Blue-Green Factor (BGF) Indication as a Hybrid Method for Mapping the Spatial-temporal Dynamics of Post Socialist Urban Landscapes

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Abstract: Post-socialist countries have experienced accelerated urban expansion trends during the last three decades. Tirana, the capital city of Albania, has expanded dramatically through unsupervised urban sprawl processes. This trend manifested with the expansion of the artificial surfaces towards the urban-wildland interface at the expense of agricultural and natural lands. The hard-scape to soft-scape ratio has changed dramatically. It affects the water-retaining capacities of urban lands, raising urban life's vulnerability to hazards such as flooding, urban heat stress, and air pollution. This study illustrates the spatial-temporal transformation process of a neighbourhood in Tirana. The Blue-Green Factor (BGF) method enables assessing both quantitative and qualitative landscape features within a locality area. BGF is applied in QGIS, and results are interpreted via descriptive statistics. Here, we bring BGF as a hybrid mapping method that relies on analogue and digital data gathering and mapping techniques. The temporal analysis relies on geospatial evidence supplied by orthophotos of 1997, 2007, 2018 (via ASIG geoportal). The empirical work was done within a graduate course in the architecture department at Epoka University in Tirana. The team was composed of master-level students in architecture with no background information in either landscape research methods or GIS technologies. The results of this work show that the study area has experienced significant artificialization ratios in two decades. The presence of soft-scape surfaces and other landscape features have been reduced drastically, while the new investments rarely integrate minimal solutions for landscape features. This study aims to raise awareness that new urban developments must integrate designed landscape features to enhance nature-based solutions for current urban challenges.

Keywords: Blue-green infrastructure, hybrid research methods, orthophoto, QGIS, Tirana

1 Introduction

The existing research shows that Blue-Green Infrastructure (BGI) is critical for climate change mitigation and adaptation (PAMUKCU-ALBERS et al. 2021, CHATZIMENTOR et al. 2020), enhancing watershed management (ZUNIGA-TERAN et al. 2019), and urban microclimate improvement (LI et al. 2020). Furthermore, BGI is accepted as a critical component of metropolitan areas for ecosystem services (ES) provision and facilitate nature-based solutions (NBS) to emerging metropolitan challenges (EEA 2012, HYSA 2021). Among environmental benefits that effective BGI provides are carbon sequestration, water purification, and balancing water flows (KEESSTRA et al. 2018). On the other hand, the BGI has a social impact on neighbourhood and architectural scales as it promotes well-being by allowing people to relate to nature (VENKATARAMANAN et al. 2019).

However, it is challenging to tackle the issue of BGI in the metropolitan areas in the post-socialist countries due to rapid urbanization and lack of supervised territorial development (HYSA et al. 2021). In Albania, where the post 90s socio-political change has been harsher, informal development has characterized the urban expansion processes during the first two

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decades (the 90s & 2000s). However, in the last ten years, the central government and the local authorities have shown more concern about supervised territorial planning. At the same time, the lack of proper legislation with relevant technical standards has resulted in a superficial formality, randomly used as the formal informality of Albanian territorial development, especially in the capital city, Tirana (HYSA et al. 2021). Thus, the remaining components of BGI of Tirana are still under continuous threat of further construction.

On the other hand, implementing effective measures to enable successful NBS is challenging world widely. For instance, a recent study identifies barriers for NBS implementation based on an interdisciplinary and transnational perspective at a pan-European level (RAŠKA et al. 2022). The lack of knowledge on proper design and technical parameters to apply these measures, and the lack of information about potential conflicts, are among the nineteen limitations identified by the authors, emphasizing the significance of young professionals' awareness and training. Thus, further efforts are needed to raise awareness among both public and professionals, especially the early career individuals like graduate students.

In this context, this paper brings the experience gained during the graduate course, which aimed to make graduate students of architecture think beyond the building design. The course was designed as a project-based learning and problem-oriented research process. The goal of the exercise was to reveal the environmental degradation dynamics in one of the unique neighbourhoods of Tirana. The assessment method was the Blue-Green Factor (BGF) developed by the Norwegian Institute for Nature Research (Norsk Institutt for Naturforskning-NINA) (HORVATH et al. 2017). We present BGF indication as a hybrid mapping method that integrates analogue and digital techniques. Our research hypothesizes that the study area has experienced significant deterioration of environmental capacities at the city block scale. During this process, the ecosystem services supplied by these suburban lands have been reduced substantially.

2 Methods and Materials

The research presented in this paper was performed within the graduate course "Arch 415-Landscape Research" in the architecture department at Epoka University during the fall semester of the academic year 2020-2021. The team was composed of 20 graduate architecture students with no previous background in landscape research methods and GIS technologies. Due to the pandemic restrictions, all activities were performed as an online course via the Google Meet platform. Students were delivered theoretical background information during the first half of the schedule based on the available literature about the importance of landscape approach in territorial management and other specific topics like ecosystems services, nature-based solutions, and landscape research. During the second half, they were introduced to the practical sessions organized as virtual workshops focusing on a real case study (see Figure 1).

A review of the existing research on blue-green infrastructure shows that it applies to three different scales: the site, the city, and the region (YING et al. 2021). Our study area falls between the micro and mesoscale of the green infrastructure: it is a regional natural system that sustains the urban environment. The study area is the new urban development neighbourhood in the western outskirts of the Albanian capital. Tirana is a post-socialist city that has faced significant urban transformations during the last three decades. As the central metropolitan area in Albania, Tirana has gone through various architectural, urban, and landscape challenges in recent years. Figure 1 shows the study area, defined by the new ring road in the eastern part, the Lana River in the northern part, and the hills of Kashar in the south-western part. The total surface area is 105 Ha subdivided into 122 localities at the city block level, following the geometries of Urban Atlas data.

Fig. 1: The study area within Tirana, including the Google satellite image of 2021

This study utilized the BGF indication method developed as a quick investigation toolbox (HORVATH et al. 2017) to quantify minimum property development standards and requirements for certain ecosystem services (ES) like surface water management, vegetation qualities, and biodiversity in outdoor areas. The current version enables a GIS-based assessment which makes easier the use of remote sensing data, GIS datasets, and CAD-based design proposals. BGF mapping consists of a semi-automated procedure that quantifies a locality's blue and green surface qualities.

The legend illustrated in Figure 3 presents a complete list of BGF classes. The method counts for both quantitative and qualitative aspects of the study area. Thus, the first set of classes consists of nine surface types concerning the water cycle, vegetation cover, and soil depth. For instance one water surfaces and vegetated surfaces on soil and bedrock have the highest value. In comparison, impermeable surfaces with drainage to a local closed storm-water drainage system have the lowest coefficient. At the second round, different qualities related to temporary water surfaces, tree crown size, vegetation type, vertical green systems, and green surface size are mapped accordingly. Thus, each surface geometry contributes to the final BGF of the study area (locality) by its BGF value. The final locality BGF value is calculated as the sum of all individual BGF values.

We performed mapping for three years (1994, 2007, 2018), relying on the available orthophotos by the Albanian state authority for geospatial information (ASIG) geoportal (https://geoportal.asig.gov.al/map). Each team member was assigned a specific locality within the study area and prepared the BGF mapping for three years according to the above-mentioned method. The results presented here rely on the merged individual files after being checked for possible inconsistency, later compiled in a common set. The mapping procedure was predominantly based on the visual interpretation of the orthophoto of each year. Questionable cases were discussed among the team members and make a group decision for other similar cases. Thinking about the pandemic restrictions which made the site visit very difficult, students benefitted from Google Street view to cross-check their interpretative classification decisions.

3 Interpretation and Discussion of the Findings

Our results show that the neighbourhood within the study area has faced significant land transformation between 1994, 2007, and 2018. Figure 2 shows the orthophotos within the study area. Ex-agricultural lands have been initially transformed to informal individual housing unit development (1994-2007), and later from informal housing to high-rise and high-density multi-family housing units (2007-2018). Even though the orthophoto of 1994 was available only in greyscale, the resolution was good enough to differentiate between agricultural lands and the existing few buildings. While the orthophoto of 2007 and 2018 was available in colour, making the surface interpretation easier.

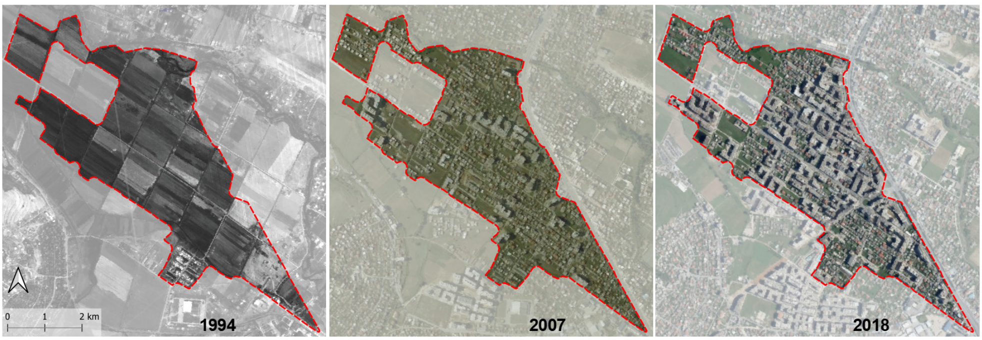

Fig. 2: Orthophotos of 1994, 2007, and 2018 within the study area

Figure 3 shows the gradual transformation of land surface from either covered by vegetation or permeable surfaces to impermeable and artificial ones. The map of 2018 visually reports areas dominated by impermeable surfaces with drainage to local closed storm-water drainage (A4 class, see Table 1), which is typical for the newly developed multi-storey housing investments. Non-surprisingly, the density of impermeability is in line with the transportation infrastructure provision, as shown in the eastern part of the study area, adjacent to the new ring road. The visual information delivered in Figure 3 is in line with the numerical information in Table 1.

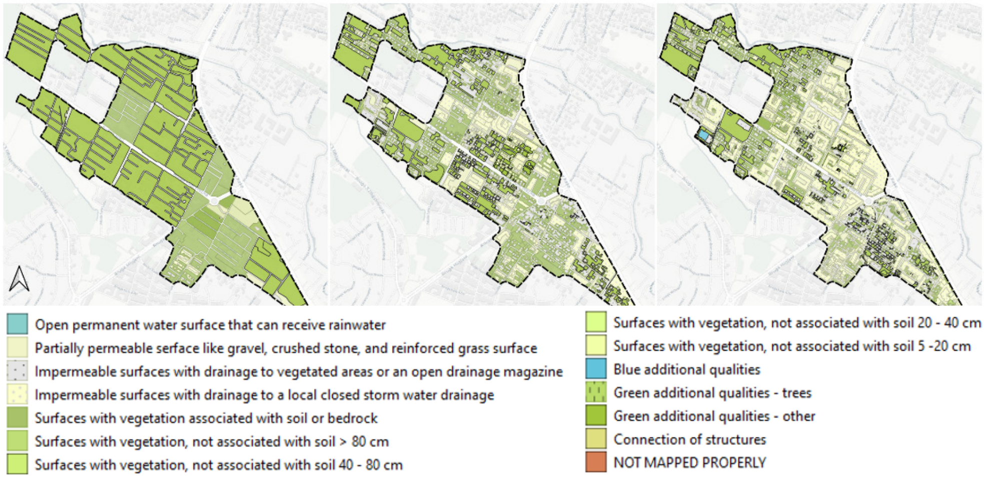

Fig. 3: According to BGF procedure and nomenclature, land use and land cover mapping are based on satellite images of 1994, 2007, and 2018

Table 1 presents the descriptive statistics of BGF classes' distribution within the study area for three years (1994, 2007, and 2018). According to the orthophoto of 1994, surfaces with vegetation on soil or bedrock (A5 class) covered more than 90% of the study area since the study area has been a sub-urban agricultural land. However, it halved in 2007 (46.12%) and almost quartered in 2018 (27%). On the other hand, the impermeable surfaces that lead the rainwater to local closed drainage infrastructure (A4 class) increased from 1.26% in 1994 to 19.52% in 2007 and 47% in 2018. In 2007 and 2018, there is an emergence of surfaces with vegetation covering artificial structures (A6-9 classes). These surfaces are typical to new courtyards of multi-storey residential blocks that lay over under-ground parking lot structures. Unfortunately, there was no vertical green elements depicted like green walls, or green roofs. Nevertheless, different qualities like tree cover type and large contiguous surfaces were present in the area and are calculated in the BGF records accordingly.

Table 1: Distribution of BGF surfaces within the study area for 1994, 2007, and 2018

BGF class	2018 Area	2018 %	2007 Area	2007 %	1994 Area	1994 %
A1- Open permanent water surface	1943	0.26	0	0.00	0	0.00
A2- Partially permeable surface like gravel	27046	3.67	62939	8.62	53314	7.36
A3- Imperm. Surf., drainage to vegetated areas	157981	21.46	187427	25.67	4127	0.57
A4- Imperm. Surf., lead to local closed drainage	345821	46.97	142493	19.52	9151	1.26
A5- Surf. with vegetation on soil or bedrock	198736	27.00	336687	46.12	657882	90.81
A6- Surfaces with vegetation not on soil > 80 cm	2208	0.30	76	0.01	0	0.00
A7- Surfaces, vegetation not on soil > 40-80 cm	2255	0.31	448	0.06	0	0.00
A8- Surfaces, vegetation not on soil > 20-40 cm	163	0.02	0	0.00	0	0.00
A9- Surfaces, vegetation not on soil > 5-20 cm	40	0.01	0	0.00	0	0.00

Figure 4 illustrates the mapping results about BGF values at the locality level. The colour gradient indicates high BGF values in green and lower ones in red, with the map of 1994 scoring the highest BGF values as most of the land was occupied by agriculture. On the contrary, the map of 2018 is dominated by red, which indicates poorly performing land surfaces regarding urban water management and other ES provision. Meanwhile, the map of 2007 completes the row as a transitory map within this transformation process.

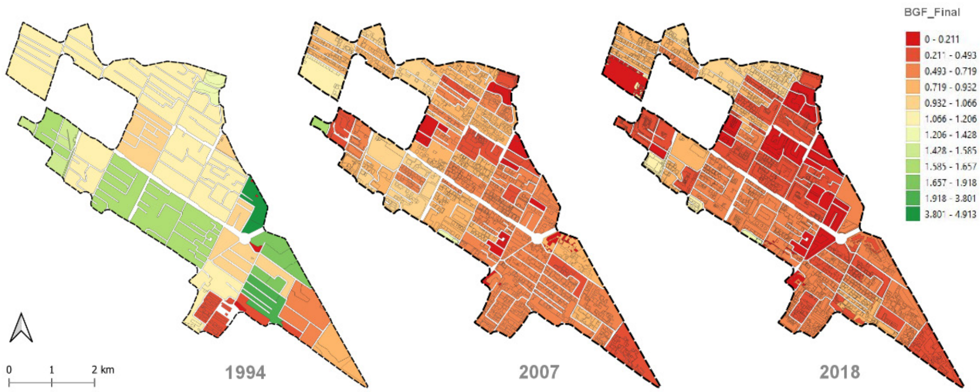

Fig. 4: BGF mapping of each locality within the study area based on satellite images of 1994, 2007, and 2018

While most of the study area surfaces have faced substantial degradation in BGF values, some critical areas like the riparian zone along the Lana River in the northern part of the study area have still relatively high BGF values in 2018. The main reason is the lack of transportation infrastructure investments in this specific site. However, this area is expected to be developed soon. Suppose the ongoing transformation trends repeat along the riparian zone. In that case, it will have adverse effects on BGF values and the rainwater discharge regimes within the river's natural floodplain. New urban design projects within the riparian zone must target high BGF values and sensitivity to native riparian vegetation.

4 Conclusion and Outlook

This paper presented BGF as a hybrid method, including analogue and digital data gathering. Interpreting is a valuable and practical tool for assessing the land transformation trends in metropolitan areas. The availability of historical satellite images makes possible spatial-temporal analysis. Our study highlights the BGF method's flexibility to combine analogue and digital data gathering and mapping techniques for analysing the blue-green infrastructure at the parcel scale. Mapping relied on the visual information provided via orthophotos. Their interpretation was challenging due to the difference between the resolution of the orthophotos of 1994, 2007, and 2018. Another difficulty during the process was related to the remote teaching process. Due to the pandemic restrictions, the team could not physically visit the site to check certain elements which were difficult to recognize from orthophoto.

Nevertheless, we used the Google Street View service to figure out street-level images of the neighbourhood in such cases. Furthermore, during mapping sessions, the team discussed the classification of certain surfaces which were uncertain. BGF as a semi-automated land classification digital tool was very useful to the team members who lacked detailed information about the classification of landscape elements.

The experience presented here resulted in some pedagogical achievements. As previously mentioned, the student's previous training has had a strong focus on architectural building scale, with no emphasis on landscape research. Thus, an objective of the course was to divert the research interest of young architects towards the landscape approach, in which the built environment is considered complementary to the natural systems of the territory. The landscape approach fundamentally relies on the most specific local properties of the context at a local scale while being aware of the prevailing challenges of the global scale (REED et al. 2016). Students became able to relate the global-scale problems like climate change, global warming, and socio-economic crisis with the local scale consequences of specific territories like the selected neighbourhood in Tirana.

Apart from the remotely sensed satellite data, the BGF mapping process must be supported by onsite observations to resolve unclear circumstances of satellite imagery. Future studies must evaluate the BGF toolbox during the design phase of urban landscape interventions upon different scenarios. It can help quantify the impact of new landscape features designed within the existing urban fabric. Moreover, the approach followed in the landscape research course aligns with the EU Green Infrastructure Strategy, aiming for the BGI to become an integral part of spatial planning and territorial development. The illustrated pedagogical approach aimed to raise future architects' awareness of their role in taking a holistic approach to design nature-based solutions.

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