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RESEARCH ARTICLE

Criticism of the Effect of Green Cover Change on Air Quality with i-Tree Canopy (Bursa-Osmangazi Region Sample)

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ABSTRACT

Anything that reflects the ethnicity of a society that has aesthetic and visual textures transferred from past generations to the present day, that is universally accepted, that contains abstract and concrete concepts, and that is intended to be preserved and transferred to future generations is called "cultural heritage". Today's urbanism continues to develop around the settlements of ancient civilisations, which are accepted as cultural heritage. Today, migration from villages to cities has increased and population density in cities has shown a rapid upward trend. The destruction of green areas due to rapid urbanisation has increased visibly and has made smart cities with green areas obligatory. In smart urbanisation, practical methods are sought to quickly identify green areas and determine the benefits provided by these areas. The most widely used software for measuring tree canopy cover is i-Tree Canopy, which allows urban planners to quantify the ecosystem services and benefits of tree communities and forests at multiple scales, including pollution reduction, carbon sequestration and storage, and runoff reduction. Within the scope of the study, the changes on green areas such as urbanisation, industrialisation, increase in transportation networks brought about by population growth in the historical city centre of Bursa and the negative and positive effects of these changes were examined. In the study, the time-dependent changes of green areas in urban heritage and urban planning were determined with GIS (Geographical Information Systems) techniques, and suggestions were developed for existing and new green areas to be planned in the city.

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1. Introduction

The target of management plans for conservation and sustainability in cultural heritage sites is to protect and develop the outstanding universal value of the field for present and future generations, and to take actions to achieve this (Öksüz Kuşçuoğlu & Taş, 2017). Regarding the structure of the Smart City concept, there are different approaches in standard, maturity assessment model, index and architecture studies (Bilgem, 2021). Smart city definitions include six main components (Yiğitcanlar, 2015; Uçar et al., 2020), namely smart "governance, economy, people, mobility, life and environment" (Lombardi et al., 2012; Uçar et al., 2020) when evaluating the performance of smart cities.

Currently, changes such as urban sprawl, industrialisation and deforestation have led to various environmental problems (Kaplan et al., 2018; Ersoy Tonyaloğlu, 2019; Yaşlı et al., 2023). Depending on health, education, transport and employment opportunities, migration from villages to cities has increased, thus the population density in cities has exhibited a rapid upward trend. In order to meet the housing needs of the population concentrated in urban centres, an increase in housing has become a must. Due to rapid urbanisation, the destruction of green areas has visibly increased and adverse conditions such as increased air pollution in urban centres and

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flooding due to the increase in impervious areas have occurred. Urban forests improve air quality and provide clean air by absorbing marine pollutants such as NO_2, SO_2, O_3, VOC, PM2.5 and PM10 from the air (Zhao et al., 2023). The location, types, analysis, spatial distribution, capacity, functionality and adequacy of urban open and green spaces are considered to be the most important components of planning and design (Gül et al., 2020). "Liveable and Sustainable Cities that Add Value to Life" is set as the vision with the strategy that focuses on "Effective and Sustainable Smart City Governance" and "Competent and Productive Smart City Ecosystem" in the focus of smart urbanism in Turkey (Bilgem, 2021).

Cities and society have to change and city dwellers demand places to enjoy their living spaces (Nagode et al., 2023). Cultural heritage is the richness that tells the common past of the people in the same society, reveals their historical accumulation, and has meaning not only for the society and future generations but also for all humanity, both abstract and concrete (Öksüz Kuşçuoğlu & Taş, 2017). Green space is an integral part of the human history of heritage cities and the inherited culture for generations (Henderson, 2013; Campagnaro et al., 2020).

Heritage is defined as a stock of values characterised by stability, continuity and acceptance in society. According to many studies, by 2050, 68 per cent of the world's population is expected to live in cities due to the growth in developing countries (Li et al., 2021). Effective and efficient management of limited resources in the face of unlimited human needs and sustainable urbanisation processes will only be possible with innovative and smart solutions (Partigöç, 2023). Therefore; the concept of smart city has emerged in recent years (Campagnaro et al., 2020).

Smart cities represent the future on both an economic and social level and their main goal is to provide a digitalisation-friendly sustainable environment and promote learning. In smart urbanisation, practical methods are sought to quickly identify green areas and determine the benefits provided by these areas. The most widely used software for measuring tree canopy cover is i-Tree Canopy based on Google Maps (Konôpka et al., 2023). Through these innovative practices and tools, managers can demonstrate the ecosystem services and benefits of tree communities and forests at multiple scales, including pollution reduction, carbon sequestration and storage, and runoff reduction (Hirabayashi et al., 2011; Uçar et al., 2020).

Planning for green spaces in historic heritage sites is a humanitarian task, especially after the devastation caused by wars (Bradford & D'Amato, 2012). Increasing the quantity and quality of urban green spaces can provide many benefits, such as improving the liveability of cities and increasing their resilience to threats such as climate change (Kim & Lim, 2016; Speak & Salbitano, 2023).

The communications and information technology revolution has led to the adoption of the concept of smart cities, which has evolved over time from digital cities, knowledge cities and sustainable cities in the mid-twentieth century to the broader concept of smart cities (Batty, 2014). Many cities around the world are seeking to become smart cities due to the many benefits that the smart cities concept provides to the city and the citizens in these cities (Campagnaro et al., 2020).

Changes in green areas in the city centre of Bursa, a UNESCO cultural heritage city hosting areas rich in cultural heritage, and the negative and positive effects of these changes on air pollution were revealed in this study. In order to determine the role that smart cities approach can play in the protection of green areas, the time-dependent changes of green areas were determined with i-Tree software and GIS techniques and new suggestions were developed for the planning and protection of green areas in the city centre according to the results obtained. In this context, revealing the time-dependent green area change of city centres with historical value together with the reasons will contribute to the protection of these areas both local and areal in the future.

2. Materials and Methods

The 28 neighbourhoods of Osmangazi district of Bursa province were selected as the study area. The land cover change in the historical areas within the boundaries of the study area (Figure 1) was determined considering population change starting from 2023 for 2011 and 1997. In the study, the increase in the population and the changes occurring accordingly in the area of the historical change of the green areas of the city developing within the scope of today's smart urbanism were evaluated. In addition, the monetary contribution change with the removal of toxic gases (CO, NO_2), which have many negative effects on human health used in air pollution calculations, pesticides used in industry and agriculture and particulate matter (PM2.5, PM10) in secondary chemical reactions (PM2.5, PM10) over the years has also been examined.

Figure 1. Study area consisting of 28 neighbourhoods in Osmangazi District of Bursa Province.

Within the scope of the study, the neighbourhood boundaries obtained from Osmangazi Municipality were overlaid with Google Earth map in ArcGIS software and 28 neighbourhoods were determined as the study area. Old orthophotos of Bursa city centre obtained from Bursa Metropolitan Municipality were used as database in ArcGIS. Cover Class ((1) Grass/Herbaceous, (2) Impervious Buildings, (3) Impervious Other, (4) Impervious Road, (5) Soil/Bare Ground, (6) Tree/Shrub, (7) Water) created for the study area in i-Tree Canopy was converted to kml/kmz file.

For the year 2023, the land classification created by random point assignment with the help of i-Tree Canopy was converted to kml/kmz format and evaluated with the orthophoto of 2011 and the aerial photograph of 1997 obtained from local administrations, and the current and past cover classes were compared separately for each point in i-Tree Canopy. When making field determination on the points, 1/600 or 1/800 scale was used to avoid deviation in the position of the point. The changed points in the study were updated separately for 1997 and 2011 in i-Tree Canopy version.

As exemplified in Figure 2, the change of Osmangazi district of Bursa province, where the study was carried out, was determined at an eye distance by moving 200-300 m closer to each point with the help of Google Earth Pro.

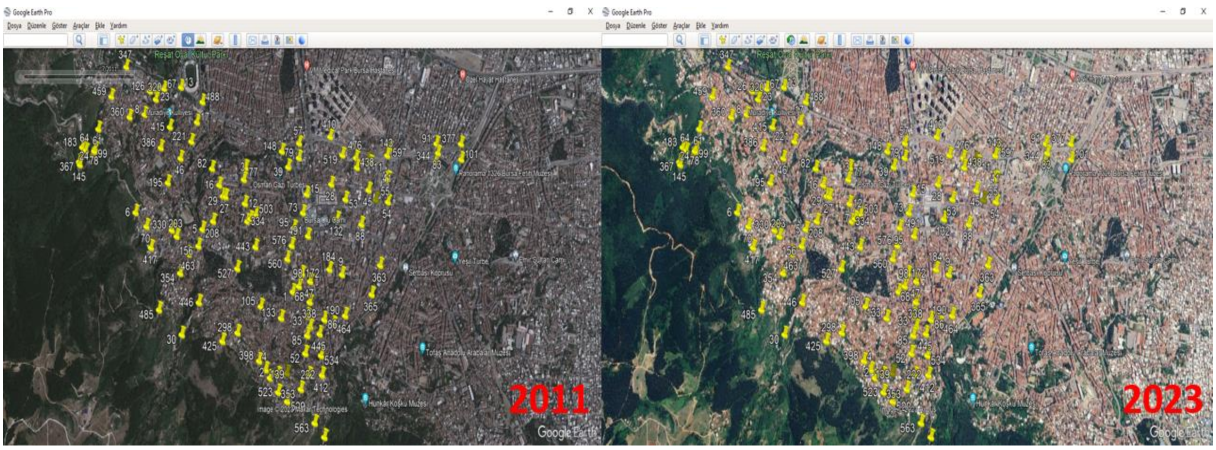

Figure 2. Representation of the sample areas on Google Earth.

i-Tree, used in the study, is a software package provided by the United States Department of Agriculture (USDA) that provides urban and rural forest area analysis and benefit assessment tools. i-Tree tools can help in planning the management of forest areas by measuring forest structure and the environmental benefits provided by trees. i-Tree software can link forest management activities with environmental quality and liveable areas according to the ecosystem cycle formed by wooded areas (URL-1).

the i-Tree Canopy program, firstly, the neighbourhood boundaries of Ulu Cami and its surroundings, which is one of the historical symbols of the city and located in Osmangazi district, obtained from Osmangazi Municipality, were transferred to the i-Tree program with ArcGIS software and the file was converted into shapefile and AutoCad shape format. The boundaries of the study area were uploaded to the i-Tree Canopy programme and the 600 points randomly assigned to the i-Tree Canopy programme were confirmed to which of the 7 different cover classes (Grass/Herbaceus, Impervious Buildings, Impervious Other, Impervious Road, Soil/Bare Ground, Tree/Shrub, Water) specified in the programme and the process was saved in kml/kmz file format. Afterwards, Cover Assessment and Tree Benefits Report was obtained from i-Tree Canopy. Which Cover Class the area selected in the report falls into, Tree Benefits: Air Pollution (metrix) values (CO, NO_2, PM2.5, PM10 in the air) were analysed in the software interface using the data obtained from the classes created according to the points randomly thrown by the program. In this analysis, it calculated the percentage error margins and gave the monetary values of the ecosystem. The Cover Assessment and Tree Area Report of the historical area covering the Ulu Mosque and its surroundings given by the i-Tree Canopy software was created separately for the dates 1997, 2011 and 2023, and the change of the factors in the report, the directions of change and the reasons for change were investigated and discussed.

3. Results and Discussion

3.1. Population Change Effects

Bursa, which is home to areas rich in cultural heritage, is an industrial city while Osmangazi district, one of the historical centres of the city, continues to receive migration for this reason. In addition, after the civil war that broke out in 2011 due to the mobbing of the Syrian regime against the people, mass migration to our country took place; Osmangazi district also increased the population of the district by receiving migration. The requirements brought by this increase, urbanisation, industrialisation, construction of transportation networks, etc. of Osmangazi district have caused negative changes on green areas.

Erdem et al. (2023) concluded that the population density of Bursa is in Nilüfer, Osmangazi, Yıldırım districts which are close to industrial zones, environmental problems are seen in these districts, the silhouette of the city has changed due to intensive migration and problems such as unplanned urbanisation have emerged. Figure 3 shows the population growth graph from the 1990s to the present day. In this thirty-three year period, there is a 57% increase in population.

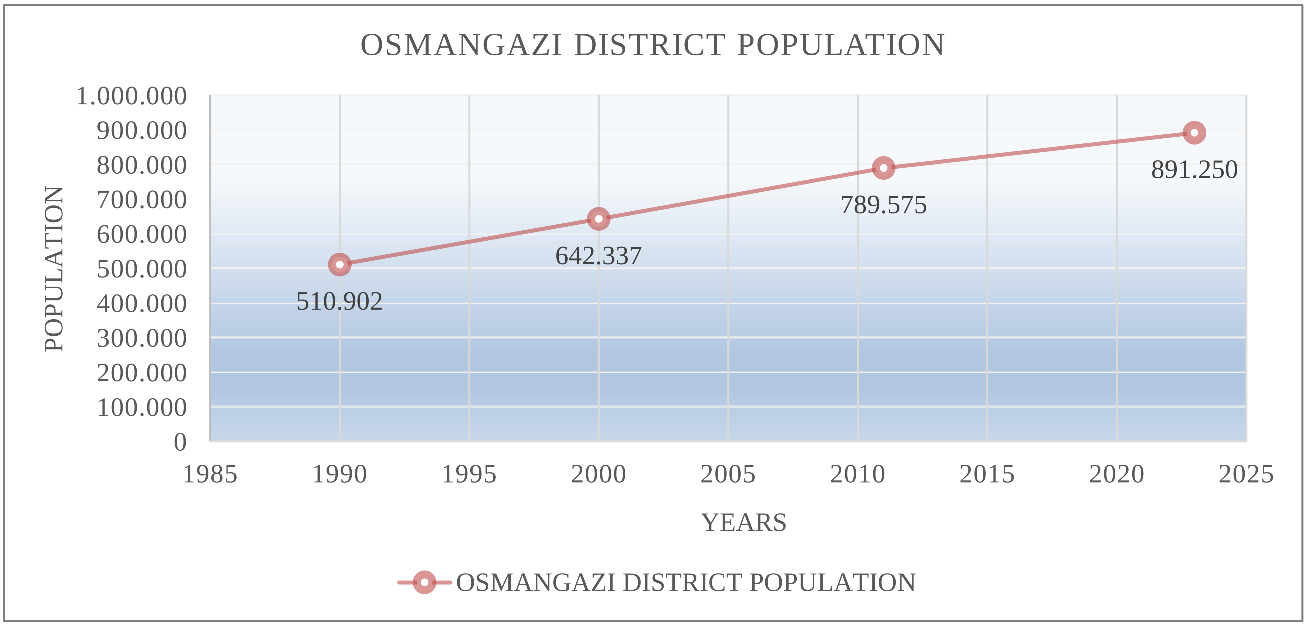

Figure 3. Population change graph of Osamangazi distict over the years (TUIK-2023).

In his study on migration, Küçükdağ (2023) revealed that mass migration does not only cause urbanisation problems, but also has intense effects on the awareness of urbanisation that requires adaptation to the city, and also emphasized that mass migration to the city brings along some environmental problems such as air, water, environmental pollution, traffic and noise.

In the study, it is clear that one of the important factors of the changes in the historical city area is the transformation of green areas into residential areas due to sudden and intense population growth.

3.2. i-Tree Canopy Area Cover Class

In the study using i-Tree software, a total of 348 points were assigned to grass/harbecus and tree/shrub classes in 1997 from 600 randomly assigned points in an area of 4.02 km^2 including the Ulu Mosque and its surroundings, which is included in the UNESCO cultural heritage list in Osmangazi district. Grass/harbecus and tree/shrub classes were calculated to cover 58% of the whole area in 1997 with a standard error of 2.83% and this area corresponds to approximately 2.23 km^2.

In 2011, a total of 243 points were assigned to grass/harbecus and tree/shrub classes. Grass/harbecus and tree/shrub classes accounted for 40.5% of the whole area in 2011 and were calculated to be approximately 1.63 km^2 with a tolerance of 2.64%.

Finally, a total of 206 points were assigned to grass/harbecus and tree/shrub classes in 2023. Grass/harbecus and tree/shrub classes were calculated as 34.34% of the whole area for 2023, approximately 1.38 km^2 with a margin of error of 2.5%.

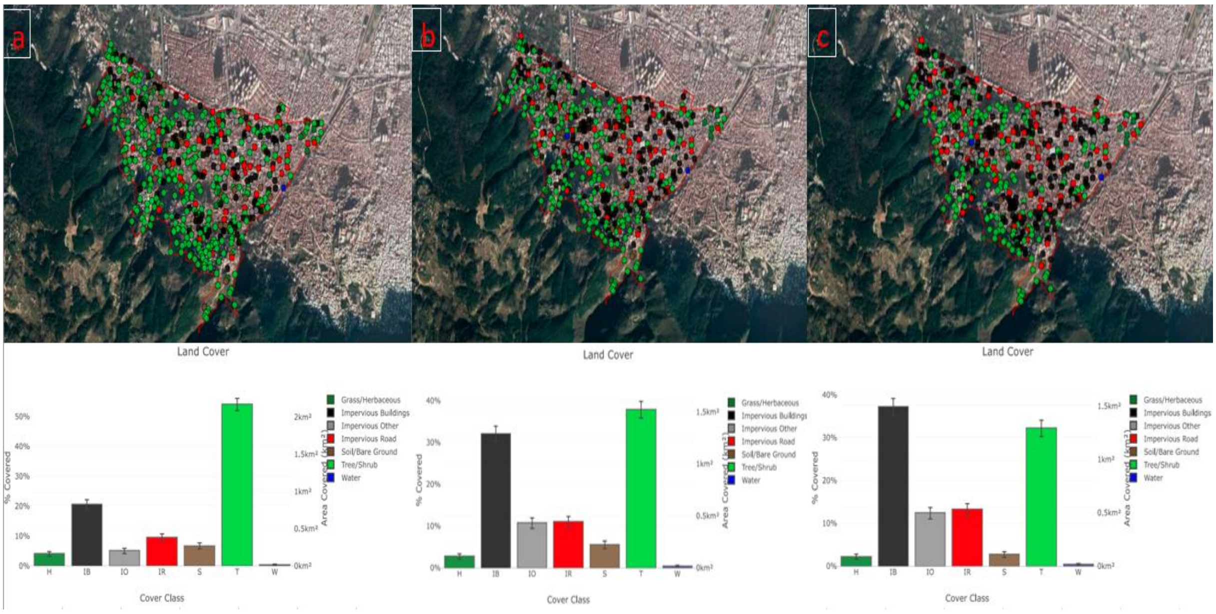

Figure 4. Change of cover classes according to years in i-Tree Canopy (a: 1997, b: 2011, c: 2023).

3.3. Impact of Air Pollutant

The increase in population in urban centres has caused a decrease in urban forests over the years, so the removal of harmful gases (CO, NO_2) and particulate matter (PM2.5 and PM10) that reduce air quality in urban centres has been calculated through i-Tree Canopy. These gases and particles can be generated by natural factors such as volcanoes, forest fires, storms, etc., as well as anthropogenic sources such as industrial activities, burning of fossil fuels, biomass burning, vehicle emissions, agriculture, construction and mining activities (Öztürk, 2023). Tor (2023) stated in his study that many studies have mentioned the relationship between PM2.5 and PM10 exposure and lung cancer risk and cardiovascular diseases, the relationship between NO_2 lung and breast cancer and that these substances cause respiratory diseases. Yaşlı et al. (2023) stated that there is concrete evidence that trees, urban green spaces and wider green infrastructure can provide significant reductions in urban temperatures and prevent health problems caused by heat waves. Many studies emphasize the role of tall shrubs, urban trees and urban forests in reducing carbon emissions, carbon capture and storage in urban areas (Goodale et al., 2002; Ersoy Tonyaloğlu et al., 2021; Öztekin Kara, 2022).

In the study conducted around Ulu Camii and its surroundings, Figure 5 shows the annual removal of CO, NO_2 and PM values affecting the air quality depending on the change of green areas. Accordingly, the amount of CO removed in 1997 was 274.93 kg with a standard error of 10.36 kg, the amount of NO_2 was 1518.82 kg with a standard error of 57.23 kg, and the amount of PM was 3926.27 kg with a standard error of 148.05 kg; compared to 1997, the amount of CO removed in 2011 was 82.31 kg (192.62 kg with a standard error of 10.08 kg), NO_2 amount 454.71 kg (1064.11 kg with a standard error of 55.69 kg), PM amount 1173.37 kg (2752.92 kg with a standard error of 144.07 kg). When 2023 i-Tree Canopy data was compared with 1997, it was observed that the amount of CO removed decreased by 111.16 kg (163.77 kg with a standard error of 9.71 kg), NO_2 decreased by 614.09 kg (904.73 kg with a standard error of 53.64 kg), and PM decreased by 1585.68 kg (2340.59 kg with a standard error of 138.76 kg).

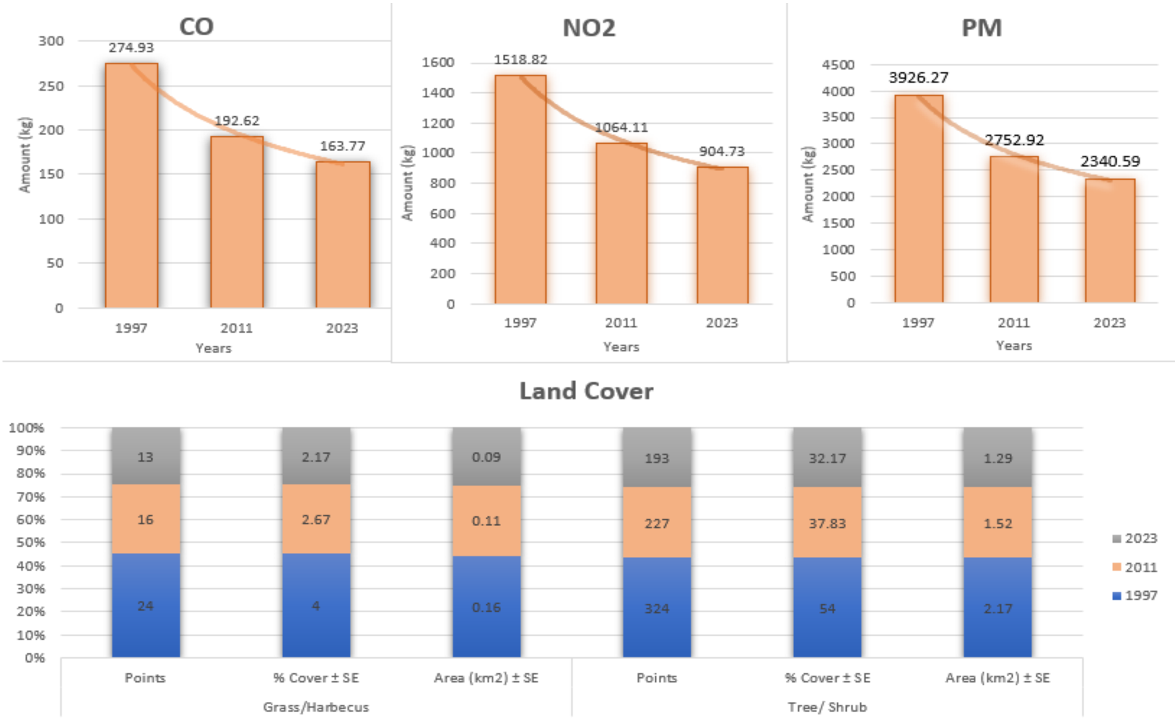

Figure 5. Graph of change in CO, NO_2, PM and green cover of Osmangazi district by years.

Table 1. 2023 Comparison of annual pollutant concentrations in Osmangazi District with Türkiye, European Union (EU) and World Health Organisation (WHO) limit values.

(µg/m³)	Average	Max. Value	Average Annual Production	Türkiye	European Union	World Health Organization
PM_{10}	43.34	300.47	520.08	40.00	40.00	20.00
$PM_{2.5}$	26.50	256.70	318.00	-	25.00	10.00
NO_2	30.91	163.01	370.92	40.00	40.00	40.00
CO	-	-	-	10.00	10.00	4.00

(Source: Air Quality Assessment and Management Regulation)

In Table 1, annual average pollutant concentrations in Osmangazi district were compared for Türkiye, EU and WHO limit values and PM10 and PM2.5 pollutants were found to be higher than the upper limit set by all three. These values are more than twice the WHO health organisation limit. NO_2 was below the averages given by Türkiye, EU and WHO. No measurement was made for CO.

Table 2. Air pollution value estimation of Osmangazi district by years.

Tree Benefit Estimates: Air Pollution (Value (USD))			
	1997	**2011**	**2023**
Description	**Value (USD) ± SE**	**Value (USD) ± SE**	**Value (USD) ± SE**
Carbon Monoxide (CO) removed annually	\$404 ± 15	\$283 ± 15	\$241 ± 14
Nitrogen Dioxide (NO_2) removed annually	\$732 ± 28	\$513 ± 27	\$436 ± 26
Particulate Metter (PM) removed annually	\$9.3345 ± 3.517	\$65.399 ± 3.423	\$55.604 ± 3.297
TOTAL	**\$94.481 ± 3.560**	**\$66.195 ± 3.465**	**\$56.281 ± 3.337**

i-Tree Canopy has calculated a financial value according to the years studied in Table 2 in air pollution forecasts. According to this calculation, while the total amount of CO, NO_2 and PM removed annually for 1997 was 5720.02 ± 214.64 kg, the financial contribution value to our country was \$94481 ± 3560; for 2011, 4009.65 ± 209.84 kg and the financial value it provided to our country (\$66195 ± 3465) constituted a loss of \$121 compared to 1997, while in 2023, the annual amounts removed were 3409.09 ± 202.11 kg and a financial loss of \$37741 was revealed in the financial value (\$56281 ± 3337) compared to 1997 data.

4. Conclusion

The study shows that the population of the Ulu Camii and the surrounding historic area has increased by 57% from the 1990s to the present day, and this increase has been accompanied by unplanned urbanisation. i-Tree Canopy land classification shows that the tree/shrub and grass/herbaceous plant classes, which covered 58% of the study area in 1997, decreased to 40.5% in 2011 and to 34.34% today. This situation has shown that green areas have been replaced by impervious buildings, roads and other impervious areas.

Due to the increase in population, the number of buildings and roads, the increase in the use of vehicles, the increase in the number of industrial zones have negatively affected the density of urban forests and green areas. Accordingly, in the years we have been working on Osmangazi district, the annual removal data of CO, NO_2 and PM from air pollutants in urban landscapes in Figure 5 and their environmental material values in Table 2 have been observed to be in a decreasing trend.

For all these reasons, in order to increase air quality within the scope of smart urbanism in Osmangazi district of Bursa city;

1. Campaigns and encouragements should be made to increase public awareness about the benefits of green areas,

2. The existing green areas should be protected by giving importance to their maintenance; afforestation works should be carried out around the roadside, refuges and industrial facilities,

3. Recreation areas should be combined with multifunctional areas such as recreation areas, children's playgrounds, sports areas and cultural performance areas,

4. Utilise technology and monitoring systems to monitor air quality, pedestrian traffic and maintenance needs of green spaces,

5. Bursa, which is an automotive city, should be encouraged to use today's technology electric vehicles, the use of renewable energy (solar, wind, geothermal energy) sources should be expanded, the integration of the arrangements of the infrastructure of industrial facilities such as drilling wells, the use of chimney filters, the use of underground resources, the establishment of treatment facilities should be integrated into smart technologies,

6. Be flexible in adapting green development strategies to changing urban and social dynamics, using continuous monitoring data and feedback from the community as a basis for measuring the relevance and success of initiatives,

7. Changes in vegetation cover, changes in air quality and their effects on tourism and the quality of life of the inhabitants should be regularly monitored and evaluated,

8. Distribution maps of existing green areas should be created, deficient areas should be identified and potential green areas should be planned together with local administrations.

With the implementation of these recommendations, the green areas of the historical centre of Bursa, which is a cultural heritage city, will be better planned within the scope of sustainability principles. In this way, both the historical texture of the city centre can be preserved and sustainable urban environments that will benefit the city residents and visitors can be created.

Conflict of Interest

The authors declare that they have no conflict of interest.

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