GREENING AND DEVELOPMENT MONITORING TO CREATE A COMFORTABLE URBAN ENVIRONMENT

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Introduction

For many decades, cities worldwide were focused on building housing and motorways. The increasing development areas and population size resulted in substantial fragmentation of the urban green coverage (Atasoy, 2018). Over the last years, urban planning has shifted sharply to increasing the number of urban green spaces (UGS). Nowadays even motorways are being razed in the cities. Planning UGS plays a decisive role in improving the quality of inhabited locations and the living standard (Liu et al., 2021). Urban green infrastructure (UGI) has the highest potential to compensate for the consequences of climate changes, and it is a critical means for alleviating the heat stress in densely populated residential districts (Zölch et al., 2016; Havrylenko et al., 2021). The investigation of the geospatial distribution of UGS for urban planning has been started energetically even in those countries where it was ignored for decades (Lotfata, 2021). A significant trend in the development of urban science is the identification of the role of UGS ecosystem services for optimizing city planning (Song et al., 2020; Bilous et al., 2021). With account to the link between supply and demand, sustained UGS development is becoming a never-ending agenda (Titz et al., 2019).

Methods and Theory

The evaluation and monitoring of the UGS-to-built-up area ratio are required for planning UGI development adapted to the urban community needs. We analysed this ratio by uploading Kyiv territory to the QGIS and using geospatial data OpenStreetMap (OSM). Data in the format of polygonal layers were taken from OSM for the correct calculation of required geometric characteristics. With ArcGIS geoprocessing tool Union, we grouped development projects of different types (offices, houses, educational institutions, garages, shops, hotels, industrial enterprises, construction sites, gas stations, parking lots, hospitals, etc.) into four categories. UGS of all kinds were combined into five categories: urban forests, urban protected areas, parks and squares, non-tree vegetation, gardens. For correct presentation of topological data and accurate estimation of attributive characteristics, all spatial data layers were reduced to a unique cartographic projection. As a result, we created polygonal shape files with the indicated categories of UGS and development within Kyiv limits. Field calculator was used to calculate the geometric characteristics of each category. This helped to rank the city's administrative districts by the UGS-to-built-up area.

Results

One of the Kyiv's most pressing challenges is the threat of destroying UGS due to the urban sprawl and densification not only in the city centre, but also in its outskirts. According to the Kyiv City Development Strategy until 2025 and the Master Plan of the City until 2040 draft, Kyiv should develop as a compact and green city. This means it should have close street links, mixed land utilization and easy-to-access UGS. The properly planned UGI of a compact city performs a number of vital functions: facilitates the creation of comfortable conditions for public recreation; protects from strong winds; improves the microclimate; creates shade and coolness in hot weather, etc. The purpose of UGI management is to provide population with a wide range of ecosystem services and improve the overall environmental situation (Bilous et al., 2020; Khalaim et al., 2021; Samoilenko et al., 2020). Therefore, one of the main ways of making a comfortable urbanised environment in the city is to develop an optimal UGI because UGS are capable of compensating for the adverse impact of development. This is why it is necessary to determine the UGS-to-built-up area ratio within Kyiv limits and substantiate the need to continuously monitor these ratios.

We created a map of the spatial distribution of UGS and development and found that in some Kyiv districts (especially on the Right Bank) high-density development is predominant (Fig. 1). At the same time, on the outskirts and in separate districts of the Left Bank development density is much lower. The building coverage ratio within city limits is 23.3% and the green coverage ratio is 54.6%. The remaining territory (22.1%) is mostly covered by water bodies and roads. This means that, as to geometric parameters, UGS are predominant; however, their spatial distribution is very irregular. With this in view, we found the UGS-to-built-up area ratio in all Kyiv administrative districts.

Having calculated the building and green coverage ratios, we found that five out of ten Kyiv's districts are overcrowded with buildings. Solomianskyi is the most densely developed district. The key criteria of compact and green cities are the presence of UGS, clean air and no dense development (Havrylenko et al., 2020). However, in order to determine whether modern Kyiv and its districts meet these criteria, the UGS-to-built-up area ratio is the most critical indicator that planners have never considered before. Additionally, we selected indicators such as average population density and air emissions from stationary pollution sources. The correspondence of calculated indicators to the criteria of a compact and green city was evaluated by assigning each indicator a certain number of points with the aid of estimation scales. The higher the sum of points of the key indicators the more comfortable living in a certain district is. Based on the results obtained, we ranked Kyiv districts by the comfort of living in them (Fig. 2).

Obolonskyi district is the leader of the living comfort rating (Fig. 3). Desnianskyi district also has high indicators. The least comfortable is the Solomianskyi district (Fig. 4). Apart from this district, the Pecherskyi and Shevchenkivskyi districts are also those with the poorest living comfort. All the rating outsiders are located in the city centre and have common problems: completely built-up area and high population density, transport congestion and the concentration of other sources of toxic emissions into the atmosphere, very scarce greenery due to displacement of UGS by buildings. Increasing the living comfort demands the smoothening of contrasts between the developed territories and UGS in different Kyiv districts.

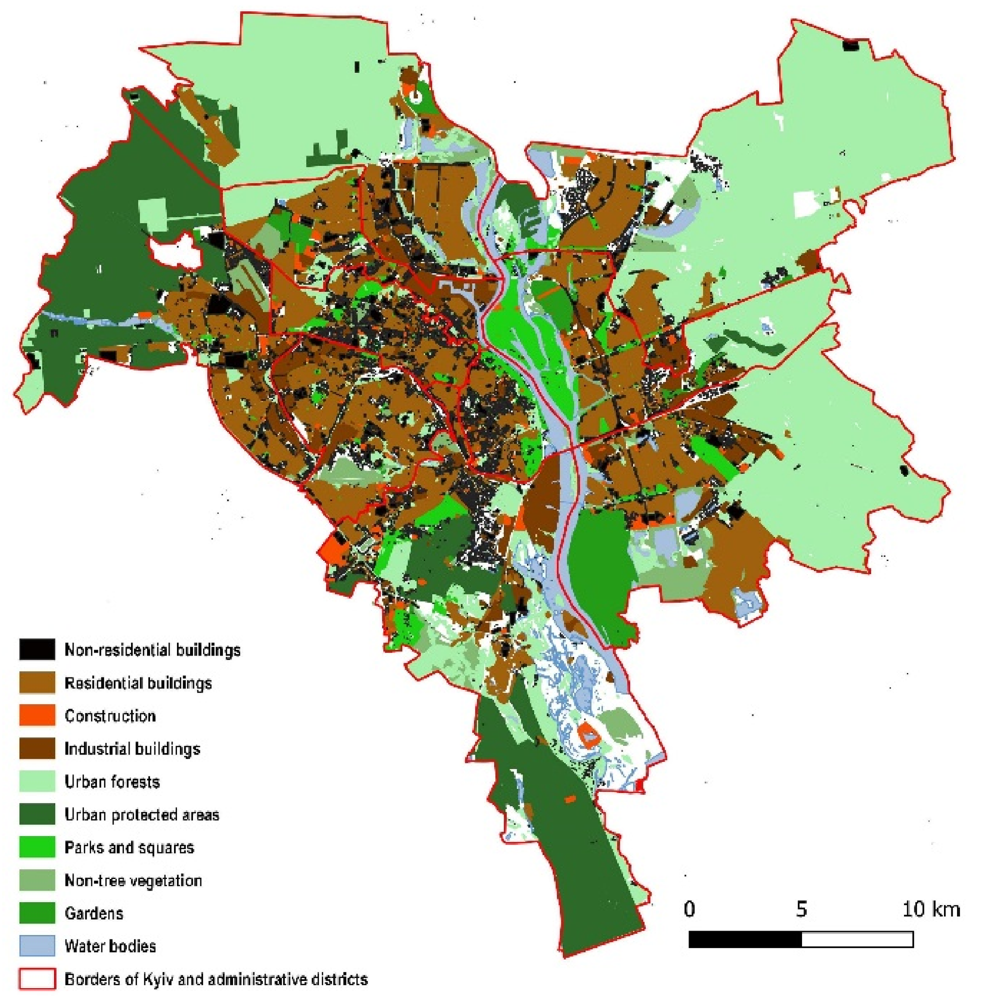

Figure 1 *Built-up areas and UGS in Kyiv*

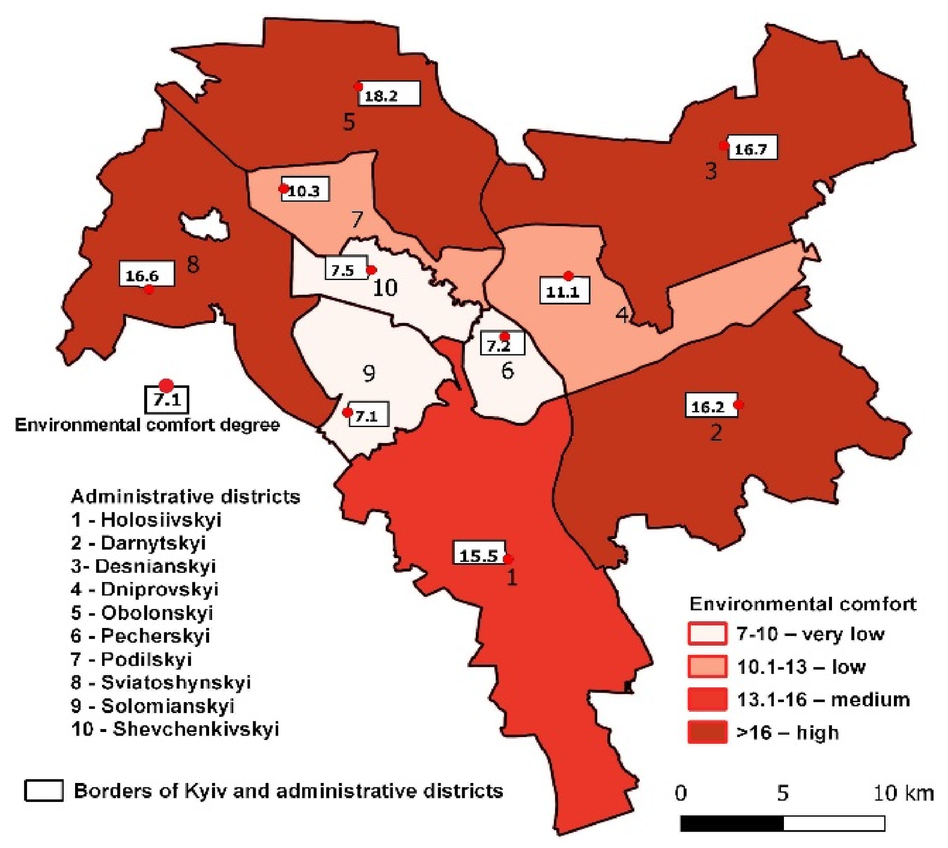

Figure 2 *Rating of Kyiv's districts according to the environmental comfort*

With this in view, the planning activities should be supported by the results of appropriate monitoring. The need for monitoring the living comfort in Kyiv is due to the large-scale chaotic development, which takes place in the absence of an approved Master Plan of City Development. We especially need such monitoring in areas that have had the lowest living comfort according to our rating for a long time.

Despite the fact that the Regulations on the system of greenery monitoring in cities were approved by the Government of Ukraine in 2008, nothing has been done since then. Urban forests specifically need integrated monitoring by remote sensing of the Earth and the application of geoinformation technologies combined with conventional ground-based observation methods. It is practical to use unmanned aerial vehicles (UAVs) for a more detailed survey of forest blocks. The UAVs output is very high spatiotemporal resolution data. They contain spectral information and the morphological parameters of vegetation, and information on the texture and vegetation indices on a scale of one tree (Samoilenko et al., 2021; Wang et al., 2021). UAVs can timely detect violations in the city forests and parklands by photo and video registration, and monitor the state of Kyiv's forest resources. UAVs can determine the exact coordinates and sites of illegal logging, and prevent the spreading of forest fires.

Official Kyiv now has the possibility of using an automated system for satellite forest monitoring Deep Green Ukraine. Its trials have begun in the Kyiv Region. This will enable the immediate detection of illegal logging and monitor the sanitary state of forests in real time. At this point, integrated monitoring is a particularly topical issue. Its implementation should start by substantiating the siting of monitoring stations according to identified problematic locations.

The choice of main locations should be based on the data of inventory and certification of all UGS and Kyiv's development. The principal objects of monitoring the UGS-to-built-up area ratio should be as follows: changes in the species composition; UGS tolerance under the influence of atmospheric air pollution; contamination of soil and natural water as well as the change in the UGS configuration due to dense development. Monitoring study results should be used to create an information database with public access.

Conclusions

Given the direct dependence of the urbanized environment comfort on the UGS-to-built-up area ratio, we found that about one-half of Kyiv's administrative districts fail to meet the comfort criteria. Their common problem, apart from high population density and extremely polluted air, is the violation of the ratio of greenery and built-up territories in favour of construction. If the UGS-to-built-up area ratio is not monitored, especially within problematic territories, the city will continue to digress from the strategic goal of increasing the living comfort in the city. This justifies the need to monitor these ratios because the increasing share of UGS will help to compensate for the adverse consequences of the relentless development. Such monitoring will be in stark contrast to typical monitoring of the UGS state. In fact, this is about monitoring the urban living comfort that largely depends on the UGS-to-built-up area ratio. As soon as this ratio increases in favour of buildings, the comfort level drops. The monitoring system foresees the use of GIS technologies, space photography and aerial photography with UAVs in combination with traditional ground methods. Special focus should be placed on the most crowded areas with the lowest greenery levels as in the Troyeshchyna and Pozniaky residential areas. Monitoring data should be in constant open access for the city community.

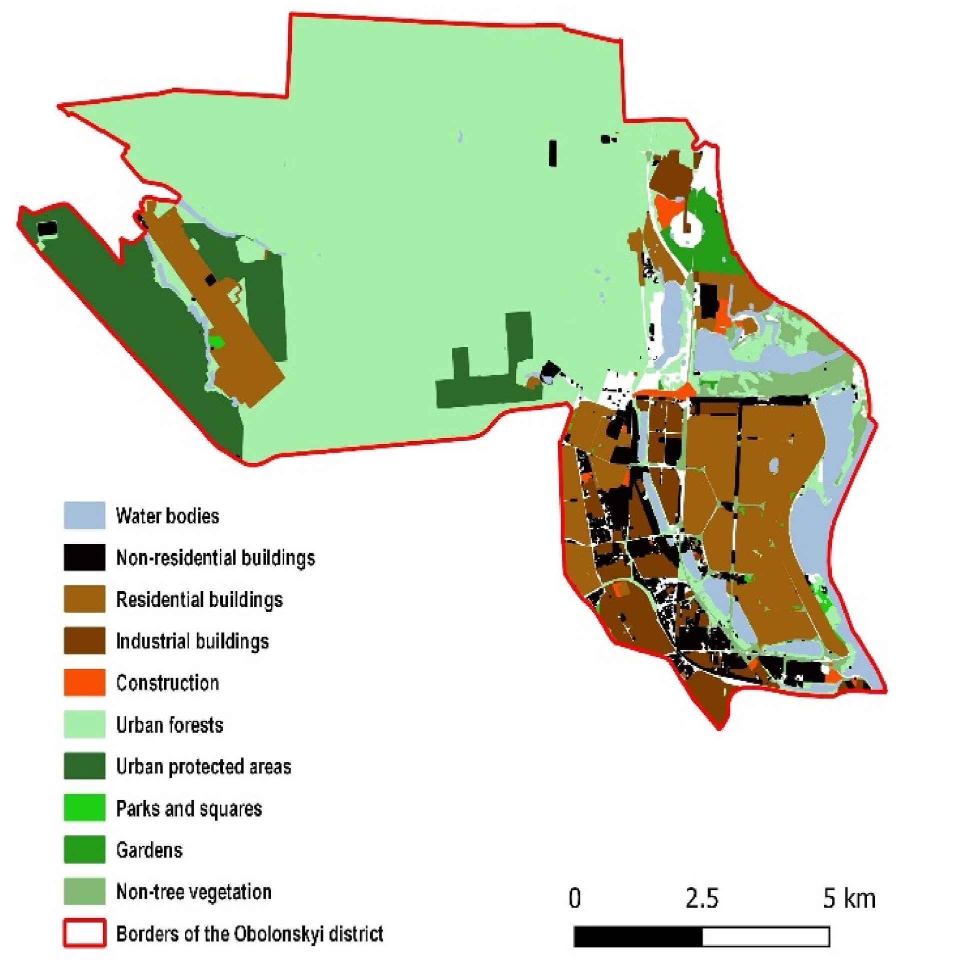

Figure 3 *Built-up areas and UGS in Obolonskyi district*

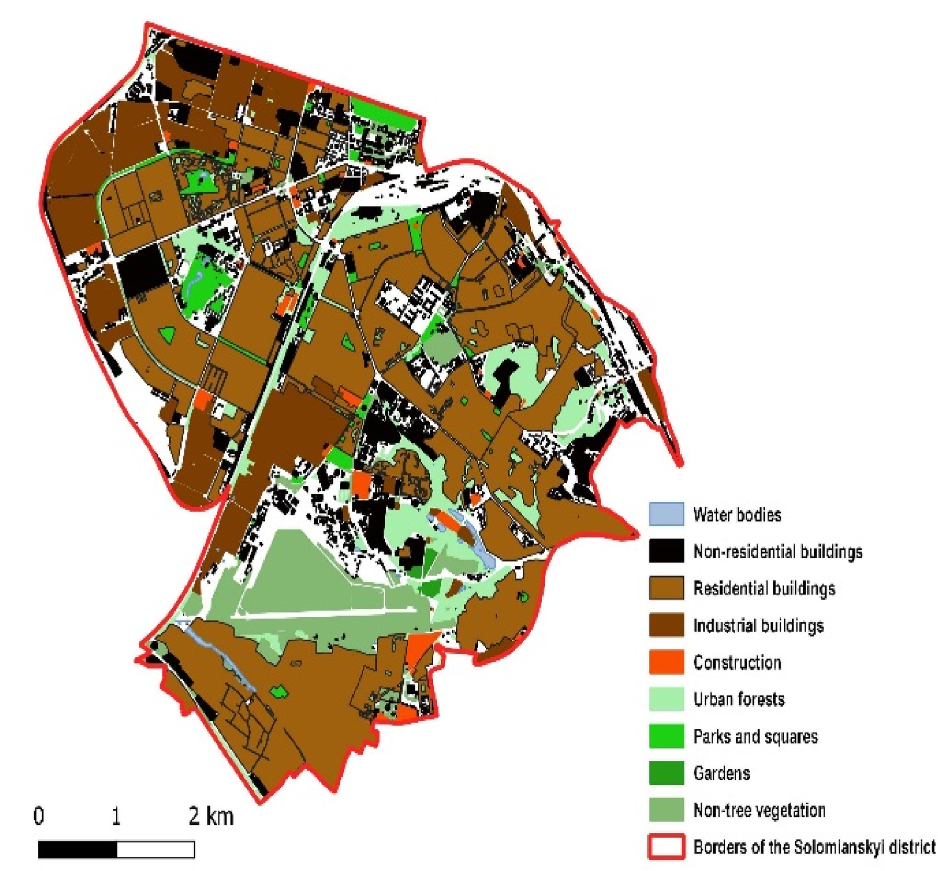

Figure 4 *Built-up areas and UGS in Solomianskyi district*

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