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Assessment of Green Infrastructure for Conservation Planning using Cadastral Data in Seoul, South Korea

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Abstract

Green infrastructure has been used for environmental conservation and management with many similar concepts such as greenspace network, greenlink network, and greenways network based on objectives of the cities for greening. Seoul established the 2030 Seoul City Master Plan that contains greenlink network projects to connect critical green areas within the city. However, the plan does not have detailed analyses for green infrastructure to incorporate land-cover information to many structural classes. This study maps green infrastructure networks of Seoul for complementing their green plans with identifying and ranking green areas. Hubs and links that are the main elements of green infrastructure have been identified through incorporating cadastral data of 967,502 parcels to 135 of land use maps using Geographic Information System. The study extracted 1,365 of green areas that represent an area of 24,530 ha within the city and buffered these areas to identify districts as critical green areas that have hubs and links. At a city scale, the study used 103,553 of parcel data for ranking extracted 20 districts, and 17,860 of parcel data for ranking extracted 42 links connecting the districts. At a district scale, this study used 87,826 of parcel data for analyzing the status of potential links within the districts and ranking these districts for green infrastructure. This assessment analyzes the main elements of green infrastructure and suggests site prioritization for green infrastructure under variable scenarios of green and developed areas in a metropolitan city.

Keywords

Cadastral data; Conservation planning; Green infrastructure; Land uses

1. Introduction

Seoul is experiencing a rapid urbanization contributed to a number of environmental issues including a decrease in green areas. An increase in impervious areas causes stormwater runoff, the urban heat island, and lower air quality (Seoul, 2014a). The central authority established the 2030 Seoul City Master Plan and the 2030 Seoul City Park and Green Master Plan that contain greenlink network projects to connect critical green areas within the city. However, the plans do not have detailed analyses for green infrastructure networks for conservation planning. Thus, this study maps green infrastructure networks of Seoul for complementing their green plans with identifying and ranking green areas. Main data of this study are land cover maps for identifications of hubs and links and cadastral data for ranks of these with incorporating land-cover information to structural classes.

Cadastre is comprised of parcels with land information such as parcel numbers, land categories, and areas (Nam, 1999). The act of geospatial management of South Korea describes that a parcel should have one number and be categorized based on its main land uses (MOLEG, 2018). Cadastral data consist of the public cadastral register books and maps administered by the government (Lee, Yang, & Baeg, 2012; Goh, Park, & Choi, 2013; Kim, 2010). The government transferred paper based data of cadastre into computerized data since 1978. Approximately 75 million cadastral maps were transferred paper into computerized data between 1999 and 2003 (Kim, 2012). The computerized data have been used to administer private and public land by the government and used in real estate market (Choi, 2000). The computerized cadastral data are constantly increased and used for analyses of economy and environment. Parcel information in the data is analyzed to assess developments such as regional unbalanced development and locally specialized industries, and environment issues such as soil pollution and stormwater runoff (Nam & Lee, 2009; Lee & Hwangbo, 2007; Kim, 2001; Lee, Sim, & Min, 2009).

Green infrastructure is an interconnected network of natural life support system consisted of hubs and links (Benedict & McMahon, 2012). Hubs are large areas of natural vegetation for wildlife with ecological processes such as reserves, managed native landscapes, working lands, regional parks, preserves, community parks, and natural areas, interconnected by links such as landscape linkages, conservation corridors, greenways, greenbelts, and eco-belts (Benedict & McMahon, 2012; Wickham, Riitters, Wade, & Vogt, 2009; Weber, Sloan, & Wolf, 2005). An increase in population and urbanized land causes a decrease in green areas (Benedict & McMahon, 2012; Gill, Handley, Ennos, & Pauleit, 2007; Schilling & Logan, 2008). Green infrastructure is a framework for conservation planning and provides ecological, social, and economic benefits (Benedict & McMahon, 2012; Wickham, Riitters, Wade, & Vogt, 2009; Sarte, 2010; Tzoulas et al., 2007). Green infrastructure provides ecosystem services with provisions including water quality, food quality, and medicine (Coutts & Hahn, 2015). Green infrastructure can be an urban system for human benefits and connects networks for neighbourhood, culture, and communities (Wolf, 2003; Wright, 2011). Green infrastructure also provides economic benefits with energy savings from reducing indoor temperature and an increase in air quality (Wang, Bakker, De Groot & Wörtche, 2014).

Geographic information system (GIS) techniques are used to map green infrastructure (Wickham, Riitters, Wade, & Vogt, 2009). GIS techniques were used to analyze the effects of green infrastructure on environment issues such as ecosystem services, climate changes, and stormwater management (Wickham, Riitters, Wade, & Vogt, 2009; Kopperoinen, 2014; Jayasooriya & Ng, 2014). Green infrastructure maps can be developed with GIS using orthophotos, cartographies, and field surveys (La Greca, La Rosa, Martinico& Privitera, 2011). The integrated method using remote sensing and GIS technique provides a significant tool to map green areas networks (Abbas, & Arigbede, 2012). Green infrastructure maps developed by GIS provides many information such as land covers, land uses, biodiversity, and other environmental variables (Zulian, Polce & Maes, 2014).

The City of Surrey in British Columbia, Canada, incorporated land cover data extracted from GIS data on impedance values for their ecosystem management (City of Surrey, 2011). Impedance values are weighted with vegetation coverage, types, age of green space, and degree of anthropogenic disturbance (Kong, Yin, Nakagoshi, & Zong, 2010). The affection values of land covers are also used to analyze ecological connectivities in a city (Chang, Li, Huang, & Wu, 2011).

The aim of this study is to assess green infrastructure for conservation planning using land cover maps and cadastral data. Land cover maps were used to identify elements of green infrastructure using GIS techniques, and cadastral data were used to analyze levels of green infrastructure using impedance values of land categories of the data. The site prioritization for green infrastructure was also done with analysis of ranks of hubs, potential links, and links.

2. Land Cover Maps and Cadastral Data for Elements of Green Infrastructure

2.1. Study Area

Seoul, selected as the study area, is the capital of South Korea and the metropolitan city with the population of 10.57 million within the area of 605,960,000 m^2. Population was rapidly increased from 0.65 million to 10.97

million between 1951 and 1992 (Seoul, 2014a). The impervious area rate was 47.28% in 2005 and 47.64% in 2010 and the forest area rate was 25.29% in 2005 and 24.96% in 2010. The urbanized area rate was 60.98% and the green and open area rate was 39.03% in 2010. The total park area was 170,100,000 m^2 that is 28.09% of Seoul and the park area per person was 16.37 m^2 in 2014 (Seoul, 2014b). An increase in impervious and urbanized areas disrupts green infrastructure networks and causes the urban heat island.

2.2. Objectives of Land Cover Maps and Cadastral Data

Land cover maps based on satellite imagery and cadastral data were the main data to analyze green infrastructure in Seoul. Land cover maps and cadastral maps provide many land information, but they provide different types of data of land uses, districts, and areas based on their objectives. Land cover maps do not have legal boundaries and are used as references and open data for studies and researches. Cadastral maps are used to tax and manage properties administered by Korean laws (Table 1).

Table 1. Differences between land cover maps and cadastral data

Resources	Land cover maps	Cadastral data
Legal limitation	No	Yes
Analysis	Spatial analysis	Data analysis
Objective	Identification of elements of green infrastructure	Ranks elements of green infrastructure

2.3. Elements of Green Infrastructure

The main elements of green infrastructure are mainly classified into hubs and links, whilst this study classified elements of green infrastructure into three elements that are hubs, potential links within hubs, and links for a detailed analysis of district priorities.

The definitions of these elements within this study are different with classical definitions of elements of green infrastructure. Hubs in a classical definition are large areas of natural vegetation, whilst hubs in this study were extracted after buffer analysis based on forest areas of land cover maps to identify significant green areas. Potential links within a hub in this study indicate areas within a hub except forest areas of land cover maps to identify interaction between green areas within a hub. Links in this study indicate straight lines of the shortest distance between hubs to identify corridors connecting hubs (Table 2).

Table 2. Elements of green infrastructure

Elements	Spatial feature	Objective
Hubs	Connected large areas of buffered forest areas of land cover maps	Identification of important areas that contain large green areas.
Potential links	Areas within a hub except forest areas of land cover maps	Identification of interaction between forest areas within a hub
Links	The shortest connection between hubs	Identification of corridors that connect hubs

3. The Process to Assess Green Infrastructure

3.1. Identification and Rank Processes

Land cover maps were used to identify hubs, potential links, and links with GIS techniques. Cadastral maps were used to analyze important levels of hubs, potential links, and links with statistical methods. Identification of hubs was a fundamental element to identify potential links within hubs and links that connect hubs. This study assumed forest areas of land cover maps as significant green areas for hubs, because forest areas have the lowest impedance value for green infrastructure (Fig. 1a).

The extracted hubs, potential links, and links were used as districts of elements of green infrastructure and incorporated with cadastral data to analyze values of green infrastructure. Hubs, potential links, and links have land categories and areas from cadastral data within their boundaries. These parcel data were incorporated on impedance values of land uses, and used to analyze priorities of hubs, potential links, and links with applying calculated impedance values of hubs, potential links, and links (Fig. 1b).

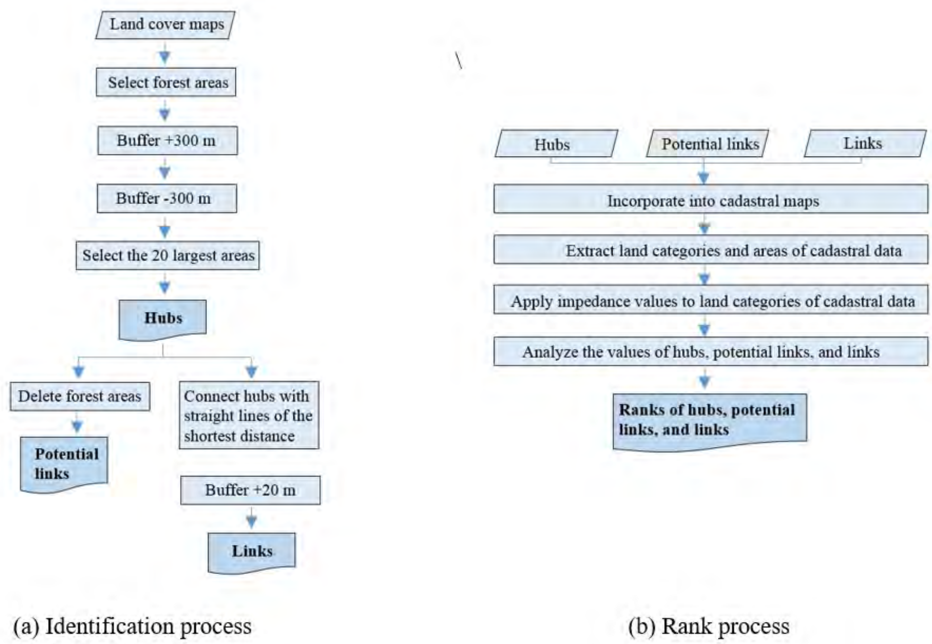

Figure 1. Identification and rank processes of elements of green infrastructure

3.2. Impedance Values

Impedance values are weighted based on vegetation coverage and type, the age of the green space, and degree of anthropogenic disturbance (Kong, 2010). Impedance values of land uses for green infrastructure from prior two studies were applied to 26 categories of land uses of cadastral data (City of Surrey, 2011; Kong, 2010). The application of impedance values to cadastral data indicates that forest areas of cadastral data are the most significant green area for green infrastructure because forest areas have a lowest impedance value among 26 categories of land uses, whilst constructed areas, industry areas, gas station, and warehouse have negative effects on green infrastructure with high impedance values (Table 3) (Park, Kim, & Hong, 2018).

Table 3. Impedance values of land categories of cadastral data

Land categories	Impedance values	Land categories	Impedance values	Land categories	Impedance values
Forest	63	Water supply site	500	Religion	1,500
Reservoir	100	Parking lot	1,000	Historical site	1,500
Park	100	Road	1,000	Graveyard/cemetery	1,500
River/Stream	150	Railroad	1,000	Miscellaneous land	1,500
Fish farm	150	River bank	1,000	Gas station	2,500

Continued on next page

Table 3 continued

Land categories	Impedance values	Land categories	Impedance values	Land categories	Impedance values
Vegetation	190	Ditch/Sewer	1,000	Warehouse	2,500
Agriculture	190	School area	1,500	Residential area	2,750
Orchard	244	Sports facilities	1,500	Industry area	2,750
Livestock farm	244	Amusement park	1,500		

3.3. Equations for Importance and Connectivity Values of Hubs, Potential Links, and Links

To analyze green infrastructure values and connectivity values of hubs, potential links, and links, this study created and used followed three equations. The Green Infrastructure Value (GIV) represents the significance of hubs and the condition of green infrastructure of hubs. The higher GIVs indicate more significant green areas for green infrastructure. GIVs are calculated as:

$$GIV_{Hubi} = [TA_{Hubi} / \sum(A_{Hubi} I_{Hubi})]\, 1000 \tag{1}$$

Where GIV_{Hubi} is the green infrastructure value of Hubi, TA_{Hubi} is the total area of parcels of cadastral data within Hubi, A_{Hubi} is the area of each parcel within Hubi, and I_{Hubi} is an impedance value of each parcel within Hubi.

Interaction between forest areas indicates the efficiency of potential links within hubs. The Interaction Value (IV) within a hub shows levels to connect forest areas for green infrastructure networks within a hub. The higher IVs indicate more significant potential links within hubs for green infrastructure. IVs are calculated as:

$$IV_{Hubi} = [TA_{Hubi} / \sum(A_{PLj} I_{PLj})]1000 \tag{2}$$

Where IV_{Hubi} is the interaction value of potential links within Hubi, TA_{Hubi} is the total area of parcels of cadastral data within Hubi, A_{PLj} is the area of each parcel that is extracted areas excepting forest areas within Hubi, and I_{PLj} is an impedance value of each parcel.

The Connectivity Value (CV) indicates the efficiency of links between hubs. The higher CVs indicate more significant links to connect hubs for green infrastructure within Seoul. CVs are calculated as:

$$CV_{Linkt} = [TA_{Linkt} / \sum(A_{Linkt} I_{Linkt})]1000 \tag{3}$$

Where CV_{Linkt} is the connectivity value of Linkt, TA_{Linkt} is the total area of parcels of Linkt, A_{Linkt} is the area of each parcel within Linkt, I_{Linkt} is an impedance value of each parcel.

4. Identifying and Ranking Elements of Green Infrastructure

4.1. Data Preprocessing

The Ministry of Environment provides land cover maps having different resolutions. Within Seoul, the land cover map is separated to 135 tile maps. This study combined the separated 135 land cover maps to a raster land cover map that has 1:5,000 scale, 1 m resolution, and seven categories of land uses. Within the map, Seoul has 660,657,635 m^2 that is a different area in comparison of the total area of cadastral maps. The map shows that impervious areas have 7,164 parcels and 352,254,286 m^2 that are 53% of the total area of Seoul. Forest areas have 1,365 land cover parcels and 143,144,713 m^2.

Cadastral maps provide important information of parcels such as objective IDs, districts, parcel numbers, and land categories. Cadastral data of Seoul indicate 605,711,407 m^2 of city areas, 25 boroughs and 967,502 cadastral parcels. With analyzing land use categories of cadastral data, constructed areas have 718,070 parcels that are 217,974,644 m^2 and road areas have 149,051 parcels that are 78,569,109 m^2. Forest areas have 20,959 parcels that are 140,548,998 m^2. Vegetation areas have 18,188 parcels that are 11,387,207 m^2 and agriculture areas have 13,386 parcels that are 12,150,105 m^2. Cadastral data shows that 49% of Seoul is constructed and road areas that can be impervious areas, whilst 23% of Seoul is forest areas.

4.2. Identifying Hubs, Potential Links, and Links

Figure 2. The extracted hubs, potential links, and links

Forest areas of land cover maps were buffered with 100 m, 300 m, and 500 m to find an appropriate buffered distance for classification of hubs. With 100 m buffer of forest areas, 172 hubs were extracted with 245,300,404 m^2. With 300 m buffer of forest areas, 43 hubs were extracted with 352,217,049 m^2. With 500 m buffer of forest areas, 16 hubs were extracted with 430,667,859 m^2. This study selected 300 m buffer of forest areas to identify hubs based on Landscape Management Areas of Seoul City. With minus 300 buffer, this study extracted 124 forest areas and selected the top 20 buffered areas in terms of surface areas as the main hubs for green infrastructure in Seoul. Within top 20 hubs, 2,570 potential links were extracted with deleting forest areas of land cover maps within 20 hubs (Fig. 2).

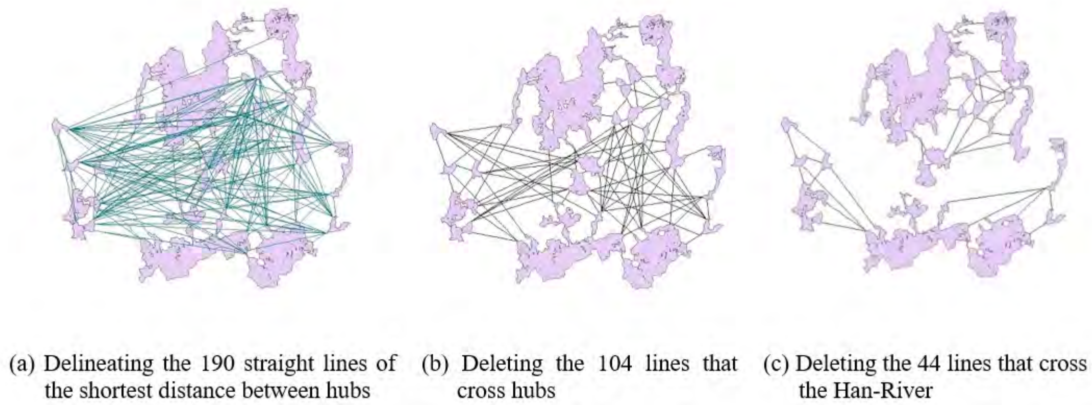

Figure 3. The process to extract links

To identify links, this study delineated 190 straight lines of the shortest distance between hubs (Fig. 3a). In 190 lines, 104 lines that cross hubs (Fig. 3b) and 44 lines that cross Han-River were deleted (Fig. 3c).

Finally, 42 lines were extracted and buffered with 20 m wide that is a same wide of three green ways of the 2030 Seoul City Park and Green Master. With these processes, this study extracted and used 20 hubs and 42 links as the elements of green infrastructure in Seoul (Fig. 4).

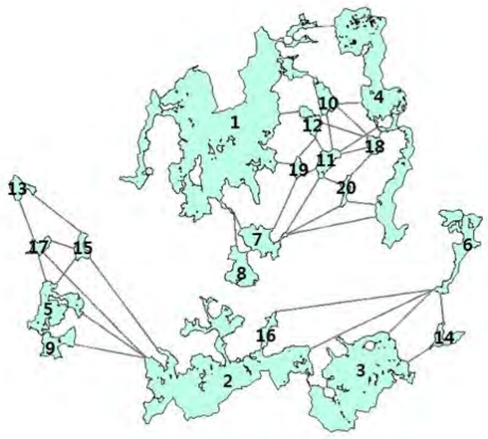

Figure 4. The extracted 20 Hubs and 42 links within Seoul.

4.3. Ranking Hubs, Potential Links, and Links

The extracted 20 hubs have a total area of 186,156,839 m2 from 103,553 cadastral parcels (Fig. 2a). Hub1 has the most parcels (45,652) totalling the largest area of 62,672,277 m2. Hub18 has the least parcels (272) with an area of 1,001,803 m2. Hub20 has the smallest area of 806,311 for 312 parcels. Within 20 hubs, parcels that have forest areas of land categories of cadastral data were comprised of 123,755,018 m2 that is 66% of the total area of hubs. Residential areas have the second largest area of 24,072,382 m2 that is 13% of the total area of hubs. GIVs of hubs indicate conditions of land categories of hubs for green infrastructure. The 20 hubs have an average of an importance value of 1.803. Hub18 that has the third smallest area has the highest GIV of 4.650. Hub8 that has the eighth highest area has the lowest GIV of 0.402. The results show that Hub18, Hub13, Hub3, Hub2, and Hub4 is the top five districts that have higher conditions for green infrastructure than other 15 hubs. Hub8, Hub11, Hub17, Hub16, and Hub19 are the districts that have lower conditions for green infrastructure (Table 4).

Table 4. Importance and connectivity values and ranks of hubs

Hubi	GIV		IV		Hubi	GIV		IV	
	Values	Ranks	Values	Ranks		Values	Ranks	Values	Ranks
Hub1	1.841	9	2.465	9	Hub11	0.933	19	1.199	20
Hub2	2.187	4	2.691	7	Hub12	1.593	11	1.911	14
Hub3	2.764	3	3.840	2	Hub13	3.587	2	1.762	17
Hub4	2.174	5	3.509	3	Hub14	1.994	8	2.506	8
Hub5	1.221	14	1.329	19	Hub15	2.092	6	2.420	10
Hub6	1.276	13	1.574	18	Hub16	0.984	17	2.261	12
Hub7	1.641	10	2.177	13	Hub17	0.960	18	2.397	11
Hub8	0.402	20	3.191	5	Hub18	4.650	1	3.479	4
Hub9	1.418	12	2.796	6	Hub19	1.156	16	1.802	16
Hub10	2.011	7	1.868	15	Hub20	1.168	15	5.894	1

Within the 20 hubs, 32% of the total area is extracted as potential links that have 59,729,682 $m^2$from 88,424 cadastral parcels (Fig. 2b). Hub5 and Hub6 have the highest rates of potential links of 50% within their areas. Hub1 has the largest area of potential links with 19,419,578 m^2 that is 31% of the total area of Hub1. Within 2,570 potential links from 20 hubs, residential areas of cadastral data have the largest area of 18,627,780 m^2 that is 31% of the total area of potential links within hubs. Forest areas have the second largest area of 17,144,331 m^2 that is 29% of areas of potential links.The IVs of hubs indicate connections between forest areas for green infrastructure within a hub. The average IV of the is 2.554. Although, Hub20 has the smallest area, it has the highest IV of 5.894. Hub3 has the third highest area and the second highest IV of 3.840. Hub11 has the lowest IV of 1.199. Hub20, Hub3, Hub4, Hub18, and Hub8 have higher connections between forest areas for green infrastructure than other hubs.

Hub5, Hub6, Hub13, Hub11, and Hub19 have lower connections for green infrastructure than other hubs (Table 4) The extracted 42 links have 17,860 cadastral parcels with 4,868,134 m^2. Although a link between Hub5 and Hub9 has 3 parcels, a link between Hub2 and Hub17 has 1,432 parcels. A link between Hub6 and Hub16 has the largest area of 442,937 m^2 from 687 parcels. A link between Hub2 and Hub16 has the smallest area of 1,358 m^2 from 5 parcels. Within 42 links, residential areas of land categories have the largest area of 2,523,686 m^2 that is 52% of the total area of 42 links. Road areas have the second largest area of 938,667 m^2 that is 19% of the total area of potential links. The eight links have higher connectivity values than 1 and 34 links have lower connectivity values than 1. A link between Hub2 and Hub3 has the highest connectivity value of 37.614 and a link between Hub2 and Hub16 has the second highest connectivity value of 27.909. A link between Hub2 and Hub9 has the lowest connectivity value of 0.005. The average connectivity value except the 10 highest and 10 lowest values was 0.577 (Table 5).

Table 5. Connectivity values (CV) and ranks of links

Links	Connectivity		Links	Connectivity		Links	Connectivity	
Hub(i, j)	Values	Ranks	Hub(i, j)	Values	Ranks	Hub(i, j)	Values	Ranks
Hub(1, 4)	1.017	8	Hub(3, 14)	3.780	4	Hub(7,20)	0.527	21
Hub(1, 7)	0.250	35	Hub(4, 7)	0.154	38	Hub(10, 11)	0.474	26
Hub(1, 8)	0.309	34	Hub(4, 10)	0.985	9	Hub(10,12)	1.147	7
Hub(1, 10)	0.876	11	Hub(4, 11)	0.072	40	Hub(10, 18)	0.638	16
Hub(1, 12)	0.077	39	Hub(4, 18)	2.618	5	Hub(11, 12)	0.632	17
Hub(1, 19)	2.197	6	Hub(4, 20)	0.012	41	Hub(11, 18)	0.563	19
Hub(2, 3)	37.614	1	Hub(5, 9)	8.694	3	Hub(11, 19)	0.741	15
Hub(2, 5)	0.480	25	Hub(5, 15)	0.453	31	Hub(11, 20)	0.469	29
Hub(2, 6)	0.421	33	Hub(5, 17)	0.973	10	Hub(12, 18)	0.597	18
Hub(2, 9)	0.005	42	Hub(6, 14)	0.872	12	Hub(12, 19)	0.462	30
Hub(2, 15)	0.747	14	Hub(6, 16)	0.497	22	Hub(13, 15)	0.788	13
Hub(2, 16)	27.909	2	Hub(7, 8)	0.483	24	Hub(13, 17)	0.473	27
Hub(2, 17)	0.212	36	Hub(7, 11)	0.488	23	Hub(15, 17)	0.436	32
Hub(3, 6)	0.207	37	Hub(7, 19)	0.469	28	Hub(18, 20)	0.532	20

5. Discussion and Conclusion

This study quantifies values of elements of green infrastructure in Seoul. The method also provides critical areas to the city for conservation planning based on different objectives. At a city-scale, hubs and links are used as the elements of green infrastructure. When the city focuses on the three green districts, Hub18, Hub13, and Hub3 are the significant hubs for green infrastructure. When the city focuses on the three green ways, links between Hub2 and Hub3, Hub2 and Hub16, and Hub5 and Hub9 are the significant links for green infrastructure. If the city needs to select green areas among Hub2, Hub3, Hub14, and Hub16 for conservation planning, Hub2 and Hub3 are the significant area based on the framework of green infrastructure. At a hub-scale, the hubs and potential links are used as the elements of green infrastructure. When the city needs to select green districts among Hub1, Hub14, and Hub19, Hub14 is the significant district for green infrastructure.

This study identified and ranked elements of green infrastructure within Seoul. Green infrastructure is mainly mapped using land cover maps with GIS techniques (Davies, Edmondson, Heinemeyer, Leake & Gaston, 2011; Gill, Handley, Ennos, & Pauleit, 2007; Wickham, Riitters, Wade, & Vogt, 2009; Xiao, Shen, Ge, Tateishi, Tang, Liang & Huang, 2006). This study also used land cover maps to map green infrastructure and incorporated land covers on cadastral data to apply the results on the policy of Seoul, because cadastral data have legal limitation in contrast with land cover maps. Forest areas are considered as significant green areas, because forest areas have the lowest impedance value for green infrastructure. The main objective of using land use maps is to identify hubs, potential links, and links with delineating districts of these elements. The main objective of using cadastral data is to rank hubs, potential links, and links analyzing land categories of parcels within their districts. Incorporating land cover maps on cadastral data to extract elements of green infrastructure, this study identified 20 hubs (103,553 cadastral parcels), 2,570 potential links (88,424 cadastral parcels), and 42 links (17,860 cadastral parcels). This study analyzes the weight of hubs, potential links, and links for green infrastructure using impedance values on categories of cadastral parcels. The three equations were created to calculate importance values of hubs, potential links, and links. Finally, this study ranked hubs, potential links, and links for green infrastructure and suggests site prioritization for green infrastructure planning in Seoul. The 2030 Seoul City Master Plan has the plan to construct the 47 green ways (117,320 m) to 2030, but their plan does not consider connection of hubs and links (Seoul, 2014a). Thus, this study suggests the significant green areas and their corridors. Site prioritization provides green areas for the urban green space strategy depending on many scenarios.

Incorporating data of land cover maps on cadastral data is a important process to support the city green strategy. The cadastral data resolve lack of land cover maps that do not have legal limitations. Incorporation allows the results to apply to the green strategy of the city. The three equations are also useful to rank elements of green infrastructure for site prioritization.

The significant data are impedance values to analyze levels of green areas for green infrastructure. Impedance values used in the two prior studies have different environmental process because the values are extracted from different countries, different methods, and different times. To achieve precise data for the city, further studies are needed to research impedance values of land uses that have characters of the city based on the wider environmental factors. The links in this study are extracted with delineating straight lines between hubs. To extract links that are appropriate to the city, further studies are needed to delineate links that have a variety of shapes depending on many strategies of the city for their conservation programs. Suggesting significant green areas for green infrastructure in this study is a part of many complex processes for green infrastructure planning (Kambites & Owen, 2006). The ideal green infrastructure planning will be proposed with the interdisciplinary further research considering variable principles for green infrastructure.

6. References

1. Abbas, I. I., & Arigbede, Y. A. (2012). Green Area Mapping of Ahmadu Bello University Main Campus, Zaria, Nigeria using Remote Sensing (Rs) and Geographic Information System (Gis) Techniques. Journal of Geography and Regional Planning, 5(10), 287-292.

2. Benedict, M. A., & McMahon, E. T. (2012). Green infrastructure: linking landscapes and communities. Island Press.

3. Chang, Q., Li, X., Huang, X., & Wu, J. (2012). A GIS-based green infrastructure planning for sustainable urban land use and spatial development. Procedia Environmental Sciences, 12, 491-498.

4. Choi, J. I. (2000). A study on utilization and reinvestigation of cadastral. Journal of the Korea Society of Cadastre, 16(2), 41-52.

5. City of Surrey. (2011). City of Surrey Ecosystem Management Study. Retrieved from https://www.surrey.ca/files/Surrey_EMS_Final_Repor_ Consolidated__ April_2011.pdf

6. Coutts, C., & Hahn, M. (2015). Green Infrastructure, Ecosystem Services, and Human Health. International Journal of Environmental Research and Public Health, 12(8), 9768-9798.

7. Davies, Z. G., Edmondson, J. L., Heinemeyer, A., Leake, J. R., & Gaston, K. J. (2011). Mapping an Urban Ecosystem Service: Quantifying Above-Ground Carbon Storage at a City-Wide Scale. Journal of Applied Ecology, 48(5), 1125-1134.

8. Gill, S. E., Handley, J. F., Ennos, A. R., & Pauleit, S. (2007). Adapting cities for climate change: the role of the green infrastructure. Built environment, 33(1), 115-133.

9. Goh, G. W., Park, M. H., & Choi, S. Y. (2013). The segmentation strategies of land category for the efficient land use and registration. Journal of the Korea Society of Cadastre, 29(2), 21-38.

10. Jayasooriya, V. M., & Ng, A. W. M. (2014). Tools for modeling of stormwater management and economics of green infrastructure practices: a review. Water, Air, & Soil Pollution, 225(8), 2055.

11. Kambites, C., & Owen, S. (2006). Renewed Prospects for Green Infrastructure Planning in the UK. Planning, Practice & Research, 21(4), 483-496.

12. Kim, H. J. (2012). A study on the improvement and problems of the land and real estate information regeneration. Journal of the Korea Society of Cadastre, 28(1), 25-42.

13. Kim, S. T. (2010). A study on the materialization for the integration management of cadastral information. Journal of the Korea Society of Cadastre, 26(2), 99-112.

14. Kim, Y. H. (2001). A study on the control conditions of soil pollution by land category. Journal of Korean Association of Cadastre Information, 3(1), 109-131.

15. Kim, Y. H. (2012). A study on the sustainable parcel management. Journal of Korean Association of Cadastre Information, 14(1), 163-187.

16. Kong, F., Yin, H., Nakagoshi, N., & Zong, Y. (2010). Urban green space network development for biodiversity conservation: Identification based on graph theory and gravity modeling. Landscape and urban planning, 95(1-2), 16-27.

17. Kopperoinen, L., Itkonen, P., & Niemela, J. (2014). Using expert knowledge in combining green infrastructure and ecosystem services in land use planning: an insight into a new place-based methodology. Landscape Ecology, 29(8), 1361-1375.

18. Korea Ministry of Government Legislation(MOLEG), (2018). Act on the deployment and management of sptial information Retrieved from https://opengov.seoul.go.kr/public/7331743 http://www.law.go.kr.

19. La Greca, P., La Rosa, D., Martinico, F., & Privitera, R. (2011). Agricultural and Green Infrastructures: The Role of Non-Urbanised Areas for Eco-Sustainable Planning in a Metropolitan Region. Environmental Pollution, 159(8-9), 2193-2202.

20. Lee, G. S., Kim, Y. R., Sim, J. M., & Min, K. S. (2009). The analysis of land category information for flood inundation area based on GIS. Journal of Korean Association of Cadastre Information, 11(2), 45-55.

21. Lee, M. K., & Hwangbo, S. W. (2007). Analysis of regional specialized industry using zone land category - Based on Jeju special province. Journal of Korean Association of Cadastre Information, 9(1), 13-28.

22. Lee, S. h., Yang, C. M., & Baeg, S. C. (2012). Improvement on location based parcel numbering system. Journal of Cadastre & Land Informatix, 42(1), 147-164.

23. Nam, N. S., & Lee, Y. J. (2009). A study on the regional development for economic vitalization of region - Focuses on utilizing regional amenity. Journal of Korean Association of Cadastre Information, 11(2), 153-171.

24. Nam, U. K. (1999). A study on development of the parcel number system in Korean. Journal of Korean Association of Cadastre Information, 1, 1-14.

25. Park, G., Kim, Y. K., & Hong, S. E. (2018). Assessing Levels of Green Infrastructure using Serial Cadastral Maps within Seoul City. Journal of the Korea Society of Cadastre. 34(2), 93-104.

26. Sarte, S.B. (2010). Sustainable infrastructure, 1st ed. New Jersey, USA: John Wiley & Sons Inc.

27. Schilling, J., & Logan, J. (2008). Greening the rust belt: A green infrastructure model for right sizing America's shrinking cities. Journal of the American Planning Association, 74(4), 451-466.

28. Seoul Metropolitan Governmen. (2014a). The 2030 Seoul city master plan. Retrieved from http://urban.seoul.go.kr/4DUPIS/sub3/sub3_1.jsp.

29. Seoul Metropolitan Governmen. (2014b). The 2030 Seoul city park and green master plan. Retrieved from https://opengov.seoul.go.kr/ public/ 7331743.

30. Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Ka?mierczak, A., Niemela, J., & James, P. (2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. Landscape and Urban Planning, 81(3), 167-178.

31. Wang, Y., Bakker, F., De Groot, R., & Wörtche, H. (2014). Effect of Ecosystem Services Provided by Urban Green Infrastructure on Indoor Environment: A Literature Review. Building and environment, 77, 88-100.

32. Weber, T., Sloan, A., & Wolf, J. (2006). Maryland's Green Infrastructure Assessment: Development of a comprehensive approach to land conservation. Landscape and urban planning, 77(1-2), 94-110.

33. Wickham, J. D., Riitters, K. H., Wade, T. G., & Vogt, P. (2010). A national assessment of green infrastructure and change for the conterminous United States using morphological image processing. Landscape and Urban Planning, 94(3-4), 186-195.

34. Wolf, K. L. (2003). Ergonomics of the City: Green Infrastructure and Social Benefits. In Engineering Green: Proceedings of the 11th National Urban Forest Conference. Washington DC: American Forests (Vol. 115).

35. Wright, H. (2011). Understanding Green Infrastructure: the Development of a Contested Concept in England. Local Environment, 16(10), 1003-1019.

36. Xiao, J., Shen, Y., Ge, J., Tateishi, R., Tang, C., Liang, Y., & Huang, Z. (2006). Evaluating Urban Expansion and Land Use Change in Shijiazhuang, China, by Using GIS and Remote Sensing. Landscape and Urban Planning, 75(1-2), 69-80.

37. Zulian, G., Polce, C., & Maes, J. (2014). ESTIMAP: a GIS-based Model to Map Ecosystem Services in the European Union. Annali di Botanica, 4, 1-7.