

ABSTRACT

Medium-sized cities articulate the territory and operate as provincial or regional reference centres, adopting the role of development nodes, providing basic services, production of goods and utilities, employment and dynamic movement of local economies. Focusing on this type of city, the main objective of this research is to establish a relationship between the concept of urban sustainability and the urban configuration present in a typical municipality. The methodology used focuses on the development of a geostatistical analysis with GIS of the indicators and standards of urban sustainability established in the Land Management Law of Extremadura. The results show notable differences between the neighbourhoods located on the periphery and the urban centre, with the latter adopting a more compact and sustainable model. This research has contributed new advances in the field of knowledge, leading to a significant improvement in decision-making in public management, which means a qualitative improvement in the quality of life of citizens.

INTRODUCTION

The sustainability of cities is increasingly present in the political agenda, in that respect, the urban environment and its constituent aspects are undergoing a change of understanding. **Sustainability seeks an urban balance between those spaces that are intended for urban functionality and organisation and those spaces that are citizen-oriented.**

The analysis of urban development in cities explores the link between **dense, compact and diverse spaces and the urban sustainability of population centres**. One of the aspects to be considered in assessing urban sustainability is the quality of urban spaces as a parameter that defines the functioning of a city. Medium-sized cities are classified as offering the best urban conditions in relation to sustainability and perform a central role within the territorial structure.

With methodologies based on **Geographic Information Systems (GIS)**, several research studies have made it feasible to assess and quantify the situation of urban spaces. The quantification and representation of these analyses allow the **quality of public space to be quantified at different levels**. The use of GIS allows the assessment of sustainability through indicators, in aspects such as the **planning and management of green spaces, mobility infrastructures and accessibility to public services**.

OBJETIVES

The main objective of this research focuses on **establishing an assessment of the formal relationship between urban sustainability and spatial morphology in a medium-sized World Heritage city**, considering:

- **Urban conditions.**
- **Geometric configuration.**
- **The distribution of the population in the territory.**

METHODOLOGY

The methodology (Figure 1) was based on a **geostatistical analysis of the indicators and standards of urban sustainability established in Article 14 of the Planning Regulation of Law 11/2018 on sustainable land and urban planning in Extremadura (LOTUS)**. In a first stage, it was necessary to carry out a careful pre-selection of the indicators that characterise in detail the urban development and sustainability of the area under study, for this reason a total of **9 indicators** were calculated: **urban population density, housing density, green areas, public facilities, compactness of buildings, urban land use, public parking, organic bins and recycling bins**.

With the aim to perform a spatially representative assessment of these indicators, the **75 neighbourhoods that integrate the urban core of the city of Cáceres** were identified as the study area for this research. This territorial approach provided a detailed understanding of the variations in sustainability and urban development at the neighbourhood level. Subsequently, in order to compare and interrelate the different parameters, **Grouping Analysis** was employed using **ArcGIS Pro software**, according to the established parameters of the K-means algorithm. It should be noted that this clustering process was performed without spatial assignment, in other words, without spatial restrictions, in order to ensure that the data were grouped according to variables and without the influence of neighbouring data. This approach guarantees an objective and precise clustering of the data, providing an in-depth understanding of the distribution and interrelationship of urban sustainability indicators in the city of Cáceres.

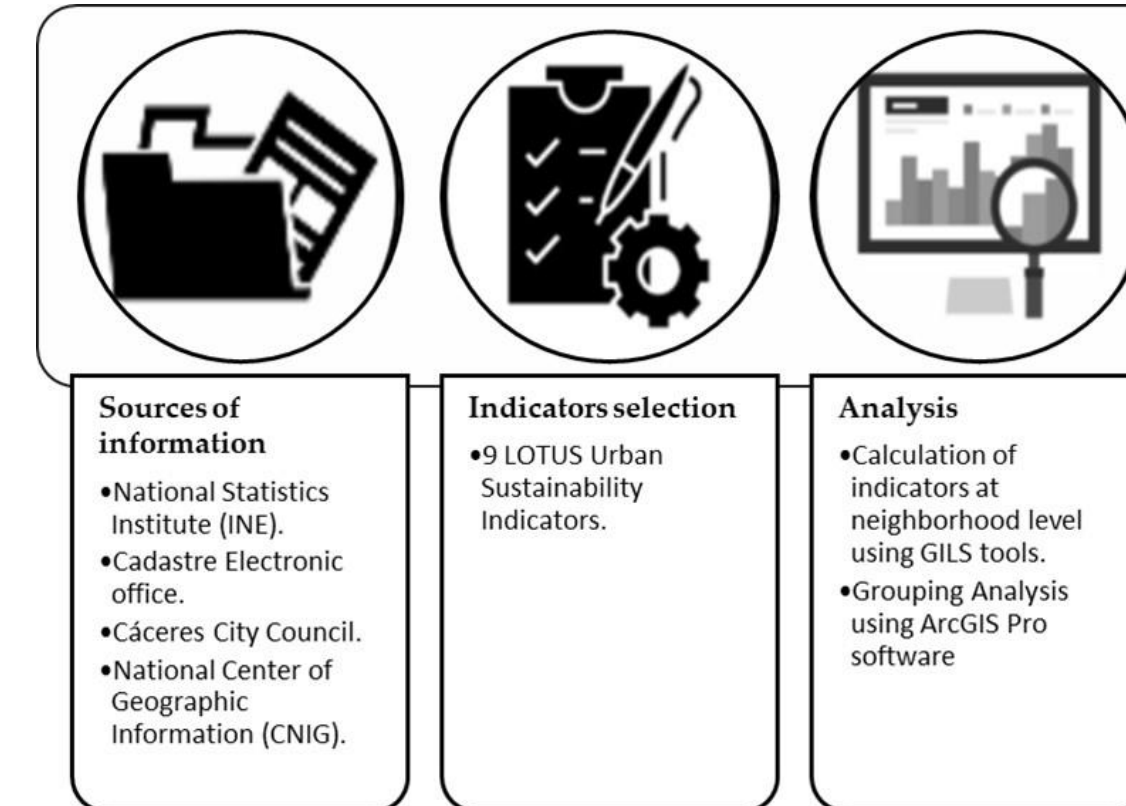


Figure 1. Methodological flowchart.

CONCLUSIONS

Considering the results obtained in this study, it is concluded that:

- The implementation of urban sustainability indicators, using GIS tools, **facilitates territorial planning and the adoption of measures to improve the liveability of the city**, especially in neighbourhoods that do not meet the parameters of reference established by the law.
- **Urban sustainability research is essential for raising the quality of life in cities**, providing crucial knowledge to address urban development problems and fostering greater efficiencies in the urban system.
- **The use of geo-information tools is considered fundamental in municipal plan-ning and management processes**, especially in medium-sized historic cities, with the potential to contribute to greater social equity and improve the quality of urban life.

This research reveals significant findings for medium-sized historic cities in Southern Europe, converting open data from public administrations into valuable parameters with practical applications. The substantial improvement in decision making, with tangible repercussions at the citizen level, is a major achievement of this study.

RESULTS

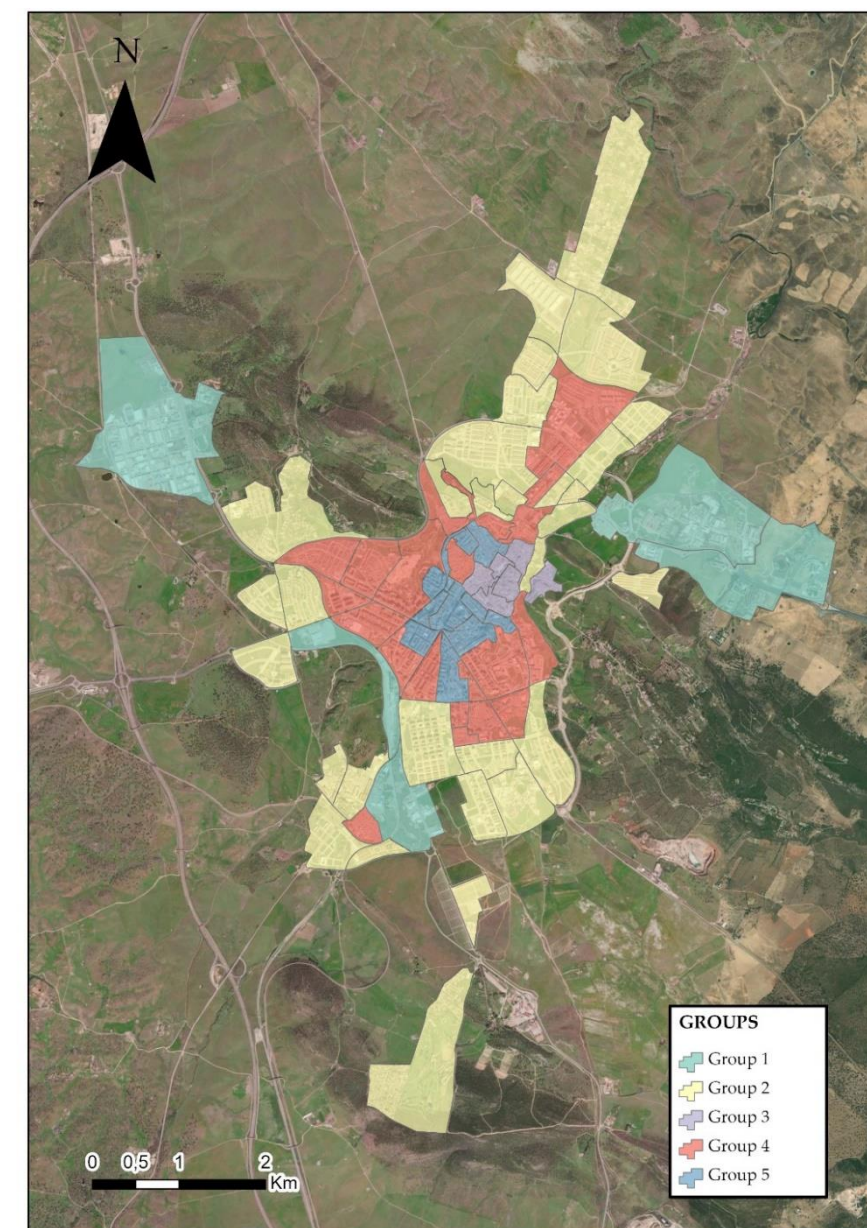


Figure 2. Routes graphic representation.

The cluster analysis of the variables identified a total of 5 clusters (Figure 2) that reveal specific relationships between them, allowing the establishment of a model that groups together neighbourhoods with similar characteristics. These **5 groups** are spatially distributed as follows: **Group 1 includes the peripheral neighbourhoods of Cáceres**, located around industrial areas or other uses that are not exclusively residential; **Group 2 comprises the external neighbourhoods where processes of urban growth and expansion are taking place**; **Group 3 is located in the neighbourhoods that constitute the historic city**; **Group 4 includes the residential areas in the outer ring around the city centre**; and finally, **Group 5 brings together the neighbourhoods in the heart of the city**, characterised by a greater dynamic due to the concentration of population and services. **This urban sustainability is assessed according to the criteria established in the LOTUS**, which supports maximum proximity and accessibility to public services, promoting the design of more liveable cities.

The results obtained in this research reveal **notable differences between the inner and peripheral neighbourhoods of the city**. Group 5 exhibits high values of urban sustainability, with a high density of urban population, housing and building compactness, exceeding the minimum standards, and located on the main arteries of the city. However, the peripheral areas, such as Group 1, show significantly lower values for indicators such as urban population density, housing density and compactness of buildings. At the same time, these neighbourhoods, with **low population density**, have **high values for variables such as green areas, public facilities and car parks**, as they are home to university campuses, sports and health complexes. Therefore, **the inner neighbourhoods of Cáceres have a compact city model, with a higher density of urban population and housing**, together with a high level of compactness in terms of buildings. In contrast, on the margins of the urban core, **a model based on land consumption is observed**, which is unsustainable as it **reduces social interrelations and reduces accessibility to the urban services offered**.

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