European Commission

JRC EXTERNAL STUDY REPORT

Results of the Collaboration Agreement among the Joint Research Centre, the Valencia City Council and the Polytechnic University of Valencia

2021-2022

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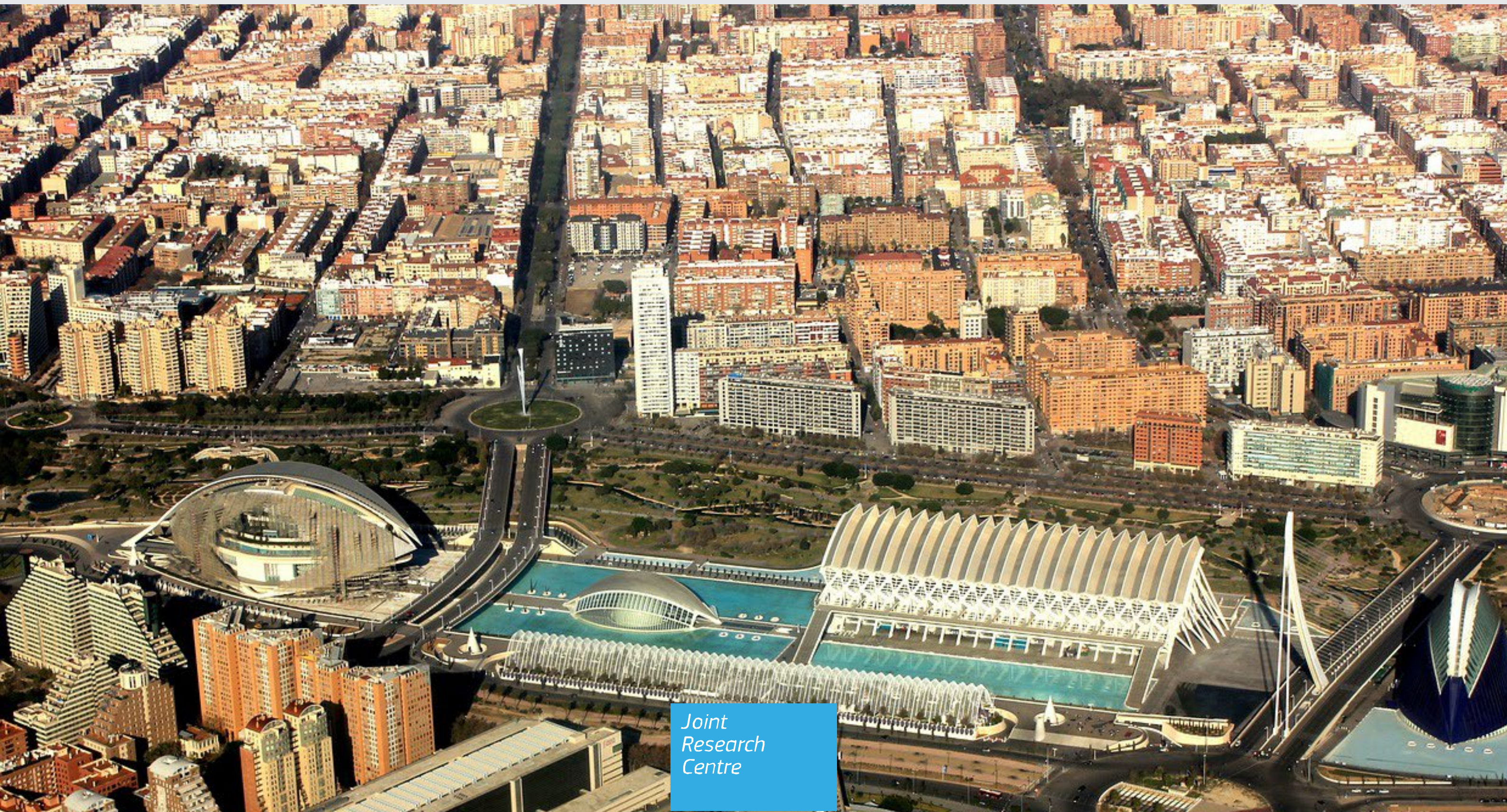

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Contents

Abstract

This report summaries the studies developed under the collaboration agreement nº 35930 between the Joint Research Centre, the Valencia City Council and the Universitat Politècnica de València during the second part of the agreement period (2021 and 2022). These studies look for innovative solutions for different problems in the city. The solutions of the studies are characterised by using Geographic Information System (GIS) or remote sensing technologies and using, improving and generating open data related to the city of València.

The conclusions and results derived from the agreement are helpful for the Valencia City Council to solve some problems of the city and for the JRC, as these solutions developed in Valencia as a city lab can be applied to other European cities.

This report contains the same projects summarised in the second deliverable, but this time the length of each project is longer, especially in the methodology section. In this case, it goes into more detail on the process followed by every project.

Acknowledgements

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1 Introduction

This document is the extension of the final report of the Collaboration Agreement No. 35930, being the second deliverable of it. This document treats some of the activities and urban aspects described in the first deliverable, Progress report on the Valencia CityLab (from March to September 2021), specifically in section 10.2, Potential Indicators and future analysis.

These areas were explored throughout different Final Thesis carried out by members of the Cátedra de Governança de la Ciutat de València in their studies of Geomatics and Topography Engineering Degree from the Escuela Técnica Superior de Ingeniería Geodésica, Cartográfica y Topográfica (ETSIGCT) at the Universitat Politècnica de València.

The studies are divided into two main branches: firstly, it describes the thesis classified as Geographic Information System (GIS) based solutions, and secondly, it describes the thesis classified as Remote Sensing based solutions.

In the first part, the studies create solutions using Geographic Information System software as its primary tool. The five studies explore and obtain results about different urban aspects such as housing affordability, energy efficiency in buildings analysing energy poverty, accessibility to public services and urban facilities, analysing environmental justice using air quality measurements with passive dosimetry sensors, the study of the situation on the Sustainable Development Goals (SDGs) on Voluntary Local Reviews (VLRs') in Valencia, and the assessment of vehicle fleet and its evolution.

In the second part, the studies create solutions using remote sensing tools based on acquiring satellite images and their processing for further analysis. The two studies explore and obtain results on other urban aspects, such as analysing environmental justice using air quality measurements with remote sensing and satellite images and big data and high-resolution information by remote sensing software.

All the studies are done with Open Data, mainly from the Open Data Portal of Valencia City Council. Moreover, an essential part of every thesis is to make quality control of the data used as part of the agreement with the Valencia City Council. This work of quality control of the data is one of the main tasks of the Càtedra de Governança de la Ciutat de València inside this Collaboration Agreement.

Each study will be organised under four or five headings; firstly, an abstract is written, then an introduction followed by a description of the data and the methodology used, and finally, the results and conclusions. Also, it is essential to know that all the Thesis are open and uploaded on the institutional repository of the Universitat Politecnica de València, RiuNet. Each link to the repository of every thesis will be in the references.

2 GIS solution-based studies

These studies present different types of problems, from social-economic issues to environmental issues. All of them are studied and analysed to offer a solution using Geospatial Information Systems techniques such as creating maps by crossing information or Geomarketing methodologies. The software used in the studies was ArcGIS, a commercial GIS Software by Esri.

2.1 Geospatial analysis of the evolution of housing prices in the city of Valencia

Summary

This study describes a geospatial analysis and research of the variation in the price of housing in the city of Valencia between 2010-2022. It also analysed the number of tourist accommodation places in the study area. The study will use geospatial analysis through Geographic Information Systems and the creation of data models of various real estate portals and thematic maps. The study concludes that the increase in tourist accommodation has impacted housing prices, especially rental prices.

2.1.1 Introduction

Access to housing is an essential issue for the population in all European cities. Housing access is becoming more complicated in recent years due to increased purchase and rental prices. In València, housing prices started to rise in 2017; in the first half of 2022, there was an annual growth of 6.9%, reaching 1.694 €/m2. However, this is an average for the city, but the price evolution is not the same in all city districts.

The upward evolution of house prices is more noticeable in cities with higher tourist activity. Valencia belongs to a region whose tourist activity represents 15% of GDP, exceeding the Spanish average of 10%. For this reason, this study seeks to analyse the correlation between the evolution of housing prices and tourist pressure in the different districts of the city of Valencia.

This project was carried out by the Càtedra Governança de la Ciutat de València, with the collaboration of the transparency and open government service of the València City Council and the Joint Research Center of the European Commission. All parties agreed to study the evolution of housing in the last ten years in Valencia. Its relationship with the number of tourist accommodation places is attractive to all parties. The city council will use the results to analyse the city's situation and act on it. The JRC will obtain a methodology that can be replicated in other European cities.

The work aims to carry out a geospatial analysis of the evolution of the price of housing in the city of Valencia and to look at the relationship with tourist rentals. The study will consider both the rental and sale prices of new and used housing. This evolution will be analysed first by a theoretical framework and then with geospatial analysis of the price data obtained through sale and purchase websites. The period that will be examined is between 2010-2022 to get an idea of how the most recent evolution has been and what may have been the most critical factors in this evolution.

2.1.2 Data and Methodology

This section describes the search, download and processing of the open data used to analyse the evolution of housing prices. Then, it explains the steps and tools used in the geospatial analysis to replicate the study in other cities.

2.1.2.1 Data

The databases used in the study were created from scratch. In other similar projects, the cadastral value of housing was used, but in Spain, this data is private. For this reason, the purchase and rental prices from 2010 and 2022 were obtained from housing portals.

The housing portals consulted were Idealista and Fotocasa. From the former, rental and purchase prices were obtained; however, only purchase prices were obtained from Fotocasa, as rental prices are rounded and do not have the necessary precision for the project.

In addition, the georeferenced districts will be obtained from the open data portal of the València City Council, which will be the basis of the geospatial analysis. The rest of the variables, such as tourist places, are obtained from statistical portals such as the National Institute of Statistics or the statistics office of the València City Council. Moreover, from the InsideAirbnb portal, data about private tourist rentals are obtained, which offers the average monthly prices in each city.

2.1.2.2 Methodology

A vital part of the study is to analyse the real estate and tourist markets to cross-reference them and see the relationship. Regarding housing, both the need to purchase and sell new and second-hand housing will be studied. In addition, the evolution of renting in the city will be reviewed.

Figure 1. The proportion of home ownership in Spain by age range (2014 – 2019).

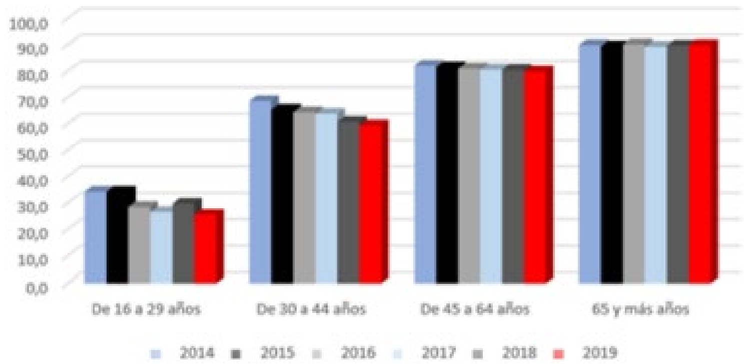
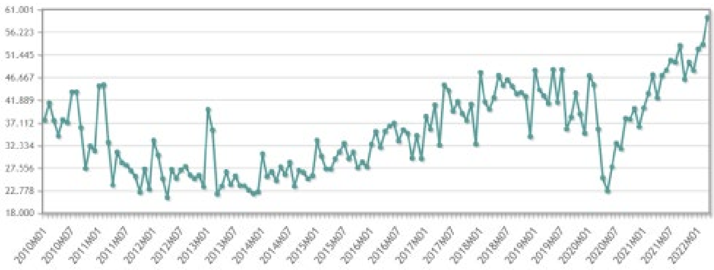


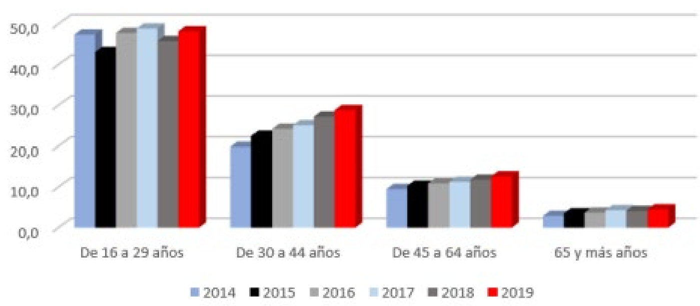
Figure 1 shows the decrease from 2014 to 2019 in the percentage of people, mainly young people and adults up to 44 years old, with dwellings in possession. However, this decrease is more subtle in the adult and older age ranges. This graph indicates that young people and adults up to 44 have more difficulties accessing home ownership. However, Figure 2 shows how house purchases increased by 57% from 2010 to the first quarter of 2022.

Figure 2. Number of housing sales in Spain (2010-2022).



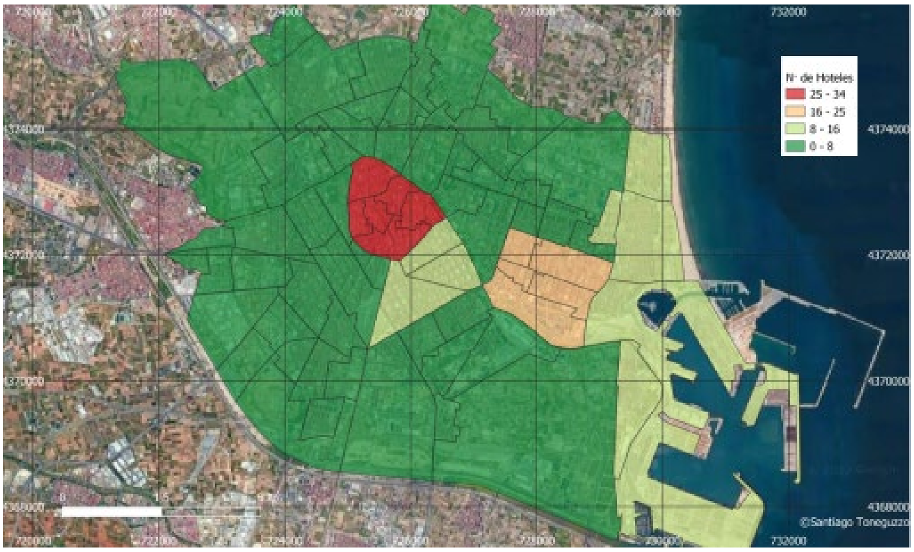
About renting, Figure 3 shows how the evolution of the percentage of the population, divided by age range, living in rented accommodation is the opposite of the change shown in Figure 1. In all age ranges, rented accommodation has increased in recent years, but in young people and adults up to 44 years, more than 25% of the population live in rented accommodation.

Figure 3. Percentage of rental housing in Spain by age group (2014-2019).



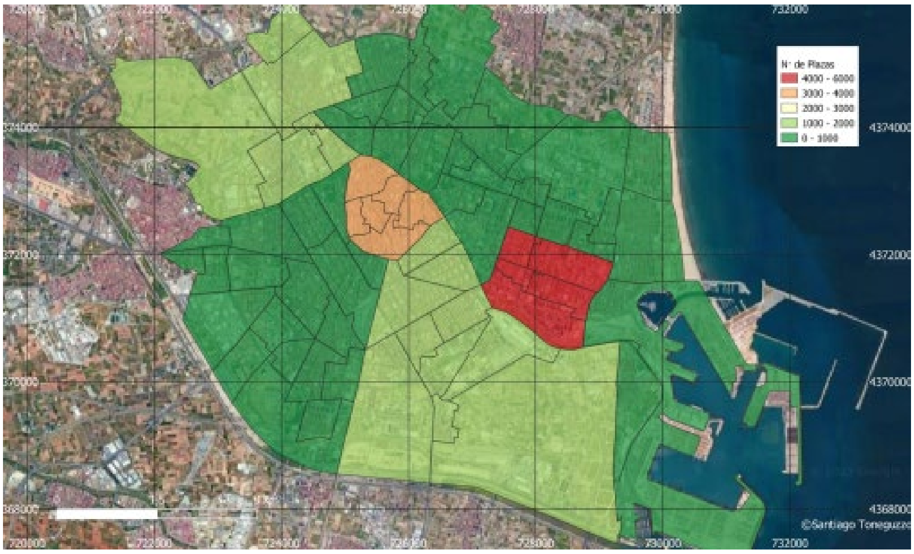
Additionally, to analysing the real estate market, the tourist situation in Valencia will be analysed to find a relationship between the two variables. The map in Figure 4 shows the distribution of hotels in the city of Valencia, which shows that they are concentrated in Ciutat Vella, the historic city centre district, and in Camins al Grau, where the City of Arts and Sciences is located, a significant tourist attraction in the city. Then, in the beach area, there are also some hotels.

Figure 4. Hotels in València by the district.



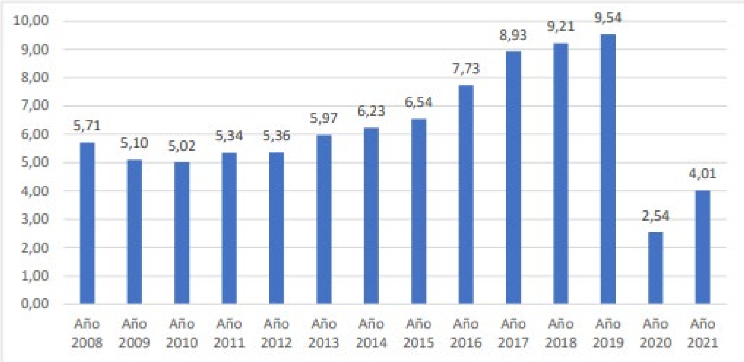
However, Figure 5 shows that the number of tourist beds in hotels is distributed differently from the number of hotels. Camins al Grau is where there are more tourist vacancies due to the presence of the largest hotels in the city, Hotel Barceló Valencia and Primus Valencia. It can also be seen on the map that although the coastal area has a low number of tourist beds in these hotels, the number of hotels in the coastal area is also deficient.

Figure 5. Tourist places in hotels by district.



The maps in Figures 4 and 5 show that the city's hotels cannot absorb the city's tourism. Since 2010 and until 2019, the last year before the COVID-19 pandemic, international population tourism in the Valencia community increased by nearly 200%, as shown in the graph in Figure 6, reaching 9.54 million tourists in the region.

Figure 6. An annual number of international tourists in millions in the Valencia Region.



Since hotel vacancies cannot absorb the city's tourist activity, tourist flats have increased their presence in Valencia, especially in areas with few hotel vacancies, such as the coast or the districts of the city's “Ensanche”. This can be seen in the map in Figure 7 and Figure 8, the number of places in tourist flats by neighbourhood; in both cases, the values and the distribution by districts are different and more intensive concerning hotels.

Figure 7. Number of Tourist Apartments in Valencia.

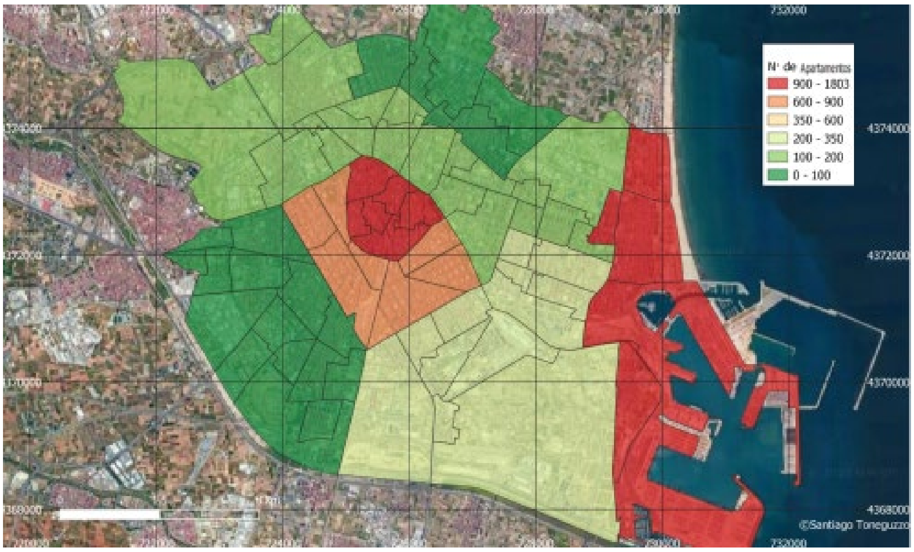
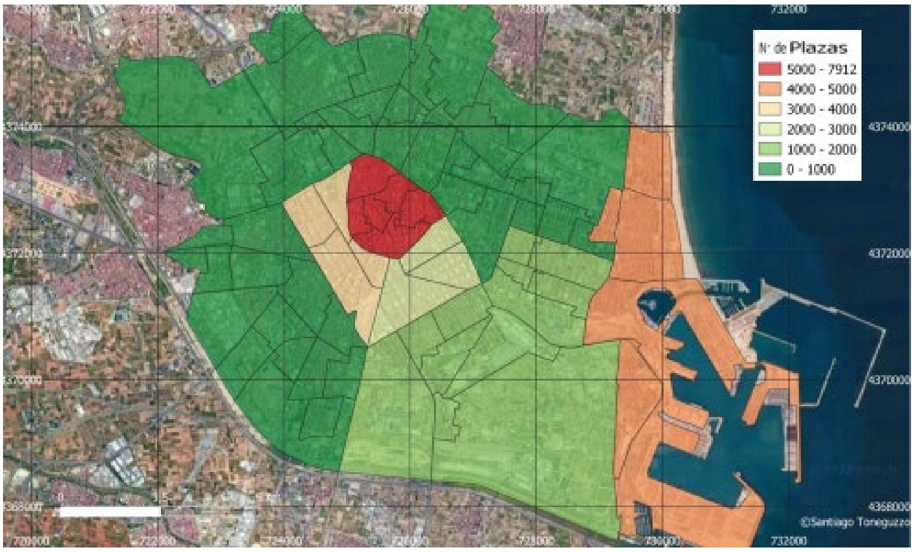


Figure 8. Existing places in Valencia Tourist Apartments.



2.1.3 Results

From the analysis of the housing market using data from the portals, we obtain the data required to compare prices between 2010 and 2022. In respect, the price for buying and selling a property in Valencia reached its minimum in 2015, with 1302 euros per square metre; since then, it has risen, reaching 1911 euros per square metre in March 2022.

In the case of rent, the minimum price of 5.9 euros per square metre was in 2014, from which it began to rise to 9.7 euros per square metre in March 2022. In this case, the price has surpassed the pre-crisis values of 2008; this has yet to happen with the sale and purchase prices, which have yet to reach the pre-crisis prices.

Figure 9. Evolution of house prices in the city of Valencia.

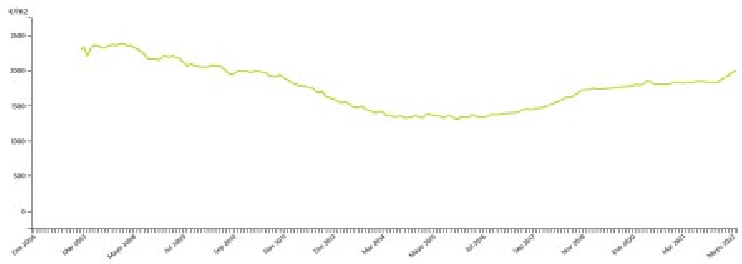
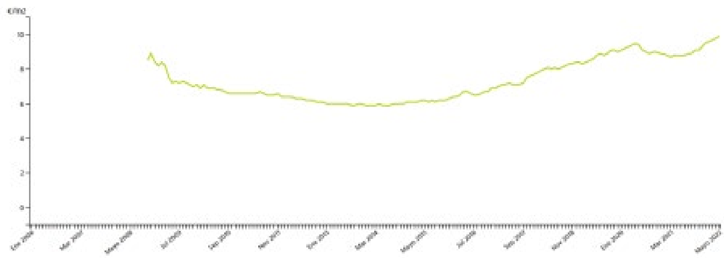


Figure 10. Evolution of rental prices in the city of Valencia.

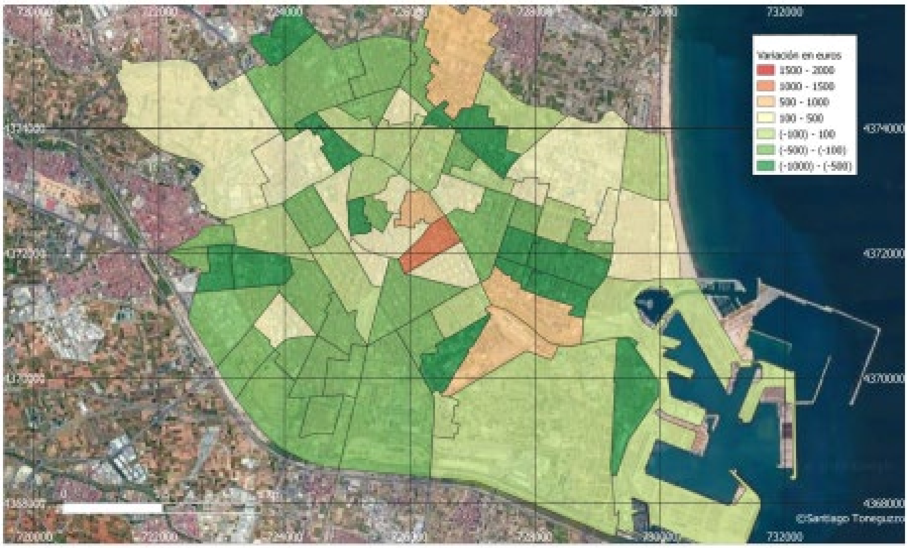


2.1.3.1 Results for sale-purchase of housing

Figure 11 shows the result on a map of house purchase prices in Valencia by districts for 2010 and 2022. The map shows that the city's central areas and west had higher prices in 2010. But in 2022, the higher-priced homes are somewhat more distributed. Figure 12 shows a map with the variation of euros per square metre of housing per district. Those more expensive in 2010 have stayed the same, such as some neighbourhoods in the centre and north of the city. Also shown are areas where housing has become cheaper to buy and sell.

Figure 11. Euros per square metre for residential sales in 2010 and 2022.

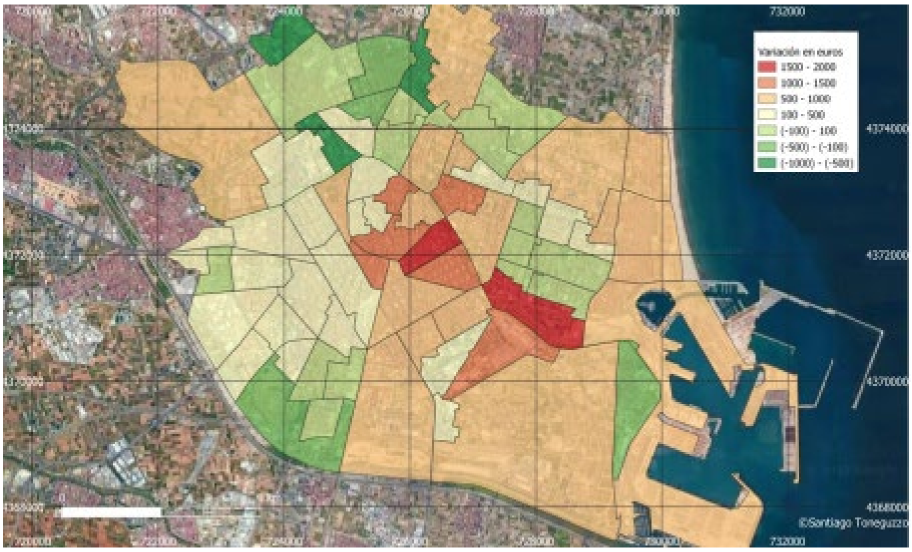
Figure 12. According to Idealista, house prices change in euros between 2010 and 2022.



In the following figures, we can see the prices of housing sales and purchases by districts for 2010 and 2022 using the values of the Fotocasa portal. In addition, Figure 14 shows the variation in prices, as does Figure 12. The values of Fotocasa are shown to be higher than those of Idealista, but the geographical pattern is similar.

Figure 13. Euros per square metre for residential sales in 2010 and 2022.

Figure 14. Change in house prices in euros, according to Fotocasa, between 2010 and 2022.



2.1.3.2 Results for rental housing

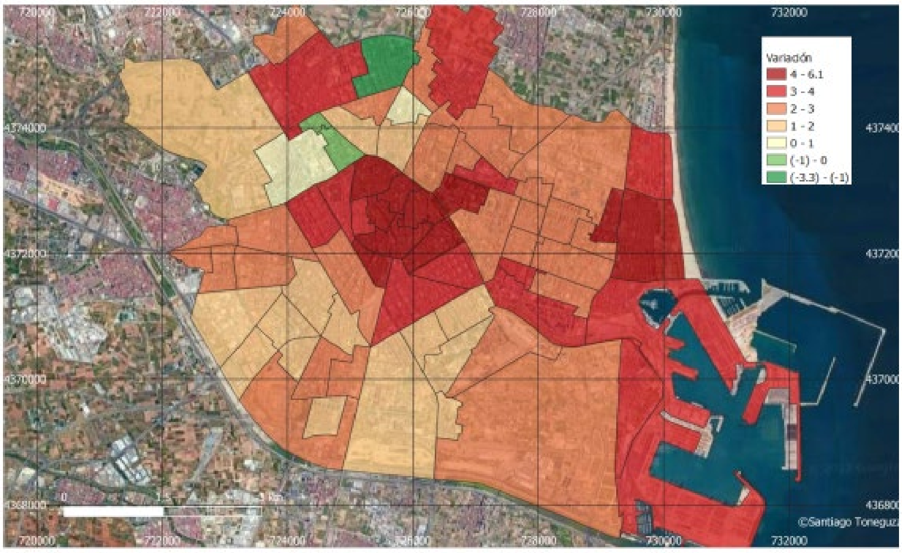
The same analysis as the previous one was done for rental housing data. In this case, the data only comes from the Idealista portal because Fotocasa does not publish data on housing rental prices. Analysing the initial rental situation, i.e. the situation in 2010, the price was between 6 and 7 euros per square metre. They found the highest prices in the historic district of Ciutat Vella and the district of Campanar, as shown in the map on the left in Figure 15.

The same map is created using 2022 rental data (right image in Figure 15), and a visual comparison is sought. In this comparison it is concluded that prices have risen in all districts of the city, remaining highest in the historic centre and Campanar. However, a significant price increase is also seen in the coastal area and the port east of the city.

Figure 15. Price in euros per square metre for rent according to Idealista in 2010 and 2022.

In addition to making a visual comparison, as in Figure 15, a map is created with the price difference between 2010 and 2022, shown in Figure 16. The map in Figure 16 shows that not only has there been an increase in prices in the city, but in some neighbourhoods, there has also been a decrease in rental prices in 2022 compared to 2010.

Figure 16. Change in rental prices according to Idealista in euros between 2010 and 2022.



2.1.3.3 Results for the Analysis of tourist rentals

In this study, apart from analysing and comparing the price of housing over the last twelve years, we have analysed the rental market for tourist use, which is a shorter-term but higher-priced rental. Using InsideAirbnb, we obtained the average price of tourist rental flats per month in the city, as shown in Figure 17.

Figure 17. Average Airbnb price per night in euros in the City of Valencia

2021						
jul	ago	sep	oct	nov	dic	Media
89,7106558	93,3579428	87,802925	82,3945588	81,2618433	82,9302457	86,178558
2022						
ene	feb	mar	abr	may	jun	Media
78,2427446	77,599317	83,230234	82,1964709	81,4979356	81,7572656	80,7645941

However, due to a lack of data over time, it is not possible to conclude that the increase in tourist rentals justifies the rise in house rental prices in the city of Valencia, although it is possible that it is one of the many factors that have affected the increase in house prices.

2.1.4 Conclusion

The study of the evolution of housing prices for renting, buying and selling and the analysis of the city's tourist pressure has been composed by obtaining open data, processing them and using geospatial analysis to create the maps that lead to the results and conclusions.

The maps that have emerged from the analysis show that the price of housing for sale and purchase in 2022 is similar to that of 2010. However, the cost of rent has increased by 50%. It should also be noted that the neighbourhoods that showed the most significant increases in the price for sale-purchase are those with the greatest potential for tourist rental.

Finally, this study concludes that the price of housing is affected by the increase in tourist pressure in the city. In addition, it is supposed that prices for sale and purchase have stayed within the figures of 2008, before the economic crisis, but rental prices have exceeded those of 2008 and continue to rise.

2.2 Geospatial analysis of the distribution of energy poverty in the residential sector of the Valencian Community

Abstract

This study consists of performing a geospatial analysis of the distribution of energy poverty throughout the entire territory of the Comunitat Valenciana (Valencian Community). To obtain this poverty, a study will be conducted on the correlation between the global vulnerability index and the energy poverty index calculated from energy certificates in the residential sector in the Comunitat Valenciana. This will establish the zones with the highest social, economic, demographic, and residential vulnerability. Also, zones with very high or low kWh consumption will be identified.

It is concluded that obtaining the areas that suffer from energy poverty is vital for society because once the rooms are located, this problem will be solved, either by doing an energy rehabilitation or by providing homes that meet these minimum requirements.

2.2.1 Introduction

This project is vital because, according to the study provided by electricity companies in their document 'Energy poverty affects 4.5 million Spaniards', 1 in 10 Spaniards suffers from energy poverty, directly affecting people in poverty or social exclusion situations. The study states that "Based on a study by the World Health Organization (WHO), between 30% and 50% of the additional deaths that occur in the coldest months are caused by insufficient heating and cooling in homes, which means that energy poverty causes more deaths than traffic accidents in our country." According to a document by the Association of Environmental Sciences (ACA), energy poverty causes about 7,100 annual deaths, nearly 3,000 more than those on the road in 2014.

Additionally, this study is of great interest as it is essential to the Valencia 2030 Urban Agenda, which features 17 Sustainable Development Goals (SDGs). Specifically, SDG 7, titled "Affordable and Clean Energy", aims to ensure access to affordable, safe, sustainable, and modern energy for all.

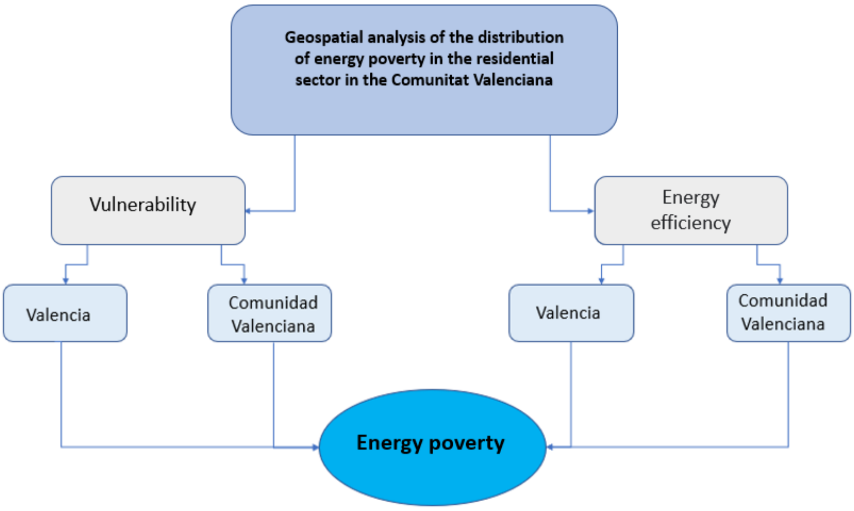
An analysis of the geospatial distribution of households' inability to reach a socially and materially necessary level of domestic energy services, hindering their effective participation in society, is intended to be carried out throughout the Valencian Community. This inability is referred to as energy poverty. To obtain the analysis, the correlation of a series of variables, primarily Socioeconomic vulnerability variables, Sociodemographic variables, and Residential variables, will be studied, allowing the calculation of the global vulnerability index, which, together with energy efficiency calculated with the help of energy certificates in the residential sector in the Valencian Community, will be decomposed into the following specific objectives (SO).

- **SO1**: Obtain and study how the global vulnerability index is distributed for the Valencian Community and Valencia. Analyse and obtain the value representing the Socio-demographic, Socioeconomic, and Residential vulnerabilities in the case of the Community. In the case of Valencia, the last one will mean a vulnerability in equipment, while the other two will remain. Obtain the average of the three vulnerabilities, representing the global vulnerability index.
- **SO2**: Obtain and study the distribution of energy efficiency both for the Valencian Community and the city of Valencia. Once the data is organised, the goal is to obtain and georeference the data to place energy certificates in the corresponding census section or neighbourhood to later calculate the energy efficiency index.
- **SO3**: Obtain and analyse the distribution of the energy poverty index for the Valencian Community and the city of Valencia. Create a logical relationship between the vulnerability and energy efficiency values that can indicate energy poverty in any area where these two variables appear.
- **SO4**: Obtain conclusions about the geospatial distribution of energy poverty in the Valencian Community and Valencia.

2.2.2 Methodology

The following diagram shows all the processes to establish the methodology. It analyses the Vulnerability and Energy efficiency levels in Valencia and the Valencian Community to obtain Energy poverty.

Figure 18. Energy poverty methodology diagram.



2.2.2.1 Vulnerability

Starting from a series of variables and indicators, three different types of vulnerability variables have been calculated for Valencia and the Valencian Community:

- **Socioeconomic variables**: income level, occupation, and level of education. These constitute objective criteria for classifying or dividing markets and are often combined to determine social class.

  For the Valencian Community, the analysis was carried out by five indicators and seven variables.

Figure 19. Socioeconomic vulnerability index and description of variables for the Valencian Community.

$$\text{Índice de Vulnerabilidad Socioeconómica } (i) = \left(\frac{100}{3}\right) * \left(\frac{PF * \left(\frac{pf2 * f2(i) + pf4 * f4(i)}{pf2 + pf4}\right) + PV * \left(\frac{pv4 * v4(i) + pv5 * v5(i) + pv6 * v6(i)}{pv4 + pv5 + pv6}\right)}{PF + PV}\right)$$

Variable code	Description
f2	AROPE factor
f4	GINI factor
v4	Population without studies
v5	Average income
v6	Unemployment rate

In the case of the city of Valencia, the following variables were studied.

Figure 20. Socioeconomic variables for the city of Valencia.

Variables	Subclasses
Academic level	Total population. Population that can neither read nor write. Less than school graduate degree.
Passenger cars of more than 16 CV	Private use Passenger cars of more than 16CV.
Average age of passenger cars for private use	
Passenger cars over 15 years old	
Cadastral value	
Average constructed area	
Middle age of buildings	
Registered unemployment	
IRPF	
IAE	

- **Sociodemographic variables**: such as sex, age, place of birth, size of the municipality of residence, and level of education. These are grouped according to socioeconomic affinity, political affiliation, and geographical relationship.

  For the Valencian Community, the analysis was carried out by five indicators and seven variables.

Figure 21. Sociodemographic Vulnerability Index and description of variables for the Valencian Community.

$$Índice\ de\ Vulnerabilidad\ Sociodemográfica\ (i)\ =$$

$$\left(\frac{100}{3}\right) * \left(\frac{PF * \left(\frac{pf1 * f1(i) + pf3 * f3(i)}{pf1 + pf3}\right) + PV * \left(\frac{pv7 * v7(i) + pv8 * v8(i) + pv9 * v9(i)}{pv7 + pv8 + pv9}\right)}{PF + PV}\right)$$

Variable code	Description
f1	AVANT factor
f3	RMEs factor
v7	Dependency index
v8	Deprivation index
v9	Inmigrant population

In the case of the city of Valencia, the following variables were studied.

Figure 22. Sociodemographic variables for the city of Valencia.

Variables	**Subclases**
Population density	
5-year population variation	Population 2021 Population 2016
Dependent population	dependent demographic index
Non-EU population	Foreign population Total population
Population older than 80 years	Total population Population between 80 and 84 years Population older than 85 years Population older than 80 years Percentage of population older than 80 years
Population over 65 years old living alone	
Population under 19 years of age	Population equal to or less than 19 years of age Total population

- **Residential variables**: sex, date and place of birth, nationality, origin and destination of movement. The analysis of internal and external flows differentiates between Spaniards and foreigners.

  For the Valencian Community, the analysis was carried out by six indicators and seven variables.

Figure 23. Residential Vulnerability Index and Description of Variables for the Valencian Community

$$\textit{Índice de Vulnerabilidad Residencial } (i) = \left(\frac{100}{3}\right) * \left(\frac{pv1 * v1(i) + pv2 * v2(i) + pv3 * v3(i)}{pv1 + pv2 + pv3}\right)$$

Variable code	Description
v1	SMH
v2	Accesibility
v3	Cadastral Value

In the case of the city of Valencia, the following variables were studied.

Figure 24. Residential variables for the city of Valencia.

Variables	Subclasses
Health	Surgery clinic specialty center Hospital
Transport	Metrovalencia EMT Valenbisi
Education	Child education Obligatory education Post-Compulsory Education
Population at risk	Older center Social services
Others	Sports Police Libraries Parkland

Finally, it is obtained a global vulnerability index for each study. The global vulnerability index is obtained based on the previous three vulnerabilities by taking the arithmetic mean of these values. Two more vulnerability indexes have been created for the Valencian Community to enrich the research process and determine which of the obtained results is better.

- The first index is calculated following the methodology of the ICV, dividing into four categories depending on whether the three vulnerability indexes exceed the percentiles or not, specifically the 66th percentile, so the data will be categorised based on whether or not they exceed the percentiles as follows:
    - Residual Vulnerability: None of the three vulnerabilities exceeds the 66th percentile.
    - Low Vulnerability: One of the three vulnerabilities exceeds the 66th percentile.
    - Medium Vulnerability: Two of the three vulnerabilities exceed the 66th percentile.
    - Comprehensive Vulnerability: All vulnerabilities exceed the 66th percentile.
- For the second case, a map has been created using the Ajuntament de València model. After obtaining the average vulnerability values, the values are sorted, and the 10th and 20th percentiles are calculated. Values below or equal to the 10th percentile are classified as "High Vulnerability," values between the 10th and 20th percentiles (including the 20th percentile) are considered "Medium Vulnerability," and the remaining values are "Low Vulnerability."

In the case of the city of Valencia, the three coded and classified indexes were used. The arithmetic mean of these indexes will be calculated, and the final coding will be performed, as only the overall vulnerability will be considered for analysis.

2.2.2.2 Energy efficiency

For the emission calculation that will appear on the certificate for the Valencian Community, the annual CO2 emissions (kg*m2) of the valuable surface area are considered. The data in the Excel file is classified using the INE code of the municipality, categorising energy certificates by census sections throughout the Valencian Community. The average kWh consumption is obtained for each census section. The ArcGIS software is used to convert the certificates into a vector layer. After getting the certificates for the census sections, the arithmetic mean is calculated for both the certificates and the reference surface of each certificate. In the vector layer, a "Join" links the attribute table information with the Excel information and relates the alphanumeric information of the reference surface and energy certificates with the graphical data.

The total kWh consumption must be calculated by multiplying the kWh and the reference surface area to obtain the energy efficiency index. The arithmetic mean of all certificates must also be calculated. The result of the previous process should be a series of data that defines the total kWh consumption. To classify this data, the percentile methodology has been utilised, dividing the data into four percentiles, categorised as follows:

Figure 25. Consumption classification for the Valencian Community.

	Percentile	Description
10%	54,4	Low consumption
36,66%	199,4304	Medium consumption
63,33%	344,5152	High consumption
90%	489,6	Very high consumption

From the previous certificates, only those located in Valencia were selected. This information is divided into approximately 1000-1500 rows batches and saved as a CSV file in UTF-8 encoding. This is because we intend to use a delicate tool that generates errors. The generated CSV files are imported in batches using the "MMQGIS" Python add-on, a tool that allows energy certificates to be vectorised through street names. Once the points representing the energy certificates have been obtained, they are separated by neighbourhoods. The facts are converted into polygons while saving the average arithmetic consumption of all certificates. Finally, we have two variables: the middle reference surface area of the neighbourhoods in Valencia and the certificates of moderate consumption. The product of these variables is then calculated to obtain the total kWh consumption, which indicates how much each neighbourhood consumes.

Figure 26. Consumption classification for the Valencia City.

	Percentile	Description
10%	7	Low consumption
36,66%	25,662	Medium consumption
63,33%	44,331	High consumption
90%	63	Very high consumption

2.2.2.3 Energy poverty

Two different maps were calculated, one with three vulnerability categories following the methodology of Ajuntament de València and another following the custom methodology to achieve the desired results. This way, six variables are obtained that progressively divide the energy poverty index.

Figure 27. Classification of energy poverty.

Energy Poverty
Very low
Low
Slight
Moderate
Significant
Very high

Figure 28. Methodology used to assign energy poverty throughout the Valencian Community in 3 vulnerability variables.

VULNERABILITY	CONSUMPTION	ENERGY POVERTY
Low Vulnerability	Low	Low
	Medium	Slight
	High	Moderate
	Very high	Moderate
Medium Vulnerability	Low	Slight
	Medium	Moderate
	High	Moderate
	Very high	Significant
High Vulnerability	Low	Moderate
	Medium	Moderate
	High	Significant
	Very high	Very high

Figure 29. Methodology used to assign energy poverty throughout the Valencian Community in 4 vulnerability variables.

VULNERABILITY	CONSUMPTION	ENERGY POVERTY
Very Low Vulnerability	Low	Low
	Medium	Slight
	High	Slight
	Very high	Moderate
Low Vulnerability	Low	Slight
	Medium	Slight
	High	Moderate
	Very high	Significant
Medium Vulnerability	Low	Slight
	Medium	Moderate
	High	Significant
	Very high	Significant
High Vulnerability	Low	Moderate
	Medium	Significant
	High	Significant
	Very high	Very high

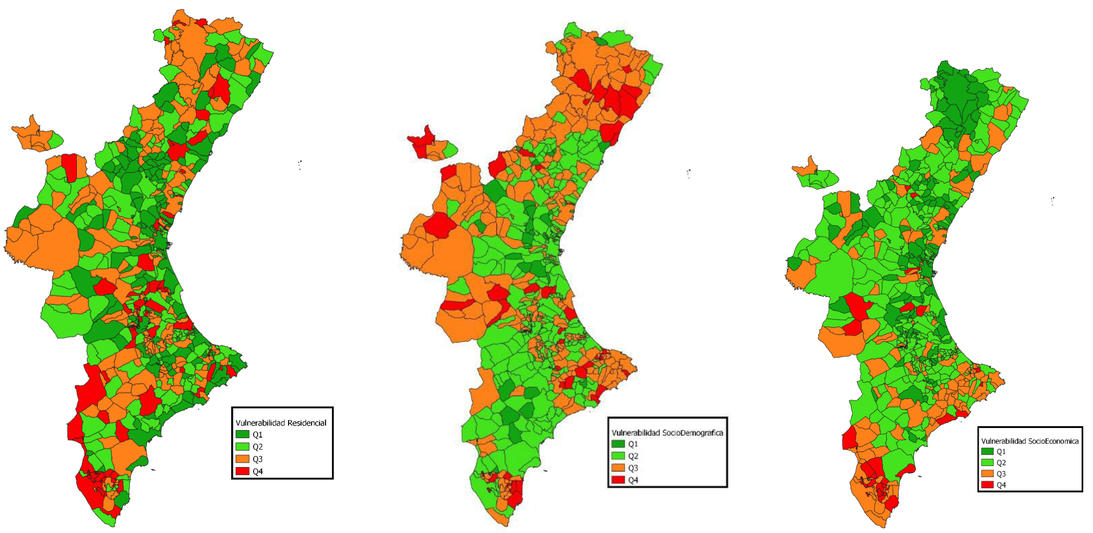
2.2.3 Results

The results of the study are maps with the vulnerabilities calculated, the energy efficiency and the final energy poverty. The global vulnerability indices for the Valencian Community and the city of Valencia are computed using the three vulnerabilities described in the methodology. Energy efficiency indices were also obtained from the ICV open data, and the area's energy efficiency was calculated as an average. Finally, the energy poverty classification can be obtained by crossing the area's vulnerability and energy efficiency.

2.2.3.1 Valencian Community Results

Once the values for each vulnerability have been calculated for each census tract, they are represented on a map.

Figure 30. Representation of residential (left), sociodemographic (centre) and socioeconomic (right) vulnerabilities layers generated for the Valencian Community.



The symbology used is based on the model generated by the ICV, which divides the data into four percentiles: Q1, Q2, Q3, and Q4. The percentile values are assigned based on the distribution of the data. The location of the most vulnerable areas must follow a clear pattern, and less vulnerable areas are more abundant. Subsequently, a map and a histogram are created based on the average of the three indices to obtain the global vulnerability index.

Figure 31. Representation of global vulnerability for the Valencian Community.

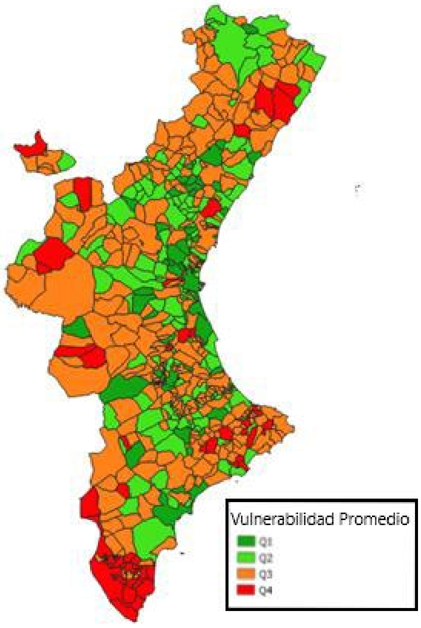
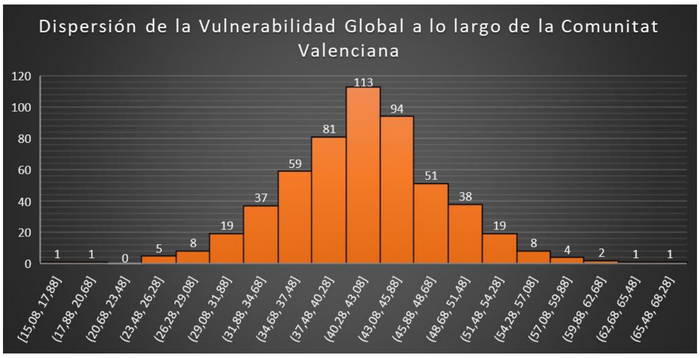
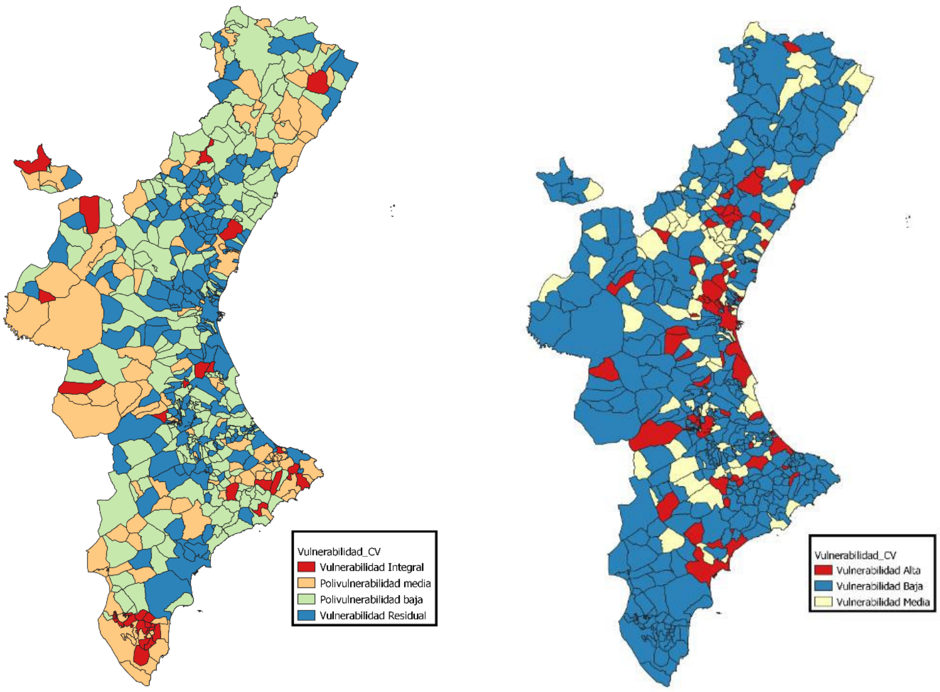


Figure 32.Histogram of global vulnerability for the Valencian Community.



To enrich the study, two more maps are made following the ICV methodology and the Ajuntament de València methodology, respectively, but for the entire territory of the Comunitat Valenciana.

Figure 33. Representation of the global vulnerability index layer using the ICV methodology (left) and Valencia City Council methodology (right)



After visualising the three results, it was decided to change the methodology to obtain the global Vulnerability index. This was done by calculating and assigning a new percentile to a new class. Sections that fall below the 10th percentile are considered high vulnerability zones, those between the 10th and 20th percentile are potentially vulnerable zones, those between the 20th and 50th percentile are regarded as low vulnerability zones, and those above the 50th percentile are considered shallow vulnerability zones.

Finally, the representation of vulnerability, energy efficiency and energy poverty is obtained.

Figure 34. Global vulnerability classification (left) and energy efficiency (right) in the Valencian Community.

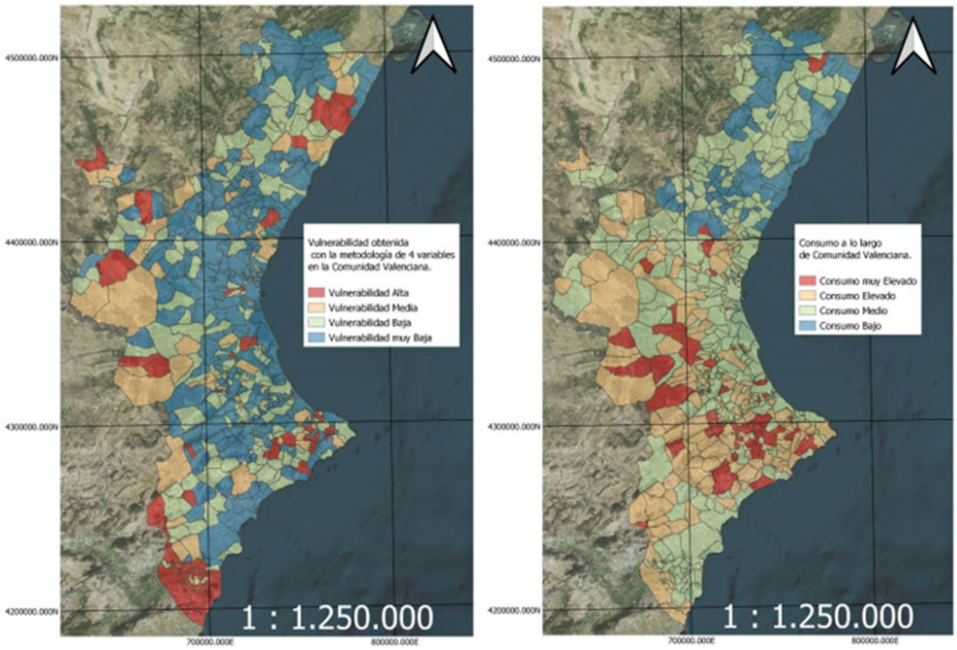
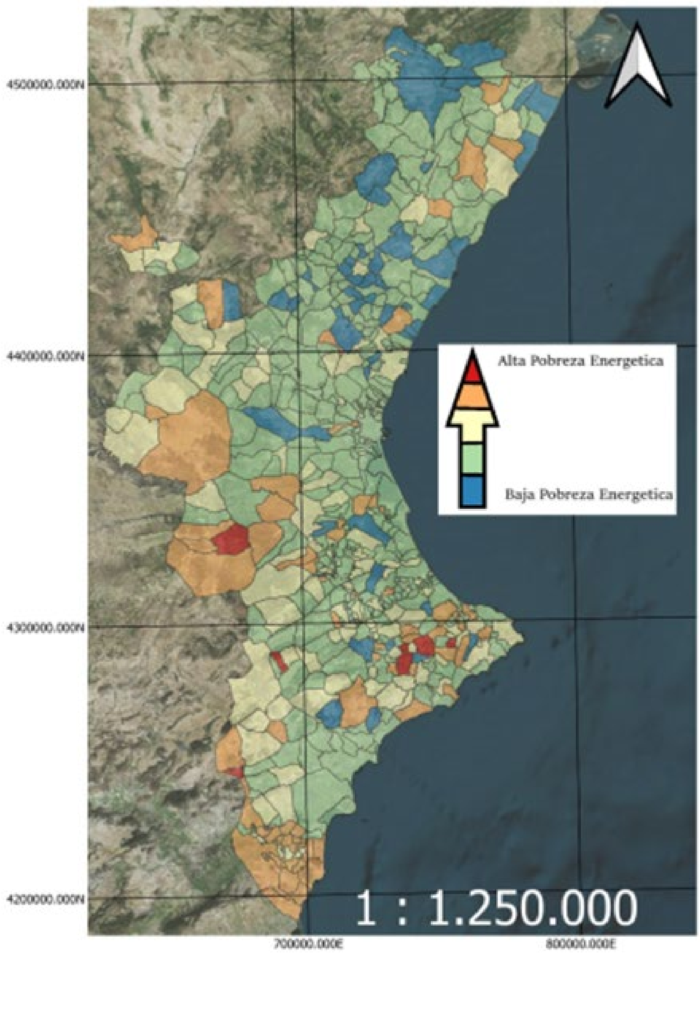


Figure 35. Energy poverty classification per area in the Valencian Community.



2.2.3.2 Valencia City Results

As before, maps of each vulnerability are obtained separately. Afterwards, a global vulnerability map is created by taking the average of the three individual maps.

Figure 36. Representation of equipments (left), sociodemographic (centre) and socioeconomic (right) vulnerabilities layers generated for Valencia.

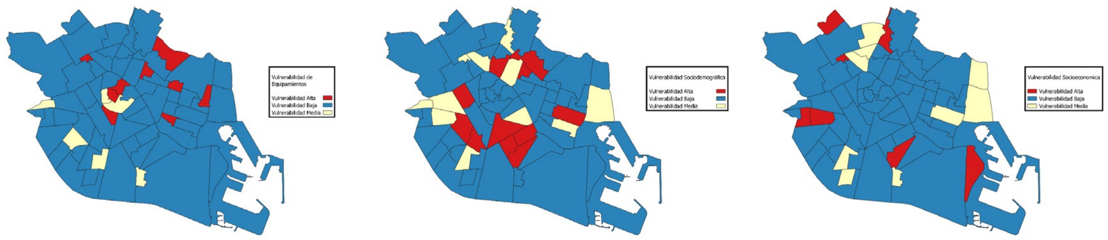
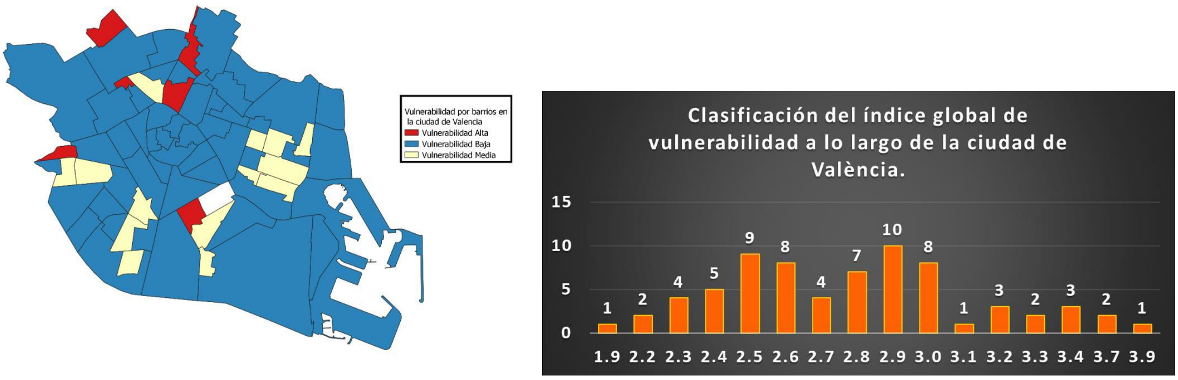


Figure 37. Representation and histogram of global vulnerability for Valencia.



Finally, the representation of vulnerability, energy efficiency and energy poverty is obtained.

Figure 38. Global vulnerability classification (left) and energy efficiency (right) in Valencia.

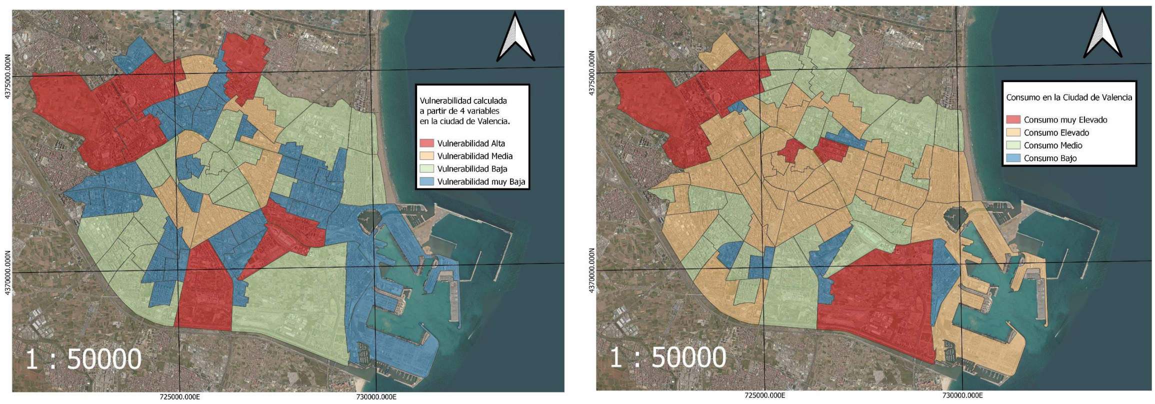
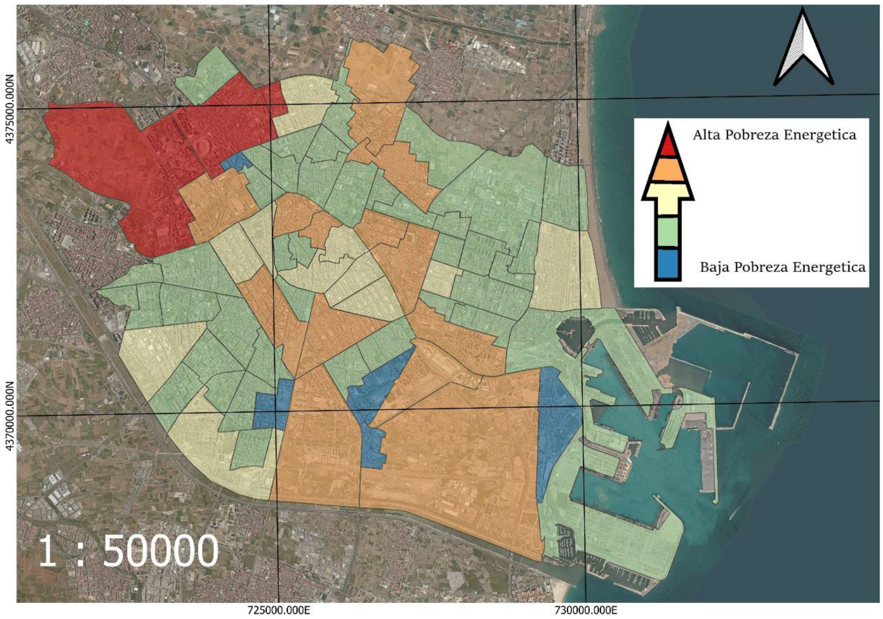


Figure 39. Energy poverty classification per area in Valencia.



2.2.4 Conclusions

The variable of vulnerability has been related to the energy efficiency variable to obtain the energy poverty index. This shows that if a municipality is highly vulnerable and has a high energy consumption, it should be controlled and treated to reduce consumption. The vulnerability should also be controlled to ensure that the energy poverty index does not exceed the maximum allowed value. The result indicates that 8.48% of the census sections have low energy poverty, such as Algimia de Almonacid, Alzira, Vistabella del Maestrat, La Llosa, and Figueroles. In comparison, 1.29% have very high energy poverty, such as Teresa de Cofrentes, Confrides, Algueña, Castell de Castells, and Campo de Mirra, which must be regulated. Meanwhile, 58.30% of the census sections have slight energy poverty, 18.81% have moderate energy poverty, and 13% have significant energy poverty.

In the case of the city of Valencia, it can be observed that 7.15% of the neighbourhoods have low energy poverty, with neighbourhoods such as El Calvari, Na Rovella, La Fonteta de Sant Lluis, La Creu Coberta, and Natzaret being the best. In contrast, 2.86% of the neighbourhoods have high energy poverty, with Benicalap, Sant Pau, La Seu, Exposicio, and La Punta being the worst. Meanwhile, 55.71% of the neighbourhoods in Valencia have slight energy poverty, 15.71% have moderate energy poverty, and 18.57% have significant energy poverty.

2.3 Analysis of environmental equity between the different neighbourhoods of Valencia city using passive dosimetry data and other vulnerability indicators

Abstract

This project will conduct a study of the neighbourhoods of Valencia City to define the level of vulnerability of each. To do this, vulnerability indices related to three topics will be calculated first: equipment, demographics and socioeconomics, from data obtained, the vast majority, from the open data portal of Valencia city. A global vulnerability index for each neighbourhood is then obtained from the three indices calculated above.

On the other hand, levels of NO_2 in the air, obtained from stations of passive dosimetry distributed throughout the city, are studied to define which neighbourhoods have better air quality and which have worse. For this purpose, the annual limit value of NO_2 established by the European Union and the World Health Organisation shall be used as a reference.

This project aims to study whether there is any relationship between neighbourhoods with high vulnerability and areas with poorer air quality. From the project results, you can know the current situation of each community and establish improvement plans depending on the topic in which you are vulnerable.

2.3.1 Introduction

This project aims to address two problems. The first is the inequality between neighbourhoods regarding the facilities in each; depending on the neighbourhood where a citizen resides, he has greater or lesser access to facilities such as public services, residences, or public transport. It will also study inequality from an economic point of view, analysing data such as IRPF or the cadastral value of plots, and inequality from a demographic perspective, learning in which neighbourhoods there are more population with advanced age or dependent. All this will be defined by calculating vulnerability indexes related to the three themes mentioned, which allow identifying city areas with several negative variables compared to the rest.

The second problem to be addressed is air quality. This project will define the neighbourhoods with better and worse air quality from the levels of NO_2 registered in stations of passive dosimetry. Nitrogen dioxide is one of the most critical primary pollutants produced by vehicles, maritime transport, power plants, industries and homes, old diesel vehicles being the primary source of emissions. It affects the respiratory system, producing asthma, bronchitis, liver, and blood.

Therefore, it is essential to identify which neighbourhoods are exposed to high levels of NO_2 and whether there is a relationship between neighbourhoods with increased vulnerability and neighbourhoods with poorer air quality. This study can enable the authorities to take decisions considering the situation of each neighbourhood to improve them so that all have the same opportunities and advantages and achieve environmental equity.

The data used to calculate each vulnerability index and air quality are:

- Vulnerability in equipment.
    - Health: hospitals, clinics and health centres.
    - Public transport: EMT, Metrovalencia and Valenbisi.
    - Schools: private, concerted and public.
    - Social resources: senior centres, social service centres and youth centres.
    - Public services: libraries, sports centres and police stations.
- Demographic vulnerability.
    - Population density.
    - Population variation in the last five years.
    - Dependent population.
    - Non-EU population.
    - Population over 80 years old.

- Population over 65 living alone.
- Population under 19.

- Socio-economic vulnerability
  - Academic level.
  - Cars over 16 CV.
  - Average age of passenger cars.
  - Passenger cars over 15 years old.
  - Cadastral value.
  - Average constructed surface.
  - Average age of buildings.
  - Unemployment on record.
  - Personal income tax (IRPF).
  - Tax on Economic Activities (IAE).
- Air quality
  - NO_2 data from passive dosimetry stations.

2.3.2 Methodology

The methodology of this project is divided into three parts:

- Calculating the vulnerability of neighbourhoods.
- Calculation of neighbourhood air quality.
- Analysis of the relationship between vulnerable neighbourhoods and neighbourhoods with poorer air quality and environmental equity.

2.3.2.1 Calculating the Vulnerability of Neighbourhoods

Four indices are calculated: vulnerability of equipment, demographic vulnerability, socio-economic vulnerability and global vulnerability. The number of facilities in each neighbourhood defines the vulnerability of equipment. The fewer facilities it has, the more vulnerable it will be.

To calculate the indices, it is necessary to normalise the variables. To do this, the variables are encoded from 1 to 5, with 1 being the worst situation and the value 5 being the best. The distribution of the values of each variable is divided into five classes by percentiles, highlighting neighbourhoods with extreme values. p0.1, p0.3666, p0.6333, and p0.9 are the percentiles corresponding to 10%, 36.66%, 63.33% and 90% of the distribution of each variable.

VARIABLE VALUE ≤ p0.1 ENCODING = 1

p0.1 < VARIABLE VALUE ≤ p0.3666 ENCODING = 2

p0,3666 < VARIABLE VALUE ≤ p0,6333 ENCODING = 3

p0.6333 < VARIABLE VALUE ≤ p0.9 ENCODING = 4

VARIABLE VALUE > p0,9 ENCODING = 5

Figure 40. Codification of the variable "Public transport".

codbar	Nombre	Transporte publico	
		Equipamientos	Codificación
11	LA SEU	5	1
12	LA XEREA	9	2
13	EL CARME	9	2
14	EL PILAR	4	1
15	EL MERCAT	6	1
16	SANT FRANCESC	34	4
21	RUSSAFA	37	5
22	EL PLA DEL REMEI	21	4
23	LA GRAN VIA	24	4
31	EL BOTANIC	10	2
32	LA ROQUETA	11	2
33	LA PETXINA	17	3
34	ARRANCAPINS	33	4
41	CAMPANAR	42	5
42	LES TENDETES	8	2
43	EL CALVARI	5	1
44	SANT PAU	35	4
51	MARXALENES	20	4
52	MORVEDRE	16	3
53	TRINITAT	15	3
54	TORMOS	8	2
55	SANT ANTONI	7	2
61	EXPOSICIO	15	3
62	MESTALLA	36	5
63	JAUME ROIG	8	2

Percentiles	Posición	Valor
10%	7	6
36.66%	25.662	11
63.33%	44.331	18
90%	63	35

The vulnerability indices of equipment, demographic vulnerability and socio-economic vulnerability of each neighbourhood are calculated using an arithmetic mean of the variables of each vulnerability. The arithmetic mean of the three vulnerabilities calculates the global vulnerability index.

Figure 41. Example of calculation of demographic vulnerability.

codbar	Nombre	Densidad de población	Variacion poblacion 5 años	Poblacion dependiente	Poblacion extracomunitaria	Poblacion mayor de 80 años	Poblacion mayor de 65 años que vive sola	Poblacion menor de 19 años	Global
11	LA SEU	4	3	5	2	3	4	4	3.6
12	LA XEREA	4	3	2	3	2	4	3	3.0
13	EL CARME	3	4	5	2	3	3	5	3.6
14	EL PILAR	2	3	5	2	4	4	4	3.4
15	EL MERCAT	3	3	5	2	4	4	4	3.6
16	SANT FRANCESC	4	4	2	3	2	3	4	3.1
21	RUSSAFA	3	2	3	3	2	1	3	2.4
22	EL PLA DEL REMEI	3	4	1	5	1	3	2	2.7
23	LA GRAN VIA	3	4	1	5	1	2	2	2.6
31	EL BOTANIC	3	3	4	3	2	3	3	3.0
32	LA ROQUETA	3	3	4	1	2	4	5	3.1
33	LA PETXINA	2	2	2	4	1	2	2	2.1
34	ARRANCAPINS	3	4	2	4	2	1	3	2.7
41	CAMPANAR	4	2	1	4	4	2	4	3.0
42	LES TENDETES	3	3	2	1	3	4	5	3.0
43	EL CALVARI	1	4	3	1	1	3	5	2.6
44	SANT PAU	5	5	2	4	5	3	1	3.6
51	MARXALENES	3	4	1	2	2	2	4	2.6
52	MORVEDRE	3	2	2	3	1	2	4	2.4
53	TRINITAT	4	3	2	2	1	2	4	2.6
54	TORMOS	2	4	4	2	3	3	2	2.9
55	SANT ANTONI	1	3	2	4	3	3	3	2.7
61	EXPOSICIO	3	3	1	5	2	3	2	2.7
62	MESTALLA	3	4	2	4	3	2	2	2.9
63	JAUME ROIG	2	3	1	5	2	3	1	2.4
64	CIUTAT UNIVERSITARIA	4	4	1	4	3	5	1	3.1
71	NOU MOLES	2	4	3	2	2	1	4	2.6
72	SOTERNES	3	2	2	2	2	4	3	2.6
73	TRES FORQUES	3	5	3	1	1	2	3	2.6
74	LA FONTSANTA	4	3	3	1	3	5	2	3.0
75	LA LLUM	2	3	3	4	3	4	3	3.1
81	PATRAIX	1	2	3	3	2	1	3	2.1
82	SANT ISIDRE	3	2	5	4	5	3	2	3.4
83	VARA DE QUART	4	2	2	4	4	3	5	3.4

Vulnerable neighbourhoods or neighbourhoods with high vulnerability will be defined as all those whose codification in a topic or the global index is equal to or less than the 10% percentile of the distribution of all the final codifications of neighbourhoods in that topic or in the global index. On the other hand, potentially vulnerable neighbourhoods or neighbourhoods with medium vulnerability will be defined as those whose codification in a case or the global index is between the percentiles 10% and 20% of the distribution of all the final codifications of neighbourhoods in that topic or in the global index.

2.3.2.2 *Calculation of neighbourhood air quality*

According to the European Union and the World Health Organisation, the annual limit value of NO_2 is 40 ug/m^3.

Figure 42. NO_2 limit values.

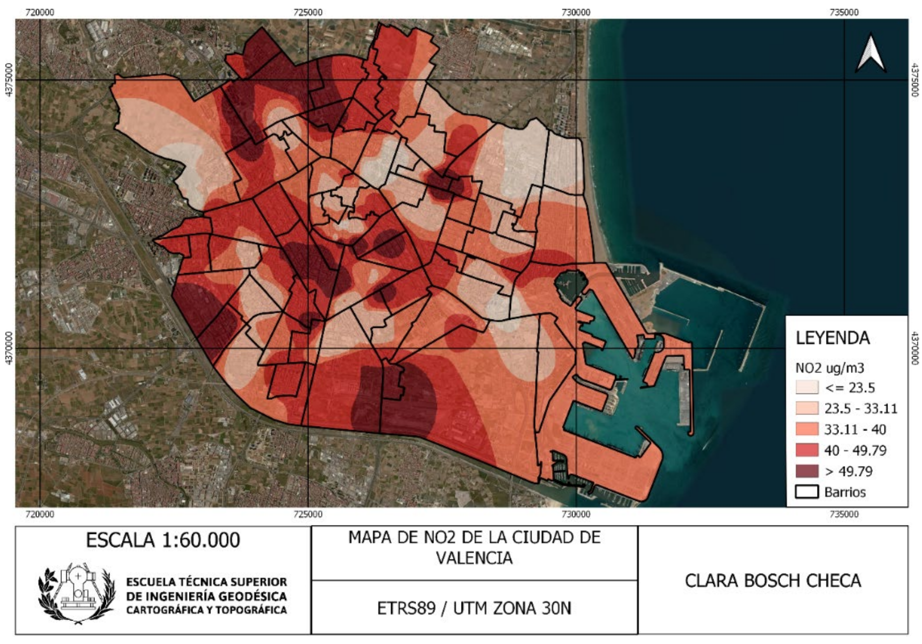
Pollutant	Concentration	Averaging period	Legal nature	Permitted exceedences each year
Nitrogen dioxide (NO_2)	200 μg/m^3	1 hour	Limit value to be met as of 1.1.2010	18
Nitrogen dioxide (NO_2)	40 μg/m^3	1 year	Limit value to be met as of 1.1.2010 *	n/a

From the passive dosimetry data, the percentiles 10%, 36.66%, 63.33% and 90% of the distribution of NO_2 values are calculated to highlight areas with low values and regions with high values. This is also intended to differentiate between neighbourhoods exceeding the NO_2 limit value of 40 ug/m^3 and those not exceeding it.

On the other hand, an IDW interpolation or interpolation by distance is made from the layer of points that represents the position of the stations of passive dosimetry and their respective data of NO_2; in this way, the whole study area will be endowed with values. The symbology of the interpolated is changed, adding five classes with the resulting values of the previous percentiles:

- < = 23.5
- 23.5 – 33.11
- 33.11 – 40
- 40 – 49.79
- > 49.79

Figure 43. Interpolation of NO_2 data.



The raster layer obtained from the interpolation is vectorised and intersects with the neighbourhoods to be studied. In this way, you get a new layer of neighbourhoods with all the values of NO_2 in each. From this layer, the average value of NO_2 is calculated for each of the neighbourhoods.

2.3.2.3 Analysis of environmental equity

The latter must be standardised to relate vulnerability outcomes to air quality outcomes. To do this, each neighbourhood will be given values from 1 to 5: neighbourhoods with value 1 have the highest level of NO_2 and neighbourhoods with value 5 have the lowest level of NO_2. It is classified as follows:

- < = 23.5 → ENCODING = 5
- 23.5 – 33.11→ ENCODING = 4
- 33.11 – 40 → ENCODING = 3
- 40 – 49.79 → ENCODING = 2
- > 49.79 → ENCODING = 1

Finally, to represent the environmental equity of the neighbourhoods on a map, each neighbourhood will be given a value of 1 to 3. Value 1 will be neighbourhoods with medium or high vulnerability and exceeding the limit level of NO_2; value 2 will be neighbourhoods with medium or high vulnerability or neighbourhoods exceeding the limit level of NO2; value 3 will be neighbourhoods that do not meet any of the above conditions.

2.3.3 Results

2.3.3.1 Vulnerability

Figure 44. Vulnerability by neighbourhoods.

codbar	nombre	Equipamiento	Asignacion	Demografía	Asignacion	Socioeconomía	Asignacion	Indice Global Vulnerabilidad	Asignacion
11	LA SEU	1.4	Vulnerabilidad Alta	3.6	Vulnerabilidad Baja	3.8	Vulnerabilidad Baja	2.9	Vulnerabilidad Baja
12	LA XEREA	2.0	Vulnerabilidad Baja	3.0	Vulnerabilidad Baja	4.0	Vulnerabilidad Baja	3.0	Vulnerabilidad Baja
13	EL CARME	2.8	Vulnerabilidad Baja	3.6	Vulnerabilidad Baja	3.1	Vulnerabilidad Baja	3.2	Vulnerabilidad Baja
14	EL PILAR	1.6	Vulnerabilidad Media	3.4	Vulnerabilidad Baja	3.4	Vulnerabilidad Baja	2.8	Vulnerabilidad Baja
15	EL MERCAT	1.0	Vulnerabilidad Alta	3.6	Vulnerabilidad Baja	3.7	Vulnerabilidad Baja	2.8	Vulnerabilidad Baja
16	SANT FRANCESC	1.6	Vulnerabilidad Media	3.1	Vulnerabilidad Baja	4.3	Vulnerabilidad Baja	3.0	Vulnerabilidad Baja
21	RUSSAFA	4.4	Vulnerabilidad Baja	2.4	Vulnerabilidad Alta	3.2	Vulnerabilidad Baja	3.3	Vulnerabilidad Baja
22	EL PLA DEL REMEI	1.8	Vulnerabilidad Baja	2.7	Vulnerabilidad Baja	4.2	Vulnerabilidad Baja	2.9	Vulnerabilidad Baja
23	LA GRAN VIA	2.2	Vulnerabilidad Baja	2.6	Vulnerabilidad Media	3.9	Vulnerabilidad Baja	2.9	Vulnerabilidad Baja
31	EL BOTANIC	2.8	Vulnerabilidad Baja	3.0	Vulnerabilidad Baja	3.3	Vulnerabilidad Baja	3.0	Vulnerabilidad Baja
32	LA ROQUETA	1.4	Vulnerabilidad Alta	3.1	Vulnerabilidad Baja	3.6	Vulnerabilidad Baja	2.7	Vulnerabilidad Baja
33	LA PETXINA	3.0	Vulnerabilidad Baja	2.1	Vulnerabilidad Alta	3.4	Vulnerabilidad Baja	2.8	Vulnerabilidad Baja
34	ARRANCAPINS	3.6	Vulnerabilidad Baja	2.7	Vulnerabilidad Baja	3.4	Vulnerabilidad Baja	3.2	Vulnerabilidad Baja
41	CAMPANAR	4.4	Vulnerabilidad Baja	3.0	Vulnerabilidad Baja	3.6	Vulnerabilidad Baja	3.7	Vulnerabilidad Baja
42	LES TENDETES	2.2	Vulnerabilidad Baja	3.0	Vulnerabilidad Baja	2.9	Vulnerabilidad Baja	2.7	Vulnerabilidad Baja
43	EL CALVARI	1.2	Vulnerabilidad Alta	2.6	Vulnerabilidad Media	1.8	Vulnerabilidad Alta	1.9	Vulnerabilidad Alta
44	SANT PAU	4.0	Vulnerabilidad Baja	3.6	Vulnerabilidad Baja	4.0	Vulnerabilidad Baja	3.9	Vulnerabilidad Baja
51	MARXALENES	2.4	Vulnerabilidad Baja	2.6	Vulnerabilidad Media	2.2	Vulnerabilidad Media	2.4	Vulnerabilidad Media
52	MORVEDRE	2.0	Vulnerabilidad Baja	2.4	Vulnerabilidad Alta	2.4	Vulnerabilidad Baja	2.3	Vulnerabilidad Alta
53	TRINITAT	3.2	Vulnerabilidad Baja	2.6	Vulnerabilidad Media	2.7	Vulnerabilidad Baja	2.8	Vulnerabilidad Baja
54	TORMOS	2.6	Vulnerabilidad Baja	2.9	Vulnerabilidad Baja	2.2	Vulnerabilidad Media	2.6	Vulnerabilidad Baja
55	SANT ANTONI	2.0	Vulnerabilidad Baja	2.7	Vulnerabilidad Baja	3.1	Vulnerabilidad Baja	2.6	Vulnerabilidad Baja
61	EXPOSICIO	2.0	Vulnerabilidad Baja	2.7	Vulnerabilidad Baja	4.1	Vulnerabilidad Baja	2.9	Vulnerabilidad Baja
62	MESTALLA	3.0	Vulnerabilidad Baja	2.9	Vulnerabilidad Baja	3.7	Vulnerabilidad Baja	3.2	Vulnerabilidad Baja
63	JAUME ROIG	1.2	Vulnerabilidad Alta	2.4	Vulnerabilidad Alta	4.2	Vulnerabilidad Baja	2.6	Vulnerabilidad Baja
64	CIUTAT UNIVERSITARIA	1.8	Vulnerabilidad Baja	3.1	Vulnerabilidad Baja	4.0	Vulnerabilidad Baja	3.0	Vulnerabilidad Baja
71	NOU MOLES	2.8	Vulnerabilidad Baja	2.6	Vulnerabilidad Media	2.3	Vulnerabilidad Baja	2.6	Vulnerabilidad Baja
72	SOTERNES	1.6	Vulnerabilidad Media	2.6	Vulnerabilidad Media	2.3	Vulnerabilidad Baja	2.2	Vulnerabilidad Alta
73	TRES FORQUES	3.2	Vulnerabilidad Baja	2.6	Vulnerabilidad Media	1.6	Vulnerabilidad Alta	2.5	Vulnerabilidad Media
74	LA FONTSANTA	3.0	Vulnerabilidad Baja	3.0	Vulnerabilidad Baja	1.6	Vulnerabilidad Alta	2.5	Vulnerabilidad Media
75	LA LLUM	1.8	Vulnerabilidad Baja	3.1	Vulnerabilidad Baja	3.0	Vulnerabilidad Baja	2.6	Vulnerabilidad Baja
81	PATRAIX	3.6	Vulnerabilidad Baja	2.1	Vulnerabilidad Alta	2.9	Vulnerabilidad Baja	2.9	Vulnerabilidad Baja
82	SANT ISIDRE	2.8	Vulnerabilidad Baja	3.4	Vulnerabilidad Baja	2.9	Vulnerabilidad Baja	3.0	Vulnerabilidad Baja
83	VARA DE QUART	2.0	Vulnerabilidad Baja	3.4	Vulnerabilidad Baja	3.2	Vulnerabilidad Baja	2.9	Vulnerabilidad Baja
84	SAFRANAR	1.6	Vulnerabilidad Media	3.6	Vulnerabilidad Baja	3.5	Vulnerabilidad Baja	2.9	Vulnerabilidad Baja
85	FAVARA	1.8	Vulnerabilidad Baja	3.7	Vulnerabilidad Baja	3.0	Vulnerabilidad Baja	2.8	Vulnerabilidad Baja
91	LA RAIOSA	2.4	Vulnerabilidad Baja	2.4	Vulnerabilidad Alta	2.7	Vulnerabilidad Baja	2.5	Vulnerabilidad Media
92	L'HORT DE SENABRE	2.8	Vulnerabilidad Baja	2.6	Vulnerabilidad Media	2.1	Vulnerabilidad Media	2.5	Vulnerabilidad Media
93	LA CREU COBERTA	1.6	Vulnerabilidad Media	3.6	Vulnerabilidad Baja	2.5	Vulnerabilidad Baja	2.6	Vulnerabilidad Baja
94	SANT MARCEL.LI	2.4	Vulnerabilidad Baja	2.9	Vulnerabilidad Baja	1.9	Vulnerabilidad Media	2.4	Vulnerabilidad Media
95	CAMI REAL	2.2	Vulnerabilidad Baja	4.0	Vulnerabilidad Baja	2.8	Vulnerabilidad Baja	3.0	Vulnerabilidad Baja
101	MONT-OLIVET	2.8	Vulnerabilidad Baja	1.9	Vulnerabilidad Alta	2.3	Vulnerabilidad Baja	2.3	Vulnerabilidad Alta
102	EN CORTS	2.0	Vulnerabilidad Baja	2.4	Vulnerabilidad Alta	2.3	Vulnerabilidad Baja	2.2	Vulnerabilidad Alta
103	MALILLA	4.2	Vulnerabilidad Baja	3.1	Vulnerabilidad Baja	2.7	Vulnerabilidad Baja	3.3	Vulnerabilidad Baja
104	LA FONTETA S.LLUIS	1.6	Vulnerabilidad Media	3.7	Vulnerabilidad Baja	2.2	Vulnerabilidad Media	2.5	Vulnerabilidad Media
105	NA ROVELLA	3.4	Vulnerabilidad Baja	2.4	Vulnerabilidad Alta	1.7	Vulnerabilidad Alta	2.5	Vulnerabilidad Media
106	LA PUNTA	2.0	Vulnerabilidad Baja	3.7	Vulnerabilidad Baja	3.0	Vulnerabilidad Baja	2.9	Vulnerabilidad Baja
107	CIUTAT DE LES ARTS I DE LES CIENCIES	2.0	Vulnerabilidad Baja	3.9	Vulnerabilidad Baja	4.2	Vulnerabilidad Baja	3.4	Vulnerabilidad Baja
111	EL GRAU	2.4	Vulnerabilidad Baja	3.0	Vulnerabilidad Baja	2.5	Vulnerabilidad Baja	2.6	Vulnerabilidad Baja
112	CABANYAL-CANYAMELAR	4.2	Vulnerabilidad Baja	2.6	Vulnerabilidad Media	1.9	Vulnerabilidad Media	2.9	Vulnerabilidad Baja
113	LA MALVA-ROSA	3.8	Vulnerabilidad Baja	2.7	Vulnerabilidad Baja	1.9	Vulnerabilidad Media	2.8	Vulnerabilidad Baja
114	BETERO	1.4	Vulnerabilidad Alta	3.1	Vulnerabilidad Baja	2.6	Vulnerabilidad Baja	2.4	Vulnerabilidad Media
115	NATZARET	3.2	Vulnerabilidad Baja	3.4	Vulnerabilidad Baja	1.5	Vulnerabilidad Alta	2.7	Vulnerabilidad Baja
121	AIORA	2.8	Vulnerabilidad Baja	2.4	Vulnerabilidad Alta	2.1	Vulnerabilidad Media	2.4	Vulnerabilidad Media
122	ALBORS	2.4	Vulnerabilidad Baja	3.0	Vulnerabilidad Baja	2.9	Vulnerabilidad Baja	2.8	Vulnerabilidad Baja
123	LA CREU DEL GRAU	2.6	Vulnerabilidad Baja	2.6	Vulnerabilidad Media	2.3	Vulnerabilidad Baja	2.5	Vulnerabilidad Media
124	CAMI FONDO	1.4	Vulnerabilidad Alta	3.0	Vulnerabilidad Baja	3.0	Vulnerabilidad Baja	2.5	Vulnerabilidad Media
125	PENYA-ROJA	2.2	Vulnerabilidad Baja	3.6	Vulnerabilidad Baja	4.5	Vulnerabilidad Baja	3.4	Vulnerabilidad Baja
131	L'ILLA PERDUDA	2.4	Vulnerabilidad Baja	2.9	Vulnerabilidad Baja	2.5	Vulnerabilidad Baja	2.6	Vulnerabilidad Baja
132	CIUTAT JARDI	1.8	Vulnerabilidad Baja	2.7	Vulnerabilidad Baja	3.1	Vulnerabilidad Baja	2.5	Vulnerabilidad Media
133	L'AMISTAT	2.2	Vulnerabilidad Baja	2.7	Vulnerabilidad Baja	2.4	Vulnerabilidad Baja	2.4	Vulnerabilidad Media
134	LA VEGA BAIXA	1.4	Vulnerabilidad Alta	2.7	Vulnerabilidad Baja	3.9	Vulnerabilidad Baja	2.7	Vulnerabilidad Baja
135	LA CARRASCA	3.0	Vulnerabilidad Baja	4.0	Vulnerabilidad Baja	4.0	Vulnerabilidad Baja	3.7	Vulnerabilidad Baja
141	BENIMACLET	3.8	Vulnerabilidad Baja	2.4	Vulnerabilidad Alta	3.0	Vulnerabilidad Baja	3.1	Vulnerabilidad Baja
142	CAMI DE VERA	1.4	Vulnerabilidad Alta	4.1	Vulnerabilidad Baja	3.3	Vulnerabilidad Baja	2.9	Vulnerabilidad Baja
151	ELS ORRIOLS	3.0	Vulnerabilidad Baja	2.6	Vulnerabilidad Media	1.2	Vulnerabilidad Alta	2.3	Vulnerabilidad Alta
152	TORREFIEL	4.2	Vulnerabilidad Baja	2.9	Vulnerabilidad Baja	1.9	Vulnerabilidad Media	3.0	Vulnerabilidad Baja
153	SANT LLORENS	3.0	Vulnerabilidad Baja	4.0	Vulnerabilidad Baja	4.1	Vulnerabilidad Baja	3.7	Vulnerabilidad Baja
161	BENICALAP	4.6	Vulnerabilidad Baja	3.1	Vulnerabilidad Baja	2.5	Vulnerabilidad Baja	3.4	Vulnerabilidad Baja
162	CIUTAT FALLERA	1.8	Vulnerabilidad Baja	3.3	Vulnerabilidad Baja	1.7	Vulnerabilidad Alta	2.3	Vulnerabilidad Alta

Neighbourhoods with a high level of global vulnerability are El Calvari, Soternes, En Corts, Orriols, Ciutat Fallera, Morvedre and Mont-Olivet. The neighbourhoods with a high level of vulnerability in equipment are Camí de Vera, El Calvari, Jaume Roig, La Vega Baixa, Beteró, Camí Fondo, La Seu, El Mercat and La Roqueta. Neighbourhoods with high demographic vulnerability are Morvedre, Benimaclet, Jaume Roig, La Petxina, Patraix, La Raiosa, Russafa, En Corts, Mont-Olivet, Na Rovella and Aiora. The neighbourhoods with high socio-economic vulnerability are Ciutat Fallera, Orriols, Calvari, La Fontsanta, Tres Forques, Na Rovella and Natzaret.

Figure 45. Global vulnerability.

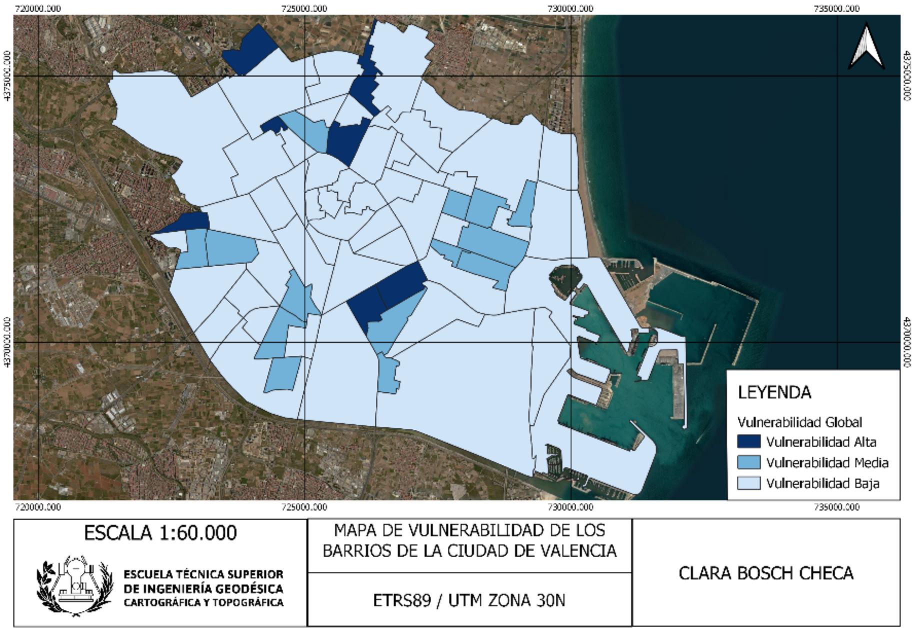


Figure 46. Vulnerability of equipments.

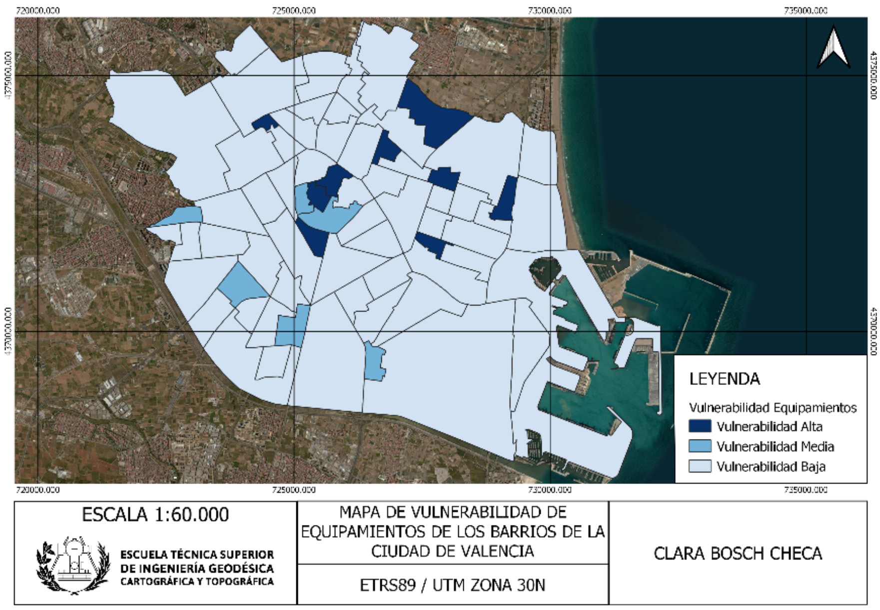
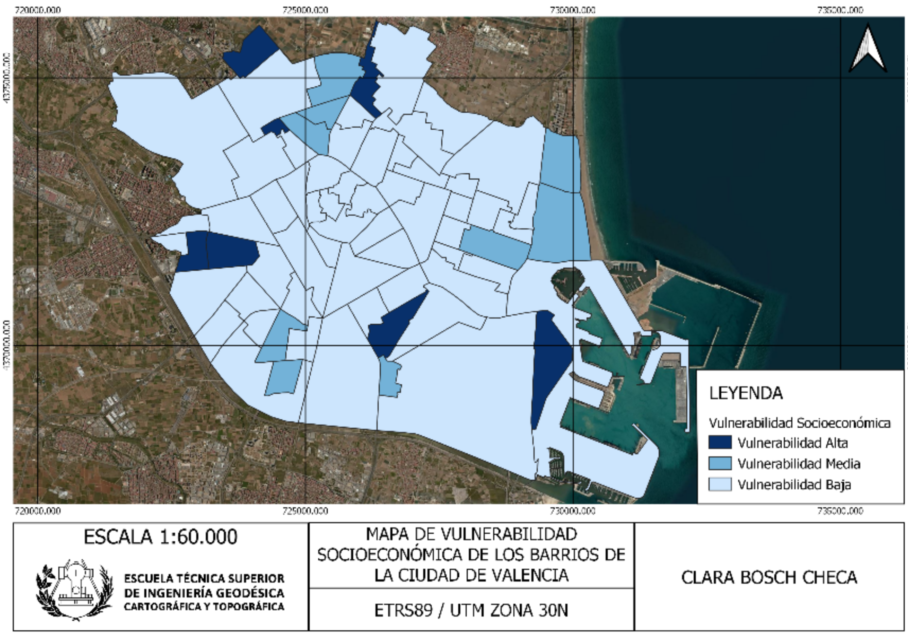


Figure 47. Socio-economic vulnerability



2.3.3.2 *Air Quality*

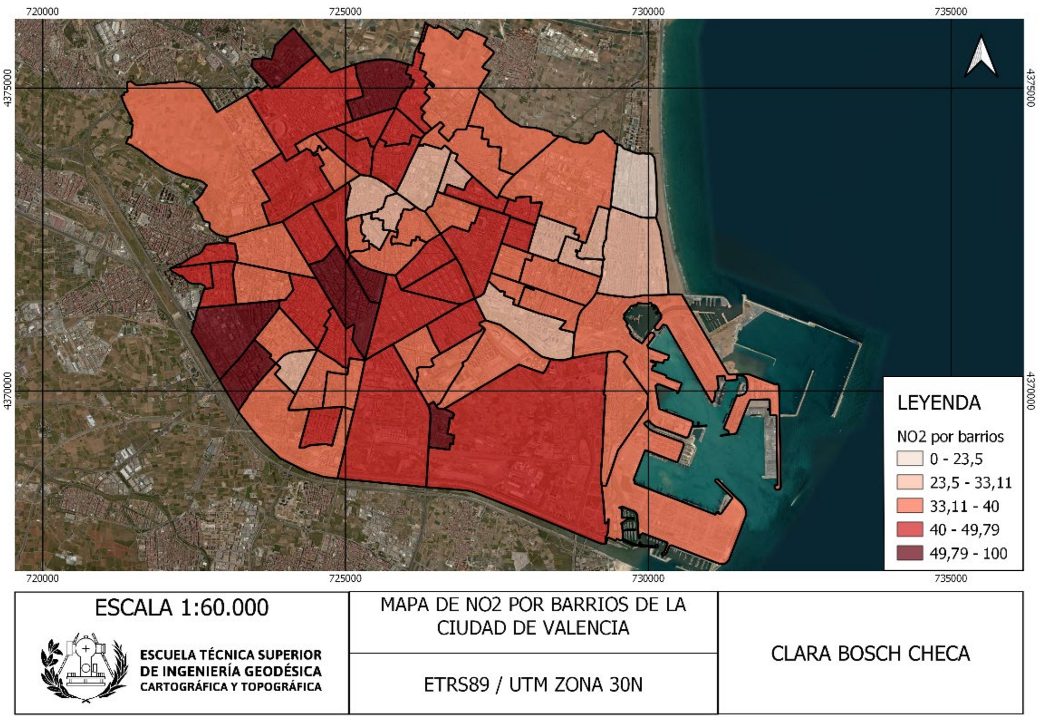
The resulting table with NO_2 data by neighbourhoods is as follows:

Figure 48. NO_2 values by neighbourhoods.

codbar	nombre	NO2
11	LA SEU	29.25
12	LA XEREA	34.10
13	EL CARME	32.69
14	EL PILAR	33.67
15	EL MERCAT	31.01
16	SANT FRANCESC	36.77
21	RUSSAFA	46.83
22	EL PLA DEL REMEI	45.53
23	LA GRAN VIA	42.94
31	EL BOTANIC	42.00
32	LA ROQUETA	49.91
33	LA PETXINA	44.00
34	ARRANCAPINS	56.22
41	CAMPANAR	40.13
42	LES TENDETES	34.38
43	EL CALVARI	37.86
44	SANT PAU	33.45
51	MARXALENES	43.72
52	MORVEDRE	44.94
53	TRINITAT	28.58
54	TORMOS	48.31
55	SANT ANTONI	47.67
61	EXPOSICIO	33.21
62	MESTALLA	43.71
63	JAUME ROIG	27.97
64	CIUTAT UNIVERSITARIA	41.42
71	NOU MOLES	38.24
72	SOTERNES	43.06
73	TRES FORQUES	35.75
74	LA FONTSANTA	43.75
75	LA LLUM	43.10
81	PATRAIX	47.96
82	SANT ISIDRE	58.14
83	VARA DE QUART	61.12
84	SAFRANAR	33.87
85	FAVARA	31.97
91	LA RAIOSA	45.22
92	L'HORT DE SENABRE	35.16
93	LA CREU COBERTA	39.67
94	SANT MARCEL.LI	40.83
95	CAMI REAL	37.99
101	MONT-OLIVET	42.08
102	EN CORTS	39.84
103	MALILLA	42.13
104	LA FONTETA S.LLUIS	53.51
105	NA ROVELLA	35.55
106	LA PUNTA	40.25
107	CIUTAT DE LES ARTS I DE LES CIENCIES	36.08
111	EL GRAU	36.59
112	CABANYAL-CANYAMELAR	30.44
113	LA MALVA-ROSA	21.88
114	BETERO	27.43
115	NATZARET	34.33
121	AIORA	37.08
122	ALBORS	37.50
123	LA CREU DEL GRAU	36.32
124	CAMI FONDO	38.50
125	PENYA-ROJA	24.88
131	L'ILLA PERDUDA	32.24
132	CIUTAT JARDI	31.73
133	L'AMISTAT	46.08
134	LA VEGA BAIXA	44.34
135	LA CARRASCA	36.69
141	BENIMACLET	36.82
142	CAMI DE VERA	35.54
151	ELS ORRIOLS	43.82
152	TORREFIEL	51.06
153	SANT LLORENS	40.00
161	BENICALAP	44.02
162	CIUTAT FALLERA	50.50

The neighbourhoods with worse air quality, that is, with values of NO_2 greater than 49.79 ug/m^3, are La Roqueta, Ciutat Fallera, Torrefiel, La Fonteta de Sant Lluis, Arrancarpins, Sant Isidre and Vara de Quart, with a value of 61.12 ug/m^3, the highest.

Figure 49. Map of NO_2 by neighbourhood.



2.3.3.3 *Environmental Equity*

The following graph shows the results obtained on vulnerability in blue and air quality by districts in orange. There is no direct relationship between the two effects. However, it is essential to highlight the existence of neighbourhoods with a medium or high vulnerability that exceeds the established limits of NO2 (40 ug/m3). These are Ciutat Fallera, Orriols, Morvedre, Marxalenes, Soternes, La Fontsanta, La Raiosa, La Fonteta de Sant Lluis, Mont-Olivet and l'Amistat.

Figure 50. Relationship between vulnerability and air quality.

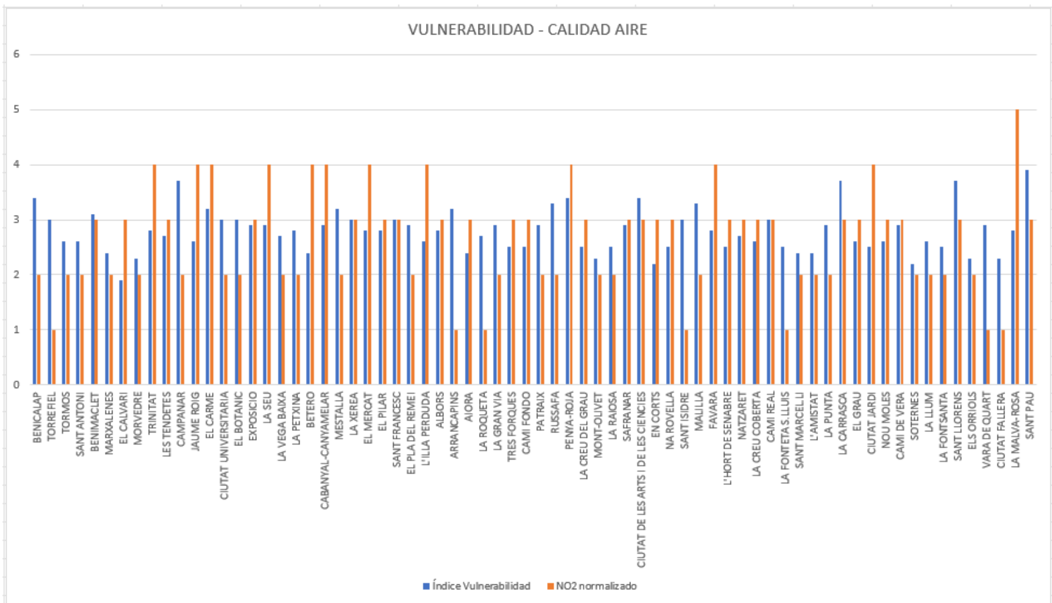
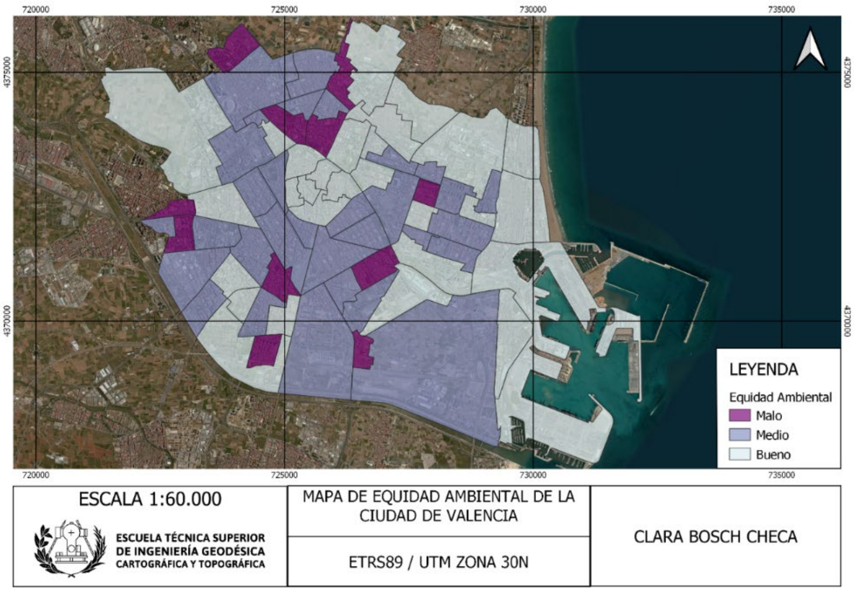


Figure 51. Environmental equity map.



2.3.4 Conclusions

This project has made it possible to identify the most vulnerable neighbourhoods of the city of Valencia, as well as their distribution. It also makes it possible to identify areas where the highest levels of NO2 are concentrated in the air and to compare these results with the vulnerability classification.

Regarding NO2 levels in Valencia, 45.7% of the neighbourhoods exceed the limit value established by the European Union and the WHO of 40 ug/m3, almost half of the neighbourhoods studied. 8.57% of neighbourhoods exceed 50 ug/m3.

It is concluded that there is no direct relationship between neighbourhoods with high vulnerability and neighbourhoods with poorer air quality. Still, it should be noted that 14.28% of neighbourhoods have medium or high vulnerability and exceed the limit value of NO2.

From the results of this project, it is possible to analyse the situation of each of the neighbourhoods to establish improvement plans in the critical areas and thus reduce the percentage of vulnerable neighbourhoods in the city of Valencia. On the other hand, with the results of air quality by neighbourhoods, strategies can be defined to reduce NO2 levels in those areas where the limit value is exceeded. All this serves to improve the city of Valencia and the quality of life of its inhabitants.

2.4 Geospatial analysis of Valencia according to the 15-Minute City Concept the city's Strategic Framework

Abstract

Currently, we live in a context of constant changes, which are reflected in people's way of life and our planet's health. Many global problems as gas emissions and Climate Change have led to the formulation of many proposals to try to hold the impact of their effects and beat the challenges of the modern world.

Accessibility for citizens to essential services without the need to use private transport needs to be explored to try to mitigate the impact of greenhouse gas emissions and, at the same time, achieve a better quality of life for citizens.

This project tries to study the existing proposals, especially in the urban world. In this way, by performing a geospatial analysis using GIS tools and geomarketing techniques, we will be able to observe Valencia regarding the accessibility of the city (a possible 15-minute city) and the situation regarding the city's strategic framework.

Finally, it is intended to obtain the existing situation about indicators that can determine the urban quality of Valencia and its districts and neighbourhoods, to implement improvements looking for the accessibility of the city and establish a line of work regarding future actions in the city.

2.4.1 Introduction

The justification for this project comes for two reasons, on the one hand, to make Valencia an accessible city or at least to have a study of the indicators that should be fulfilled to achieve this accessibility, and on the other hand, to show the power of the geospatial variable in decision making.

This led to two main goals of this project:

- **Urban context study**: Study the existing situation at the urban planning level both in Valencia and internationally to select and align indicators for Valencia.
- **Geospatial analysis**: Carry out a geospatial analysis of some indicators for Valencia, thus marking a line of work for achieving objectives and generating results in this final degree project.

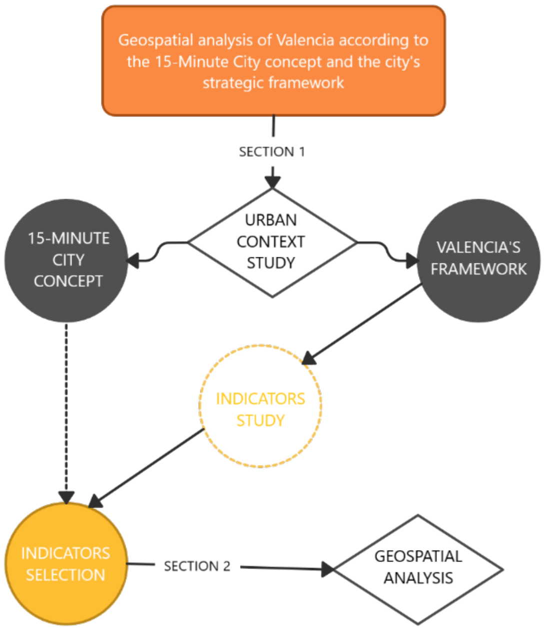
Also, there are a bunch of specific goals:

- **SO1**: Study novel concepts such as 15-minute cities and their possible application to Valencia.
- **SO2**: Study the urban context of the city and the international context.
- **SO3**: Align the goals and objectives of the city framework with the international environment.
- **SO4**: Conduct an analysis and a selection of indicators to measure cities from various sources.
- **SO5**: Selection of indicators to carry out a geospatial analysis using GIS in Valencia.
- **SO6**: Comparison of the analysis results concerning the objectives set.
- **SO7**: Drawing conclusions for the city planning.

2.4.2 Methodology

First, the following diagram shows all the processes to establish the methodology. As mentioned before, the procedure is divided into two sections.

Figure 52. Methodology Diagram

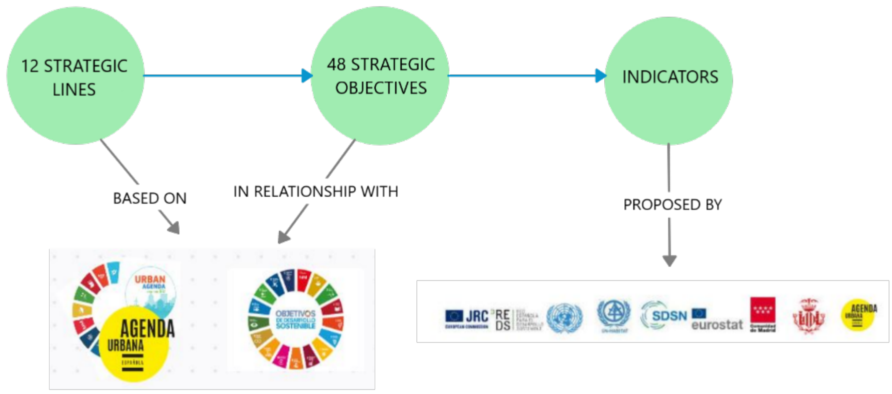


2.4.2.1 Urban context analysis

Before making any analysis, it is necessary to study and analyse the existing situation at an urban level internationally and their application in Valencia to select and align indicators for the city. As an urban planning strategy, it has been studied the concept of accessibility where a great exponent is the 15-minute city concept. This concept proposes to reach six essential functions (housing, work, commerce, health, education, and leisure) from any point in the city within that distance on foot or by bicycle. There are several cities where these concepts are or have already been applied, with Paris (MORENO, C. et al. 2021) and Melbourne (Victoria State Government, 2018) being among the most successful cities.

Regarding Valencia's urban planning, the city has a Strategic Urban Framework "Marco Estratégico de la Ciudad de Valencia: Estrategia Urbana 2030". This framework has the SDGs of the Agenda 2030 and the Urban Agendas (United Nations, European and Spanish) as their basis for developing the strategy. All these strategies have a structure of Strategic Lines, Strategic Goals, and Indicators.

Figure 53. Valencia's Strategic Structure.



Before the selection of indicators for the analysis, it has been established the alignment and relationship between the SDGs and Urban Agendas with the Valencian Strategy.

Figure 54. SDGs alineation for Valencia's Strategic Line 1.

SDG-EL1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
CÁTEDRA																	
MISSIONS VLC																	
SDGs for VLC																	
FINAL																	

Finally, for performing the geospatial analysis, it is necessary to study different indicators from different sources and select them according to the city's requirements. A series of tables have been created with the indicators for Valencia grouped by strategic lines and objectives. A few of the most interesting indicators for performing the analysis have been selected among those indicators. However, the following methodology could be replied to for every indicator.

2.4.2.2 Geospatial analysis

In this section, it is presented the methodology of analysis used. The methodology of geospatial analysis for indicators was developed using GIS software and geomarketing techniques.

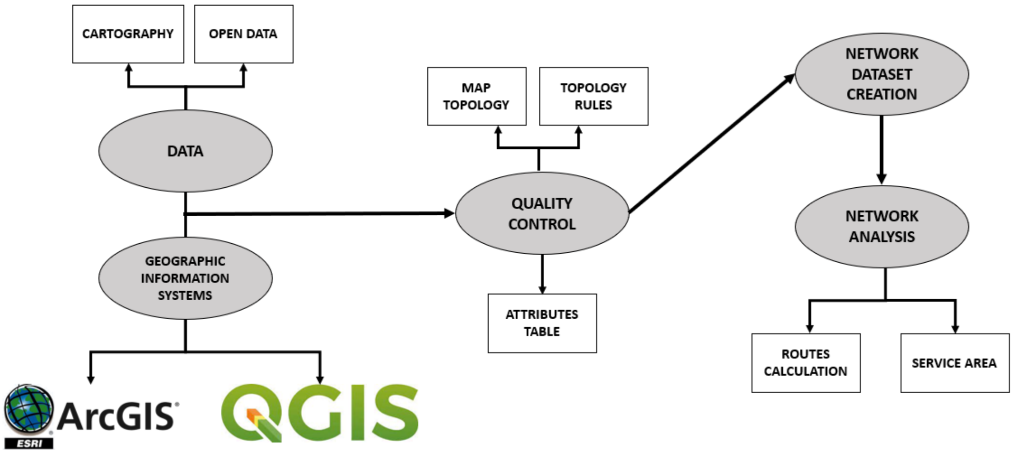
The process starts with the acquisition of Open Data, mainly from the Valencian Council Portal; this data should come from thematic layers according to the indicators, essential mapping layers, and a network layer representing the network of Valencia needed to develop the network analysis. All the data acquired should be loaded in GIS software; in this case, ArcGIS is used, a proprietary commercial software. However, this could work in other Open-source software, such as QGIS.

Then it is needed to process the data and make quality control for every layer. Firstly, layers do not faithfully reflect reality when superimposed on the orthophoto. For this reason, first quality control will be carried out, modifying, and creating new elements, thus eliminating the grossest errors; this is called Map Topology. Also, for the Network layer will be created a topology layer for checking the topology rules. This way, all axes will be linked, not repeated, and a connected and well-defined network can be generated.
As the last quality control, it is necessary to focus also on the attributes table. For this case, two fields must be added, one for the time and the other for the distance for every line of the network, to be able to calculate later in the process. As the analysis was developed based on a pedestrian network to study

walking accessibility, those two extra fields are only needed. If the analysis was developed based on a public transport or vehicle network may need another structure.

Finally, the Network Dataset could be built into the software, and since that, using the Network Analysis tools, it has been possible to obtain results for the different indicators. The service area is the mainly used tool, which defines a polygon that calculates the area generated from a point according to a given distance or time over the developed network. Then this area could be intersected with a population layer and extract how many inhabitants have this accessibility for each facility or service in a determined range. Also, there are other interesting tools, such as route calculation.

Figure 55. Methodology of geospatial analysis for indicators.



2.4.3 Results

The project has different results as the SDGs alignment, indicators selection and methodology creation for indicators analysis. But the main results are the different values of indicators obtained. These are some of them:

- Related to the Green Areas, Valencia lacks accessibility, mainly in the city centre, as it is historically residential and very dense. Valencia has 13,58 m^2 of green areas per person. This value complies with the law's limits but is lower than in other similar Spanish cities.
- Concerning public transport, 80,63% of the population has 5 minutes of access to bus transport, which is quite good. However, analysing simultaneous public transport (bus, subway and tram, public bikes...), we obtained a 56.8% of the population which simultaneous access, which is lower than the recommended 80%.
- Related to the accessibility of public services within a range of 15 minutes it has been studied the services of Health, Education, Social Services, Police, Public Libraries...Being some of them in a percentage of the population lower than 75% with optimal accessibility.

Figure 56. Population with accessibility to green areas.

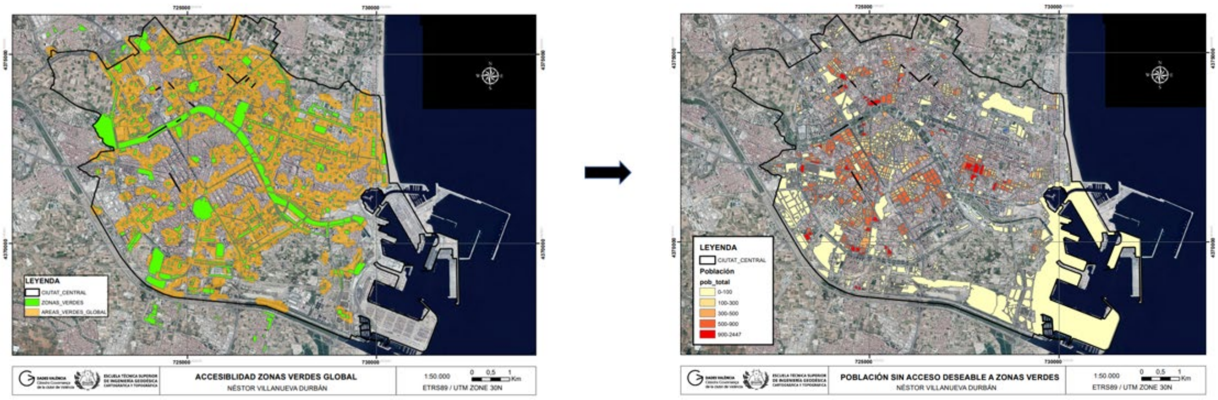


Figure 57. Population with accessibility to services in a 15-minute range.

INDICATOR	15 Min range HAB.	% of Accessibility
Health	663.712	87,47%
Education	738.347	97,31%
Youth Centres	348.226	45,89%
Senior Centres	640.449	84,41%
Social Centres	460.264	60,66%
Sports Centres	667.175	87,93%
Police	289.991	38,22%
Libraries	575.181	75,81%

2.4.4 Conclusions

In this Project, are extracted different conclusions as it has diverse sections:

The first part was the analysis of the urban context and its indicators. It has been proven that studying every plan and urban proposal from every institution is necessary to make every city more liveable and caring for the Earth's health. Moreover, these plans and indicators need to be adapted to every city.

Regarding the collection of indicators, using spatial analysis tools, it is possible to carry out an analysis and obtain results that would not be possible without this component. This is why performing those analyses by a Geospatial Engineer and using GIS software is vital.

Moreover, it is necessary to have Open Data in the study area to perform it. The possibility of accessing free data easily accelerates the process and allows the realisation of infinite analysis. However, these Open Data must be quality data; otherwise, the study would be useless. Cities need to obtain results by applying this or similar methodologies to improve their plans and indicators and show their improvements to the citizens.

2.5 Analysis of the evolution of the emissions of the mobile fleet of the CV by municipalities

Abstract

The gases that reach the ozone layer are a problem, not only for future generations but also for the present. One of the main generators of this situation is the infinite number of vehicles that circulate daily. The automotive world has been evolving following different branches: power, autonomy and finally, the reduction of emissions to avoid the destruction of the ozone layer and reduce the number of polluting gases emitted into the atmosphere.

Different technologies have been developed over the years to reduce emissions, and this project arises to check them. This project studies and analyses the emissions of different gases at various times to see the evolution and development of the vehicle fleet in all municipalities of the Valencian Community and thus study the trends in all areas. The work explores the variation of gas emissions in different periods to determine whether they have been reduced, increased, or maintained.

2.5.1 Introduction

In this project, the emissions of diverse types of gases are studied. The first thing to do is to differentiate between two types of gases: greenhouse gases and pollutant gases.

Greenhouse gases act in the infrared range by emitting and absorbing radiation. These types of gases make the Earth's temperature habitable, but human activity has caused the amount of Greenhouse Gases (GHGs) in the atmosphere, causing temperatures to rise.

Gaseous pollutants are gaseous wastes that, in large concentrations, can be toxic to living beings, causing heart and lung problems and diseases.

The Greenhouse gases are:

- CH^4 (Methane)
- N^2O (Nitrous oxide)
- Pb (Lead): Lead does not occur in a gaseous state but can be absorbed in tiny particles.
- CO^2eq (Carbon Dioxide equivalent): It is used to calculate the carbon footprint; it works by comparing tonnes of gas with tonnes of CO^2.

The Gaseous pollutants are:

- CO (carbon monoxide)
- NH^3 (ammonia)
- NMVOC (volatile organic compounds other than methane)
- NO^x (nitrogen oxide)
- PM (particulate matter)
- SO^2 (sulphur dioxide)
- VOC (volatile organic compounds)

The general objective of this work is to study the emissions of the vehicle fleet in the Valencia Region. The following specific objectives (SO) must be met to achieve this.

- **SO1**: Obtain data according to vehicle type, municipality of residence, fuel, and age.
- **SO2**: Relate the data obtained with the EURO Regulation corresponding to each case.
- **SO3**: Obtain the number of vehicles in each municipality and relate each type to its corresponding emissions.
- **SO4**: Calculate emissions for each type of emission.

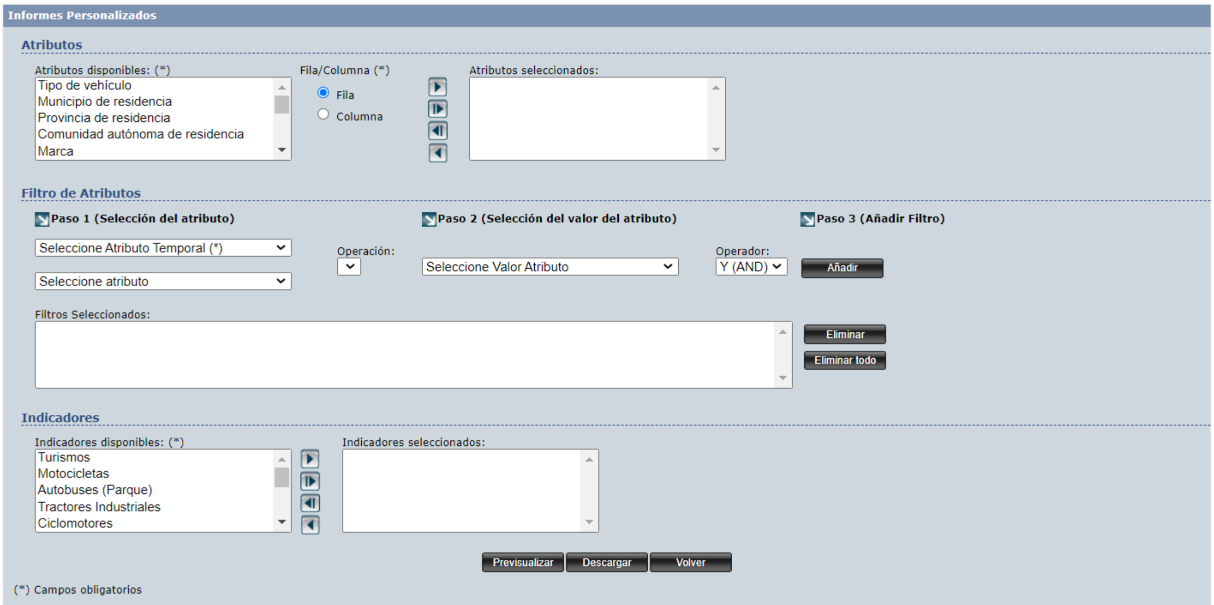
- **SO5**: Compare the values obtained from different years to observe the development.
- **SO6**: Create an atlas from all the data obtained.

2.5.2 Methodology

To conduct this project, vehicle information is needed, so the platform with the largest amount of this type of information is the DGT statistical portal. You must go to Vehicles/Park/Customised Reports inside the platform.

The Custom Reports tab has different sections to select the data to be obtained. The first section is the attributes section, where you must indicate the types of data you need. Next is the attribute filter, where the primary filters to apply are the year of data collection (2010 and 2017). Finally, there is the indicators section, where you indicate the type of vehicles you wish to obtain.

Figure 58. Statistical Portal of the DGT.



Once all the files have been downloaded, they must be linked to their corresponding EURO standards. The vehicle type, fuel, and age fields are used to relate to the regulations. EURO standards are mandatory European regulations that aim to reduce vehicle emissions and air pollution.

Once all the normative values have been acquired, the next step is to obtain the number of vehicles of each type and the total number of vehicles in each municipality. From this data, with the number of emissions of each kind of vehicle, the total emissions of each municipality will be obtained.

The methodology for determining the emissions generated by each municipality is divided into:

- Using Customised Reports and aggregating vehicles with the same attributes. The emission factors of the vehicle fleet can be grouped according to vehicle typology or categorisation.
- The second step using 'EMEP/EEA air pollutant emission inventory Guidebook 2016-Technical guidance to prepare national emission inventories (EEA)'. This is the primary document consulted to obtain the emission factors. Its two essential functions are:

- Provide procedures to enable users to compile emission inventories that meet the quality criteria for transparency, consistency, completeness, comparability, and accuracy (TCCCA criteria)
- Providing estimation methods and emission factors for inventory compilers at various levels of sophistication

From this document and the corresponding filtering according to vehicle type, vehicle class/technology and fuel type, the following has been obtained:

- Emission factors directly for most air pollutants.
- Emission factor calculated as indicated in the IPCC Guidelines update.

Following this methodology, the values of gases emitted by each type of vehicle are obtained. Using the number of vehicles, the municipality obtains and filters the average emission value for each gas. In this way, the emission values for all municipalities are obtained; this process has to be carried out for each year of the study. All the information obtained has to be related to a layer of the area using GIS tools to get the maps.

Figure 59. Gases emitted by municipalities.

Municipios	CO	VOC	NOx	PM	NMVOC	EC (MJ/km	SO2	NH3	Pb
Adsubia	1,44221824	0,31791225	0,90631091	0,07437403	0,30880033	2,039065763	0,15996278	0,00647717	8,0678E-06
Agost	1,71756035	0,42502247	1,08362753	0,08818214	0,38307367	2,225557028	0,19330133	0,00711105	0,00017599
AGRES	1,36449567	0,34886803	0,94069231	0,08211758	0,33959012	2,034218296	0,17760648	0,00537474	7,8334E-06
AIGÜES	1,21149154	0,28444104	0,95220195	0,07113116	0,27538259	2,12520711	0,16096649	0,00654151	7,4255E-06
ALBATERA	1,606623	0,39287782	1,16374274	0,09530823	0,37558805	2,306373198	0,22071594	0,0073738	0,00020935
ALCALALI	1,63462803	0,34484663	0,94207337	0,07556633	0,33312488	2,045630238	0,18511246	0,00867231	7,4697E-06
ALCOCER DE PLANES	1,27579778	0,29394719	0,83014991	0,07565786	0,28616466	1,967313473	0,15365701	0,00638063	8,7676E-06
ALCOI	no data	no data	no data	no data	no data	no data	no data	no data	no data
ALFAFARA	1,37932246	0,3607448	0,95750512	0,08927108	0,34978602	2,06807627	0,20222733	0,00645749	8,1394E-06
ALGORFA	1,6069259	0,34295566	1,03121117	0,09000101	0,3295522	2,152624654	0,19907155	0,00696534	6,8921E-06
ALGUEÑA LA	1,56031152	0,37474107	1,09026835	0,08840485	0,36017156	2,191591649	0,20018179	0,00665209	7,2464E-06
ALICANTE	no data	no data	no data	no data	no data	no data	no data	no data	no data
ALMORADI	1,77709341	0,41993646	2,51997076	0,12383027	0,38790811	4,244114922	0,31124272	0,0066268	8,395E-06
ALMUDAINA	1,33821214	0,25918058	0,91993003	0,07467436	0,24832994	2,039921535	0,14841066	0,00569211	8,7682E-06
ALTEA	2,3273157	0,48837168	2,63129575	0,13090669	0,45342063	4,383262181	0,31667443	0,00829466	1,3536E-05
ASPE	1,69381386	0,37576028	1,92120406	0,10254541	0,35097888	3,295292932	0,2640267	0,00832573	7,4678E-06
AIN	1,40664103	0,29987404	0,90985091	0,06255122	0,28914623	2,066380474	0,14908288	0,00482698	8,8358E-06
ALBOCASSER	1,38964154	0,2800781	0,99453792	0,08409131	0,26745815	2,130598532	0,17607968	0,00741107	7,1373E-06
ALCALA DE CHIVERT	1,70998048	0,37643464	1,04716625	0,08774129	0,36175601	2,206778551	0,19829934	0,00910123	6,6936E-06
ALCORA	1,64452268	0,37801718	1,13551646	0,09438102	0,36106267	2,308557938	0,22189679	0,00894326	0,00020404
ALCUDIA DE VEO	1,6772792	0,35967123	0,87324752	0,05924627	0,34967339	2,031912086	0,12025185	0,00733157	8,6936E-06
ALFONDEGUILLA	1,66202984	0,34197077	0,93433857	0,08182581	0,33095198	1,968699047	0,17649417	0,00564275	7,7205E-06
ALGIMIA DE ALMORACID	1,45674013	0,32042556	1,08954505	0,09381319	0,3060067	2,134649589	0,22315017	0,00542584	7,6857E-06
ALMAZORA	no data	no data	no data	no data	no data	no data	no data	no data	no data
ALMEDIJAR	1,06030172	0,27344047	0,88187272	0,08394603	0,26564933	1,972218371	0,15908985	0,00521932	8,3769E-06

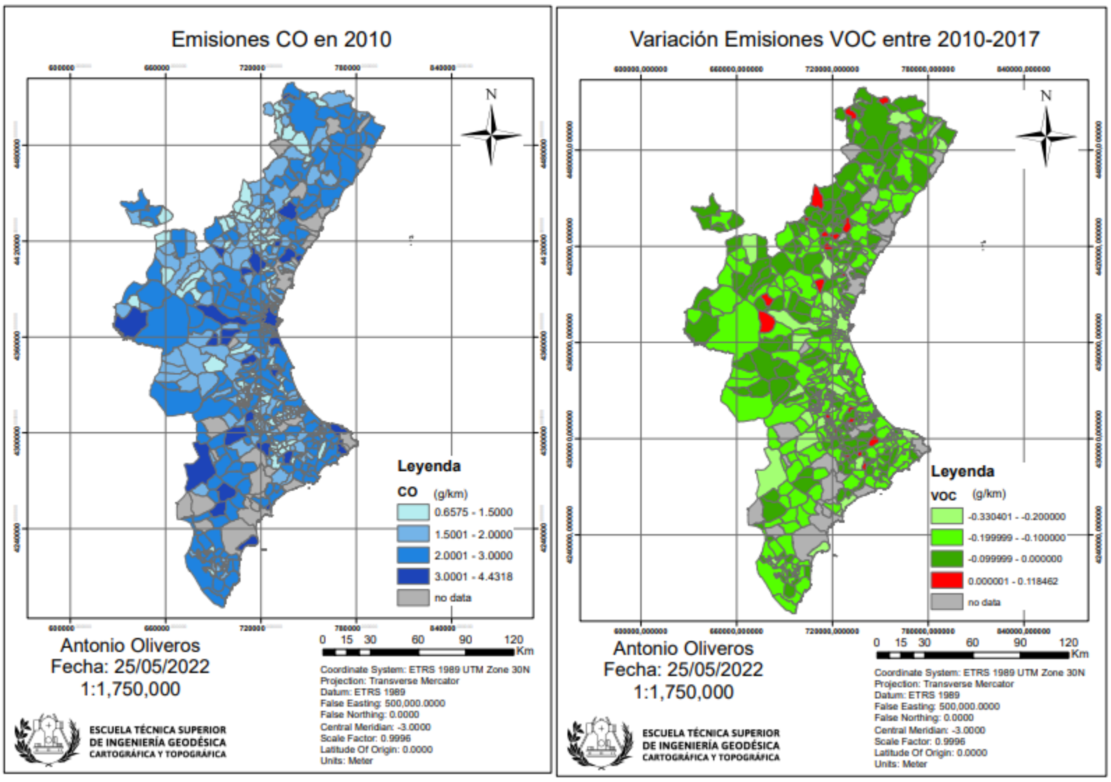
2.5.3 Results and Conclusions

In this project, the emissions of different gases and compounds have been assessed over time, making it possible to analyse these emissions and their variations with a municipal spatial resolution.

After studying all emissions, it has been concluded that emissions have been reduced or are in the process of being reduced, as municipalities that still have many older vehicles will upgrade at some point, causing emissions to go down. It should also be noted that emissions are decreasing even though the number of vehicles in all municipalities has increased.

Further emission reductions must be rapidly achieved to mitigate climate change and improve air quality. Maps showing emission factors, theoretical emissions, and theoretical emissions per inhabitant for the different gases in all years studied and their comparison over time have also been obtained.

Figure 60. CO Emissions in 2010 (left) and Change in VOC emissions between 2010 and 2017 (right).



3 Remote sensing solution-based studies

These studies present different types of problems ranging from environmental issues linked to the population's health to the location of hot spots of pollutants. They both study and analyse a series of environmental data to present a solution using massive data collection techniques through programming and remote sensing techniques to perform the analysis. The tools used in both studies are Python, SNAP from ESA and Google Earth Engine from Google.

3.1 Download, treatment, and analysis of measurements of atmospheric pollutants in the Valencian Community

Abstract

The population's exposure to high levels of atmospheric pollutants can cause severe health impacts such as respiratory infections, strokes, dermatological diseases, allergies, immune disorders, heart disease and even cancer.

It is necessary to monitor the levels of pollutants. In the Valencian Community, the Valencian Network of Monitoring and Control of Atmospheric Pollution (RVVCCA) registers different types of pollutants and AEMET climatological data at the national level.

The project's objective is to create methodologies for the massive download of data, such as meteorological and ground pollutant stations and Sentinel 5P satellite images of different products, applying a treatment that governs the order and quality of the data.

Another complementary objective is conducting analyses and geostatistical comparisons of the data obtained. As an applied objective, the creation of a cartography of nitrogen dioxide (NO_2) levels in the Valencian Community is proposed.

3.1.1 Introduction

Monitoring atmospheric pollutants requires a large volume of data, both of the pollutants themselves and meteorological data. These are decisive factors in any project that involves them due to the significant variability caused by climatological factors, such as rain, wind, etc., in atmospheric pollutants.

This Project aims to create a methodology to obtain this large volume of data through programming, including various platforms and different languages, so that a large amount of data that would otherwise be a tedious process can be obtained simply.

These data are:

- Climatological data
- Satellite data
- Pollutant data

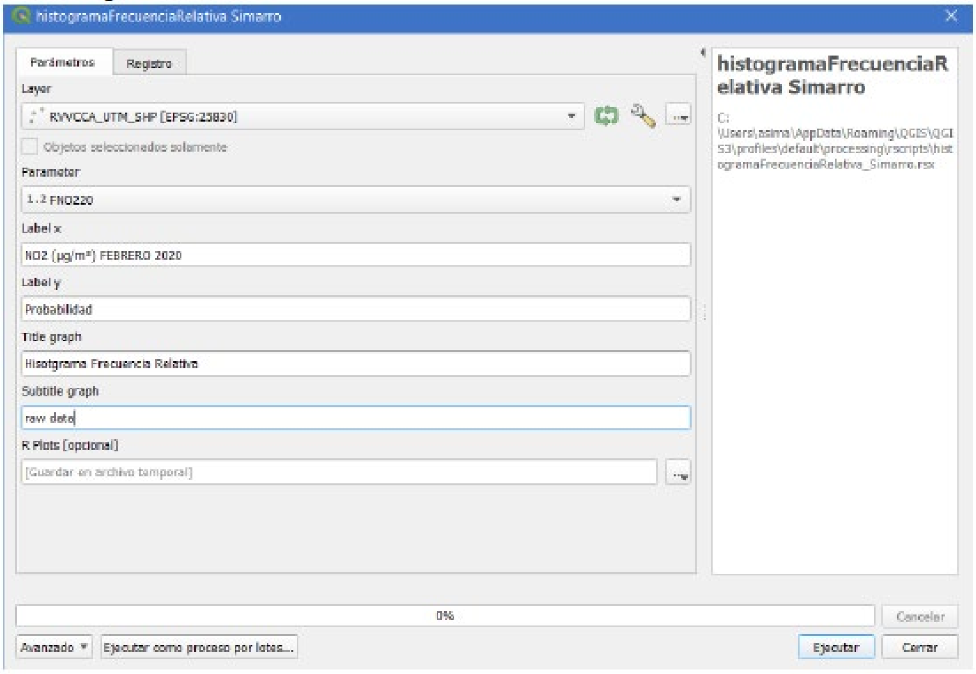
3.1.2 Methodology

Python will be used to create download codes by implementing various platforms, such as Google Earth Engine, and creating codes to process the downloaded data.

- Automatic download of hourly massive meteorological data AEMET in CV.
- Bulk download of daily AEMET data.
- Mass download of Sentinel 5P images using GEE API in Python.
- Meteorological data and pollutant levels processing.
- Python program in Jupyter Notebook for data calculation and processing.

Subsequently, after the preprocessing, the georeferenced information will be added in QGIS, where R will be used to analyse the downloaded data. In addition, geostatistical studies such as frequency histograms and relative frequency histograms.

Figure 61. QGIS histogram creation tool.



In addition, QGIS will be used to perform interpolations of the points of the stations with the IDW method for creating maps of the concentrations of NO2 levels in the Valencian Community symbolised according to the ranges implemented by Directive 2008/50.

3.1.3 Results

3.1.3.1 Results of the download methodologies

AEMET's 24-hour functional automatic download program has proven to work adequately; in addition to being created using free platforms, it has collected daily hourly meteorological data for 13 months, generating a large data set. The Sentinel 5 satellite image download program through GEE has proven to work adequately and with a fantastic speed for downloading years of images. The duration of the downloads takes about an hour to check the 5110 annual images of any Sentinel 5P product to just download our area of interest. The AEMET data download program using the API has been shown to correctly indicate the time or service filters you want to indicate to perform the download simply and locally.

Figure 62. KeepAlive code Python.

keep_alive.py

```python
from flask import Flask
from threading import Thread

app=Flask('')

@app.route('/')
def home():
    return "Hello, i am alive!"

def run():
    app.run(host='0.0.0.0',port=8080)

def keep_alive():
    t=Thread(target=run)
    t.start()
```

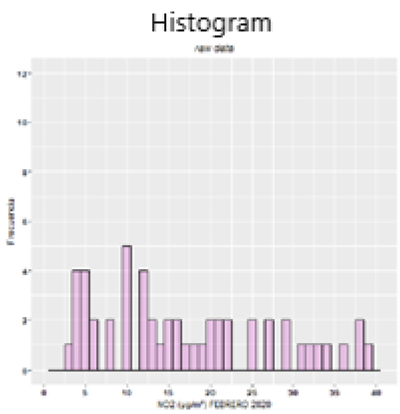
3.1.3.2 Results of the geostatistical analyses of NO_2 concentrations

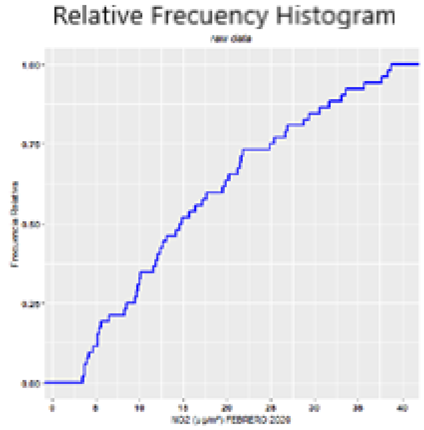
The statistical results have two histograms, one is a frequency histogram, and the other is a relative frequency based on probability. How to interpret each of the histograms will be explained below:

- The frequency histogram is a ratio of the concentrations of NO2 levels and how many times they are repeated; on the X axis, we have the NO2 concentrations from 0 to 40 (μg/m³) in 1 by one range and on the Y axis we have the frequency, i.e., how many times those concentrations are repeated.
- The relative frequency histogram shows the probability that a NO2 measurement is less than or equal to the total.

Figure 63. Statistic Table with histograms for February 2020.

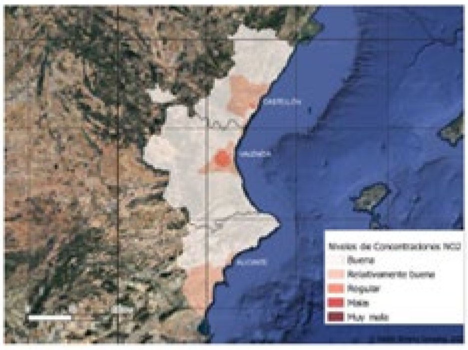
FEBRUARY 2020





Ranks by directive	Frecuency	Probability
<=10 Good	18	P(10>=x)= 0.25
10<=20 Quite Good	16	P(10<=x<=20)=0.63-025=0.38
20<=30 Regular	10	P(20<=x<=30)=0.85-0.63=0.22
30<=40 Bad	8	P(30<=x<=40)=1-0.85=0.15
>40 Very Bad	0	P(40<x)=0
TOTAL	52	1

Figure 64. Interpolation maps for February 2020 and 2021.

MONTH	YEAR 2020	YEAR 2021
February		

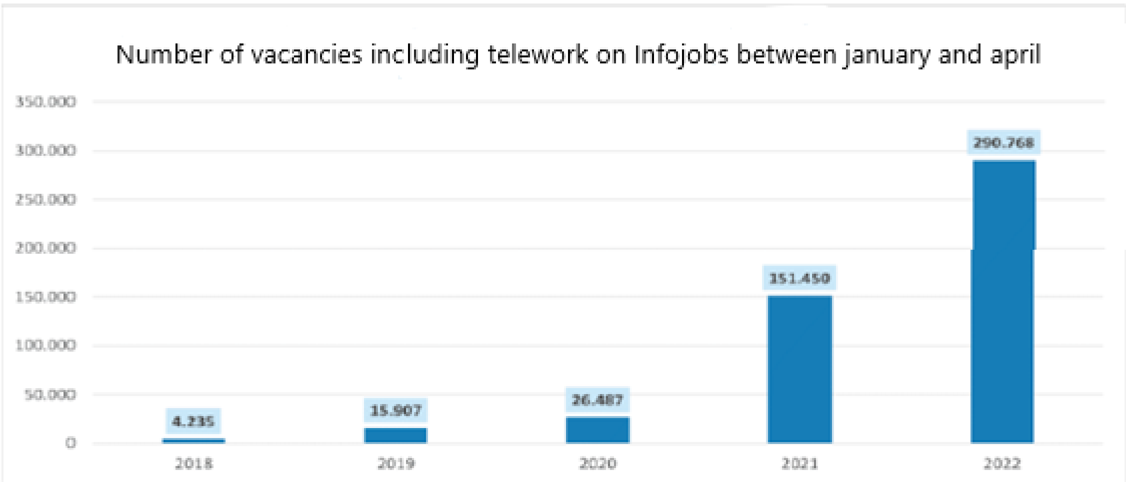
3.1.4 Conclusions

Following the stated objectives, the performance and effectiveness of the mass data download programs for Sentinel 5P satellite station data and images have been demonstrated.

Geostatistical analyses and interpolation maps have allowed us to observe a decrease in NO2 levels in 2020. According to an article in National Geographic Spain supported by European Space Agency (ESA) studies, environmental pollution has decreased thanks to the industrial and mobility standstill: "The abrupt halt of human activities has, paradoxically, a great beneficiary: the environment. The decrease in the number of motor vehicle trips and industrial production and consumption translates into less pollution, cleaner water and clearer skies. From China to Venice, Barcelona to Madrid, these are some of the positive side effects of the health crisis".

Regarding the NO2 concentrations in 2021, little change has been observed between the months observed, but they have not returned to those high values presented in February 2020. According to a report by InfoJobs, a private online job exchange, there has been an increase in telecommuting offers in the pandemic that then multiplied in the following years: "Telework burst onto the scene with a vengeance during the strict confinement at the start of the covid health crisis two years ago. And, although the landscape since then has changed a lot, remote work is a rising reality in Spain: the number of vacancies registered on the InfoJobs job portal that included some form of teleworking during the first four months of 2022 is double the figures for the same period in 2021 and 10 times those of 2020."

Figure 65. Telework job offers



This would explain why NO2 concentrations have been reduced after one year of confinement and have not returned to how they used to be in 2021.

Obtaining massive meteorological and pollutant data is a starting point for other works, such as " Treatment of Sentinel 2 images for use in calculating aerosols in the city of Valencia", in which the aim is to measure pollutants using satellite images with a resolution of 10 meters in the city of Valencia.

3.2 Treatment of Sentinel 2 images for use in calculating aerosols in the city of Valencia

Abstract

This project is part of a research project whose objective is to define a methodology capable of measuring levels of pollutants such as NO^2 and $PM_{2.5}$ in the city of Valencia using satellite images. Determining the amount of aerosols (AOD) in the atmosphere makes it possible to define pollution. However, the challenge of the work in which this project is included is to determine the AOD values from high spatial resolution satellite images. The images used come from the Sentinel-2 satellite, and the pollutant values are obtained from different dosimetry campaigns in the city of Valencia.

Within the methodology defined in the research work, an important part lies in detecting areas with clouds where the measurement of AOD is not possible. In addition to determining the non-changing zones of the study area, that will allow the calculation of the surface reflectance necessary for the determination of the AOD. This project focuses on obtaining these two parameters.

The work in which this project is included has a tremendous social utility; it allows us to control the polluting gases in the cities quickly and without costly campaigns that only show punctual data and not in the whole city. Until now, similar works to this have already been done. However, it differs by using a much larger number of images and data from many ground stations.

3.2.1 Introduction

This project aims to determine the pollution level in the city of Valencia and covers some of the procedures necessary to achieve it. The tasks to be carried out, which are also the main objectives of the project, are as follows:

- To carry out the massive downloading of the satellite images used in the study.
- Define areas covered by clouds to eliminate them from the general study.
- To determine areas without temporal changes.

This project uses satellite imagery as a primary source of data. The study area has a large spatial variability and a tiny area. It is also intended to study the concentration of the pollutants, their concentration, and their variation over time.

These needs make it necessary to look for a satellite that offers images with high spatial resolution and can obtain images with a reduced temporal resolution.

Sentinel-2, consisting of the Sentinel-2A and Sentinel-2B satellites, has been chosen among all the satellites analysed. However, these satellites have the disadvantage of not having a direct product of the gases to be explored. For this reason, this project also determines the methodology for obtaining the AOD values and, subsequently, the pollutant values.

3.2.2 Methodology

The main idea behind the methodology is to distinguish the reflectance of the aerosols from the reflectance measured on the satellite, which is the sum of the reflectance of the aerosols, the ground, and the molecules.

This methodology consists of performing an atmospheric correction of the downloaded 1C images using a Radiative transmissive model (RTM), in this case, the 6SV model, generated by Look-up tables (LUT).

Different options for cloud masking were studied, such as Sen2Cor or Fmask4.3. Finally, it was decided to use Google Earth Engine's s2cloudless. This method does not apply a threshold to classify cloud pixels; it was chosen for its versatility for masking. The s2cloudless's code could detect clouds according to their probability and select a buffer around the clouds.

Figure 66. S2cloudless masking.

Masks with a percentage of 10%, 30% and 50% have been used. All clouds have been removed with a mask of 10%, but in the lower part of the image, for example, many pixels have been masked as clouds but are not.

On the other hand, with a probability of 30%, good masking is shown for almost all of the clouds, and the number of pixels mistaken for clouds is nearly zero.

Finally, with a probability of 50%, clouds are detected much worse, which leaves the part of the clouds undetected, while at the 30% probability, it is masked to a large extent.

Once the AOD values had been determined, we wanted to study their variation over time. For this purpose, we used the vector of change method to explore areas that have not undergone variations and are considered invariant areas. The technique of change vector detection consists of the definition of the modulus and direction of the vector linking pixel values in a space defined by two spectral bands of different dates. In this method, the vector consists of the modulus, which shows the magnitude of the change, and the direction, which shows the type of change occurring. The Sentinel-2 red and NIR (Near Infrared) bands have been chosen because they have the highest signal contrast between all bands.

Using this method, a picture of changes was obtained in which each tone represents a type of change, and the brightness or intensity is related to the magnitude of the change. The objective is to define two classes of invariant and variant zones. Different samples were created in both images to represent those to obtain the averages and standard deviation values.

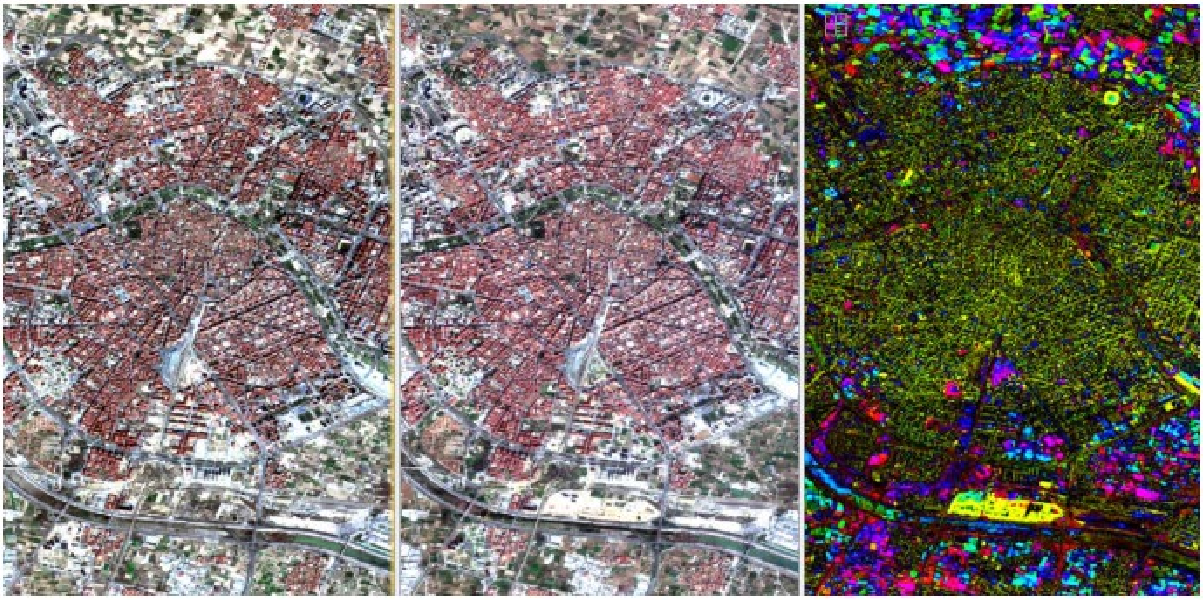
3.2.3 Results and Conclusions

In this project, the results can be divided into three: cloud masking using s2cloudless, the visual study of the change in reflectance in the study area using the RGB combination of the elements of the change vector and, finally, the determination of the invariant regions.

Regarding cloud masking, several images show the results obtained from the selected methodology, which offers a good balance between cloud detection and not eliminating too much information.

Concerning the RGB image of changes defined through the change vector, the changes that have occurred during this time can be observed simply according to the image's tones.

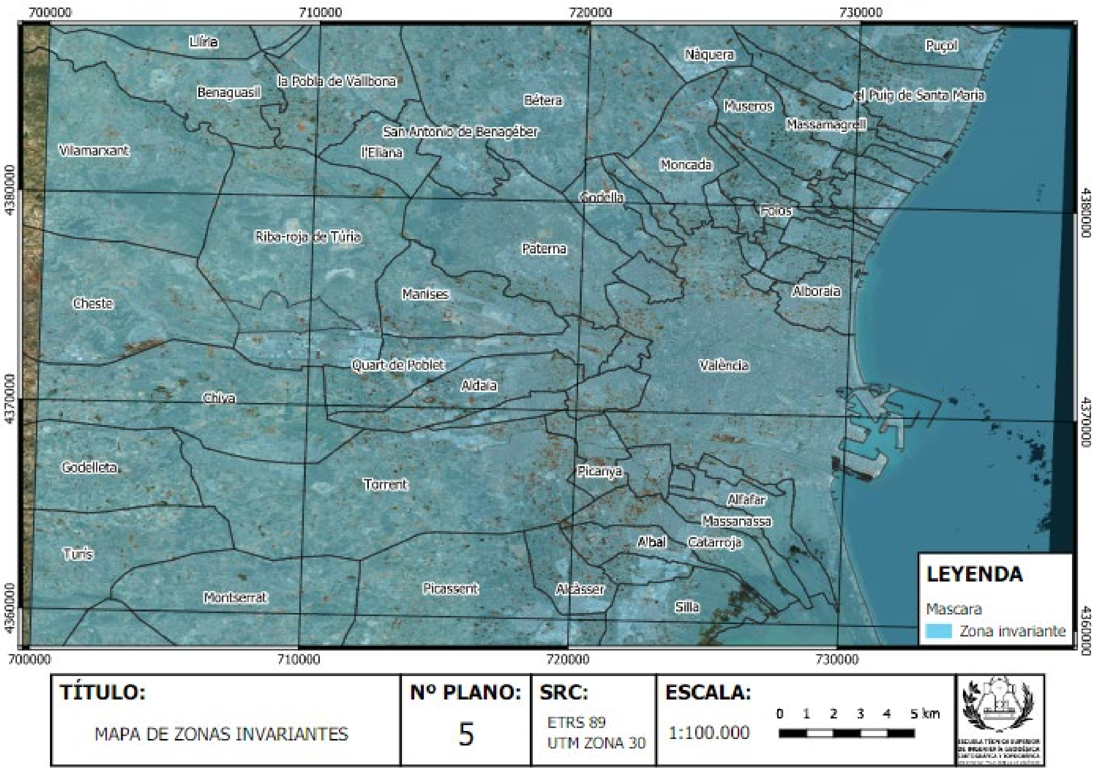
Figure 67. Example of RGB (green) image of changes.



3.2.4 Conclusions

To conclude, an invariant zone mask has been obtained, showing that a large part of the image has been classified as an invariant zone, and the most marked variations have not been included in the mask.

Figure 68. Invariable zones map.



This project has vastly studied satellite imagery and its characteristics.

A possible improvement for the masking section would be to perform custom masking on each image instead of applying the same probability to all images. This is possible due to the small amount of data to be used. However, if the process were to be replicated on a large scale, a self-learning code would be necessary to implement the best cloud probability for each image automatically.

On the other hand, with the change vector method, a valuable visual result has been obtained, as it shows if and where the change has occurred and, thanks to its RGB visualisation, it is possible to study how the change is produced.

Finally, the calculation of the invariant zones has been carried out by studying both changing and non-changing zones, which provides greater certainty of definition than by simply using the population of invariant zones since it allows visualising the degree of confusion between the two. In this case, the usefulness and the qualification of the result as good are relative because it has not yet been applied to the final result to see if the invariant zones should be further delimited. It can simply be affirmed that the process involved in this project differentiates the most marked changes from the rest.

4 Conclusions

During the second year of the collaboration agreement between the Valencia City Council (VCC), the Joint Research Center and the Universitat Politecnica de Valencia, the main result was the seven theses summarised in this report. The **studies developed by students of the UPV** looked for solutions to issues proposed by the JRC, using the city of Valencia and its region, the Valencian community, as the study case. Therefore, the final results are seven **methodologies to approach different issues of the European cities detected by the JRC** and **specific analysis with quantitative effects of these issues for the city of Valencia that the VCC can use to create policies**.

The topics presented were looking for issues interesting for the JRC that can be applied to València and related to the studies of the UPV. The result is seven projects with topics regarding the European cities' environmental and social-economics problems. The results are a geospatial analysis of the issues, supported by an open data quality control.

The projects were officially presented to the head of the services signing this agreement as the VCC, Fernando Gallego, and to Carolina Perpiña, representing the JRC, on the 6th of October 2022. And afterwards, a summary of them was shown during an in-person meeting in the JRC's offices of Seville with the extended team of the EC-JRC.

Figure 69. Results presentation for the VCC and the JRC representatives.

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