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PËRDORIMI I INTELIGJENCËS ARTIFICIALE NË HARTAT MJEDISORE NË TIRANË. NJË RRUGË DREJT PLANIFIKIMIT URBAN TË QËNDRUESHËM.

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Abstract

Tirana, the capital of Albania, has experienced rapid urban development, resulting in significant environmental challenges. Historical data reveal a drastic reduction in green space per capita, from approximately 10 m² during the communist period to a concerning 0.5 m² in recent years. This decline highlights the urgent need for sustainable urban planning strategies that prioritize ecological resilience.

This study explores the innovative application of Artificial Intelligence (AI) platforms to compile comprehensive environmental maps of Tirana, aiming to address the city's sustainability challenges. By integrating AI techniques with urban planning, the research seeks to offer a novel approach to enhancing urban environments and ecological sustainability.

Utilizing a diverse array of AI techniques, including machine learning algorithms, remote sensing data analysis, and predictive modeling, the study aggregates and interprets vast datasets. These methods are employed to produce detailed environmental maps that highlight key features and challenges within the city, such as the distribution of green spaces, pollution hotspots, urban heat islands, and water management areas.

The generated maps provide unprecedented insights into Tirana's environmental dynamics, illuminating the areas most in need of intervention. This mapping enables the classification of the city into climatic zones, aiding in the identification of urgent regulatory plan interventions. The findings underscore the potential of AI in revolutionizing environmental monitoring and management, facilitating informed decision-making for urban development strategies.

By presenting Tirana as a focal point, this research showcases the practical applications and benefits of AI in environmental mapping and sets a precedent for other cities aiming to integrate advanced technologies into their environmental planning processes. The study emphasizes the importance of creating public and green spaces within urban settings, highlighting Tirana as a case study for avoiding environmental degradation in similar contexts. With population projections indicating significant growth, the necessity for adopting AI-driven environmental planning becomes increasingly evident as a means to ensure sustainable urban development and ecological resilience.

Keywords: *Artificial Intelligence, Environmental Mapping, Sustainable Urban Planning, Tirana, Green Spaces, Urban Development*

1. Introduction

Albania is one of the most vulnerable countries in terms of the trend of climate change in the Western Balkans. Tirana is located in the heart of Albania and represents the country's capital. It has a Mediterranean hot summer climate (Csa by the Köppen-Geiger system) with 14.8 °C average annual temperature and 1136 mm precipitation ⁽¹⁾.

Changing weather patterns have already been observed over the last 15 years with increasing temperatures, decreasing precipitation, and more frequent extreme events like floods and droughts. According to the World Bank publication "Reducing the Vulnerability of Albania's Agricultural Systems to Climate Change", projections indicate a decline in summer rainfalls of about 10 percent by 2020 and 20 percent by 2050 ⁽²⁾. Among the most affected cities is Tirana, which is the main focus of this study. It is the largest municipality in the country in terms of territory.

The phenomena of urban heat islands (UHIs) implicates two of the most serious environmental issues of our times: population growth and climate change. The most widely used method for mapping urban climate zones is based on the Stewart & Oke study ⁽³⁾. Using geospatial methods from remotely sensed data or local geo-databases, the method can be used to classify spatial units by some important factors such as: the proportion of building floor area, the proportion of impervious surface, the proportion of impervious surface and the height of roughness elements. These factors have a significant impact on the climate of the urban environment and should therefore be mapped as part of urban development concepts. The method is called Local Climate Zone (LCZ) mapping.

In 2014, the Municipality of Tirana occupied an area of about 42.8 km² and included only the urbanized part. According to the new administrative division of year 2015, the municipality of Tirana has increased about 25 times its territory and has approximately an area of about 1110.98 km² of which 99 km² belongs to the built-up area, 400 km² protected areas and 220 km² which used to represent agriculture but now has become urban.

According to the Institute of Statistics of Albania ⁽⁴⁾, in January 2021 the population of the country was 2,829,741 inhabitants, of which 912,190 live in Tirana. The continuous increase of the population, which in January 2020 marked the largest increase in the country at the quota of + 1.2%, has led to an increase in the concentration of construction in the territory of this municipality. Inevitably, these areas have become problematic areas in terms of the environment, as they reflect the consequences of the actions of the citizens themselves and decision makers. The city has undergone a metamorphosis compared to previous decades. Most of the land has been used for residential development. Despite the percentage of new constructions, the lack of realization of public spaces and green spaces inside the blocks remains problematic. For this reason, Tirana is already considered as an alarm bell to avoid the degradation of other cities in the country, but also in the region.

The main focus of this study remains the environmental mapping, making it possible to classify the city according to climatic zones, where the areas that are most urgent to intervene through regulatory plans can be easily identified.

The aim is to provide the most comprehensible and accurate map representation of urban climate

1 Climate-Data.org

2 SUTTON W. R., SRIVASTAVA J. P., NEUMANN J. E.: *Looking Beyond the Horizon: How Climate Change Impacts and Adaptation Responses will Reshape Agriculture in Eastern Europe and Central Asia. Directions in development: Agriculture and Rural Development*, (2013), Washington, DC: World Bank. <https://openknowledge.worldbank.org/handle/10986/13119>

3 STEWART I. D., OKE, T.: *Local Climate Zones for Urban Temperature Studies*. Bulletin of the American Meteorological Society, 12 (2012), vol.93, pp. 1879–1900. doi: 10.1175/BAMS-D-11-00019

4 *Institute of Statistics Reports*

zones. To do this, we examined three methods, two using freely available data and one using high-resolution, but not freely available, data of the city.

Incorporating an AI component into this research enhances its value significantly, as it enables dynamic, real-time assessments of urban conditions that are challenging to capture through ground observations or human resources alone. This technological advancement allows for more efficient and precise environmental monitoring and decision-making.

1. Data and Methods

Based on the theoretical base of the method published by Stewart & Oke the map of recent urban climatic zones was compiled in three different approaches:

- a) By using GIS spatial queries on detailed vector and raster data. ⁽⁵⁾
- b) By using LCZ Generator, which is described as an online platform that maps a city of interest into LCZs, solely expecting a valid training area file and some metadata as input ⁽⁶⁾.
- c) By using an ArcGIS based Toolbox, which provides an alternative LCZ GIS-based classification, based on freely accessible Copernicus Land Monitoring service datasets ⁽⁷⁾.

LCZ mapping on a large scale analysis required detailed vector data like:

- Building's database, giving information about building's number of floors or height;
- Road network, represented as polygon feature;
- Impervious and pervious surface;
- Canopy height.

Facing the fact that we did not have such complete detailed data on the entire territory of Tirana's municipality, a pilot area was chosen. The canopy height was derived by subtracting the DTM from the DSM, but also other among the above-mentioned layers were obtained by processing and analyzing these raster data. The DSM was a high resolution product (1m) of the project named as "1x1m DEM for Tirana", which was conducted in 2018. This project was focused on the city of Tirana and it covered an area of approximately 49 km². Through GIS spatial queries, the large scale map of recent urban climatic zones of the pilot area was compiled, by using QGIS.

The local climate zone mapping according to LCZ Generator approach, was compiled using the open source web application, which works on Google Earth Engine. It provided a supervised classification on the whole municipality of Tirana in 100 by 100 m ground resolution. This satellite data based analysis was done by using 5-15 training areas for each LCZ types.

The process required drawing attention to maintaining the shape of the digitized polygons as simple as possible, keeping a minimum distance from one polygon to another, respecting the homogeneity principle and making sure to distribute the training areas over the entire region of interest.

5 UNGER J., LELOVICS E., GÁL T.: *Local Climate Zone mapping using GIS methods in Szeged*, (2014), Hungarian Geographical Bulletin, 63(1), 29-41.

6 DEMUZERE M., KITTNER J., BECHTEL B.: *A Web Application to Create Local Climate Zone Maps*. *Frontiers in Environmental Science*, 23 (April 2021), vol.9. doi: 10.3389/fenvs.2021.637455

7 OLIVEIRA A., LOPES A., NIZA S.: *Local climate zones classification method from Copernicus land monitoring service datasets: An ArcGIS-based toolbox*. *MethodsX*, (2020), vol.7. doi: 10.1016/j.mex.2020.101150

Local climate zone classification according to the method named “Local Climate Zones from Copernicus ArcGIS Toolbox (LCZC) required a list of mandatory inputs (except BH) freely accessible from the Copernicus Land Monitoring Service (CLMS). As a result, it creates a raster-type map, which has a ground resolution of 50 by 50 m.

Table 1: List of datasets used in this study

Dataset	Resolution	Version	Date of publication	Original format
Dominant Leaf Type (DLT)	10m	2018	Sep. 18, 2020	Raster GeoTiff
Corine Land Cover (CLC)	100m	2018	Jun. 14, 2019	Vector Shapefile
Grassland (GRA)	10m	2018	Aug. 18, 2020	Raster GeoTiff
Imperviousness Density (IMD)	10m	2018	Aug. 18, 2020	Raster GeoTiff
OpenStreetMap (OSM)	n/a	n/a	n/a	Vector Shapefile
Tree Cover Density (TCD)	10m	2018	Sep. 18, 2020	Raster GeoTiff
Urban Atlas (UA)	10m	2018	Apr. 16, 2020	Vector Shapefile
UA Building Height (BH)	10m	2012	Apr. 19, 2018	Raster GeoTiff

2. Results

By using the LCZ Generator approach, a total area of 107.3 km² was analyzed and categorized into LCZ classes, where the most significant results correspond to compact midrise in the value of 5.78 km² (5.38%), 5.2 km² (4.48%) classified as compact low-rise and a value of 3.21 km² (2.3%) was categorized as compact high-rise.

Further analyzes focusing only on the pilot area cannot be done, because the output obtained is a simple image and the statistical data provided is summarized for the whole covered territory. However, the characteristics of the satellite image based LCZ map are less complex and more generalized compared to the results of the large-scaling mapping, which appear more distinct (Figure 1).

While referring to the classification based on LCZC this class doesn't even stand as a separate classification, but it is included in a mixed category, named “LCZ 123 Compact (mixed-rise)”. The only categories that match in terms of the name of the LCZ class are shown on the table below, but it is important to highlight the fact that none of calculated values correspond.

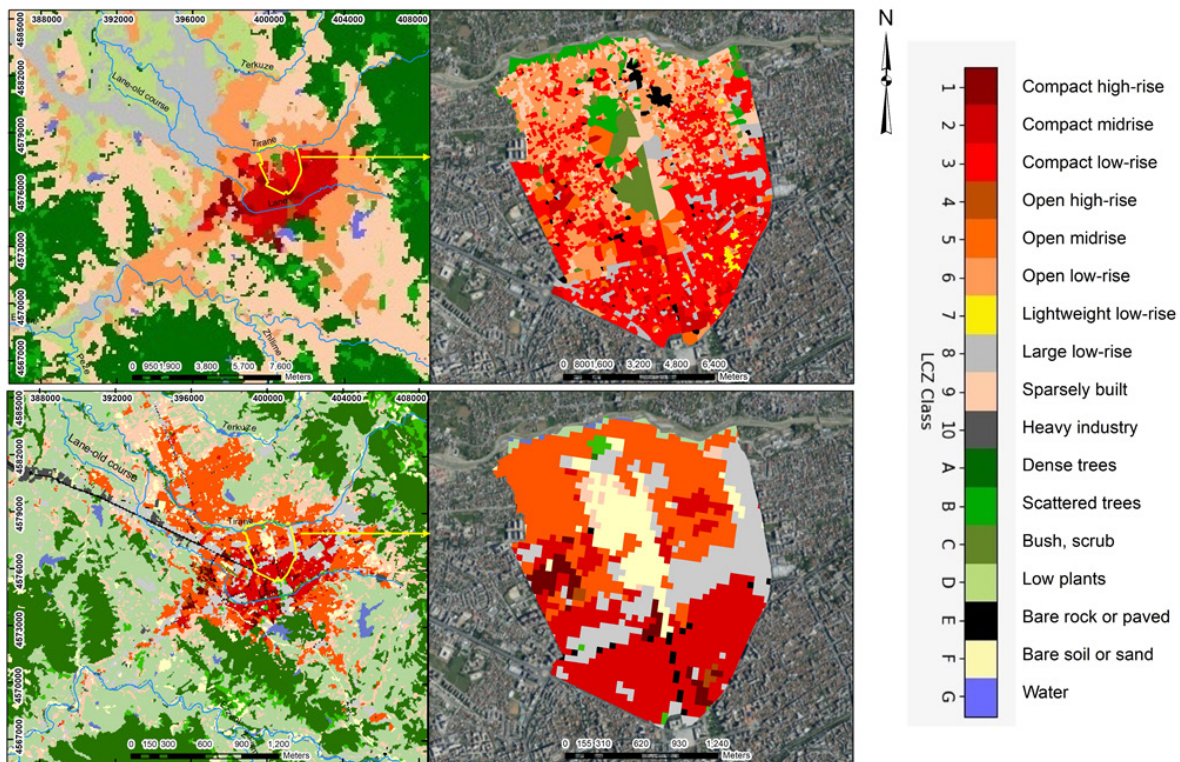
It was noticed that almost 10% of the pilot's area, which was classified as LCZ B (Scattered Trees) and LCZ C (Bush) was considered as LCZ F (Bare soil or sand) according to LCZC classification technique. In reality, this area corresponds more to LCZ type B, so the first method is considered more accurate.

Local Climate Zone		Large scale analysis approach [%]	LCZC approach [%]
1	Compact high-rise	-	3.59
2	Compact midrise	5.2	29.86
3	Compact low-rise	36.76	-
	Compact (mixed-rise)	-	0.84
4	Open high-rise	-	0.55
5	Open midrise	4.48	26.71
6	Open low-rise	24.79	-
	Open (mixed-rise)	-	3.17
7	Lightweight low-rise	0.77	-
8	Large low-rise	5.98	19.55
9	Sparsely built	10.27	1.77
A	Dense trees	-	0.06
B	Scattered trees	4.39	0.68
C	Bush, scrub	5.3	
D	Low plants	-	1.23
E	Bare rock/paved	1.96	1.11
F	Bare soil/sand	-	10.57
G	Water	-	0.31

Table 2: Differences in obtained results from the above-mentioned approaches for the same LCZ classification, in the same pilot area

Although in the foreground it may seem as if the fluctuations of the figures are small, we must keep in mind that these values are very significant when referring to neighborhoods or areas on a micro scale. Therefore, it is very important and necessary that the analysis reflects the factual situation as accurately as possible, to ensure that appropriate measures are taken in order to improve the environmental conditions of the area.

According to the results of the above mentioned approach, almost 88% of the pilot area was classified as urban climate zones, while the remaining percentage corresponds to nature climate zones, proving that constructions predominate over green spaces.

Figure 1: Local Climate Zone maps of Tirana municipality through different approaches.

2. Discussion

When comparing traditional methods to AI-enhanced approaches in urban environmental mapping, the adaptability and forecasting capabilities of AI emerge as significant advantages.

2.1 Traditional Methods

Traditional environmental mapping techniques primarily rely on static data gathered through ground observations and remote sensing. This data, while accurate, represents a snapshot in time and lacks the ability to adapt to new information without manual intervention.

Forecasting using these methods generally involves extrapolating from historical data based on pre-set models, which do not dynamically update with incoming data. Consequently, predictions are often linear and may not adequately capture sudden environmental changes or anomalies.

2.2 AI-Enhanced Methods

Adaptability: AI models, particularly those based on machine learning, excel in their ability to integrate and adapt to new data in real-time. This continuous learning process allows the models to refine their predictions and improve their accuracy over time as they are exposed to more diverse data scenarios. In the context of urban planning, this means that AI can adjust its forecasts to reflect ongoing changes in urban development, population density, and environmental policies.

Forecasting: AI's predictive capabilities are rooted in its ability to analyze vast quantities of historical data and identify patterns that might not be evident to human analysts or traditional methods. By learning from these patterns, AI can forecast future urban environmental conditions with a higher degree of precision. For instance, AI can predict the potential development of urban heat islands before they become problematic, enabling proactive urban planning. This proactive approach not only

helps in mitigating the adverse effects of such phenomena but also assists in planning for sustainable urban growth.

2.3 Comparison and Integration

When directly compared, the results obtained from AI methods can provide a more dynamic and forward-looking perspective than traditional methods. Traditional data might indicate a trend based on past and present observations, but AI can extend these trends into the future with predictive analytics, offering a foresight that is invaluable for urban planners.

Integrating AI with traditional methods can enhance the overall effectiveness of environmental mapping. Traditional methods provide the foundational data and validation for AI predictions, while AI contributes its adaptive and predictive strengths, creating a comprehensive toolset for urban environmental management (^{8,9}).

3. Conclusion

The three Local Climate Zone (LCZ) map representations of Tirana each present their unique advantages and drawbacks. The large-scale mapping, following the theoretical model by Stewart & Oke, excels in delineating varied urban climate zones, which is crucial for city planning. This map effectively captures the city's structural layout, highlighting details such as individual buildings or small parks. However, its primary limitation in a rapidly evolving urban setting is the static nature of the building patterns it analyzes, coupled with the challenge of accessing the necessary data.

On a medium scale, the map produced using the LCZ Generator encompasses a broader area compared to the large-scale map derived from GIS spatial queries. It leverages freely available data and an online platform, making it accessible but somewhat limited in detail. This map is primarily suited for providing a general overview, as its resolution is insufficient for capturing the intricate structures of urban areas (¹⁰). A full comparison of these scales across the entire municipality of Tirana will be conducted in future studies.

The LCZC Toolbox offers another advantage by utilizing free data from the Copernicus Open Access Hub, yielding better resolution for case studies than the LCZ Generator. However, it requires local execution in an ArcGIS environment, which can lead to compatibility issues due to different settings and versions. Additionally, the content and categorization of the map visualization using the LCZC Toolbox sometimes differ from other maps, which may lead to inconsistencies.

LCZ maps serve as a critical tool to enhance public awareness about the urban environment and its dynamic changes. They provide valuable insights into the current state of urban areas and aid in fostering a collective understanding of the standards expected from decision-makers in Albania and elsewhere.

Integrating AI into this process presents significant advantages, primarily in terms of adaptability and enhanced forecasting capabilities. AI can dynamically adjust to new data, learn from historical

8 KAMROWSKA-ZAŁUSKA, D. *Impact of AI-Based Tools and Urban Big Data Analytics on the Design and Planning of Cities*. Land 2021, 10, 1209. <https://doi.org/10.3390/land10111209>

9 AMERICAN PLANNING ASSOCIATION, *AI in Planning: Opportunities and Challenges and How to Prepare*, 2022

10 CENAMERI A., ALBERT G.: *Local climate zone mapping of Tirana, Albania*, (2021), Abstracts of the ICA, 3, 49.

patterns, and predict future urban conditions with greater accuracy. This allows for proactive urban planning, which is crucial in rapidly changing urban landscapes, thus providing a strategic edge in urban management and planning.

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