"Is Urban Green Space Equitably Distributed as a Common Good Within Citizens' Daily Living Areas?"

National Institute of Forest Science
Republic of Korea

Exploring Population Exposure Patterns to Urban Green Spaces Using the 2SFCA Methodology

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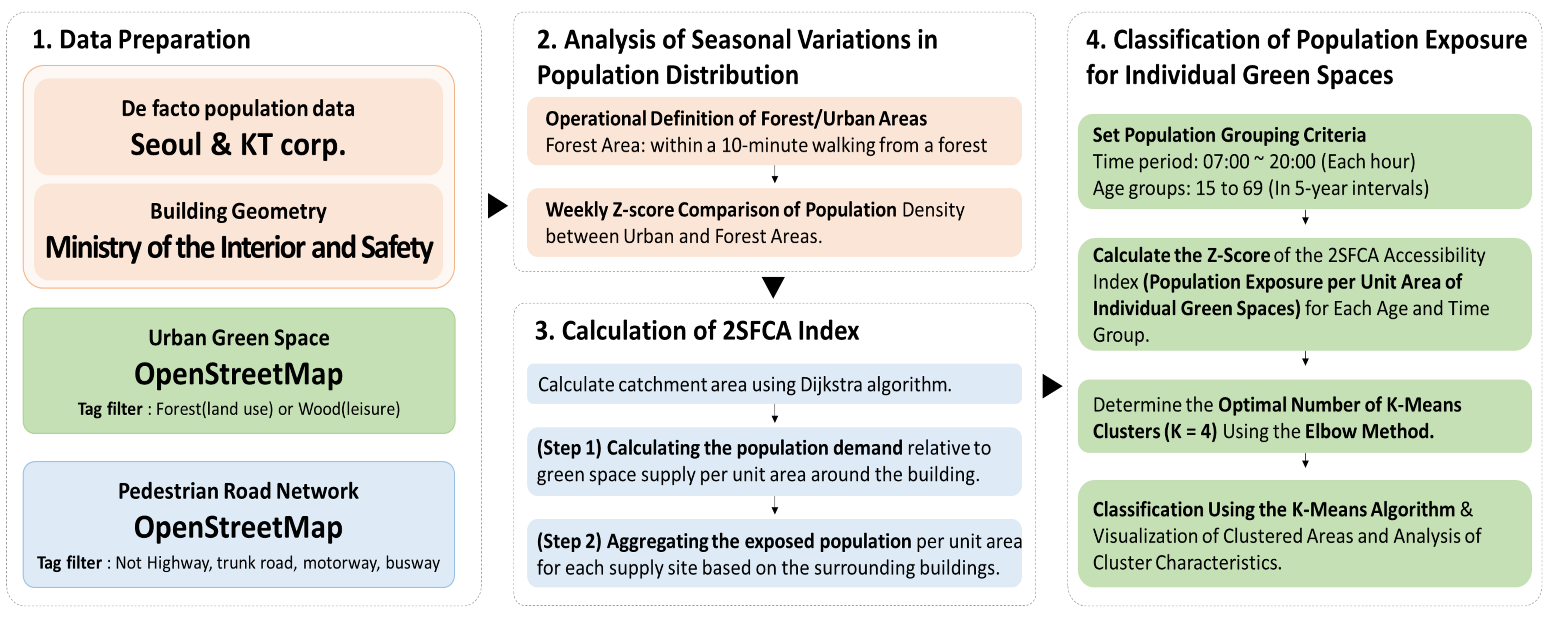
1. Research Background

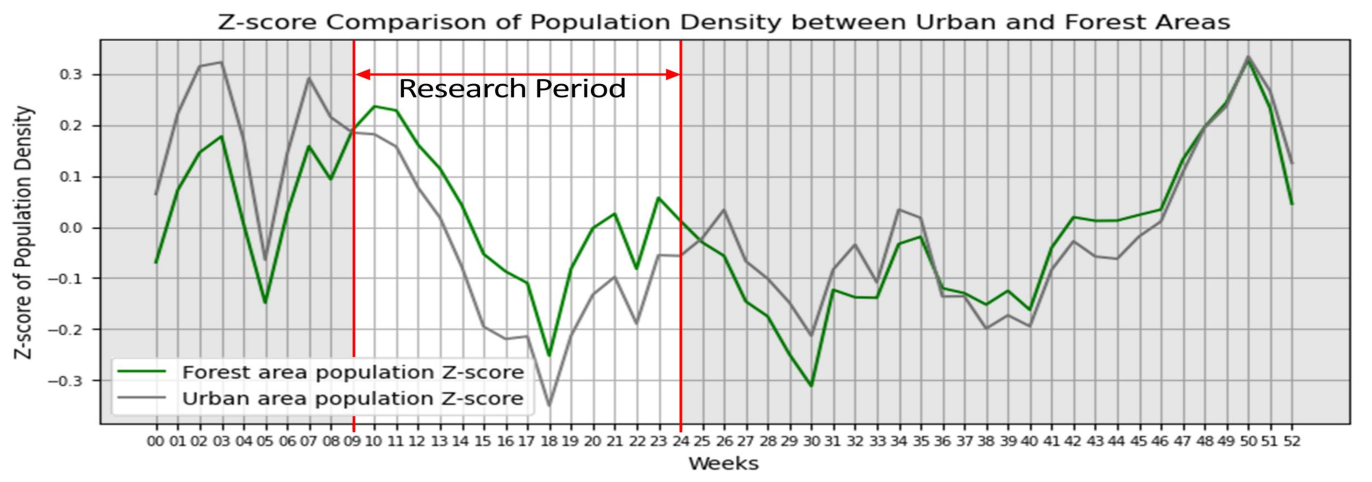
- Urban green space, such as forests and woods within walking distance have been shown to significantly improve the quality of life for city dwellers (Korea Forest Research Institute, 2023).
- Urban green spaces are a non-excludable common good, meaning they are available to everyone. However, their limited availability leads to competition among users, reflecting the characteristics of shared resources.
- There is a need for research on quantitative methods to calculate accessibility indicators that account for the competitive effects among demands near green spaces and the cumulative opportunity effects of supply.
- 2SFCA (Two-Step Floating Catchment Area) method (Luo & Wang, 2003) was used to calculate accessibility.
- This study applies the G2SFCA (Gravity-based 2SFCA) methodology to quantify accessibility to urban green spaces, specifically in residential areas of Seoul, South Korea.
- De facto population data, including attributes such as age and time collected from telecom companies, was utilized in the research to reflect detailed population distribution.
- While the 2SFCA approach is typically used to quantify accessibility from the demand side, this study focuses supply side, analyzing which types of citizens are being provided with opportunities to access urban green spaces.

2. Research Method

- **Data Preparation**
- Population data from Seoul Open Data Plaza (KT's mobile user data), building data from the Ministry of the Interior and Safety, green space data from OpenStreetMap (OSM), and pedestrian road network data were collected and processed using GIS techniques.
- Estimated building-level population by distributing population based on floor area. Larger buildings were assumed to house more people, reflecting greater demand for green spaces.
- Collected green space data with forest or wood attributes from OSM and divided it into 100-meter grids (1 hectare) to prevent overestimation. Green spaces within 100 meters of pedestrian roads were used for analysis.
- Constructed a pedestrian network using OSM road data, excluding highways and vehicle-only roads. Incorporated slope data using DEM to account for gradient effects on walking speed.



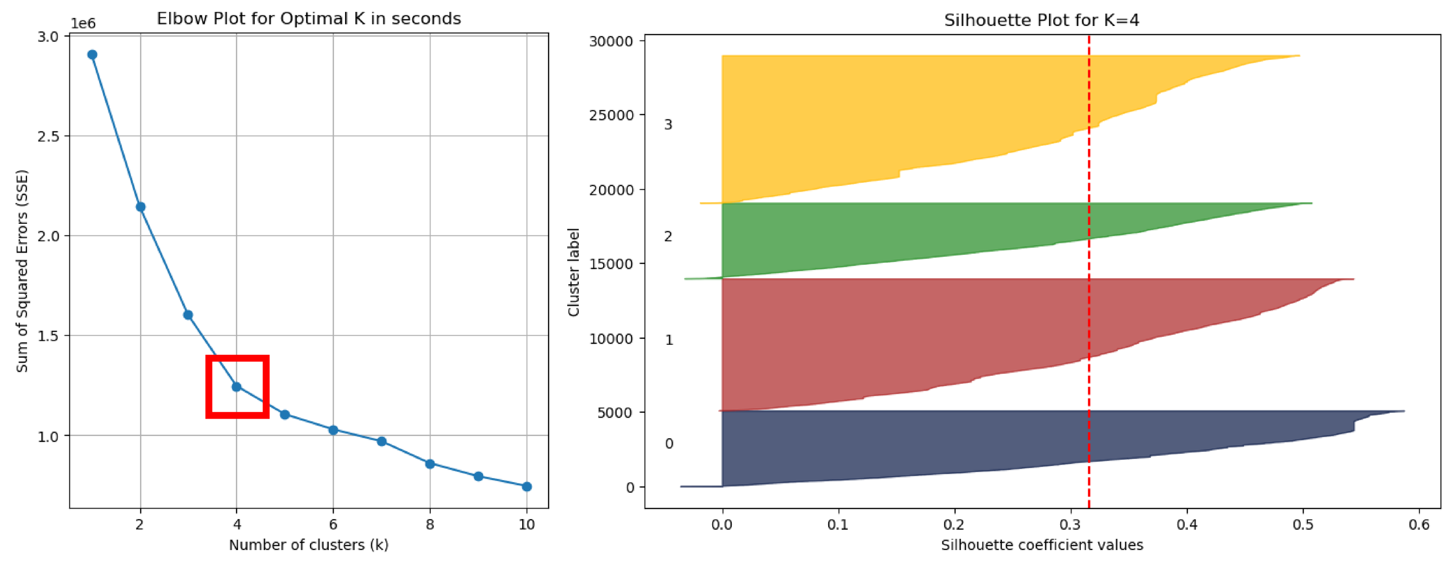
- **Analysis of Seasonal Variations in Population Distribution**
- Seasonal changes and holidays influence the destinations and distribution of urban populations. To account for this, the study area was divided into forest and non-forest zones based on a 10-minute (600 seconds) walking distance to the nearest forest.
- The analysis of population distribution across 52 weeks, differentiating between weekdays and holidays, revealed that the forest zone population surpassed the non-forest zone from the 10th to the 25th week. This phenomenon was more pronounced on weekdays. Therefore, the study focused on analyzing population exposure to green spaces using data from weeks 10 to 25 during weekdays.



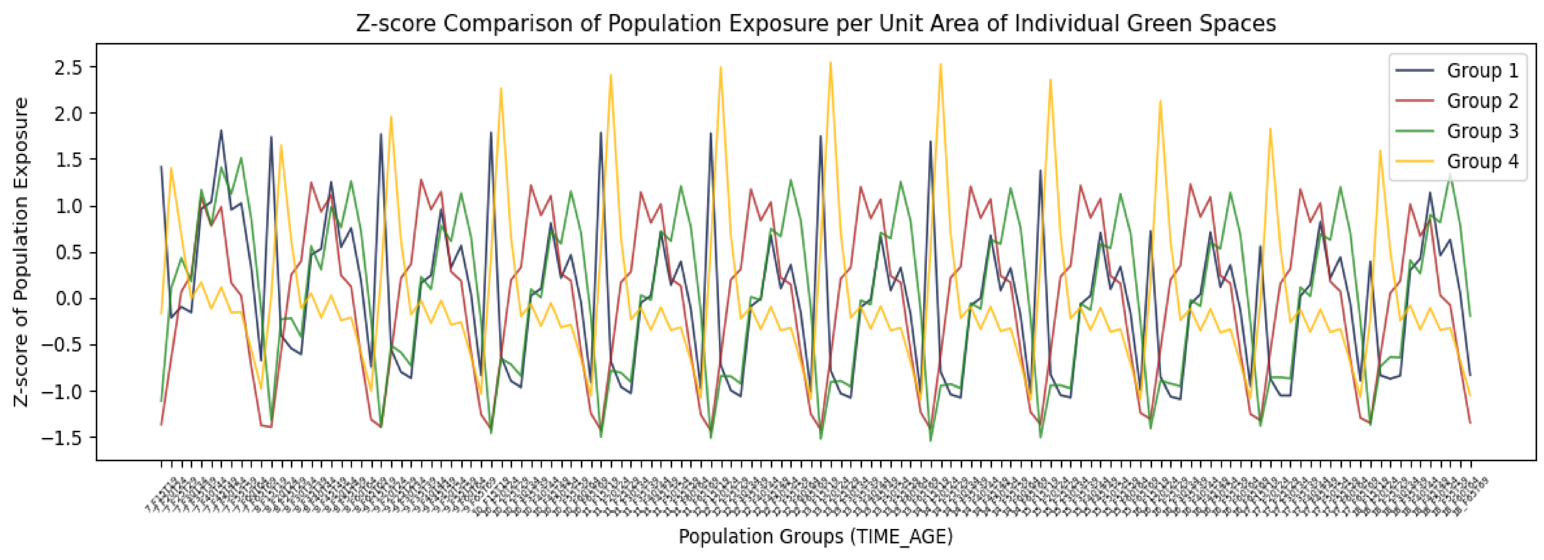
- **Calculation of 2SFCA Index**
- Calculated the distance between buildings and forest points using the Dijkstra algorithm, applying Gaussian weight to account for reduced interaction over longer distances (distance decay effect).
- Conducted 2SFCA analysis in two steps:
  (1) Calculate population demand relative to green space supply per unit area
  (2) Aggregating exposed population per unit area for each supply site based on surrounding buildings.
- **Classification of Population Exposure for Individual Green Spaces**
- Applied Z-score normalization to 2SFCA results to standardize population exposure values and determined the optimal number of clusters using the Elbow Method.
- Visualized clustered areas and analyzed the characteristics of each cluster based on demographic composition, proximity to green spaces, and frequency of use.

3. Result

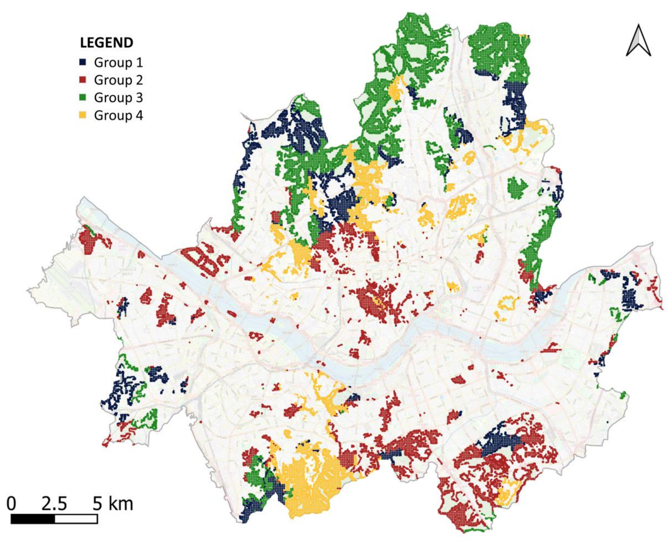
- **Population Grouping and Z-Score Calculation:**
- Divided the population into 132 groups based on time (07:00-20:00, each hour) and age (15 to 69, in 5-year intervals). For example, the population group aged 15 to 19 at 7:00 is labeled as "7_F15T19." The Z-Score of the 2SFCA Accessibility Index was then calculated for each group.



- **K-Means Clustering and Elbow Method**
- Determined the optimal number of clusters using the Elbow Method and classified population exposure patterns using the K-Means algorithm, finalizing the number of clusters (K) at 4.



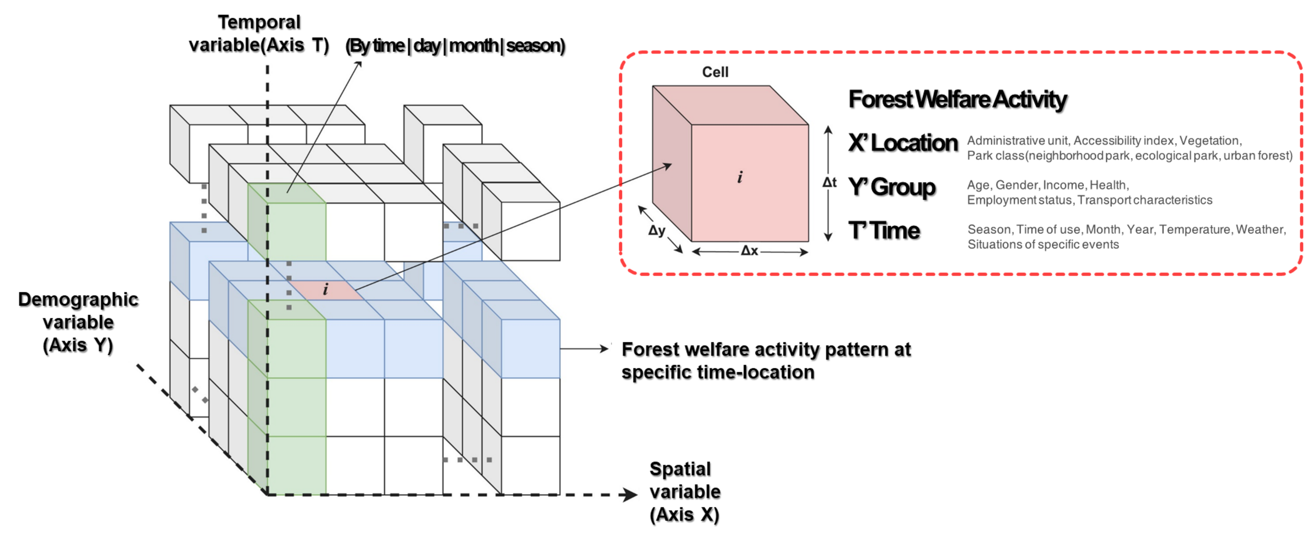
- **Analysis of Population Exposure Variations**
- Analyzed how green space utilization opportunities vary across different population groups based on age and time of day, revealing distinct temporal and demographic variations in green space exposure. Certain clusters showed higher exposure during specific times, particularly for specific age groups, highlighting the interaction between different population segments and urban green spaces.



- Group 1 (Blue) shows significant fluctuations in population exposure during work hours. Notably, exposure is high for the 15 to 19-year-old age group between 7 AM and 3 PM, while the 35 to 55-year-old group shows lower exposure during the same period, only to increase after 3 PM.
- Group 2 (Red) shows relatively little fluctuation in the types of population exposure. The population primarily consists of individuals aged 30 to 49, with a steady level of exposure across different times.
- Group 3 (Green) Similar to Group 2, this group exhibits minimal changes in population exposure throughout the workday. However, the key difference is the higher proportion of individuals aged 50 and above.
- Group 4 (Yellow) experiences noticeable fluctuations in population exposure across the workday. The 20s age group dominates, with exposure steadily increasing in the morning, peaking during the lunch hours (12 PM - 2 PM), and gradually declining afterward.

4. Conclusion

- As population data has evolved, it now allows for detailed analysis by distinguishing demographic characteristics, such as age, and temporal factors like weather and time. This study leverages these characteristics for its analysis.
- Previous studies have suggested the potential for future research to explore green space activity models, as shown in the figure below, by repeatedly calculating accessibility indices for various population groups and applying the K-Means clustering algorithm. This study explores such suggestions and presents a concrete methodology.



Reference

- National Institute of Forest Science (NIFOS), 2023, "Evaluation of the Contribution of Forest Welfare Services to the Quality of Life of the Korean Population"
- Luo, W. & Wang, Fahui., 2003, "Measures of spatial accessibility to health care in a GIS environment: synthesis and a case study in the Chicago region", *Environment and Planning B: Planning and Design*, Vol. 30, Page 865-884.