Reclassification of Green Infrastructure Types and Functions: 
Focused on Matsudo City, Chiba Prefecture, Japan

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ABSTRACT

Background and objective: Globally, the sustainability of urban areas is being compromised due to indiscriminate urban development, making the creation and management of green spaces increasingly critical. Green spaces play a pivotal role in connecting degraded natural ecosystems, and the concept of Green Infrastructure is gaining prominence as a strategy for managing green networks. A Green Infrastructure (GI) is a network of interconnected green spaces that provide benefits to humans through their utilization and management, fulfilling environmental, social, and economic functions. However, in most urban areas, green spaces lack connectivity between each other and are not managed in an integrated manner. Additionally, the types and functions of green spaces defined by policies and regulations vary, making it challenging to implement GI. Therefore, this study aims to examine and reclassify precursor indicators in order to effectively apply GI to urban strategies. It seeks to discuss management approaches based on GI, with the aim of facilitating its implementation.

Methods: The city of Liverpool in the UK has presented a multifunctionality strategy for GI, which has been utilized as a global exemplary case. This study adopts the multifunctionality GI strategy proposed by the city of Liverpool, and reclassifies the types and functions of GI. It selects indicators through Focus Group Interviews (FGI) with GI experts and field surveys. The selected indicators of GI were utilized in a survey for evaluation of multifunctionality. The quantitative data collected through the survey were mapped using overlay techniques, in which led to the deriving a multifunctionality map of GI. In the process of mapping, weights derived from Analytic Hierarchy Process (AHP) analysis were applied to enhance the reliability of the quantitative data from the survey.

Results: In this study, suitable indicators for GI in the study area were selected, and the functionality of each land cover (LC) type was evaluated. As a result, the study area was found to provide multifunctionality within a single land parcel. The highest-scoring LC type is Woodland, and the predominant functional category is Human-Wildlife Coexistence. The lowest-scoring LC type is Cemetery, with the least represented functional category being Timber Production.

Conclusion: GI fulfills multiple functions that provide a range of benefits to humans (multifunctionality). To maximize such multifunctionality, it is crucial to manage scores for each functional category according to LC type. GI is not solely focused on specific functions, but also requires strategies to enhance functionalities lacking in LC types with low multifunctionality scores. The GI indicators proposed in this study and the GI multifunctionality assessment can serve as essential data for review when local authorities are formulating spatial plans related to urban areas, green spaces, forests, and other relevant areas.

Keywords: green space network, indicator, land cover (LC), multifunctionality, visualization

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Introduction

Around the world, the sustainability of urban areas which for most countries, hold approximately half of the population (European Commission, 2019; UN, 2022) is being threatened by indiscriminate development (Hartmuth et al., 2008; Xing et al., 2009; Wu, 2010; Mieg, 2012; Kou and Tsou, 2015; Cohen, 2017). The fragmentation, degradation, and disconnection of green spaces within and outside of urban areas must be addressed to improve and maintain urban sustainability (Kong et al., 2010; Bakhshi, 2015; Kruize et al., 2019; Chi et al., 2020; Wang et al., 2022; Zhou et al., 2023). Green spaces not only play a key role in connecting natural ecosystems that have been isolated or degraded by urbanization, but also provide benefits to humans (Cetin, 2015; Akpinar et al., 2016; Mu et al., 2020; Vidal et al., 2020). As such, green space connectivity is attracting attention as an important means of creating sustainable cities, and research on the creation and management of green-space networks is also actively underway (Short et al., 2017; Constantinescu et al., 2019).

In particular, the concept of Green Infrastructure (GI) has been in the limelight, and is being considered as a management strategy for green-space networks to achieve urban sustainability (Sandstrom, 2002; Pauleit et al., 2019; Wang, 2022; Hoover, 2023).

A GI is a network of interconnected green spaces that provide benefits to humans through their use and management (Williamson, 2003; Benedict and McMahon, 2006; Mell, 2008; Kaplan, 2012; Andreucci, 2013; Lindholm, 2017; Wang and Banzhaf, 2018; GI The Conservation Fund Web-Page, 2024). It includes different types of green spaces within natural systems and urban infrastructure, such as waterways, wetlands, agricultural lands, street trees, urban parks and gardens (Weber et al., 2006; Naumann et al., 2011; Andreucci, 2013; Lee et al., 2014; Zhang et al., 2022). As such, green spaces distributed within and outside urban areas have different functions for each type, and promote the performance of GI functions through interconnection (Naumann et al., 2011). GIs provide environmental and ecological functions that mitigate urban heat islands, reduce flood damage, remove air pollutants, improve water quality and provide habitat (Winslow, 2021), as well as social and cultural functions that include recreation, education and culture (Tzoulas et al., 2007). However, although GIs have the benefit of providing environmental, social and economic functions (Pitman et al., 2015; Symons et al., 2015; Parker and Baro, 2019; Honeck et al 2020; Mell and Clement, 2020; Jezzini et al., 2023), most urban green spaces lack connectivity and are not managed in an integrated manner, which limits the capacity of urban GI to actively fulfill its unique functions (Pozoukidou, 2020).

Green spaces, the most basic element of GI, are classified by land cover and are altered by human actions, including changes in land use, and development activities. Changes in land use can alter land cover, improving or maintaining the connectivity and functionality of individual green spaces (Staccione et al., 2022). Land cover (LC), which is what covers the terrestrial surface, reflects the use and function of each green space (Gregorio, 2005; Campbell and Wynne, 2011; Phiri and Morgenroth, 2017; Zaitunah et al., 2022) and is used as a tool to derive the characteristics and roles of each green space and GI (Kang and Kim, 2015; Kim et al., 2023). Based on the LC of each green space, the purpose of GI network formation and utilization plans can be established (Zang et al., 2022); such a network can provide complex functions in addition to the unique functions of GI (Stürck and Verburg, 2017; Isola et al., 2022; Hansen et al., 2019; Kim and Song, 2019). Since the multi-functionality of GI refers to the complex functions that benefit humans when a tightly connected network of green spaces is formed, spatial connectivity must be considered as essential to achieve maximum multi-functionality (Dige et al., 2011; Lähde et al., 2019; Korkou et al., 2023). As a result, when GI is combined with integrated operation and management, humans can receive many benefits from each green space and GI (Papageorgiou and Gemenetzii, 2018; Monteiro et al., 2020; Chen et al., 2022).

The UK has developed the concept of GI and applied it to actual urban planning and management. There has also been active research into the function of GI, and the network of green spaces (Llausas and Roe, 2012). Key examples of this research include studies on urban water management using GI (Ellis, 2013; Hoang and Fenner, 2016; Li
et al., 2020), ameliorating urban heat islands through LC change (Emmanuel and Loconsole, 2015; Tiwari et al., 2021), the impact of green space accessibility on human public health (Leese and Zubaidi, 2023), predicting changes in biodiversity and ecosystem services based on an analysis of species and habitat patterns in cities (Brunbjerg et al., 2018), and the possibility of restoring green space in urban areas for food security (Dobson et al., 2020). As such, in the UK, GI has been considered as an important element for urban operation and management, and together with research on it in various fields, it is being applied and used in actual urban operation and management strategies (Fisher et al., 2020). For example, the city of Liverpool, UK, which is featured as a global best practice, has applied GI to the management and planning of green spaces within the city at the local government level (Kinoshita et al., 2016, Wendl er et al., 2022), and has developed and disseminated an action plan for implementation (Liverpool City, 2010). According to the Liverpool City Green Infrastructure Strategy (Liverpool City, 2010), the city has established an integrated approach to green spaces based on GI in land use planning and management, and has proposed a multi-functional GI strategy that provides various functions in addition to the natural functions unique to each green space. Specifically, each LC was classified into 17 types and 28 functions, and based on this, plans for the operation and utilization of GI were prepared by mapping the entire city.

However, we encounter the limits to the Liverpool City GI Strategy, which is attracting global attention, when we attempt to directly apply it to other urban areas (Kinoshita et al., 2016), as LC, which is the basis of GI types, is categorized by the laws and systems of each country, and thus Liverpool's GI cannot be fully replicated (Diogo and Koomen, 2016). Japan's population has become concentrated in urban areas due to the country's rapid urbanization since the 1960s (Urushima, 2015). This has led to a rapid change in LC, which has reduced the amount of rainwater penetration in urban areas, resulting in severe urban flooding (Nakaguchi and Komori, 2020), and caused urban problems such as a reduction in green space due to urban sprawl and expansion (Koohsari et al., 2022). In response, the Japanese government built satellite cities to disperse the population of large cities during the bubble economy era (Yutaka, 2019), but most of these were built without considering the concepts of green space and GI (Otsuka et al., 2020), and are currently facing regional decline and need effective management (Kumada, 2002). After the Great East Japan Earthquake in March 2011, the introduction of the GI concept into urban operations and management began to be discussed in earnest, and research on the need and function of GI has continued (Iwasa, 2015). Moreover, the importance and use of GI are emphasized in the National Land Formation and Land Use Plans, which are plans for sustainable land development and management at the national level (Ministry of Land, Infrastructure, Transport and Tourism (MLIT), 2023b). However, Japan's LC is mainly categorized by urban infrastructure facilities rather than the concept of green space, including outdoor spaces in architecture, roads, and facility maintenance, making it difficult to directly apply GI to policies and systems (Natuhara, 2018). Therefore, in order to effectively apply GI to urban strategies, it is necessary to closely examine the legal issues, including the area, use, and function of green space as defined by relevant laws and systems, as well as the types and functions of Japanese GI.

In this study, GI types and functions suitable for Japanese urban areas were reclassified based on the GI indicators of the city of Liverpool, UK, a global best practice. In addition, the GI types and functions proposed in this study were mapped by applying them to an actual target site. Using this as the basis, we sought to discuss sustainable management approaches for GI.

**Research Methods**

**Study Area**

The target area of this study is Matsudo City, in Chiba Prefecture, Japan, which has a total area of about 61.38㎢, and is located about 20 km from downtown Tokyo. It is adjacent to the metropolitan city of Tokyo, bordered by the Edo River to the northwest, and has developed into a suburb of Tokyo, centered on National Route 6 and the JR Joban Line, which connects to Tokyo (Matsudo City Official Web-Page, 2024). The population of Matsudo City is ap-
approximately 498,000 and has been increasing by about 0.23% per year for the past 10 years (2014 to 2023). By age, the largest demographic group is the 45–50 age group, but the largest influx of people is occurring in the 20–24 age group (Matsudo City, 2022a). This influx seems to be the result of Tokyo's urban sprawl turning the area into one of its commuter towns (Ermilova et al., 2018) with a high commuter rate (37.9%; Ouchino News, 2024). In the past, Matsudo City, whose residents were mainly farmers, began a land improvement project in 1955, and developed industrial complexes centered on the Matsudo area (Table 1-7) and residential complexes centered on the Tokiwadaira area (Table 1-1) and Kogane area (Table 1-6), resulting in the typical characteristics of urbanization (Son and Yoon, 2011).

Yet despite this urbanization process, Matsudo City has excellent green space resources, with the distribution of green space accounting for 25% of the total area (Matsudo City, 2022b). Since the city has a large area of farmland around the Edo River in the northwest and borders the Shimosa Plateau in Chiba Prefecture in the east, there is a large area of forest and grassland that has not been developed during the urbanization process (Yoon et al., 2010). There are 29 major green spaces in the study area, including the Forest and Park for the 21st Century located in the center of the area (Table 1), and they are preserved through the "Forest Conservation System" (Matsudo City, 2022a). As such, major green spaces in the area are managed in compliance with land use regulations. Notably, to prevent indiscriminate urban development, LC types are managed by dividing them into urban and non-urban areas based on the characteristics of the land.

In this study, LC types that are managed according to land use regulations were examined, which can be considered as GI. For the LC types used in this study, 4 types were selected for urban areas and 9 types for non-urban areas (Fig. 1). The types for urban areas include Agricultural Land, Woodland, Water Body and Other Nature, while those for non-urban areas include Ordinary Land, Public Facility Site, Cultural and Educational Site, Open Space, Derelict Land, Defense Area, Transportation Facility Site, Traffic Site and Road Site. Reclassification of LC types and reorganization of functions are required since it was challenging to apply the selected LC types directly as a GI concept, and the functions of each green space are different. Therefore, in this study, to apply the GI concept to the study area, we sought to classify them according

Fig. 1. Map of Study Area and Land Cover Status. Source: Matsudo City Official Web-Page, 2024 and Matsudo City Town Improvement Dept, Urban Planning Div. (2018, updated data).
to Japanese laws and policies based on the GI indicators of Liverpool City, UK, an excellent case.

**Methods**

In this study, GI indicators from Liverpool, UK, a representative case, were selected and collected, but LC types and functions of GI were reclassified to enable them to be defined according to Japanese laws and policies (Fig. 2). The reclassified types and functions were selected as indicators through focus group interviews (FGI) with GI-related experts and field surveys. The selected LC type and function indicators were used in a multifunctionality assessment survey of GI. Quantitative data collected through the survey were mapped using an overlay technique, resulting in a multifunctional map of GI. In the mapping process, weights derived through the Analytic Hierarchy Process (AHP) were applied to increase the reliability of the quantitative data obtained from the survey. In this study, GI indicators were collected and selected, and GI was mapped by conducting a multifunctionality assessment using the selected GI indicators. Based on this, we aimed to identify considerations for the effective application of the GI of the study area to the urban strategy, and to suggest implications.
Reclassification of Green Infrastructure Types and Functions: Focused on Matsudo City, Chiba Prefecture, Japan

Reclassification of GI Indicators for Land Cover Types and Functions

Since the GI indicators for LC types and functions of the GI strategy of the City of Liverpool, UK (Liverpool GI Strategy) adopted in this study were difficult to apply directly to the study area in Japan, a process of reclassification of the indicators to suit the area was carried out. In the reclassification process, to ensure the rationality of each indicator, the national territory, urban, green space, and land-related plans and policy literature of Japan's MLIT, Chiba Prefecture, and Matsudo City, the study area, were reviewed. Furthermore, a focus group interview (FGI) was conducted with a total of 10 relevant experts to secure expertise in GI: the group consisted of five holders of PhDs in landscape architecture and urban planning with research experience in GI, and five public officials who perform or have experience in urban planning and green space-related work. The GI indicators for the City of Liverpool were reclassified from 18 LC types to 13, and from 28 functions to 17, through processes of inclusion, exclusion and reclassification appropriate to the study area.

The GI LC typology reconstructed by excluding some of the Liverpool GI indicators in the process of reclassification into the Japanese LC typology is as follows (Table 2 and Fig. 3). Since the City of Liverpool classified transportation facilities such as railways and roads and industrial and commercial areas as urban infrastructure and

<table>
<thead>
<tr>
<th>Liverpool of U.K. GI land typology</th>
<th>Matsudo of Japan Land Cover typology</th>
<th>Selection</th>
<th>Matsudo of Japan GI Land Cover typology</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural land</td>
<td>Rice field</td>
<td>→</td>
<td>Agricultural land</td>
<td></td>
</tr>
<tr>
<td>Orchard</td>
<td>Field</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allotment</td>
<td>Agricultural land</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wetland</td>
<td>Grassland, moorland, Wetland</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woodland</td>
<td>Woodland</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water body</td>
<td>Water body</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water course</td>
<td>Other nature (River, aqueducts and running water)</td>
<td>→</td>
<td>Water course</td>
<td></td>
</tr>
<tr>
<td>Private domestic garden</td>
<td>Residential land</td>
<td>→</td>
<td>Private domestic garden</td>
<td>NDVI</td>
</tr>
<tr>
<td>Institutional grounds</td>
<td>Public facilities site</td>
<td>→</td>
<td>Institutional grounds</td>
<td>NDVI</td>
</tr>
<tr>
<td>General amenity space</td>
<td>Cultural and education site</td>
<td>→</td>
<td>General amenity space</td>
<td>NDVI</td>
</tr>
<tr>
<td>Park or public garden</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cemetery</td>
<td>Open Space</td>
<td>→</td>
<td>Cemetery</td>
<td></td>
</tr>
<tr>
<td>Outdoor sports facility</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Derelict land</td>
<td>Derelict land</td>
<td>→</td>
<td>Derelict land</td>
<td></td>
</tr>
<tr>
<td>Street trees</td>
<td>None</td>
<td>→</td>
<td>Exception</td>
<td></td>
</tr>
<tr>
<td>Green roof</td>
<td>None</td>
<td>→</td>
<td>Exception</td>
<td></td>
</tr>
<tr>
<td>Coastal habitat</td>
<td>None</td>
<td>→</td>
<td>Exception</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Defense area</td>
<td>→</td>
<td>Exception</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Transportation facility site</td>
<td>→</td>
<td>Exception</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Traffic site</td>
<td>→</td>
<td>Exception</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Road site</td>
<td>→</td>
<td>Exception</td>
<td></td>
</tr>
</tbody>
</table>

Source: Matsudo City, Town Improvement Dept, Urban Planning Div (2018, updated data)

Table 2. Selected Indicators for Land Cover Typology of GI
Hyein Kim and Kyunghun Min

Journal of People, Plants, and Environment Vol. 27, No. 3, 2024

Fig. 3. Matsudo City’s Land Cover Typology of GI Map.

excluded them from its GI typology, these LC types were excluded from this study. Due to the regional characteristics of the study area, there is no coastline, and management standards and spatial data are not available for green roofs and street trees, so these were also excluded. In addition, Normalized Difference Vegetation Index (NDVI) data were used to derive green spaces of Private Domestic Garden, Institutional Ground, and General Amenity Space, and spatial data were reclassified using an FGI.

The types that were excluded and integrated in the process of reconstructing the function typology indicators are as follows (Table 3). There are differences between the green travel route and recreation functions in Liverpool and the corresponding definitions in Japan. The green travel route function in Liverpool was defined as green space for pedestrians and bicycle paths, but it was excluded in Japan, as it corresponds to general roads. The recreation function was checked and integrated through a field survey, as the scope and purpose of use of public and private spaces in Liverpool differ from those in Japan.

In Japan, the Corridor for Wildlife function is separately designated and managed as a management area, but since this function is not designated in the study area (Chiba Prefecture, 2022), it is difficult to determine. Therefore, it was replaced by the human-wildlife coexistence function (Sefi Mekonen, 2020) to include both the Habitat and Corridor for Wildlife functions. In addition, in Japan's National GI Strategy (Ministry of Land, Infrastructure, Transport and Tourism, 2023a), the functions of soil/water pollutant removal, air pollutant trapping, and carbon absorption and storage are integrated into the soil/water pollutant removal function, and the functions of rainwater infiltration, conveyance, and interception are integrated into the disaster prevention function.

The characteristics of the selected GI indicators are as follows (Table 4). While the LC types were classified into physical factors (Jones et al., 2022), natural factors (Fatti et al., 2019) and productive factors (Oh et al., 2007), the function types were classified into social function (Mansor and Said, 2008), economic function (Maes et al., 2015) and ecological function (Jim, 2013). Based on this, we sought to examine the characteristics of the study area to
identify what benefits the GI indicators provide to people.

**Functional Assessment by GI Land Cover Type**

After reviewing the GI LC typology used in Liverpool, UK, a globally advanced case of GI strategy, each LC type and function was reclassified to match the status of Matsudo City, Japan, the study area (Table 2 and 3). In this process, a direct survey of relevant specialists/majors was conducted to verify the objectivity, representativeness, and rationality of the LC types and each function. Moreover, to compensate for the limitations of the survey,
a FGI was conducted with experts, and the relative importance was derived using the AHP method (Table 5). Since relative importance is used to calculate weights to compensate for the limitations of the spatial data-based scoring process (Shin, 2015; Min, 2016; Min et al., 2019), specialist weights were assigned to the results of the specialist survey to derive realistic and convincing results.

A direct survey of 41 graduate students majoring in landscape architecture or urban planning, who had lived in the study area for at least five years and had GI expertise, was conducted using a questionnaire that included photos of the area in 2018 and a description of the photos. A 3-point scale was used to ensure smooth scoring of the survey responses. The degree of all functions for each LC type was assessed by assigning a score of 0, 1, or 2 for each question.

The AHP was implemented based on the decisions/judgments of ten experts who participated in a FGI in the process of reconstructing GI LC type and function indicators. They were interviewed using a 9-point scale method and an AHP Excel template to compare the relative importance of each LC type (Goepel, 2013). The consistency index of the judgments was verified (less than 0.1), three categories of LC types were classified, and pairwise comparisons were made between each of the 15 LC types.

**Results and Discussion**

Function scores for each GI were derived for each LC type through a survey. They indicated the degree of function of the relevant land types, which was converted into a score. For each LC type, the function scores were added up to derive the multifunctionality score and rank, and for each function, the function scores of each LC type were also added up to derive the total function score and rank (Table 6). A GI multifunctionality map was constructed by overlaying and mapping the multifunctionality scores for each LC type (Fig. 4).

The higher the score for each function, the lower the degree of external disturbance and damage, indicating that the function is well served in the LC type. The lower the score, the more urbanization has already occurred, indicating a need for conservation or management of the function. The LC type with the highest multifunctionality score was
Table 6. Evaluation of the GI Typology Based on Land Cover and Functions

<table>
<thead>
<tr>
<th>GI Land Cover Typology</th>
<th>Recreation</th>
<th>Learning</th>
<th>Cultural Assets</th>
<th>Heritage</th>
<th>Food Production</th>
<th>Timber Production</th>
<th>Biofuel Production</th>
<th>Waste Management</th>
<th>Water Management</th>
<th>Social and Economic</th>
<th>Environmental Benefits</th>
<th>GI Function Typology</th>
<th>Score</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>General amenity space</td>
<td>0.331</td>
<td>0.316</td>
<td>0.185</td>
<td>0.185</td>
<td>0.193</td>
<td>0.054</td>
<td>0.015</td>
<td>0.015</td>
<td>0.092</td>
<td>0.169</td>
<td>0.177</td>
<td>0.031</td>
<td>0.031</td>
<td>0.015</td>
</tr>
<tr>
<td>Outdoor sports facility</td>
<td>0.499</td>
<td>0.454</td>
<td>0.118</td>
<td>0.109</td>
<td>0.227</td>
<td>0.009</td>
<td>0.018</td>
<td>0.018</td>
<td>0.054</td>
<td>0.118</td>
<td>0.082</td>
<td>0.054</td>
<td>0.045</td>
<td>0.036</td>
</tr>
<tr>
<td>Open Space</td>
<td>1.532</td>
<td>1.386</td>
<td>0.875</td>
<td>0.924</td>
<td>1.361</td>
<td>0.267</td>
<td>0.194</td>
<td>0.292</td>
<td>1.240</td>
<td>1.459</td>
<td>1.410</td>
<td>1.377</td>
<td>1.288</td>
<td>1.313</td>
</tr>
<tr>
<td>Derelict land</td>
<td>0.123</td>
<td>0.079</td>
<td>0.062</td>
<td>0.044</td>
<td>0.079</td>
<td>0.062</td>
<td>0.026</td>
<td>0.070</td>
<td>0.194</td>
<td>0.144</td>
<td>0.114</td>
<td>0.114</td>
<td>0.070</td>
<td>0.097</td>
</tr>
<tr>
<td>Cemetery</td>
<td>0.051</td>
<td>0.056</td>
<td>0.123</td>
<td>0.184</td>
<td>0.077</td>
<td>0.005</td>
<td>0.005</td>
<td>0.010</td>
<td>0.087</td>
<td>0.046</td>
<td>0.041</td>
<td>0.046</td>
<td>0.046</td>
<td>0.046</td>
</tr>
<tr>
<td>Institutional grounds</td>
<td>1.393</td>
<td>1.271</td>
<td>1.149</td>
<td>1.149</td>
<td>1.540</td>
<td>0.122</td>
<td>0.220</td>
<td>0.293</td>
<td>1.222</td>
<td>1.515</td>
<td>1.418</td>
<td>1.515</td>
<td>1.515</td>
<td>1.515</td>
</tr>
</tbody>
</table>

Notably, it was found that "Woodland" provides multiple benefits: an ecological environment suitable for habitat (e.g., sun and wind shelter for humans and wildlife), a social environment (learning and recreation), and economic resources (timber and biofuel). A field survey revealed that the forest areas in the study area, which correspond to "Woodland," had various plant communities, including deciduous and coniferous forests and bamboo forests, and were maintained in a natural state without damage or disturbance by humans (Table 7). On the other hand, the LC type with the lowest GI function score was "Cemetery," accounting for 4.5% (1.09㎢) of the total area. "Cemetery" had high scores for social and ecological functions, with Heritage having the highest score, followed by Cultural Assets, Human-Wildlife Coexistence, Aesthetic, Accessible Water Storage and Disaster Prevention, while it had low scores for economic functions, with Timber Production.
having the lowest score, followed by Biofuel Production, Food Production, and Wind Shelter. For "Cemetery," it seems that only its social functions were emphasized, including history and culture, and its environmental and economic functions were considered very low, thus it was not recognized as GI. In fact, in 1980, a large-scale cemetery was built at the national level within the study area to meet the demand for cemeteries due to population growth in Tokyo. Only half of the total area of the cemetery consisted of graves, and the remaining area consisted of open spaces (e.g., plazas and green areas) corresponding to the GI LC types, and habitats of *Pinus densiflora*, *Pinus thunbergii*, and *Zelkova serrata*, as well as various shrub forests, with their good management status confirmed by a field survey (Table 7). Various educational and promotional actions are needed to change the perception of "Cemetery" as a GI LC type.

By conducting a multifunctional analysis, it was found that the LC types of natural factors categorized in Table 4 have high function scores, and what they provide corresponds to ecological functions. In other words, the LC types of Woodland, Water Body, Water Course, and Wetland provide the ecological functions of "Human-Wildlife Coexistence," "Shading from Sun," "Wind Shelter," "Evaporative Cooling" and "Noise Absorption." As these LC types may be under pressure from urban development and are vulnerable to damage by humans, their ecological function must be maintained through special and ongoing management. There are LC types with low multifunctionality scores that only have high scores for specific functions; continuous, multi-faceted measures should be sought to improve their low-scoring functions.

To maximize the multifunctionality of GI, which provides various benefits to humans, it is important to manage the score for each function according to the LC type. By analyzing the scores of each function, it was found that the scores of ecological functions were significantly high and those of social functions were significantly low. In oth-
er words, the study area has not provided the maximum possible benefits to humans due to the large variance in the scores for each function. LC types with low multifunctionality scores that focus only on specific functions will require actions to increase scores for functions other than those specific functions. Moreover, when promoting the maintenance or development of non-GI elements, including buildings and roads, it is necessary to consider ways to enhance the social functions of the study area that are lacking. If the study area obtains equal function scores by resolving the areas in which functions are inadequate, its multifunctionality scores will be higher, increasing the benefits to humans.

Conclusion

In this study, Japanese GI type and function indicators were reclassified, reorganized, and applied to the actual target site based on Japan's green space-related laws and systems. The multifunctionality scores for each GI type were the highest for Woodland and the lowest for Cemetery. The scores for each GI function were the highest for Human-Wildlife Coexistence, and the lowest for Timber Production. Woodland had the highest function scores for Human-Wildlife Coexistence and Shading from Sun, and the lowest for Food Production. Meanwhile, Cemetery had the highest function score for Heritage and the lowest for Timber Production. Considering the operation and management aspects of GI, Woodland requires continuous conservation and management as it provides shade from sun and wildlife habitat. Meanwhile, although Cemetery had a high heritage value, most of its function scores were lower than those of other land types. For this reason, it can easily be considered a non-functional LC and may be under constant development pressure. Furthermore, there should be ongoing discussions about actions to maximize the historic value of Cemeteries or actions to improve the multifunctionality score by applying other functions to improve the scores for each function.

The Japanese GI and function typology suggested in this study seems sufficient to be used as basic data that should be reviewed when each local government in Japan makes spatial plans related to cities, green spaces, forests, and more. However, to develop the methodology more realistically, the status of the study area needs to be analyzed sufficiently and thoroughly. Moreover, in addition to the professional knowledge of experts, it is necessary to explore in depth the GI types and functions that ordinary study area residents think about, as well as their satisfaction with and improvements to the current GI. Proper use and appropriate management plans for GI are needed to obtain sustainable benefits from nature.

References


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