

# SPATIO-TEMPORAL ANALYSIS OF GREEN INFRASTRUCTURE AND OPTIMIZATION OF THE URBAN MODEL SUSTAINABLE MANAGEMENT IN TÂRGOVIȘTE CITY

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## Abstract:

Urban green spaces are essential in improving sustainable cities' quality of life. They help reduce pollution, regulate temperature, and provide refuge for biodiversity. It also promotes physical and mental health through opportunities for recreation and relaxation. Green spaces stimulate social cohesion, providing meeting places for the community. Investments in these areas increase real estate value and attract tourists, thus contributing to economic development and urban sustainability. This study combines GIS techniques, remote sensing, and urban modeling to provide a clear vision of the spatial dynamics of green infrastructure and to propose effective solutions for the sustainable management of the urban environment in Târgoviște City. This analysis used data from the following sources: high-resolution aerial images to analyze the evolution of green spaces and GIS maps for mapping the current distribution, information from urban planning documents, and local strategies. The results obtained highlight the dynamics of the surface of urban green spaces, the extension of the built area, and the development of road infrastructure, but also the need to develop urban regeneration plans by rehabilitating degraded green areas and connecting them by creating green corridors, all of which represent a series of important challenges.

**Key words:** green infrastructure, urban model, spatiotemporal analysis, Târgoviște City

## Introduction

Urbanization is considered one of the most significant global trends specific to the 21st century, being a transformative force that can be harnessed to stimulate economic growth, productivity, and development. In this context, the Board of Executive Directors of the UN Coordination System (CEB) adopted, in May 2019, the 'United Nations System-Level Strategy on Urban Development,' responding to a request made by the General Assembly through Resolution 72/22 (UNSCEB, 2019).

This resolution sets out ten key principles highlighting how urbanization can support sustainable development and ten levers for action through which the UN system can make these principles a reality (UNSCEB, 2019). Also, urban sprawl is a major challenge for metropolitan areas, impacting the quality of life. This trend concerns the scientific community, authorities, and other stakeholders looking for solutions to reduce or diminish its effects (Gavrilidis et al., 2019).

The literature and strategic documents at the national and international levels highlight the creation of urban green spaces as a means of improving the quality of life (Humă, 2022). Urban green infrastructure is seen as an important factor in increasing the quality of life and creating an environment conducive to the development of sustainable cities (Badiu et al., 2016). Integrating natural elements into the structure of cities promotes sustainability and supports the well-being of urban communities. Urban green infrastructure also contributes to increasing the resilience of cities. It promotes sustainable resource management (Ioja et al., 2014) by reducing environmental impact, preserving biodiversity, and optimizing water and energy consumption.

The scientific community, administrative leadership, and civil society increasingly recognize urban green spaces' essential role in ensuring ecosystem services. In all cities, urban planners seek to balance the location of these spaces with accessibility for the population (Stoia et al., 2022). In this context, the present study aims to outline a coherent perspective on the spatial dynamics of the urban green infrastructure in the municipality of Târgoviște from 1990 to 2023 and to highlight the role of urban green spaces in improving the city's appearance by creating a pleasant and attractive urban landscape. Equally, we want to identify solutions for interconnecting urban green spaces and creating green routes to increase accessibility, accompanied by concrete proposals for efficient solutions for sustainable management of the urban environment in the municipality of Târgoviște.

## Study area

The municipality of Târgoviște is located in the sub-hill plain with the same name, a component of the high Piedmont plain, near the 45° parallel. The hills around the city reach an altitude of 425 m, and the

hilly area is characterized by numerous valleys formed by torrents (Local Agenda-21, 2004). The relief is slightly arched in the western part of the locality, representing the contact area between the Ialomița and Dâmbovița rivers, forming an interfluvial threshold. The city's heart is bordered to the east by the Ialomița River and is located about 10–15 meters above its floodplain (Fig. 1).



Fig. 1: Location of the municipality of Târgoviște

Târgoviște has been the capital of Dâmbovița County since 1968. It is a medium-sized city with a pronounced industrial dominance. In 2023, it had approximately 87,238 inhabitants, a significant decrease from 1992, when there were 98,155 (INSSE Tempo Online, 2023).

The city's built-up area has expanded from 110.8 ha in 1990 to 172.782 ha in 2023 (Tab. 1) (INSSE Tempo Online, 2023).

Tab. 1: Built-up area dynamics (1990-2023)

Year	Total built-up area (ha)	Public property (ha)	Private property (ha)
1990	110.8	14.2	96.6
2023	172.782	3.734	169.048

The built-up area of the locality increased from 1949 ha to 2164 ha between 1993 and 2023 (INSSE Tempo Online, 2023). Târgoviște City Hall has started a series of ambitious projects to transform the city into a greener and friendlier space for its inhabitants. These include rehabilitating Chindia Park and expanding green areas in residential neighborhoods. The City Hall also plans to create theme parks with children's play areas, sports spaces, and relaxation areas for adults (Târgoviște City Hall, 2023).

## Material and methods

The working methodology responded to several analysis and research objectives and required using GIS and remote sensing techniques, statistics, and legislation in the urban field.

### *01. Analysis of the dynamics of urban green spaces in the municipality of Târgoviște in the time intervals 1990-2023*

For the spatio-temporal analysis of the urban green spaces in the municipality of Târgoviște, the interval 1990-2023 was taken as a reference, considered extensive enough to highlight the changes that occurred during this period. To collect the necessary data for the proposed time interval, high-resolution aerial images rectified in the Stereo70 projection system were used (Google Earth Pro, 2023), declassified topographic maps, scale 1:25 000, 1990 edition (ESRI Romania, 2024) and satellite image sets Landsat 8-9, OLI/TIRS C2 L1 with 30m resolution for 2023 (USGS, 2023). In parallel with these, information was collected from urban planning documents, local strategies, normative acts, and legislation in the field. All the data obtained were validated in the field through two campaigns between July and August 2023.

The final information was stored in a GIS database, which was essential for establishing, delimiting, and classifying the elements of urban green infrastructure according to Law 24/2007: public green spaces with free access, green spaces for specific uses etc. (Official Gazette, 2009).

The ArcGIS Pro 2.8 application, with a free student license, made all geospatial analysis of urban green space surfaces and the creation of the GIS database possible (ESRI Romania, 2023).

## **02. Identifying vulnerable areas and creating green routes**

After carrying out the spatiotemporal analysis of the urban green spaces in the municipality of Târgoviște, the vulnerable areas, deficient from this point of view, were identified, and solutions were proposed for the interconnection of urban green spaces by creating green routes that increase their accessibility. Concrete proposals regarding implementing efficient solutions for sustainable urban environment management in the municipality of Târgoviște will complement this approach.

## **Results**

### **01. Analysis of the dynamics of urban green spaces in the municipality of Târgoviște in the time intervals 1990-2023**

The geospatial analysis of urban green spaces for the reference year 1990 was carried out by mapping all surfaces using declassified topographic maps, scale 1:25 000, 1990 edition. These old maps were previously scanned and georeferenced in the Stereo70 projection. All vectorized data were verified and validated by superimposing them with high-resolution aerial images from the same period available online using the Google Earth Pro application (Google Earth Pro, 2023). The results of this analysis highlighted a major difference between the areas with agreement forests (1173.11 ha) and agreement parks (23.87 ha) (Tab. 2).

Tab. 2: Types of green spaces in 1990

YEAR	TYPES OF GREEN SPACES	AREA (HA)
1990	Areas related to public facilities	55.15
	Sports Bases or Parks	1.65
	Forest curtains to infrastructure	6.69
	Planted strips	72.86
	Gardens	485.97
	Agreement forests	1173.11
	Parks	23.87
	Squares	2.09
	Green spaces for the protection of lakes and watercourses	0.68
TOTAL		1822.08

The land areas occupied by agreement forests are parts of old forests preserved from the last century. In general, it is observed that for this analyzed year, the total area of urban green spaces is approximately 1822.08 ha, representing 33.89% of the total area of the Târgoviște ATU.

For 2023, maps of urban green areas were made using Landsat 8-9, OLI/TIRS C2 L1 satellite image sets with 30m resolution. All elements were also vectorized with the help of the ArcGIS Pro program (ESRI Romania, 2023) and were identified, classified, and integrated into the GIS database. Two field campaigns were carried out for data validation between July and August 2023. The results obtained showed a significant increase in urban green spaces, compared to 1990, especially in the areas occupied with gardens (1812.62 ha) and intended for public facilities (nurseries, kindergartens, schools, hospitals, religious buildings, cemeteries, public institutions, etc.) (371.04 ha). The explanation is that during this time interval (1990-2023), the built areas and implicitly urban green spaces related to these projects expanded.

The total areas with urban green spaces in 2023 were approximately 3470.09 ha (Tab. 3.).

Tab. 3: Types of green spaces in 2023

YEAR	TYPES OF GREEN SPACES	AREA (HA)
2023	Areas related to public facilities	371.04
	Sports Bases or Parks	6.05
	Forest curtains to infrastructure	4.79
	Planted strips	55.82
	Gardens	1812.62
	Agreement forests	1102.97
	Parks	55.21
	Squares	3.60
	Green spaces for the protection of lakes and watercourses	57.97
TOTAL		3470.09

## **02. Identifying vulnerable areas and creating green routes**

It is obvious that compared to 1990, in 2023, there is an improvement in the appearance of the city, and this new urban landscape is pleasantly visible and attractive.

A less pleasant aspect is determined by the lack of interconnections between these green spaces, connections that increase accessibility to and between them. A project in the planning phase aims to connect the city's main areas through bicycle lanes to encourage sustainable transport (Târgoviște City Hall, 2023).

The present paper proposes creating these routes, at least in densely populated areas, and connecting them with the largest areas of agreement, such as parks, gardens, religious buildings, open-air museums, zoos, etc.

Thus, nine routes, totaling 8.98 km, were created and arranged in different city areas (Fig. 2).

These routes connect the densely built-up inhabited areas with the large parks and cultural edifices within the locality, thus contributing to increased accessibility and a much more efficient and sustainable urban environment management.

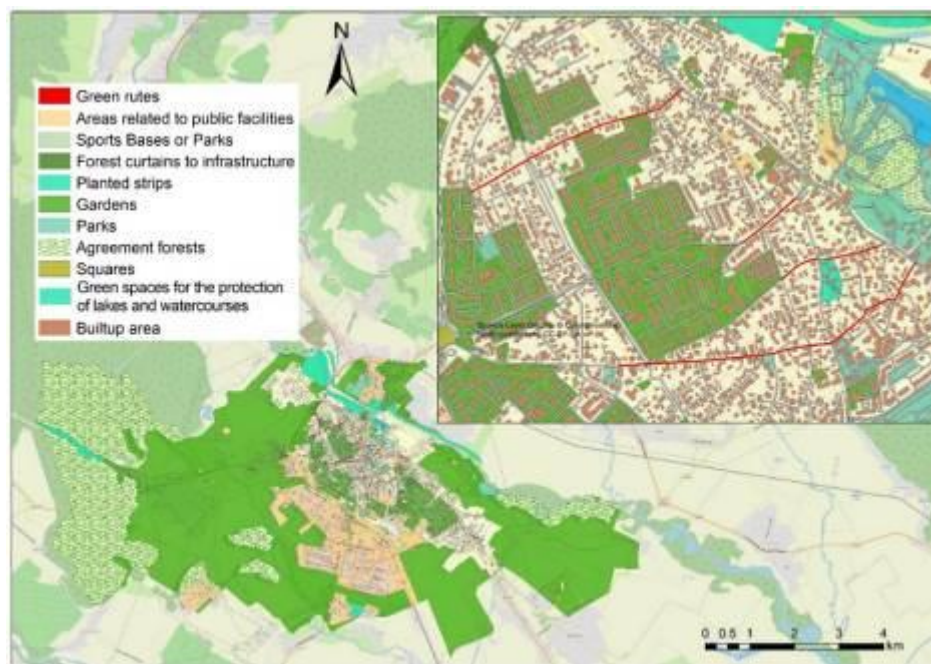


Fig. 2: Proposed green routes for accessibility

## Discussion

Preserving and developing green infrastructure in urban areas is essential to ensure a healthy and balanced environment. Investing in such areas not only supports the physical and mental health of citizens but also increases the attractiveness and sustainability of cities in the long term. An uneven distribution of green spaces in the city can create disproportionate access for the population to these areas. This lack of access can negatively influence people's perception of green spaces and worsen social inequities, such as differences in health status between different population groups. The spatio-temporal analysis of the green infrastructure in the municipality of Târgoviște between 1990 and 2023 highlighted an upward dynamic of the surfaces. However, an urban expansion was also recorded at the level of the built areas. In this sense, urban growth modeling is essential to understand and anticipate the loss of agricultural and natural land due to the expansion of cities, and an important element of the analysis could be the identification of the ecological value of soils (Oprea et al., 2016). The problem currently exists in the poor interconnectivity between urban green spaces, agreement areas, tourist attractions, and residential areas, which results in relatively deficient accessibility between them.

This work proposed nine green access routes, totaling approximately 8.98 km, on which bicycle lanes can be arranged and which can be integrated into future projects or even into the new Zonal Urban Plan of the municipality of Târgoviște.

## Conclusion

The evolution of the urban green spaces in the municipality of Târgoviște reflects the significant transformations through the city's evolution over time. Having a long history and an important cultural

and historical role within Romania, Târgoviște has gone through various stages of urban development that have directly influenced how green spaces are arranged and managed.

In this context, the present paper highlights the dynamics of the urban green infrastructure in Târgoviște from 1990 to 2023. It emphasizes sustainability and improvement of environmental conditions, proposing the creation of green accessibility routes to public green spaces, leisure areas, recreational forests in the locality, and existing places of worship. In this way, we can consider contributing to a healthier and more attractive environment for the municipality of Târgoviște.

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## Souhrn

Městská zeleň má zásadní význam pro zlepšení kvality života v udržitelných městech. Přispívají ke snižování úrovně znečištění, zmírňují teplotu a nabízejí klíčová stanoviště pro biologickou rozmanitost. Kromě toho podporují fyzickou i duševní pohodu tím, že poskytují prostory pro relaxaci a rekreační aktivity. Tyto prostory také podporují sociální interakci tím, že slouží jako místa společného setkávání. Investice do zelené infrastruktury nejen zvyšují hodnotu nemovitostí a přitahují návštěvníky, ale hrají také významnou roli v ekonomickém růstu a udržitelném rozvoji měst.

Tato studie integruje technologie GIS, dálkového průzkumu Země a městského modelování, aby představila podrobný pohled na prostorový vývoj zelené infrastruktury ve městě Târgoviște s cílem navrhnout účinné strategie telnou správu městského prostředí..

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