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Review Article

Evaluating the Impact of Environmental Heritage on Urban Sustainability

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Abstract

The present paper aims to highlight the impact of tree density on air pollution and climate change. In recent years, Athens has experienced significant effects related to climate change, emphasizing the need for sustainable urban planning. The main objective of this study is to visualize tree density using Geographic Information Systems (GIS) software, specifically ArcGIS Pro. The number of trees within urban environments holds substantial importance for environmental protection, particularly in terms of air purification, carbon sequestration, temperature regulation, and the water cycle. Moreover, urban trees contribute to human health by improving air quality, enhancing psychological and physical well-being, and providing noise reduction. Trees in cities also play a crucial role in the absorption and dispersion of nitrogen dioxide (NO_2), a pollutant primarily generated by vehicle emissions. As part of the research, the study includes a SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) related to tree density in Athens, accompanied by maps and statistical data to support the analysis. Ultimately, climate change represents a major challenge for the future of cities. Citizens, in cooperation with local, national, and global governance, share the responsibility of making informed decisions that promote effective environmental and strategic urban planning.

Climate Change a New Challenge

Today, climate change is a major challenge. Examining its origins, adapting to climate-related risks, assessing impacts on human behaviour, and developing effective policies and strategies are key to a sustainable environmental future. Policy, governance, business, and civil society increasingly recognize and respond to climate change [10].

Municipalities, cities, corporations, and markets adapt within constraints imposed by technologies, regulations, and current understanding of future risks [1]. Although greenhouse gas emissions from developed nations primarily drive anthropogenic climate change, its adverse effects are expected to fall disproportionately on developing countries [12].

The greenhouse effect refers to the process by which a portion of the Sun's energy, reflected by Earth, is retained as heat within the lower atmosphere. Gases such as carbon dioxide and water vapour contribute to the retention of this heat, thereby maintaining the planet's temperature stability [3].

Climate change influences animal health through direct and indirect mechanisms, primarily resulting from changes in environmental factors such as air temperature, relative humidity, precipitation patterns, and the frequency and intensity of extreme events, including heatwaves, severe droughts, intense rainfall, and coastal flooding [8]. Current estimates indicate that approximately 20–30% of plant and animal species assessed to date are at increased risk of extinction if the global mean temperature increases by more than 1.5–2.5°C [4].

Consequently, learning from past experiences and designing effective adaptive strategies are of particular importance in the context of development. Over the past five decades, development paradigms have evolved from a focus on economic growth to priorities of equity and sustainability; yet, to remain relevant amid escalating climate risks, they must now explicitly integrate adaptive dimensions [2].

European Commission Political Decisions

On 24 June 2021, the European Parliament adopted the EU Climate Law, which establishes a legally binding target to reduce greenhouse gas emissions by 55% by 2030 and achieve climate neutrality by 2050 [6]. The accurate measurement of pollution is crucial, given its significant implications for policy formulation and implementation. The designation of an area as polluted, along with the assessed degree of pollution, directly influences the distribution of political and economic resources allocated to mitigation efforts and determines the effectiveness of environmental regulation [7]. While economic growth is frequently correlated with negative environmental impacts, these effects tend to intensify during periods of economic expansion.

In response, the European Parliament has proposed that 30% of total expenditures be dedicated to climate-related actions, and 10% to biodiversity initiatives, within the upcoming Multiannual Financial Framework (MFF) 2021–2027 and the Next Generation EU program [13]. The European Union is prioritizing circular solutions as a core strategy for enhancing competitiveness and achieving climate goals. One example is the upcoming EU Green Week Brussels conference, "Circular Solutions for a Competitive EU," scheduled for 3 to 5 June 2025. Initiatives such as the Circular Cities and Regions Initiative provide knowledge sharing and technical and financial support across cities and regions. This comprehensive support helps local authorities, industry, research organizations, and civil society advance circular economy projects throughout their lifecycle [16].

These actions directly contribute to the EU's broader international commitments, including the United Nations' 2030 Agenda for Sustainable Development and the European Green Deal, both aimed at achieving environmental targets and climate neutrality by 2050 [5]. Policy professionals can participate in these initiatives by attending the EU Green Week conference, where they can engage in workshops and discussions, connect with experts, and explore funding opportunities for circular economy projects.

Health Benefits from Trees and Forests

Human health is influenced both directly through factors such as air and noise pollution and indirectly, via broader environmental processes including climate change and biodiversity loss. Properly managed urban environments can significantly enhance environmental conditions and overall quality of life [15]. Environmental characteristics, such as the quality and accessibility of green spaces, play an important role in determining their use for physical activity [9].

Recent research has increasingly demonstrated a positive association between the availability of green spaces within residential areas and individuals perceived general health [14].

Air pollution is characterized by several key pollutants, including carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), lead (Pb), sulfur dioxide (SO_2), and particulate matter, specifically particles smaller than 10 microns (PM_{10}) and those smaller than 2.5 microns ($PM_{2.5}$) in aerodynamic diameter. Exposure to these pollutants has been linked to adverse effects on pulmonary, cardiovascular, vascular, and neurological systems (*Nowak DJ, et al. 2014*).

Evidence also suggests that the presence of green infrastructure contributes to improvements in allergic respiratory conditions, cardiovascular health, and psychological well-being [11]. Trees influence air quality by directly removing atmospheric pollutants, modifying local microclimates and energy consumption patterns, and emitting volatile organic compounds (VOCs), which may contribute to the formation of ozone (O_3) and fine particulate matter ($PM_{2.5}$) (*Nowak DJ, et al. 2014*).

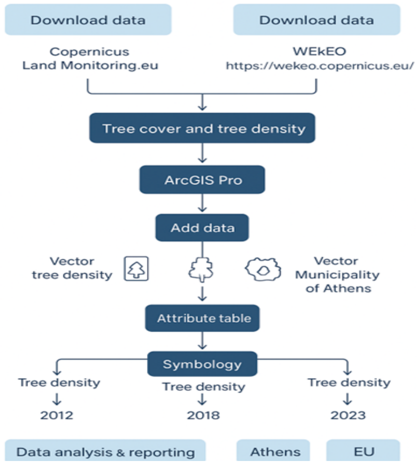
Methodology

The methodology follows a dynamic workflow designed to produce both cartographic outputs and statistical results. The core datasets consist of vector and raster data, integrated and processed within the ArcGIS Pro environment. Over the past 10–15 years, Geographic Information Systems (GIS) have undergone substantial advancements as a scientific field. Progress in geospatial technologies has improved mapping capabilities, enhanced the visualization of spatial datasets, and increased the precision and analytical power of derived statistical indicators. The methodological process is organized into the following key stages:

1. Access the Copernicus platform.
2. Download the vector datasets representing tree density.
3. Access the WekEO platform.
4. Download the raster datasets associated with tree density.
5. Launch ArcGIS Pro for data preprocessing and spatial analysis.
6. Calculate the area of each spatial feature.
7. Apply appropriate symbology to ensure effective data visualization.

8. Produce three maps corresponding to the years 2012, 2018, and 2023.
9. Generate statistical metrics to support quantitative analysis (Table 1).

Table 1



The results include three maps illustrating tree cover for the years 2012, 2018, and 2023. In addition, statistical indices were generated to quantify the total area, the percentage of tree cover, and the comparative variations among selected European cities.

Mapping the Tree Density in Athens

Figure 1 illustrates the tree density within the Municipality of Athens in 2023. The highest concentration of trees is observed in eastern Athens, particularly in the vicinity of the Ancient Kallimarmaro Stadium and the Zappeion Megaron.

The city features three prominent hills Strefi, Lycabettus, and Filopappou, as well as several green areas and parks. Numerous neighborhoods in Athens, including Filothei, Koukaki, Panormou, Petralona, Mets, and Kypseli, are characterized by narrow streets and small squares lined with trees.

The city's greenery contributes to improved air quality and environmental rejuvenation, while also serving as important spaces for recreation and relaxation for its residents (Figure 1).

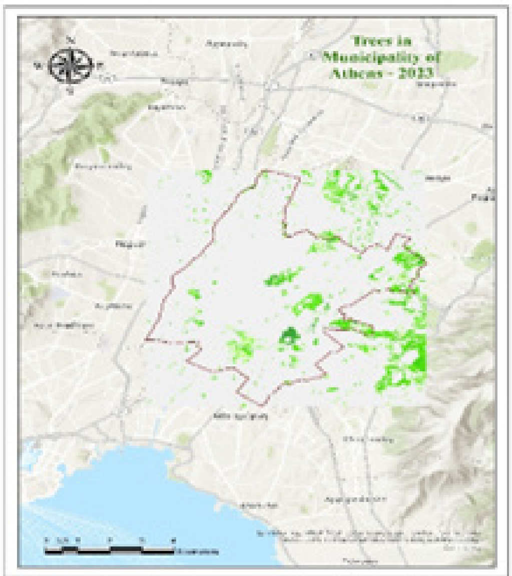


Figure 1: Trees density in Municipality of Athens – 2023.

The map includes a scale bar, a north arrow, and an appropriate title. The vector datasets utilized comprise the Municipality of Athens boundary and the raster dataset is street tree layer. sFigure 2 presents the tree layer within the Municipality of Athens in 2018. The layer has been clipped to the municipal boundaries. The map includes a scale bar, a north arrow, and a descriptive title. Additionally, it incorporates two vector shapefiles: the municipal boundary of Athens and the street tree layer (Figure 2).

Figure 3 illustrates the tree density within the Municipality of Athens in 2012. The orange colour represents the areas of tree density (Figure 3).

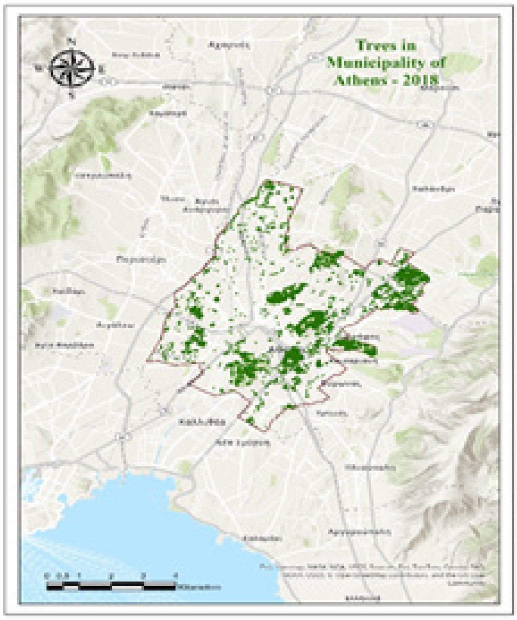


Figure 2: Trees density in Municipality of Athens – 2018.

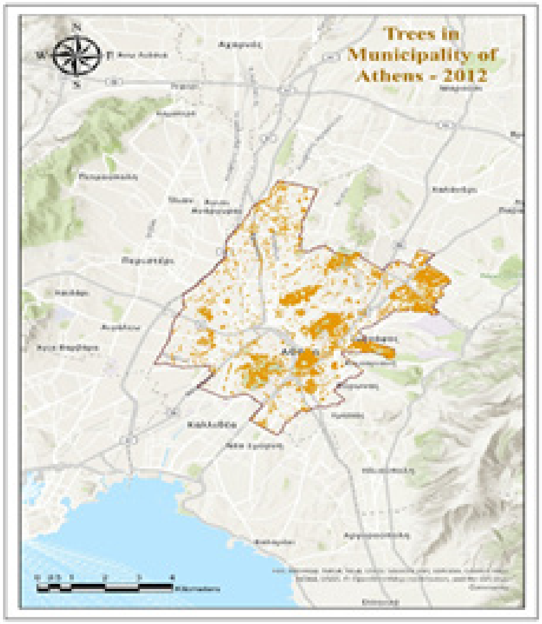


Figure 3: Trees density in Municipality of Athens – 2012.

Environmental Statistics

Table 2 shows total tree-covered area was 4.516.918,90 square meters in 2012 and 3.636.365,39 square meters in 2018. This represents a decrease of 880.553,51 square meters, corresponding to a 19.49% reduction over the six-year period.

Table 2

Area of Trees	
2012	4.516.918,90
2018	3.636.365,39

This notable decline indicates a significant loss of urban green space, highlighting the need for enhanced environmental management, sustainable urban planning, and targeted reforestation initiatives to mitigate ecological and climatic impacts.

Table 3 presents the quantitative data regarding the tree area ratio. The analysis is based on two key measurement variables: the total tree-covered area and the total municipal area of Athens.

Table 3

$$\text{Tree Area Ratio} = \frac{\text{Area covered by trees}}{\text{Total area of the city}}$$

These parameters provide the basis for evaluating spatial distribution patterns, ecological density, and temporal variations in urban vegetation, contributing to a deeper understanding of environmental sustainability, land-use efficiency, and the city's capacity to adapt to ongoing climatic transformations.

Table 4 presents the total area of Athens and the corresponding percentage of tree cover, which decreased from 11.91% in 2012 to 9.59% in 2018.

Table 4

Area of Athens	Percentage Cover of Trees	
	2012	2018
37.912.387,65	11.91%	9.59%

As illustrated in Table 5, a comparative study was conducted among Berlin, Paris, Vienna, and Athens, focusing on the proportion of tree-covered areas in each municipality.

Statistical analyses were conducted using ArcGIS Pro.

Data was obtained from

Table 5

Comparative Study in EU Cities		
Vienna	Berlin	Paris
~25%	~12%	~9%

- https://land.copernicus.eu/
- https://wekeo.copernicus.eu/

ChatGPT was frequently employed to verify the results.

Results

Figures 3 present the spatial distribution and density of trees in the Municipality of Athens for 2012 and 2018, respectively. Both maps employ vector data sets to delineate municipal boundaries and tree locations, which are superimposed on a base map to provide geographic context. Essential cartographic elements, such as a scale bar, north arrow, and descriptive title, are included to ensure clarity and spatial accuracy.

In 2012, the spatial pattern of vegetation, depicted in orange, demonstrates a relatively dispersed distribution of trees. Notable concentrations are observed in central and southern Athens, particularly near Kallithea, Zografou, and the Filopappou area. Tree density is moderate, with limited clustering in the northern sections.

This distribution indicates that green coverage was uneven during this period, with open urban areas predominating in the city's central core. By contrast, the 2018 map, symbolized in green, shows a marked increase in tree density and spatial continuity, especially in the northern and northeastern sectors of Athens.

The expansion of tree-covered areas suggests either enhanced urban greening initiatives or improved data acquisition through updated remote sensing and GIS methodologies. Notably, the vicinity surrounding the National Garden, Lycabettus Hill, and the Zappeion area exhibit high vegetation density, reflecting both historical and recent urban forestry efforts (Figure 4).

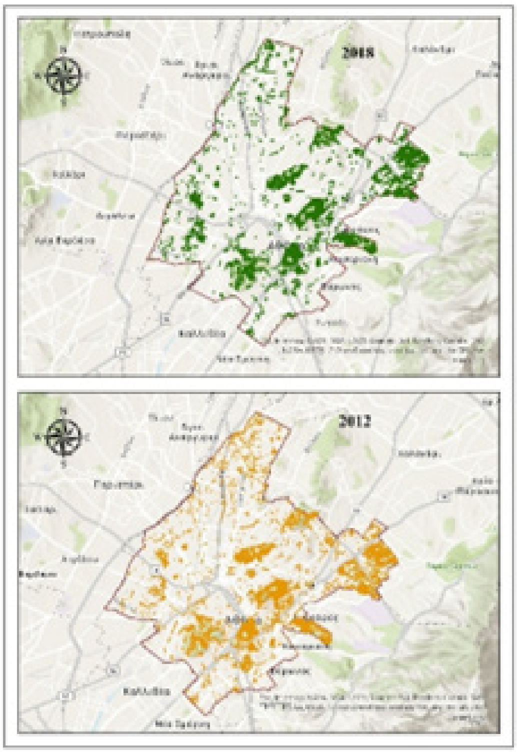


Figure 4: Comparative maps in 2012 & 2018.

Comparing the two temporal datasets reveals a visible enhancement in the urban tree network over the six-year period. This increase contributes to improved urban microclimates, air quality, and the overall ecological resilience of Athens.

The observed spatial transformation underscores the importance of continuous environmental monitoring and the integration of green infrastructure into urban planning strategies for sustainable city development.

Figure 5 illustrates the spatial distribution of trees within the Municipality of Athens for the years 2018 and 2023. Both maps employ vector datasets representing the municipal boundary and tree layers, accompanied by essential cartographic elements such as a scale bar, north arrow, and descriptive title to ensure spatial clarity and consistency.

The 2018 map displays a relatively high density of tree cover, particularly in the central and southern areas of Athens, including regions around the National Garden, Zappeion, and Filopappou Hill. Tree clusters are also evident in the northern parts of the city, indicating well-established green zones integrated within the urban fabric (Figure 5).

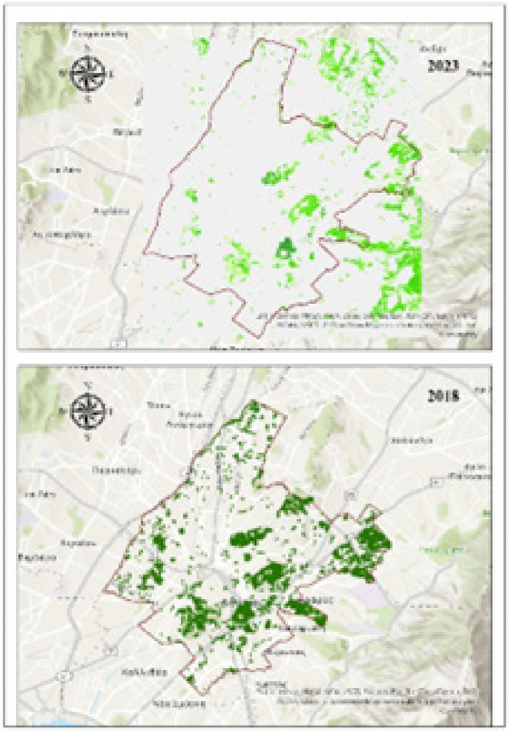


Figure 5: Comparative maps in 2018 & 2023.

In contrast, the 2023 map reveals a noticeable decrease in tree coverage, particularly across the central and western sectors of the municipality. The distribution appears sparser and more fragmented, with denser vegetation mainly limited to the eastern parts of Athens near Ilisia and Zografou. This reduction in green cover may reflect urban redevelopment, land-use change, or environmental degradation.

Overall, the comparison highlights a significant decline in urban vegetation density between 2018 and 2023, underscoring the need for enhanced urban greening strategies and sustainable land management policies to preserve ecological balance within the city.

Acknowledgement

I would like to express my sincere gratitude to the Editorial Team of the American Journal of Biomedical Science & Research for the kind invitation to share my perspectives on the intersection of cartographic science and public health. The digital visualization of health-related data represents an essential instrument for addressing poverty, mitigating social inequalities, and promoting environmental protection initiatives.

Conflict of Interest

None.

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