What are the best spots to live in Vernier?

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Introduction

Nowadays, territorial inequalities are a major and common problem in cities around the world. It has been shown that inequality presents multiple dimensions: social, economic and cultural [1]. Since a couple of years, additional factors are becoming increasingly significant: this is the case of the environmental aspects, which is essential to ensure a more cohesive, harmonious and well-balanced territory [2]. Some studies have addressed dimensions of this territorial inequality in relation to mobility [3], other ones in term of housing situation [4], while most of them adopt a multi-factor approach [5]. Considering multiple factors is more reliable and realistic as it is extremely difficult to isolate and address the links between a single aspect and the precarity.

This paper, on its hand, aims at exploring the influence of some chosen parameters on spatial welfare disparities. The investigated region is the municipality of Vernier (figure 1), located in the Canton of Geneva, Switzerland. This exploration is based on three fundamental indexes of the built environment implemented at the scale of Vernier: **a)** accessibility - to natural zones, heaths points and public transport; **b)** pollution - air, daily noise pollution and insalubrity. As the indicator of air pollution, nitrogen dioxide (NO_2) concentration is chosen. Released during combustion (heating, electricity production, engines of motor vehicles and boats), it is recognized as a major pollutant of the earth's atmosphere [6]. The last index developed is the **c)** population - literally the density of inhabitants. Whereas the first index has already been addressed in our previous individual works, the two others are specially designed for this study. At the end of the analysis, we should be able to identify which districts are the most pleasant to live in.

In 2011 the territory of Vernier was considered as the denser commune of Canton of Geneva, with a population showing the highest signs of precariousness of the whole Canton [7]. In addition to being globally precarious, the territorial disparities in Vernier were significant. Of the 22 sub-sectors considered in the OCSTAT study [7], "Les Libellules" is in 2^{nd} place, "Le Lignon" in 8^{th} position and "Les Avanchets" in 12^{th} position of the most precarious districts. "Vernier-Village" is shown to be a more prosperous and pleasant neighbourhood (see figure 1). Our own results will be compared with the findings of this study.

Data

A set of data, including common features for the three developed indexes and specific features to each of them, were used to perform the analysis.

Common features

- **Territorial boundaries:** A vector file highlighting the limits of the territory of Vernier have been furnished by the Laboratory of Geographic Information Systems[1] of EPFL (LASIG). The dataset was produced by the Federal Office of Statistics OFS[2].

- **Grid:** A regular grid surrounding the Vernier municipality with a spatial resolution of $100 \cdot 100\,m$ was created on the basis of both, the hectometric geometry of the population file (see below for information on this file) and the territorial boundaries (see above).

Index-specific features

Accessibility

- **Bus:** The vector layer of bus stops was produced by the Geneva public transport group TPG[3]. The layer was made with a ground accuracy of $2\,m$. The last version was updated on 07.04.2017.

[1]URL: http://lasig.epfl.ch/
[2]URL: http://geostat.admin.ch/
[3]URL: https://tpg.ch/

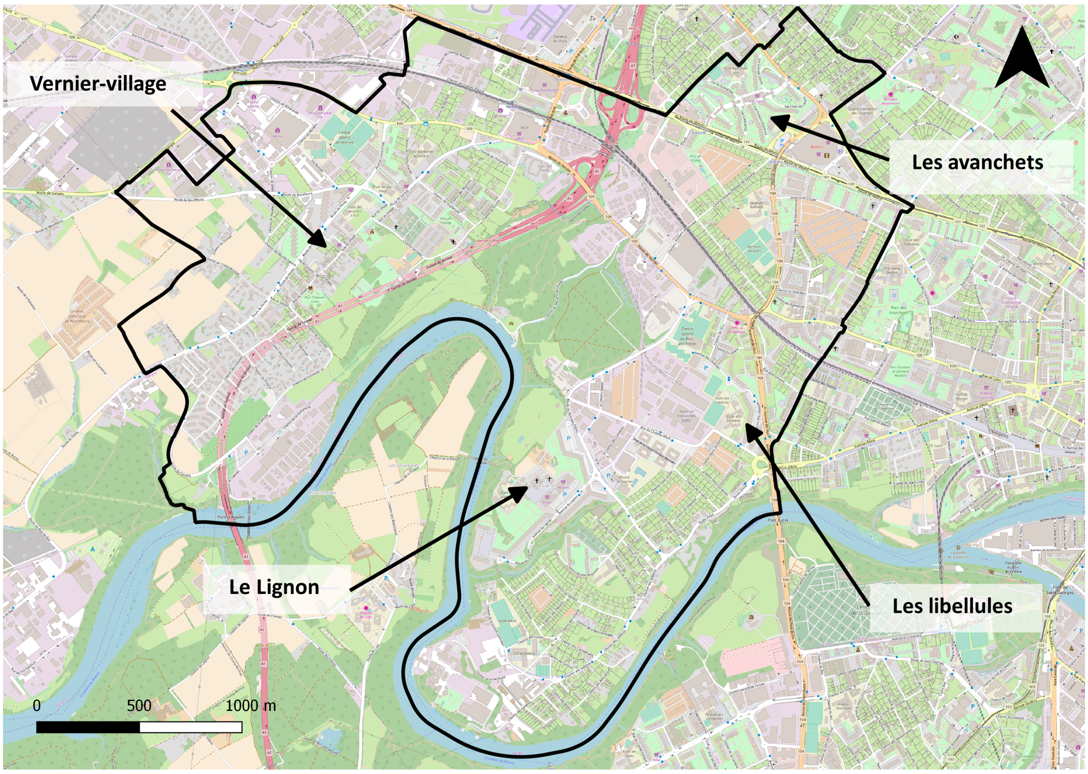

figure 1 – The municipality of Vernier and its main geographical centres (*background map: OpenStreetMap, Steve Coast (2006). URL: http://www.openstreetmap.ch*)

- **Green area**: Polygon layers, for the vegetation over the territory, were downloaded from the open data catalog of the Geneva Canton SITG[4] (name of the file: "Carte de la végétation au 1/25 000"). A ground resolution of 5 m at a scale of 1:25 000 was used.

- **Health data:** As health-related data, an exhaustive list of occupational activities in the social and medical sector was employed. This record dated 31.12.2016, cover the whole territory of Geneva. The Département de la sécurité et de l'économie DSE, Office cantonal de l'inspection et des relations du travail and the Répertoire des entreprises du canton de Genève REG participated in its achievement.

Pollution

- **Daily noise:** A sonBase file containing the daily noise for Vernier and its periphery in 2010 was investigated. Calculations based on an important series of data were carried out in order to produce this raster layer. Noise calculations were conducted from noise generated by distinct sources. For this purpose, information from several Federal Offices was combined (e.g. Federal Offices of Roads FEDRO, Transport FOR, Civil Aviation FOCA). Geographic features required for the noise calculation were issued from the Federal Office of Topography (i.e. the vectorised map of Switzerland 1:25 000; and the digital elevation model DEM, DHM25).

- **Average of NO_2 imissions:** A polygonal layer containing the average NO_2 imissions over an eight-year period for the canton of Geneva was chosen. It was carried out from passive sensors distributed throughout the territory and from air quality measurement stations. Thus, different sources of pollution are being considered. This layer was once again obtained from the SITG website[5]. It was updated in 2014, with a ground accuracy of 100 m.

Population

The total permanent resident population for the year 2015 was investigated. The statistic was issued from the Geostat platform defined as the *Competence center for geoinformation and digital processing of digital images* managed by the OFS. Data collection was achieved by geocoding on the basis of the Federal Register of Buildings and Housing (regBL).

[4]URL: http://ge.ch/sitg
[5]URL: http://ge.ch/sitg

Methods

In order to evaluate the best spots to live in Vernier, the initial data were loaded on QGIS[6] first and secondly on the GeoDa software[7]. All layers were georeferenced using the same Swiss coordinate systems *CH1903+ LV03*.

Index construction

Accessibility index

This first index is designed based on the study on the urban accessibility index of the University of Texas at Austin [8]. We decided to consider three principal aspects to compose this index. The proximity to green zones is the first one and is calculated by computing the distance from the centroid of the cell and the closest point composing the natural areas (NN join plugin available on QGIS). The second aspect consists of the number of health points in a range of $500\,m$ from the centroid of each cell. Since the Vernier territory is relatively small, this distance seems to be consistent with our vulnerability analysis. Moreover, one should notice that the points that are located outside the territory of Vernier but inside the buffer, will be considered. Finally as last aspect of this index, the number of bus stops in a circular area of a radius of $300\,m$ around the centroids of the cells was computed. According to the Office Fédérale de la Statistique [9], $341\,m$ (rounded to three hundred meters) is the effective average distance that a Swiss citizen walks to reach a public transportation point from his home. In order to synthesize these three aspects over a unique index, one should consider a normalization of the terms. The process is carried out using the following relationship [10]:

$$Normalized\,value = \frac{value - min}{max - min} \tag{1}$$

The minimum is zero and the maximum is the biggest encountered value of the dataset. The accessibility index can now be built as a linear combination of the three parameters with different weights (N nature, H health points and B bus stops).

$$Index\,1 = 0.3 \cdot N + 0.2 \cdot (1 - H) + 0.5 \cdot (1 - B) \tag{2}$$

The different ponderation weights were chosen in order to give more importance to the accessibility to public transport, then proximity to nature and finally the accessibility to health points. In terms of accessibility, the proximity to the public transport network reduces on one hand the usage of private cars, and on the other hand ensures that those who do not have private vehicles are also independent. Despite the fact that the presence of nature in towns has been proved to be a source of serenity and well-being which then benefits to human health [11], access to nature is mainly a question of comfort. Finally, health points must be accessible to all and at a suitable distance, but their use is not daily. A large value of the accessibility index means higher distance to reach the considered service and thus a less convenient situation.

Pollution index

The index of pollution has been constructed to assess the nuisance rate of a given area. It is composed of three variables. The first one is the daily noise due to traffic. The values have been normalized (equation 1) using as minimum $10\,dB$ (average lower range of human hearing [12]). For the maximum value, we refer to the *"Ordonnance sur la protection contre le bruit"*, where the alarm value, for a degree of sensibility II and III, is fixed at $70\,dB$ over the day[8]. The second term that composes the index of pollution is the NO_2 concentration. In order to normalize the data (equation 1), the minimum value of $0\,\mu g/m^3$ has been chosen since the amount in pure air is extremely small (almost zero)[9]. A maximum value of $31\,\mu g/m^3$ was adopted (maximum encountered in our dataset) even though that the imission's limit values recommended by the Swiss law (OPAir) is $30\,\mu g/m^3$ [10]. The last component of this index is insalubrity. This variable is set to 0 if no relevant problems are encountered in the cell, it is set to 0.5 if occasional problems occur and finally to 1 if recurrent problems of insalubrity arise. Generally in the municipality of Vernier no relevant problems occur but there are still some areas that are affected by recurrent problem of insalubrity, especially near most densely populated zones. As for the previous index, the pollution index can now be built as a linear combination of the three parameters with different weights (N sound noise, NO_2 concentration and I insalubrity).

$$Index\,2 = 0.4 \cdot N + 0.4 \cdot NO_2 + 0.2 \cdot I \tag{3}$$

The decision of the attributed weights in equation 3 was taken to give the same importance to the noise due to traffic and to the pollution of NO_2. In our

[6]QGIS Development Team, 2014. QGIS Geographic Information System. Open Source Geospatial Foundation. URL http://qgis.osgeo.org

[7]GeoDa, Anselin, Luc, Ibnu Syabri and Youngihn Kho (2006). GeoDa: An Introduction to Spatial Data Analysis. Geographical Analysis 38 (1), 5-22. URL https://spatial.uchicago.edu/geoda

[8]*Ordonnance sur la protection contre le bruit 814.41*, Annexe 3. [online] Available at: https://www.admin.ch/opc/fr/classified-compilation/19860372/index.html

[9]URL: https://www.engineeringtoolbox.com/air-composition-d-212.html

[10]*Ordonnance sur la protection de l'air 814.318.142.1*, Annexe 7. [online] Available at: https://www.admin.ch/opc/fr/classified-compilation/19850321/index.htmlapp7ahref1

thought, the insalubrity parameter is the less relevant factor in this index since it is something that can be easily modified by changing the waste collection system. Large results of the pollution index mean higher exposure to a polluted and noisy environment, resulting in a negative impact on life quality.

Population index

This index is designed knowing that for the Geneva region, the most populated regions are those with the highest signs of precariousnes [7].

The total permanent resident population for the year 2015 is the only variable that was investigated in order to create this last index. The population index corresponds to the density of the population per cell. As in previous cases, the values have been normalized (equation 1) with the minimum of 0 inhabitants and the maximum of 651, corresponding to the maximum encountered number of inhabitants in the dataset. As for the previous index, large results of the population index imply denser areas and thus high precarity.

Overall index

Finally, an overall index has been created in order to merge the three previous indexes and identify the more vulnerable zones. As in previous cases, the index has been built as a linear combination with specific weights.

$$Index\,4 = 0.4 \cdot Index\,1 + 0.4 \cdot Index\,2 + 0.2 \cdot Index\,3 \quad (4)$$

The different ponderation weights were chosen so that the accessibility and the pollution indexes have more importance compared to the population index. Indeed, the latter is composed of only one parameter, compared to the others that are constructed with three variables. Large results of the vulnerability index imply a negative impact on life quality and thus is it possible to identify the worst zones in the municipality. On the other hand, a low result of the vulnerability index allows identifying the best spots in Vernier.

Statistical analysis

The statistical analysis was implemented mainly in the GeoDa software and exclusively for the overall index. Based on the personal previous work of Brouillet C., the stationary hypothesis of the observed spatial phenomena does not seem realistic. A regression with a dependent spatially weighted variable is suitable in order to obtain a regression line for each spatial unit:

$$y_j = \beta_0 + \beta_1 \cdot x_{j1} + \rho \cdot w_i \cdot y_i + \varepsilon_j \quad (5)$$

with w_i the weight of the spatial unit i relative to the spatial unit j and rho the spatial lag computed by taking the weighted average of the neighbouring cell. The parameters were calculated on the basis of weight value which takes into account the hypothesis that the closest observations are more important than the farther ones. The weight file was created with the Queen contiguity rule of second order. Indeed, as each cell of the grid is only $100m$ wide, we can assume that the value of a cell is not only affected by the immediately contiguous units, but also by the second order contiguous units. The histogram of the frequency of neighbours based on the ID of the cells, is displaced in Annexe, figure 9.

As next step, a univariate LISA algorithm (Local Indicators of Spatial Association) was applied to the values of the overall vulnerability index. It should be noted that, considering our grid of data, some cells do not have direct neighbour and therefore will not be considered in the LISA process. The results are a Moran Scatter Plot, a Clustered map and a Significance map[11]. Concerning the moran scatterplot, one should know that the value of the Moran's I is a measure of spatial autocorrelation which is the correlation of the considered cell's result among nearby locations cell's value [13]. According to the literature,*"this tool measures spatial autocorrelation (feature similarity) based on both feature locations and feature values simultaneously*[12]. Moran's I equals the slope of the linear fit: a positive value implies positive autocorrelation and thus a spatially distributed phenomena. The clustered map shows the principal agglomerates in terms of similarities between neighbour. Indeed an area that is characterized by High-High correlation means that the considered cell is surrounded by cells with similar high results, in term of overall index. On the other hand, a region that is qualified with a Low-Low correlation, implies that the considered cell is characterized by a low results of the overall index and that the cells in its vicinity are also considered as vulnerables. Furthermore, the clustered map allows to identificate the cells with a different trend with respect to the neighbour. In fact, a High-Low or a Low-High correlation implies either a higher value among low results of the proximity cells, or a lower value surrounded by high cell's results[13]. The LISA significance map allows to understand, in term of p-value, where the location of spatial association is either really significant or meaningless. In fact a p-value of 0.05 implies a less reliable result compared to a p-value 0.0001; later in the discussion, we will focus exclusively on the cells with more significance.

[11]URL: https://www.e-education.psu.edu/geog586/l9-p11.html
[12]URL: http://resources.esri.com/help/9.3/arcgisengine/java/gp-toolref/spatial-statistics-tools/how-spatial-autocorrelation-colon-moran-s-i-spatial-statistics-works.htm
[13]URL: https://www.researchgate.net/figure/294870442-Anselins-Moran-scatter-plot-interpretation-guide

Results

Qualitative analysis

In order to visualize the spatial distribution of the three complementary indexes and compare their differences as well as their similarities, a map for each of them have been produced. Later, to assess their respective influence on the overall index, a map for the global index has also been generated. All the maps have been constructed using the Natural Breaks criterion for the classes settings.

Regarding figure 2, we can clearly see inequalities in terms of accessibility among the territory of Vernier. The north-west part of "Vernier-Village" have pretty high values of the accessibility index (dark blue), and on the contrary, east border of Vernier presents smaller values (pale blue). Unsurprisingly, these gaps are mainly influenced by the distribution of bus stop along the main road axis. This favours the east edge of the territory, that is well connected to the network. However, the influence of the two others parameters (distance to natural zones and number of health point in the proximity) should not be neglected. Indeed, the northern side of Vernier does not benefit of green zones, which are mainly along the Rhone river, and this affects the scores of accessibility (middle shade of blue).

The results considering the index of pollution are shown in figure 3. Analysing the layer of NO_2 in QGIS we could observe a gradient of this pollutant over the territory of Vernier. The vicinity of the city of Geneva may explains this phenomenon. Indeed, the upper part of the municipality has a higher NO_2 concentration compared to the lower side. Thus, one should conclude that, the closer we are to the city of Geneva and to its airport, the more vulnerable we are in terms of pollution. Zones which were considered quite good in terms of accessibility to public transport are now slightly more sensitive to pollution. It is the case of the north-eastern border of Vernier. However, some areas are in agreement with the previous index and show low scores of pollution too; this is the case of the zone located south of "Le Lignon", that is in the proximity to green zones and reasonably well-connected to the rest of the territory. Indeed, this region seems less affected by pollution adverse impacts since it is the farest place from the city and it is not localized nearby important roads, principal source of noise. Other regions are showing bad results both in terms of pollution and accessibility. The region that best illustrates this remark is located around Balexert (north-east).

The last index, the one that corresponds to the population density, reflects the distribution of people in the main districts of Vernier (figure 4, dark red cells). Indeed, the neighbourhoods of "Les Avanchets", "Les Libellules" and "Le Lignon", famous and impressive block of buildings built in the eighties, can be clearly distinguished. In addition to them, the centre of "Vernier-Village", which is experiencing a rather recent increase in its population, also demonstrate pretty high values of precarity in terms of population density.

Combining the three previous indexes in one map, allow to get a general overview of the vulnerability of the territory (figure 5). The overall index ranges in a set of values between 0.275 and 0.748 and is used to detect the best and worst spots to live in Vernier. Considering the chosen parameters, the north and extreme west regions are less pleasant to live in, compared to the south part of the territory. The best place is by far the surrounding of "Le Lignon".

Statistical analysis

As explained before, the LISA algorithm was applied only on the overall index results. The positive value of the Moran's I coefficient (0.482) allows to state that there is an effective positive autocorrelation of the overall vulnerability in the territory of Vernier (figure 6). This means that the studied phenomena are spatially dependent.

The clustered map (figure 7) allows to identificate the agglomerate of High-High correlation as well as the Low-Low zones. One should notice two principal clusters of High-High values that correspond to the "Les Avanchets" (upper-eastern part of the territory) and to the western part of Vernier-village. On the other hand, two Low-Low clustered areas are also visible. The biggest one, in the bottom-east part of the territory, covers the neighbourhood of "Les Libellules" and "Le Lignon". The second one corresponds to the center of "Vernier-Village". Considering the significance map (figure 8), one should notice that only the two neighbourhood of "Les Avanchet" (upper part) and "Le Lignon" (bottom part) are meaningful in term of significance and thus reliables (dark green).

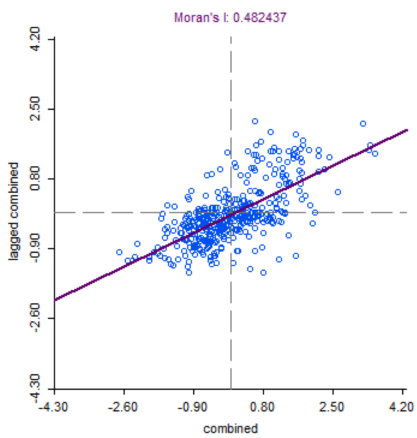

figure 6 – Moran Scatter Plot of the overall vulnerability index (x axis : overall index, y axis : spatial lag)

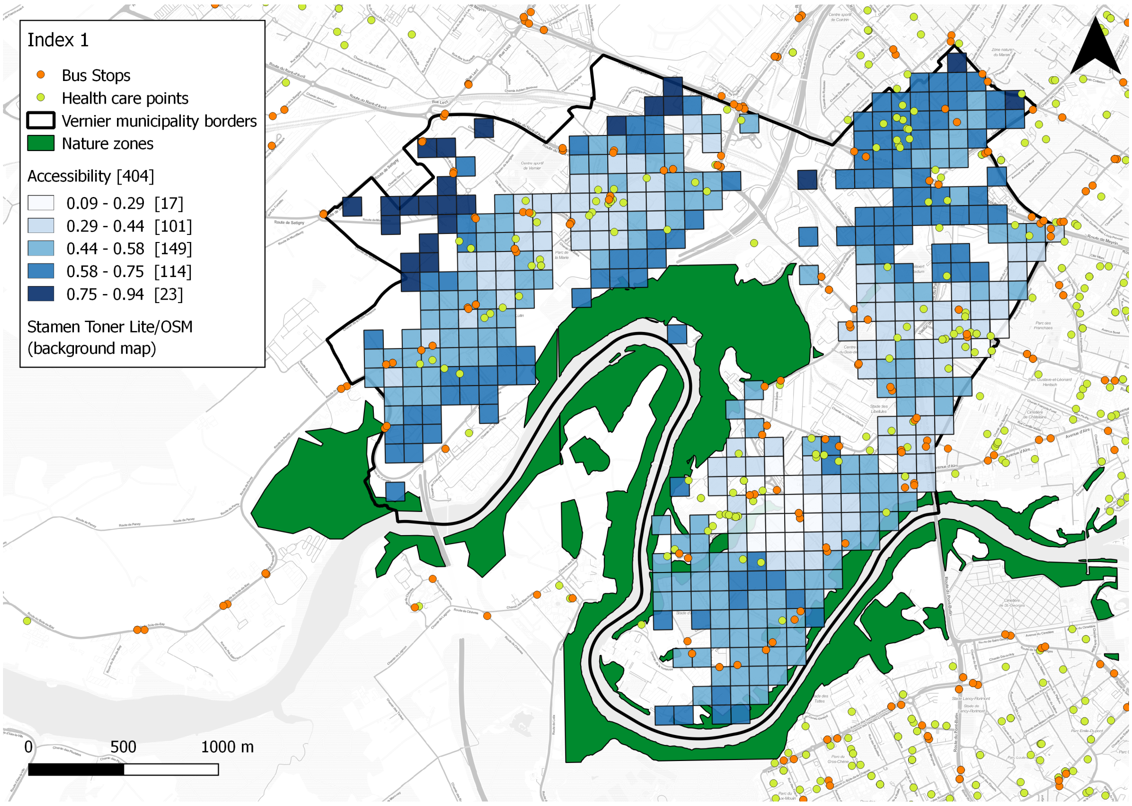

figure 2 – Accessibility index

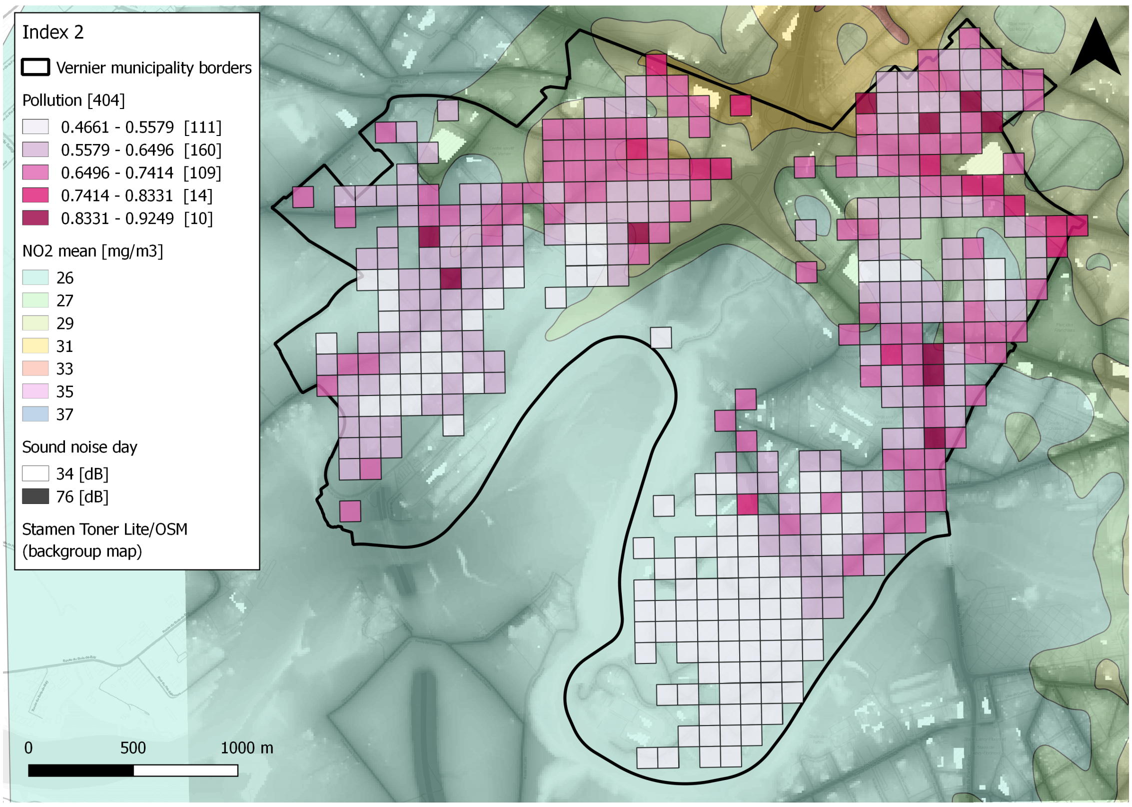

figure 3 – Pollution index

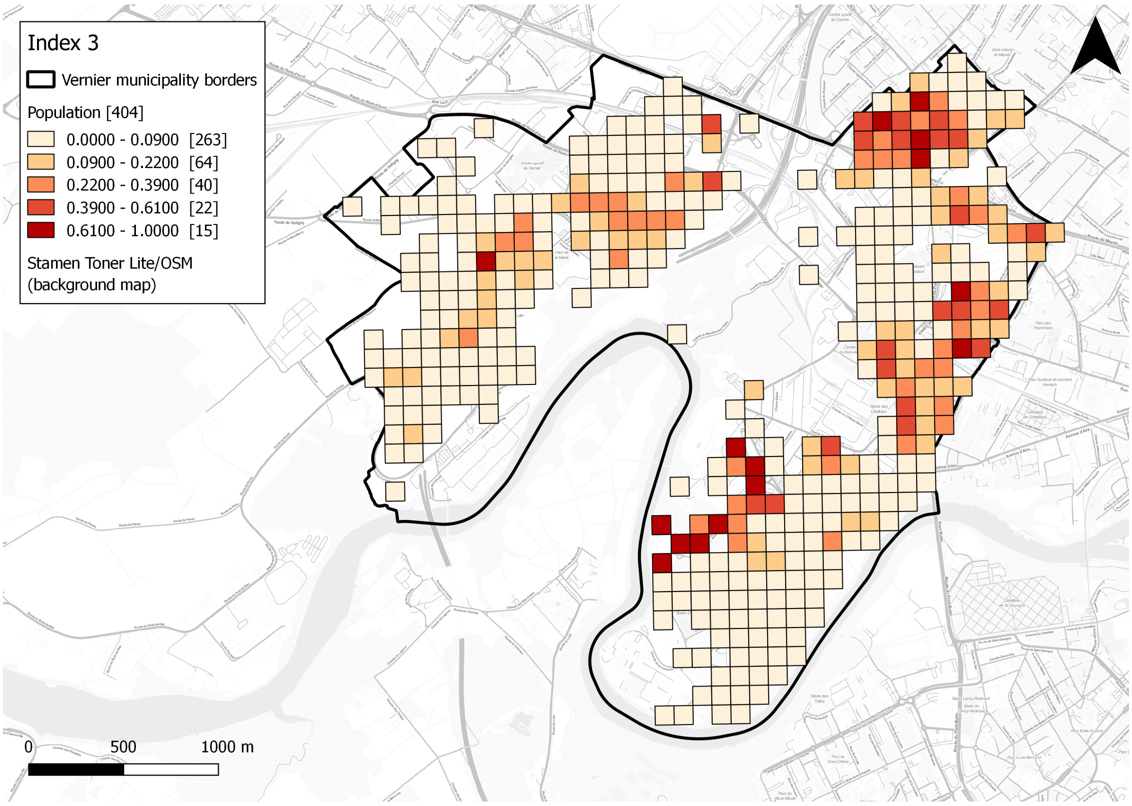

figure 4 – Population index

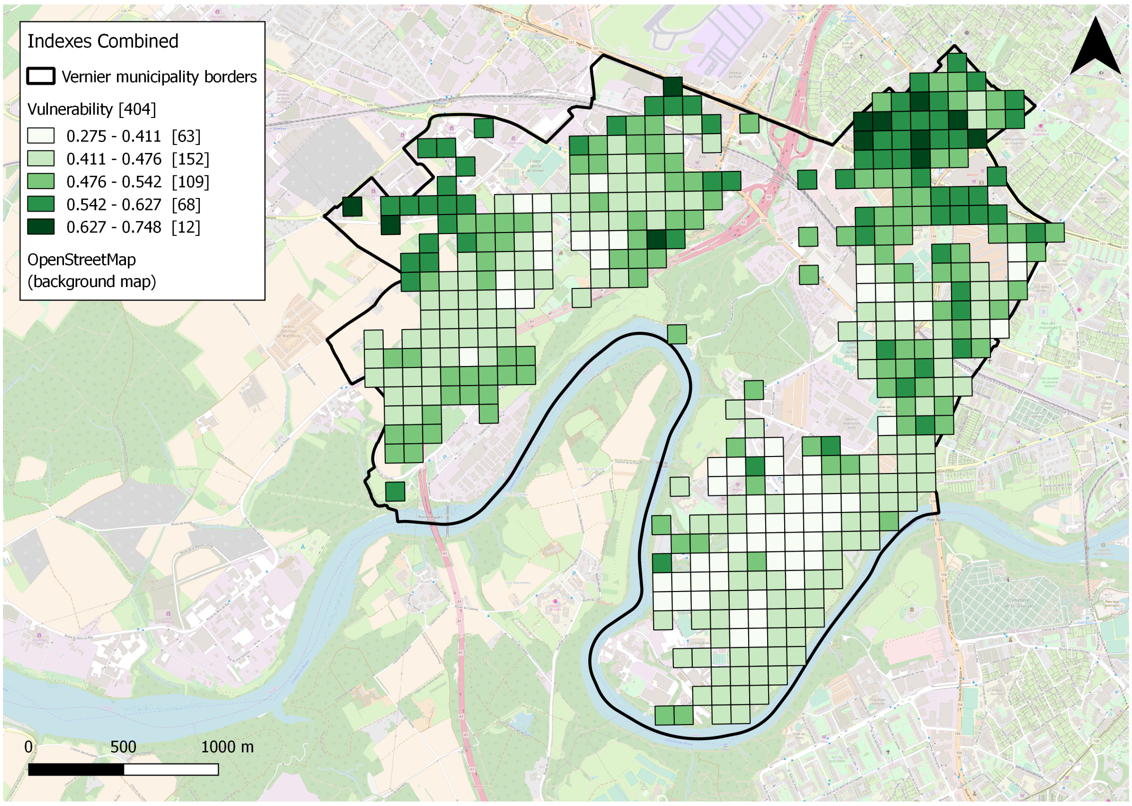

figure 5 – Vulnerability overall index

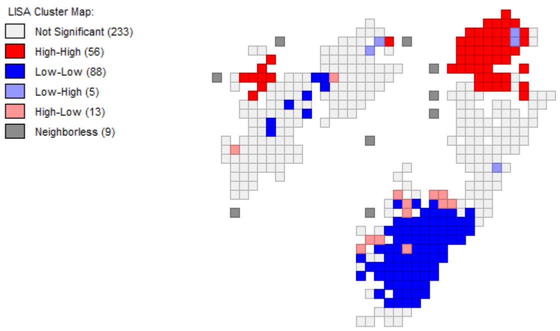

figure 7 – LISA Clustered map of overall vulnerability index

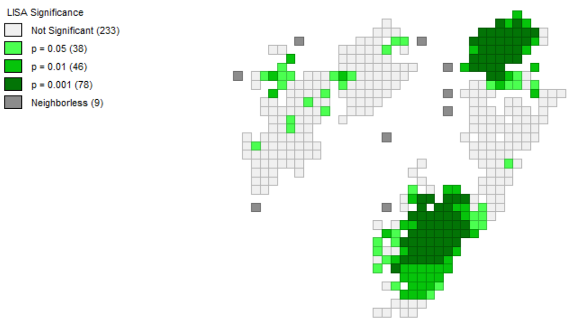

figure 8 – LISA Significance map of the overall vulnerability index

By analysing the outcomes of the LISA algorithm as a whole, the north region seems to be less pleasant to live compared to the south part of the territory. Finally, this analysis enlight that the ideal place to live seems to be the surrounding of "Le Lignon", and this result can be trustable (figure 8).

Discussion

The results obtained throughout our investigation show some interesting features. The analysis of the three indexes taken separately, and next unified together into an overall index, allows to focus on the different influence that each of them have on the Vernier municipality. It is clear that multiple are the factors to determine the precarity of a zone, a neighbourhood or an entire village. Whereas in this study only a reduced range of them has been investigated.

Often, to reach qualitatively sustainable living characteristics, a neighbourhood does not necessarily have to be excellent on a specific parameter, but rather have good compromises of different factors. As Blanco et al. [3] asserted, the proximity to green areas is nowadays a determinant factor for an harmonious and well-balanced territory. Nevertheless the achievement of this goal can penalize a district by diminishing, for example, the accessibility to public transport, health care points or other commodities. The figure 2 (accessibility index) confirms this hypothesis. Looking at the southern zone of the neighbourhood of "Aire" (see Annexe, figure 10), which is considered a quiet, residential zone and pleasant to live in - as confirmed by figure 5 (overall index) - the values of the first index reveal that, afterall, it is not the best spot considering our parameters and their respective weights. Nonetheless, the lack of public transports and health points in this zone can probably be overcomed by the quality of life lead there. We suppose that, since the neighbourhood is "residential" and has a low population density, less people will need to travel by bus. Moreover, the relative high economic possibilities of the residents [14] let us suppose that inhabitants of this district may have a private car and so do not need to rely on public transportation.

Our study, on the other hand, also highlight how "Les Lignon", neighbourhood having a high population density, which is a very relevant factor on the territorial precariousness [7], is not such a bad place to live in, if additional parameters, like the greenness proximity or/and the relative low pollution, are taken into account. This result differs from the literature [7] which place the neighbourhood, as mentioned before, at the 8^{th} position of the most precarious zone in the Geneva region.

Analyzing figure 3 (pollution index), and its distribution of vulnerable zones according to the index, in parallel with figure 5 (overall index), it is possible to appreciate the strong influence of pollution gradient on the quality of neighbourhoods. It is clear how important and necessary it is to keep the pollution levels as low as possible if we want to create a global health area. A solution to reduce noise pollution, while increasing the general welfare of a municipality, could be to introduce new green belts and zones rich on vegetation. As previously demonstrated by Andreetti et al. [15] in their study focused on the municipality of Vernier, perception of noise due to road traffic increases in dense dwelling zones. Thus, a neighbourhood with more green areas will result in a higher quality of life with respect to the sound noise.

Finally, as regards the LISA Clustered map (figure 7) it is possible to see two important cluster zones. Both regions are significant, as verified by the p-value map (figure 8). The LISA analysis shows how a cell strongly influence the closest cells around it and tells clearly which neighbourhoods are the best to live in (Low-Low) or the worst (High-High). The quite big distance between the two cluster let suppose a strong difference in vulnerability from south to north of the territory. Interesting is also the fact that those agglomerates are quite big and respectively isolated in the map.

In conclusion, analyzing the overall index (figure 5), it is possible to identify the best, and the worst, neighbourhoods to live in. The proximity to Geneva and to the airport, which creates a strong pollution in the atmosphere, mixed with the high population density and the distance from nature spots, lead "Les Avanchets" to be one of the less pleasant place to live in. Nevertheless, also "Contrin" (see Annexe, figure 11), that on its hand has a minor population density, due to the influence of parameters coming from indices 1 and 2, enters in the list of non suitable neighbourhoods. The others districts that are considered as "worst neighbourhoods to live in" are "Les Libellules" and the edges of "Vernier-Village". On the opposite situation are "Aire", "Lignon", the central part of "Vernier-Village" and a sector of "Châtelaine" (see Annexe, figure 12). Here, as previously said, the unexpected neighbourhood is the "Lignon": considering the parameters implemented in this paper, such as proximity to bus lines, greenness and health care points, together with the lower pollution levels, it results in a global good environnement where it is proper to plan to live.

Conclusions

The relationship between a global welfare of neighbourhoods and the influence of multiple parameters have on it, has been investigated in this paper. Overall, the study allowed us to determine the best and the worst spots to live in the municipality of Vernier. The original hypothesis, stating that spatial welfare disparities over the territory are depending on considered parameters, was verified.

The results obtained were generally quite satisfying and reliable, then useful to verify our assumptions and do some new hypothesis for possible further investigations. We were able to demonstrate how, in accord to the literature [2] [3], environment and mobility can influence the precariousness of a district. Manipulation of data have allowed to report informations on the territory well-being and stated that disparities among neighbourhoods exists. These knowledge could be useful to suggest family with babies or old people to live in certain places instead of others and furthermore it can be helpful especially to identify where the authorities should act in order to reduce these disparities.

Nonetheless, this paper only propose some possible analysis that can be done and further investigations should be pursued. For example, it could be interesting to check on the influence of population density on the overall vulnerability index by changing the weights in the different equations; or maybe implement other sources and parameter to create new indexes to compare and merge together such as, economic revenues, criminality, people's age, social infrastructures, etc. These are possible suggestions that might enrich our study, other possibilities could be explored.

Contribution of the authors

All the authors performed the analysis of the data set using QGIS and GeoDa and looked for the conclusion and references. Q.A. conceived the maps. B.C. wrote the introduction and data chapters; A.A. drafted the methods; A.A. and B.C. wrote the results; Q.A. composed the discussion and conclusion paragraphs. B.C. arranges the references and A.A. finalize the annexes and the presentation of the report.

References

[1] Audirac, I. (2017). Introduction: Shrinking Cities from marginal to mainstream: Views from North America and Europe. *Cities*. [online] Available at: https://www.sciencedirect.com/science/article/pii/S0264275117311927 [Accessed 2 Jan. 2018].

[2] Sánchez-Zamora, P., Gallardo-Cobos, R. and Romero-Huertas, C. (2017). Assessing the determinants of territorial cohesion: Evidence from Colombian departments. *Geoforum*, [online] 87, pp.48-61. Available at: https://www.sciencedirect.com/science/article/pii/S0016718517302932 [Accessed 2 Jan. 2018].

[3] Blanco, J. and Apaolaza, R. (2017). Socio-territorial inequality and differential mobility. Three key issues in the Buenos Aires Metropolitan Region. *Journal of Transport Geography*. [online] Available at: https://www.sciencedirect.com/science/article/pii/S0966692316303623f0005 [Accessed 2 Jan. 2018].

[4] Prout Quicke, S. and Green, C. (2017). Precarious residence: Indigenous housing and the right to the city. *Geoforum*, [online] 85, pp.167-177. Available at: https://www.sciencedirect.com/science/article/pii/S0016718517302245 [Accessed 2 Jan. 2018].

[5] García-Ayllón, S. (2016). Rapid development as a factor of imbalance in urban growth of cities in Latin America: A perspective based on territorial indicators. *Habitat International*, [online] 58, pp.127-142. Available at: https://www.sciencedirect.com/science/article/pii/S0197397515300072/fig4 [Accessed 2 Jan. 2018].

[6] Labrousse, J. (2018). *Le dioxyde d'azote (NO_2), Respire*. [online] Respire-asso.org. Available at: http://www.respire-asso.org/ dioxyde-dazote-no2/ [Accessed 7 Jan. 2018].

[7] Office cantonal de la statistique (2012). La précarité à Genève dans une optique territoriale. *Communications*

statistiques, 42. [online] Available at: https://www.ge.ch/statistique/tel/publications /2012/analyses/communications/an-cs-2012-42.pdf [Accessed Nov. 2017].

[8] Center for Transportation Research, the University of Texas at Austin (2000). *Urban accessibility index: Literature review.* Austin: Texas Department of Transportation. Available at: http://ctr.utexas.edu/wp-content/uploads/pubs/4938-1.pdf [Accessed 19 Dec. 2017].

[9] Confédération suisse - Office fédéral de la statistique (2016). *MONET – Distance moyenne jusqu'au prochain arrêt de transports publics.* Available at: https://www.bfs.admin.ch/bfs/fr/home/ statistiques/developpement-durable/monet/tous-selon-themes/mobilite-transports/distance-prochain-arret-transports-publics.html [Accessed 17 Dec. 2017].

[10] Klugmam, J. (2011). *Durabilité et Equité: Un Meilleur Avenir Pour Tous.* Rapport sur le développement humain 2011. [online] New York: Programkme des Nations Unis pour le Développement, p.186. Available at: http://hdr.undp.org/sites/default/files/hdr-2011-fr-complete.pdf [Accessed 19 Dec. 2017].

[11] Van Renterghem T., Botteldooren D. (2015). The effect of outdoor vegetation as seen from the dwelling's window on self-reported noise annoyance, 10th European Congress and Exposition on Noise Control Engineering. *Euronoise*, pp. 2395-2398.

[12] Smith, S. (1997). Chapter 22: Audio Processing. In: S. Smith, ed., Digital Signal Processing. [online] Hard Cover. Available at: http://www.dspguide.com/ch22/1.htm [Accessed 27 Dec. 2017].

[13] Li, H., Calder, C. and Cressie, N. (2007). Beyond Moran's I: Testing for Spatial Dependence Based on the Spatial Autoregressive Model. *Geographical Analysis*, 39(4), pp.357-375.

[14] REPUBLIQUE ET CANTON DE GENEVE - Office cantonal de la statistique (2009). [online] Available at: https://www.ge.ch/statistique/tel/compresse/2009 /geneve-cp-2009-46.pdf [Accessed 8 Jan. 2018].

[15] Andreetti A., Brouillet C., Quilici A. V.(2017, September 26). Greenness influence on sound noise perception. Exploratory Data Analysis and Geovisualization (Exercice1). [online] Available at: https://sandbox.zenodo.org/record/132281.Wld9 LajibIU, http://doi.org/10.5072/zenodo.132281

Annexe

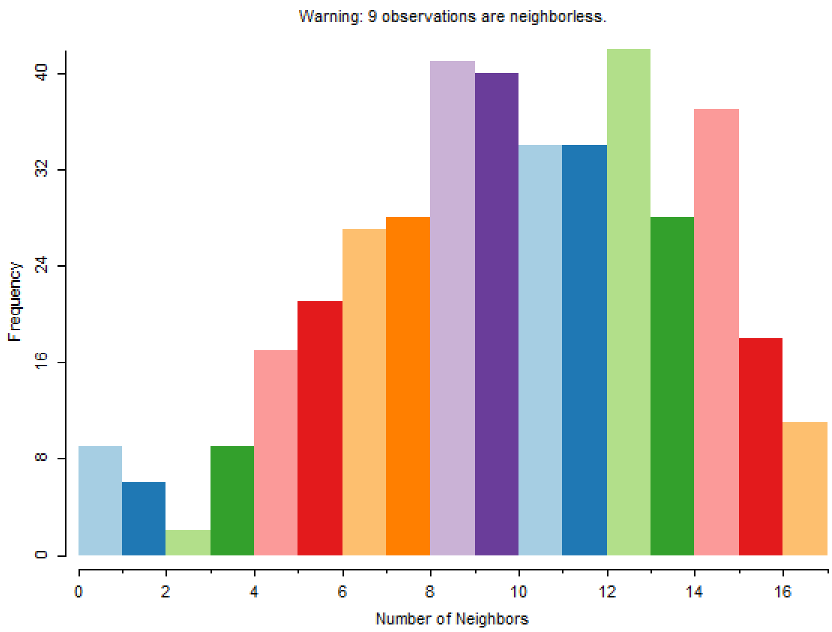

figure 9 – Histogram of the Queen weighting scheme (GeoDa), order of contiguity 2.

figure 10 – Neighbourhood of Aïre.
http://www.vernier.ch/fr/portrait/presentation/lesquartiers/

figure 11 – Neighbourhood of Contrin.
http://www.vernier.ch/fr/portrait/presentation/lesquartiers/

figure 12 – Neighbourhood of Châtelaine .
http://www.vernier.ch/fr/portrait/presentation/lesquartiers/