comprises large contiguous areas, and so this must be further elaborated in terms of the various types of physical activities that people can engage in there.

6 Discussion

6.1 Evaluation of databases reviewed at various spatial levels

A review of available databases showed that there is currently no data layer in Slovenia that could be directly used for identifying green spaces suitable for spatially concentrated forms of physical activity. Relevant aspects are included in various data sets or are not defined at all. Hence, the initial hypothesis has been partly confirmed, and the reasons are presented in detail below.

The review of international databases showed that data from the Copernicus programme (EEA, 2018) are relatively imprecise and insufficiently updated. They are useful because they cover both urban and rural areas, and they define green spaces in the broadest sense of the word (i.e., in terms of their occurrence, not function). Data from Slovenia's official records at the national level are more accurate and thus more useful for the aim of this study, but they do not cover all the relevant green spaces and criteria for identifying those suitable for concentrated forms of physical activity. Especially problematic in this regard are green spaces within residential areas (built up with apartment buildings) and next to public buildings, which are key to estimating green space provision. Spatial data suitable for estimating the provision of relevant green spaces are collected and presented in databases and registers of various sectors, with various purposes and approaches. The relevant green spaces may also be included in the records of various sectors (e.g., they can be part of land-use registers, the agricultural and forestry land-use database, forestry management plans of the Slovenian Forestry Institute, the Slovenian Water Agency

registers, protected areas, and so on). Slovenia does not have a comprehensive overview of data in place at the national level suitable for identifying the green spaces in question. There is a lack of an expert-based and uniform data collecting approach, which is the result of the different and frequently insufficient understanding of public green spaces and the absence of a harmonized method for creating databases at the local level. A similar dispersion of data can also be observed at the municipal level, where certain public green spaces are included in several registers (of public utilities, sports infrastructure, playgrounds, street furniture, etc.). It should be noted that many of these data are not presented on maps and thus cannot be used directly to produce green space provision maps.

The finding that data registers and databases have been produced for other purposes but are nonetheless useful if processed appropriately confirms the authors' hypothesis to some extent. However, the study also showed that data usability is hindered by a lack of cross-sector connectivity and coordination, and often even a conflict of interests in designating the use and role of areas with green space characteristics. Consequently, the data also do not match spatially (e.g., the agricultural and forestry land-use database and the building land register). The study only covered spatial data presented on maps. Some other available data, such as registers of sports structures, were therefore not useful.

Based on the above, the authors' hypothesis cannot be fully confirmed. The available registers and databases were useful to develop the method, but they cannot be directly applied to identify green spaces suitable for physical activity at the local level. Therefore, additional manual corrections are required.

6.2 Evaluation of the approach and further research options

A review of Slovenian and international documents showed that the "green space provision" concept derives from the current premises of various sectors and spatial planning legislation, and it can form the basis for developing the indicator of green space provision at the local level in Slovenia. The proposed approach to identifying green spaces suitable for concentrated forms of physical activity to develop a provision indicator is conceived from the perspective of identifying current publicly accessible green spaces, the scope of which (i.e., their size and location) is calculated based on existing data. Due to insufficient data on public accessibility, this information must be specifically asked for, but other methods can also be used, such as an adaptation of the walkability index formula, depending on accessible data (Leslie et al., 2007; Frank et al., 2010; Lestan, 2017). Public accessibility of green spaces suitable for physical activity forms a link between aspects at the first level (green space identification) and those at the second level (green space evaluation) because defining publicly accessible green spaces is just as key as examining their accessibility ratios at various levels and from diverse aspects. In fact, it is difficult to distinguish green space accessibility from both the connectivity of green spaces and residential areas, and the interconnection of green spaces themselves.

The advantage of the approach presented is that it clearly identifies the area for calculating public green space provision because defining the borders of an area studied can have a strong impact on the results of calculating the amount of green space per capita. The suitability of using the required amount of green space per capita as an indicator was already questioned in a 2012 study (Gupta et al., 2012). Moreover, the selected size of 200 m^2 covers the green spaces that the authors estimated as relevant for physical activity, including small ones, such as pocket parks. This is relevant due to the small size of Slovenian towns and the importance of such spaces for spatially concentrated forms of physical activity. The limited use of this approach at the local level hence derives from the minimal size of 200 m^2 used, which is smaller than the ReSPR50 requirements. Because of this, the results cannot be directly used to examine the national strategic goals, but they can be used for regional comparisons (e.g., between settlements of the same size).

In principle, satellite data proved very useful for eliminating areas without green space characteristics, but errors caused by merging raster (10 × 10 m cells) and vector data may be a problem. Therefore, the results of testing the variants are only approximate, and it would make sense to examine other data merging options. In producing the final green space layer, a major error was related to the (un)reliability of OSM data on parking areas because that data layer is very deficient. The error would have been smaller if an official register of parking areas had been available or if all parking areas had been drawn in OSM. These deficiencies were partly removed through manual inventorying.

The approach used to identify green spaces suitable for spatially concentrated forms of physical activity constitutes the first level or identification of these spaces, which forms the basis for their further evaluation based on their quality and suitability for spatially concentrated forms of physical activity. The authors acknowledge that, to improve the approach, testing should be conducted on a larger and more diverse sample of settlements or towns (e.g., including in scattered settlements or entire urban areas), and that larger distances to green spaces should also be tested, especially due to differences in user fitness. In this context, accessibility with various means of transport, especially electric (e-bikes and e-scooters),

is not considered an important access criterion because the basic premise is that green spaces should be accessible for all under the same conditions.

A few recommendations for improvements in recording green spaces are presented below as a starting point for establishing an indicator of green space provision for physical activity. Improvements can be made from two aspects. First, spatial databases on green spaces should be refined, which includes providing high-quality and useful data on the state of green spaces. This is key for realistically assessing public green space provision in a specific area in Slovenia as defined by legislation. It is vital that the categorization of green spaces be examined and harmonized by experts, and that the spatial data collected match those included in the databases of other sectors (e.g., agriculture, forestry, and sports). It would make sense to set up a uniform portal for collecting and viewing data because the current situation in collecting spatial data referring to green spaces is still unclear and deficient. Second, long-term cross-sector collaboration and interconnection of measures should be established in collecting and using data at the national level to create synergies in implementing the planning, decision-making, and spatial development goals set in the public interest. Producing high-quality municipal registers of publicly accessible green spaces, other open spaces, and trees would also significantly help improve the situation because these data would effectively support the comprehensive planning of green spaces (green systems) and their systemic management and maintenance. Establishing green space registers is key to monitoring the state and maintenance of green spaces (Šuklje Erjavec et al., 2020a). This is also supported by the Environmental Protection Act (Ur. l. RS, nos. 44/22, 18/23 – ZDU-1O, and 78/23 – ZUNPEOVE, 2022) through the requirement of municipal public utility services to maintain and clean public areas. These types of municipal registers could provide the basic data source for using the indicator of green space provision for physical activity at the municipal level.

By further developing this approach, the results of identifying green spaces suitable for physical activity can be improved (depending, for instance, on higher-capacity software and higher-quality data), and the approach itself can be conceptually expanded to establish a green space provision indicator. It makes sense to analyse the distance of settlement areas from green spaces to define those parts of a human settlement that are provided with adequate green spaces and those that are not or in which residents have poorer opportunities for daily recreation. For the analysis, it is key that it include up-to-date information and any planned projects that may affect the calculation of the distance (e.g., spatial barriers), and that it also examine spatial issues and potentials. Such an analysis, which also shows deficiencies, provides key guidance for municipal plans.

7 Conclusion

Slovenia's public health policies and documents follow the latest *WHO Guidelines on Physical Activity and Sedentary Behaviour* (World Health Organization, 2020). In its recommendations for various population groups on the amount of physical activity required to offer significant health benefits and mitigate health risks, the WHO highlights the fact that physical activity can take place in various ways, depending on various opportunities to be physically active and various settings. In Slovenia, people's needs for physical activity are the same as in other countries, and green spaces are recognized as important settings for recreation (Žlender & Gemin, 2023). Their proper definition is key to plan high-quality and stimulating urban environments. Based on a review of literature, relevant legislation, and databases, this study defined the concept of green space provision for physical activity and developed a method for identifying green spaces suitable for spatially concentrated forms of physical activity.

Green space provision for physical activity is a complex concept that requires a holistic approach at the strategic, implementation, and management levels. It is vital to understand that the concept is directly related to the context of use, which includes various aspects, such as the ecological value of green spaces, public accessibility, social benefits, and the promotion of physical activity and an active lifestyle. To ensure adequate green space provision for physical activity, collaboration between various sectors, such as spatial planning, public health, and sports, is key. It is also vital to conduct further research in this area and develop approaches that will take local special features and the residents' needs appropriately into account. This will contribute to better planning and management of green spaces in Slovenia, and it will help improve the quality of life and promote healthy lifestyles.

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