Green Infrastructure in Métropole du Grand Paris

1. Introduction

1.1. Background

Green Infrastructure (GI) refers to the network of natural and semi-natural areas that provide ecosystem services and preserve biodiversity in both rural and urban settings [1]. Parks, gardens, rivers, beaches, playgrounds, basketball courts, pools, plazas, bike trails, bridges are all examples of GI. Ecosystem services provided by GI are numerous involving clean air, climate regulation, flood prevention, pollination, and recreation [2]. Thus, GI is important for achieving sustainable development, and mitigating adverse effects of climate change.

Maintaining and developing GI is challenging in urban areas as they continue to expand both in terms of density and horizontal area. Several European strategies have so far been introduced to foster urban GI emphasizing the spatial dimension of the problem [2]. Enhancing GI is a spatial problem for several reasons. First, GI is an interconnected ecological network, and networked nature of this infrastructure has to be assured at different scales. Second, spatial distribution of GI has implications regarding spatial-equity, ecological balance, and thus territorial cohesion. Therefore, spatial pattern of GI is as important as its amount.

Urban plans are a main source of information to study spatial patterns of GI; however, these plans do not reveal information on social relevance of public spaces, or user's preferences. Location-Based-Social-Networks (LBSN) permit analyzing GI from user point of view and guide GI management and planning at different levels [3].

1.2. Problem Statement

Métropole du Grand Paris is the largest urban region in the European Union [4]. It already faces the effects of global warming [5] and aims to improve resilience of the area via sustainability transition [6]. Maintaining and developing GI is thus crucial for the area. The objective of this study is to explore the spatial pattern of GI in Métropole du Grand Paris by taking user's preferences into account and shed some light on the spatial-equity dimension of the current GI in the area.

2. Sources and Description of Data

Métropole du Grand Paris consists of the city of Paris and some communes located in the inner and outer suburbs of the city. The city of Paris contains 20 arrondissements, which I will treat as individual neighborhoods. Communes located in inner suburbs refers to all 123 communes of Hauts-de-Seine, Seine-Saint-Denis, and Val-de-Marne. Whereas communes located in outer suburbs refer to 7 communes located in l'Essonne and le Val-d'Oise. The arrondissements in the city and the communes make in total 150 neighborhoods.

I obtained the list of arrondissements of the Paris city from the website of INSEE, which is the National Institute of Statistics and Economic Studies [7]. The data file includes information on the population and surface area of the arrondissements. I completed the information on neighborhoods by acquiring data on communes of the Métropole du Grand Paris from an open platform for French public data [8]. This data file also includes information on the population and surface area of the communes. Using the same open platform, I accessed data on geographical coordinates of the neighborhoods [9].

Next, I obtained the list of Foursquare categories that can be considered as GI elements from the study of Marti et al. [3] and get data on venues from Foursquare. According to Marti et al. [3], all venues in Outdoors and Recreation category except states and municipalities and unclassified venues can be considered as GI.

Lastly, from the open platform stated above, I obtained polygonal representation of the neighborhoods of the Métropole du Grand Paris [10]. The data is in json format and it is used to generate choropleth maps in the descriptive analysis.

3. Methodology

The methodology of the analysis consists of three steps. In the first step, I make use of choropleth maps to describe spatial distribution of population density and GI venues. I calculate population density of a neighborhood, by simply dividing its population by its surface area (in km^2). To calculate the number of GI venues, I first obtained all Outdoors and Recreation venues by restricting the Foursquare query using the category identifier "4d4b7105d754a06377d81259". It turned out that except one venue, all the other venues can be considered as a GI element according to Marti et al. [3].

In the second step, I investigate the correlation between population density and GI. On the one hand, one may expect these GI elements to be co-located with people. On the other hand, one may also expect a trade-off between population density and GI because of land requirements. So, I calculate the pearson correlation coefficient between population density and number of GI venues. I also conduct a hypothesis test, where the null hypothesis is population density and number of GI venues in neighborhoods are not correlated. I also visualize distribution of these two variables by means of a scatterplot and identify neighborhoods with extreme values.

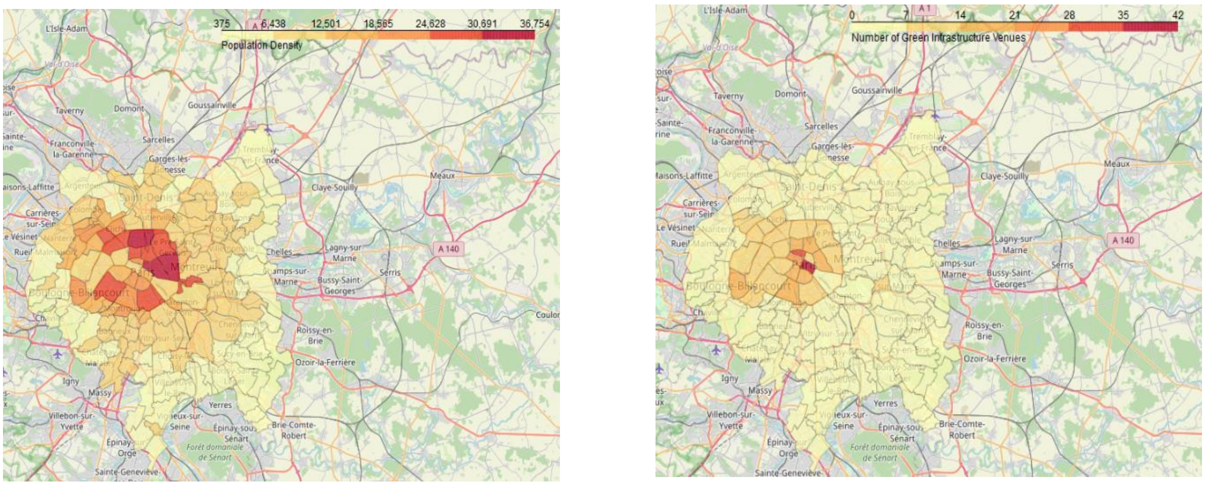
In the third step, I use k-means clustering to analyze spatial pattern of (user-based) GI in Métropole du Grand Paris. In this step, I work on a subsample of neighborhoods because for most neighborhoods Foursquare query returned very few venue categories. The issue here is to select neighborhoods with at least ***n*** venue categories and cluster them according to top ***m*** venue categories, with ***n > m.*** As I increase ***n***, I end up with few neighborhoods to cluster. As I decrease ***n***, I end up with very few dimensions to cluster on. I experimented with several values of ***n*** and ***m,*** and used the heuristic Elbow method to check whether I can find k clusters in the sample. In the results presented below ***n=7***, and ***m=5***. However, as I discuss below, the results are not robust with respect to this choice.

4. Results

4.1. Spatial distribution of population density and GI venues

Figure 1-a shows the spatial distribution of population density as a choropleth map. The most densely populated neighborhoods are arrondissements in the Paris city. Broadly speaking, as one moves from the city to inner and outer suburbs, population density decreases. Whereas Figure 1-b shows the spatial distribution of the number of GI venues as a choropleth map. Again, GI levels are observed to be higher in the city center. Less spatial heterogeneity is observed in GI distribution as compared to

population density, nevertheless it has to be noted that here GI is not measured as the physical green infrastructure in urban plans but from users' point of view based on the strong assumption that Foursquare check-ins are representative of the preferences of the whole population.



(a) Population Density (b) Number of GI Venues

Figure 1. Choropleth Maps of the Métropole du Grand Paris

4.2. Correlation between population density and GI venues

The Pearson correlation coefficient of population density and GI venues is 0.594 and it is statistically significant with a p-value of 0.000. This means that the null hypothesis that the distribution of these two variables are not correlated can be rejected at 99% confidence level. Indeed, the magnitude of the coefficient implies a moderate level of correlation.

This can be observed from the scatterplot given in Figure 2. In the figure the horizontal and vertical reference lines indicate the mean values of GI venues and population density, respectively. Most data points are in the high-high and low-low regions, i.e. neighborhoods above (below) the average regarding population density are also above (below) the average regarding the number of GI venues.

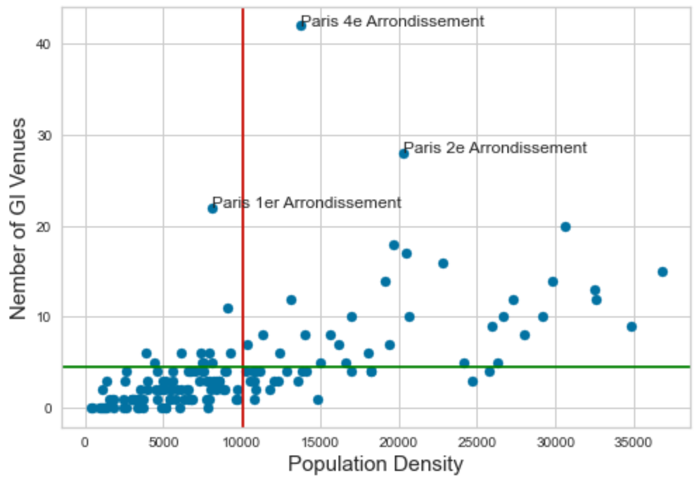


Figure 2. Scatterplot of Population Density and the Number of GI Venues

Again, from Figure 2, it is observed that the 4th and the 2nd arrondissements in the Paris city are the neighborhoods with the highest number of GI elements. 1st arrondissement, however, differs from other neighborhoods. Although its population density is less than the average, it has more GI venues than the average.

4.3. Clustering neighborhoods with respect to top GI categories

Selecting neighborhoods with at least 7 venue categories decreases the sample greatly, yielding 28 neighborhoods. These neighborhoods comprise arrondissements in the city of Paris and close communes. As shown in Figure 3, the heuristic Elbow method suggests to group neighborhoods into 7 clusters according to top 5 venue categories.

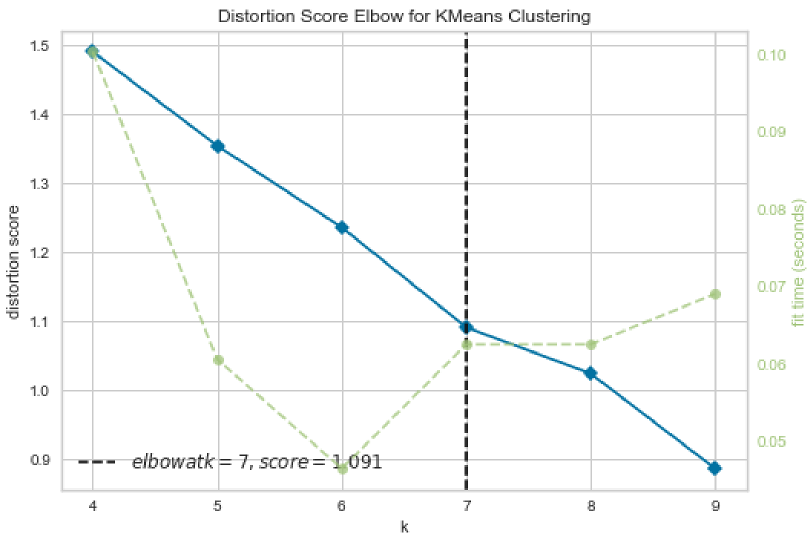


Figure 3. Elbow Method

The size of the clusters is given in Table 1. It is difficult to come up with a cluster typology. Nevertheless, it is possible to characterize some of the clusters. For instance, 3rd cluster contains neighborhoods that all have Plazas as the top venue category along with sports facilities and green areas. 4th cluster includes neighborhoods having open public places such as parks, plazas, gardens as top venue categories. 5th cluster have either parks and plazas as first rank categories and then sports facilities. Finally, 6th cluster is similar to the 5th one except that sports facilities are more highly ranked.

Table 1. Size of the Clusters

	Cluster ID						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Number of Neighborhoods	1	2	6	4	7	7	1

As explained above, differences between clusters are not sharp. Similarly, no specific spatial pattern is observed in distribution of clusters, which is given in Figure 4.

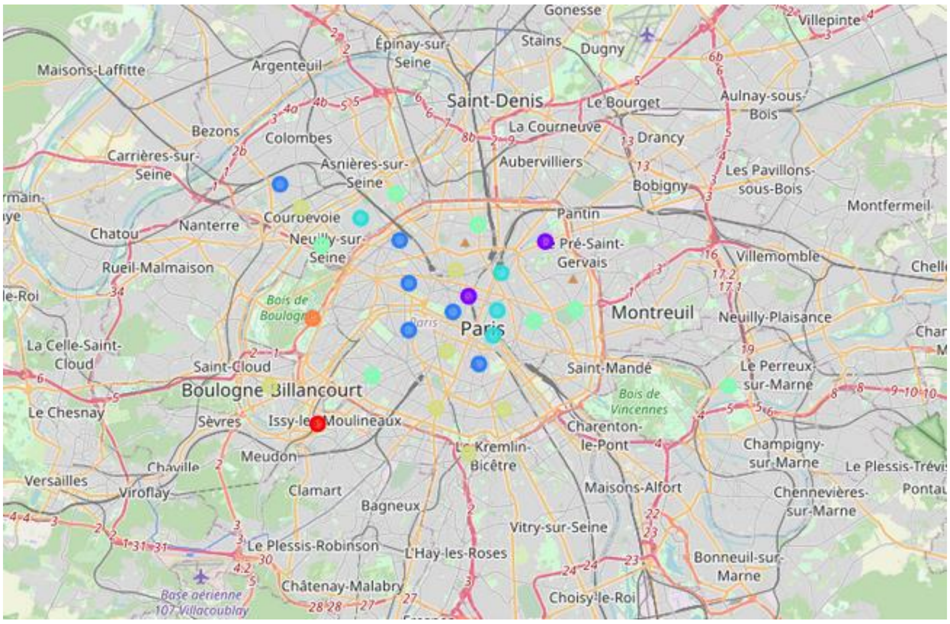


Figure 4. Spatial Distribution of Clusters

5. Discussion

These results should be taken with great care for at least two main reasons. First, in this analysis GI is considered from user's point of view and without much questioning a possible selection bias resulting from the use of Foursquare data. It is possible that Foursquare data does not reflect preferences of children or elder people but particular age cohorts with particular ICT usage patterns. In this regard, complementing this analysis with data from urban plans would be essential to draw conclusions for GI management and planning.

Second, clusters identified in the study are overly sensitive to certain methodological choices. Small increases in the sample size or in the number of top venue categories considered lead to vastly different results, and in some cases, it becomes impossible to identify clusters. Data triangulation and integrating theoretical insights from spatial planning can help obtaining more robust results.

6. Conclusion

In this study spatial pattern of GI in the Métropole du Grand Paris is analyzed from users' point of view. Thus, instead of using urban plans to identify GI elements, Outdoor & Recreation venues obtained by Foursquare are used to quantify GI. Distribution of GI is described by using choropleth maps and compared with the distribution of population. Lastly, k-means clustering is used to identify neighborhoods that have similar GI structures. The results are far from being robust and experimental in nature, still the exercise illustrates an Location-Based-Social-Networks (LBSN) approach to inform GI management and planning.

References

[1] Green Infrastructure Definitions. Retrieved from: https://www.interreg-central.eu/Content.Node/Definitions.html (Accession date: 21.06.2020)

[2] What is green infrastructure? Retrieved from: https://www.eea.europa.eu/themes/sustainability-transitions/urban-environment/urban-green-infrastructure/what-is-green-infrastructure (Accession date: 21.06.2020)

[3] Marti et al. (2020) Green Infrastructure Planning: Unveiling Meaningful Spaces through Foursquare User's Preferences. *Land Use Policy*, 97: 104641

[4] List of metropolitan areas in Europe. Retrieved from: https://en.wikipedia.org/wiki/List_of_metropolitan_areas_in_Europe (Accession date: 21.06.2020)

[5] Lemonsu, A., Kounkou-Arnaud, R., Desplat, J. et al. (2013) Evolution of the Parisian urban climate under a global changing climate. *Climatic Change* 116: 679–692:

[6] Découvrez le Plan Climat Air Energie de la Métropole du Grand Paris. Retrieved from: http://www.planbatimentdurable.fr/decouvrez-le-plan-climat-air-energie-de-la-a1263.html (Accession date: 21.06.2020)

[7] Base comparateur de territoires. Retrieved from: https://www.insee.fr/fr/statistiques/2521169#consulter (Accession date: 19/06/2020)

[8] Adhésion des communes à un établissement public de coopération intercommunale (EPCI) à fiscalité propre en France métropolitaine et Dom. Retrieved from: https://www.data.gouv.fr/fr/datasets/adhesion-des-communes-a-un-etablissement-public-de-cooperation-intercommunale-epci-a-fiscal-00000000/#

[9] Correspondance entre les codes postaux et codes INSEE des communes Françaises. Retrieved from: https://www.data.gouv.fr/en/datasets/correspondance-entre-les-codes-postaux-et-codes-insee-des-communes-francaises/ (Accession date: 19/06/2020)

[10] APUR : Communes - Métropole du Grand Paris https://www.data.gouv.fr/fr/datasets/apur-communes-metropole-du-grand-paris/ (Accession date: 28/06/2020)