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A Study on the Development of Green Infrastructure Information Systems for Carbon Neutral Society

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SUMMARY

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As the damage and threats caused by climate change intensify globally, the urgent need to introduce carbon neutrality policies is becoming increasingly evident. In response, a transition to a carbon-neutral society that achieves both climate change mitigation and adaptation is being urged, based on the "Framework Act on Carbon Neutrality and Green Growth for Coping with Climate Crisis," which came into effect in 2023. Moreover, the government has designated "Transition to a Green Economy through Establishing Scientific Carbon Neutrality Implementation Plans" as a national agenda, focusing on devising measures to achieve carbon neutrality.

According to the Intergovernmental Panel on Climate Change (IPCC), green infrastructure is a sustainable approach that can be effectively utilized for both climate change mitigation and adaptation. Particularly, green infrastructure has been selected as one of the most feasible options applicable in urban areas where large-scale physical environmental changes are challenging to implement. Alongside various studies and policies, efforts are being made to achieve a carbon-neutral society through green infrastructure. Both domestic and international policies consider green infrastructure as a carbon sink or a component for disaster response to climate change. Numerous studies are also analyzing the effects of green infrastructure on mitigating urban heat islands, reducing floods, and absorbing carbon.

However, in Korea, the insufficient construction of green infrastructure data hinders its full utilization as a tool for achieving a carbon-neutral society. The lack of data makes it difficult to assess the current status of green infrastructure and to establish plans for additional deployment. Therefore, this study aims to: 1) analyze the demand for green infrastructure to achieve a carbon-neutral society through policy and literature review; 2) comprehensively analyze domestic data related to green infrastructure to identify the data that need to be constructed in the future; 3) organize the relevant laws for constructing green infrastructure data through analysis of related laws and systems. Additionally, 4) by reviewing previous studies on green infrastructure data collection technologies, we aim to derive the necessary technologies and basic data for constructing data for each green infrastructure element; and 5) propose the construction direction and promotion strategies of a green infrastructure information system through comprehensive analysis and expert focus group interviews (FGIs).

Domestic climate change mitigation policies are primarily presented in the "National Carbon Neutrality and Green Growth Basic Plan" and its detailed tasks. By organizing the green infrastructure-related contents of this plan, we can summarize the utilization plans and demand for green infrastructure in climate change mitigation. The plan sets medium- to long-term goals such as expanding carbon sinks, with detailed tasks including the construction of forests, urban forests, green spaces, and reservoirs among green infrastructure elements. These elements are all calculated at the area unit level. For example, policies are formulated, and current statuses are evaluated using average or total values at the area unit level—such as forest area, the number of trees within a unit area, and canopy area—rather than at the individual tree level.

Both domestic and international studies unrelated to policies also deal with similar green infrastructure elements. In summary, studies focus on methods to expand carbon sinks targeting forests, green spaces, and trees, as well as analyzing carbon absorption and storage amounts. Compared to the utilization plans presented in domestic policies, there is active research at the individual tree level with higher resolution, handling attribute information such as diameter at breast height (DBH), tree height, and the number of individuals more precisely.

To achieve climate change adaptation, the "3rd National Climate Change Adaptation Plan" serves as a major policy, accompanied by studies developing national climate

change risk diagnosis methods and the "Vulnerability Assessment Tool to build Climate Change Adaptation Plan (VESTAP)." According to these tools, green infrastructure elements like forests, green spaces, rooftop greening, and trees are proposed to respond to floods, heat waves, and ecosystem damage. For evaluating the current status of green infrastructure or planning, area unit information such as forest area, green space area per capita, and rooftop greening ratios are mainly utilized.

Research on climate change adaptation utilizing green infrastructure frequently addresses individual tree-level elements, in addition to area-unit elements like forests and green spaces. Detailed information such as DBH, tree height, tree species, and leaf area index of individual trees within green spaces is used. While policy analysis and planning are conducted at the local government level, quantitative results are also presented at street and individual tree levels.

Currently, domestic policies utilize green infrastructure information at the area unit level, such as the area of forests and green spaces within a unit area. In contrast, studies analyzing the effects of green infrastructure and proposing utilization plans present results based on individual tree-level information. This indicates that domestic policies are using relatively low-resolution green infrastructure information, and there are no policies utilizing high-resolution data or detailed attribute information. Therefore, to enhance the utilization of green infrastructure for achieving a carbon-neutral society, it is necessary to understand the current status of green infrastructure information in Korea and identify what information needs to be constructed in the future.

To grasp the current status of green infrastructure data construction in Korea, we analyzed public datasets likely to include green infrastructure elements. Ten types of data from the Public Data Portal and the Environmental Spatial Information Service were analyzed, including the Forest Type Map, Land Cover Map, Urban Ecological Status Map, Ecological and Natural Map, Vegetation Map, National Environmental Assessment Map, and Street Tree Data. We organized the green infrastructure elements and attribute information being constructed in each dataset, and summarized constructing and providing institutions, legal grounds, and construction scopes to identify necessary improvements for enhancing data quality and additional construction.

Our investigation revealed that most data are constructed on a national scale, but

datasets like the Urban Ecological Status Map, Aquatic Ecosystem Health Assessment Map, and Street Tree Data are mainly managed at the local government level. Data at the local level have limitations such as inconsistent construction across regions and irregular updating cycles. In contrast, nationally constructed data have legal enforcement, allowing for relatively systematic collection and updates under government management.

Most green infrastructure data are constructed at the area unit level due to the challenges of collecting individual tree-level information or utilizing high-resolution and 3D data across wide spatial ranges. However, some attribute information (e.g., DBH, tree species, tree height, age class, dominant species) is constructed as average values or statistical figures of individual trees within area units.

Data constructed at the local government level tend to include high-resolution information at the individual tree level. However, such data often rely on field surveys, resulting in inconsistent construction methods nationwide and sometimes lack regular updates.

In summary, significant green infrastructure information is included in datasets like the Urban Ecological Status Map, Ecological and Natural Map, Land Cover Map, and Forest Type Map. However, when comparing various data types defined in related laws, data construction for small-scale green infrastructure is relatively insufficient. Area-unit parks, green spaces, and forests are mainly constructed through land cover or ecological maps, and some attribute information is built at the area-unit individual tree level using the Urban Ecological Status Map and Ecological and Natural Map.

To achieve a carbon-neutral society, green infrastructure elements can be organized by scale as forests, urban forests, green spaces, residential areas, rooftop greening, wall greening, and trees. Among these, data at the level of green spaces and smaller are highly applicable for climate change mitigation and adaptation and are often suitable for urban implementation. However, current data construction in Korea is relatively lacking, necessitating the construction of data related to these elements in the future.

To prepare measures for producing and managing green infrastructure information, we analyzed related laws and systems. Approximately 12 laws pertain to green infrastructure, each defining different types from various perspectives.

Laws focusing on urban parks, green spaces, and gardens include the "Act on Urban Parks, Green Areas, etc.," the "Act on the Creation and Management of Urban Forests, etc.," the "Building Act," and the "Housing Act." These laws encompass not only the functions of green infrastructure but also roles in providing urban convenience and rest spaces. Laws treating green infrastructure as foundational facilities include the "National Land Planning and Utilization Act" and the "River Act," regulating elements like rivers, reservoirs, urban natural parks, parks, and green spaces for flood control. Additionally, the "Natural Environment Conservation Act" and the "Natural Parks Act" address green infrastructure as ecological landscapes and natural parks, covering both ecosystem conservation and infrastructural roles.

Comparing with the current status of data construction, the laws that handle underdeveloped but highly utilizable urban green infrastructure elements can be summarized as the "Building Act," the "Housing Act," the "Act on Urban Parks, Green Areas, etc.," and the "Act on the Creation and Management of Urban Forests, etc." The "Building Act" and "Housing Act" deal with elements like rooftop landscaping, wall greening, and landscaping facilities connected to buildings or within sites. The "Act on Urban Parks, Green Areas, etc." covers green infrastructure types like urban parks and park green spaces, classified as green spaces in existing data and research. The "Act on the Creation and Management of Urban Forests, etc." includes street trees alongside urban and living forests. From a data perspective, urban and living forests can be classified as green spaces or forests based on scale, while street trees can be categorized as individual tree data.

To determine the feasibility of constructing currently unbuilt green infrastructure data and identify the necessary technologies and foundational data, we reviewed previous studies on data collection. The analysis indicates that green infrastructure data can be classified by scale into 'national and urban units,' 'area units,' and 'individual tree units.' Technologies for constructing 'area unit' and 'individual tree unit' data—necessary for achieving a carbon-neutral society—utilize high-resolution images like aerial photographs and UAV images, 3D data like LiDAR, and street view images.

Area unit data apply to medium-scale green infrastructure types such as urban parks and green spaces. These data offer more detailed attributes than national and urban unit data, allowing high-quality construction using high-resolution and 3D data like

hyperspectral and LiDAR data. Key attributes include tree species, DBH, above-ground biomass, and carbon storage amount, collected using aircraft-based hyperspectral and LiDAR data, UAVs, and ground-based LiDAR sensors.

Individual tree unit data aim to precisely represent the locations and attributes of individual trees like street trees. Utilizing high-resolution techniques, these data analyze and collect detailed information such as tree locations, species, DBH, height, and crown size. Similar technologies to area unit data are used, including hyperspectral images, UAV images, and various LiDAR sensors. Additionally, methods employing Google Street View and image-based deep learning technologies are also applied.

Consequently, this study proposes the foundational direction for constructing a green infrastructure information system to achieve a carbon-neutral society, encompassing construction direction, promotion strategies, and tasks. We also suggest improvements to related laws and systems to ensure continuous production and management of green infrastructure information according to the system, and present a conceptual diagram of the green infrastructure information system.

Keywords :
Green Infrastructure, Information System, Carbon Neutral Society, Green Spaces, Trees