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GREENSPACE PLANNING AND ASSESSMENT USING THE NORMALIZED DIFFERENCE VEGETATION INDEX IN NEIGHBOURHOODS NEXT TO RIGA FREEPORT, LATVIA

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Abstract. In urban planning, greenspace in spatial plans is typically understood as specifically defined functional land use zones. However, in relation to the establishment of green corridors and the provision of ecosystem services as well as for the health of residents, greenery located outside of greenspace zones is equally important. In Latvia, the minimum area of greenery located on a land parcel is defined by the free area greenspace indicator. The objective of the research was to identify the changes in greenery cover on land parcels with different functional land use zoning using the normalized difference vegetation index (NDVI) method. The study was undertaken in five neighbourhoods in Riga. The results of the analyses indicate that adherence to the minimum free area greenspace indicators that are specified for different functional zones will result in a significant decrease in the amount of free area greenery in the studied neighbourhoods. The largest reduction in free area greenery is expected in non-residential functional zones. Greenspace zones, such as forest parks and parks, which are to undergo major upgrades in recreational ammenities, will experience a reduction the size of the natural areas by as much as one third. The application of the NDVI method is well-suited for monitoring the amount and distribution of urban vegetation cover and for assessing spatial development at the neighbourhood level. However, due to the structure of existing zoning regulations in Riga, which can differ at the level of individual land parcels, the systematic application of the NDVI method in Riga is not presently possible.
Keywords: urban greenspace, spatial planning, normalized difference vegetation index, neighbourhoods, land use

Introduction

In urban planning, greenspace in urban spatial plans is typically understood as specifically defined areas within one or more land parcels, where the main function is linked to nature, such as, forests, parks, squares, family gardens, and other greenery. For the monitoring of urban sustainability, the accessibility of greenspace zones and its size per capita is included in the assessment of basic services [1]. The European Common Indicators [2], for example, state that there must be greenspace with at least 5,000 m2 within 300 metres of a residence. This greenspace must be publically available, without charge and allow pedestrians and cyclists to engage in recreation, and furthermore, such areas are free of motorized traffic. Greenspace in the urban environment not only provide a variety of recreational opportunities, but are also an indispensable element in the provision of ecosystem services, including addressing the most pressing urban quality issues today - creating a favorable microclimate, maintaining biodiversity, adapting to and mitigating climate change, and rainwater management [3;4]. From a social standpoint, accessibility to public outdoor space and green outdoor space is not only important for maintaining the physical and mental health of residents, but also for socialization and community-building activities [4]. However, despite their functional role as natural areas, they are subject to development pressures.

The vegetation on each non-greenspace zone land parcel, also makes a significant contribution to the urban environment [5]. Without trees along streets, green courtyards, raised flower beds, greenery along water bodies, and green window sills, walls, balconies and roofs, there is no respite from a high density urban landscape, nor the possibility to connect greenspace into a single network.

Many European cities and regions have experienced declining population numbers, and such shrinking cities have to choose between adaptation or transformation strategies for urban resilience [6]. The range of actions in this case includes both the expansion of greenspace and the reduction of building density to create a higher environmental quality, land use change to adapt to the special needs of the municipality, zoning sites as temporary use, and the further attraction of investments for new building projects in the hope that these objects will attract users [7]. The assessment phase in the cycle of land use planning and implementation is critically important which ensures that the results of adopted policy measures can be identified prior to formulating further development policies. The implementation of desired land use policies and the monitoring of results is the driving force for the selection of most appropriate indicators and monitoring instruments [1]. The development of technologies has resulted in the broader use of remotely sensed research data, whereby the normalized difference vegetation index (NDVI) has demonstrated its applicability for measuring different types and quality of vegetation [8].

Riga, the capital city of Latvia, as many cities in Europe is confronted by variety of development challenges. With an area of 307 km2, in 2025 Riga had a population of 592 thousand, a 35% decrease since the 1990s due to a low birth rate nationally, outmigration and suburbanization processes stimulated by more attractive housing and living conditions in neighbouring municipalities. Riga is a Baltic Sea port city. The Riga Freeport is the fifth largest port in the Baltic Sea transit corridor. Previous Riga Spatial Plans, binding for the periods 1995-2004 and 2005-2018 were developed and adopted in a period of rapid economic growth, in part ignoring the demographic decline [9], and rezoning about 1/3 of the greenspace existing in 1994. However, as a result of both the 2009 financial crisis and the continuing "shrinkage" process, contradictions exist between what is proposed by the Riga Spatial Plan and actual development processes on the ground. Large areas of undeveloped greenfield land have undergone multiple changes in ownership and are still "waiting" for an investor or the right market conditions to be developed.

The non-alignment between planned development scenarios and actual development trends impacts on how greenspace in Riga is perceived and viewed in the context of future development. The general impression of a "green" city still persists, however, when a greenfield is unexpectedly converted to a construction site, public protests by concerned citizens are not uncommon [10]. Residents of the city do not

live their lives in the visions of spatial plans, but rather in the existing urban landscape, and the majority of residents are not aware of the development consequences of spatial plans. Furthermore, the size and complexity of the Riga Spatial Plan does nothing to encourage non-specialists to be interested and to participate in public discussions. In 2021, the draft Riga Spatial Plan 2030 consisted of more than 143 separate files on 1825 pages, including 94 files containing cartographic material. At the same time, a short easy to understand summary of proposed changes in the size of functional zones, including greenspace is not made available to the general public.

Greenspace is regulated in two different ways in the Riga Spatial Plan: firstly, as "nature and greenery" or greenspace zones based of cadastral units and, secondly, as minimum "free area" greenspace indicators. The latter represents the undeveloped portion of a land parcel that must remain with a cover of greenery or vegetation. Discussions with the Riga Planning Department reveal that the recently adopted Riga Spatial Plan 2030 has rezoned 400 ha previously zoned for development as greenspace. On the other hand, the city of Riga does not have a system in place for measuring and monitoring free area greenspace. Consequently, the areal coverage of free area greenery in different neighbourhoods and on different functional zones it is not known, nor how close or far the defined minimum free area greenspace indicators are from the actual situation on land parcels.

The objective of the research was to analyse the planned changes in free area greenspace indicators defined for different land use functional zones in Riga Spatial Plan 2030 and to measure the actual amount of free area greenery in five neighbourhoods and to compare this with the defined minimum free area greenspace indicator values. Measurement of the actual free area greenery was undertaken using the normalized difference vegetation index (NDVI).

The territory selected for the study were the five of 58 neighbourhoods in Riga: Vecmīlgrāvis, Daugavgrīva, Kundziņsala, Mangaļsala and Bolderāja, located on the periphery of Riga about 10-15 km from the city center. These neighbourhoods are in the lower reaches of the Daugava River, but they are separated from the river by the Riga Freeport. The neighbourhoods are similar in that they have a sizeable industrial function both inside and outside the Riga Freeport. Residents in these neighbourhoods are alarmed by the air and noise pollution caused by companies operating in the port area, which in certain locations exceeds permissible health standards [11]. 43% of the residents of the studied neighborhoods have considered the possibility of moving elsewhere mainly due to issues related to poor environmental quality [12]. In turn, the presence of nature in the residential areas, including forests, water bodies and nature parks is the most pleasant aspect of the neighbourhoods, as indicated by 58% of the surveyed respondents in these neighbourhoods [13]. Thus, to some extent, it can be said that presence of nature and greenspace are critical factors for ensuring residents continue to be satisfied with the neighbourhood as a home.

Methodology

To contextualize the analysis, the regulatory frameworks that define the amount of natural and greenspace in populated areas in Latvia were reviewed. This includes the "Territorial Development Planning Law" of the Republic of Latvia, as well as at the local level - the Riga Spatial Plan [14]. The functional zoning map Riga Spatial Plan was used, which depicts the location of areas zoned greenspace, and the associated Land Use and Building Regulations, which define the minimum amount of "free area" greenspace, such as greenery and lawn area, on each land parcel according to the functional zoning. The analysis did not include an analysis of greenspace in the historical centre of Riga, which is designated a UNESCO world heritage site, as it has its own separate land use and building regulations, but significantly less greenspace and greenery. Thus, this would warrant a separate study.

In order to compare the amount of free area greenspace specified by the Riga planning regulations and to determine the trend and magnitude of possible changes, the NDVI was used. Vegetation cover on clusters of land parcels were assessed using Sentinel-2 satellite optical data analysing NDVI changes in the period 2016-2020. NDVI is calculated from red and near-infrared spectral channels [15] and has been widely used for vegetation status assessment and change monitoring [8; 16]. It has been also widely used for urban greenspace assessment [17; 18; 19]. The main benefit of freely available Sentinel-2 satellite data is a wide coverage with relatively high observation frequency that allows remote NDVI assessment anywhere on the planet with new observations up to every 5 days during cloud-free conditions [20]. Cloudy weather limits the amount of useful data, however, at least one observation per month could be expected even in Northern regions such as Latvia providing a sufficient amount of data for land cover mapping [21]. The spatial resolution of Sentinel-2 data-based NDVI is 10 m/pix which limits its applicability to a minimum area of 1000 m2 to avoid mixed border pixels. NDVI is useful for mapping areas covered by vegetation as well as vegetation intensity and health assessment, however, it does not provide information on vegetation functional type, species composition or use. Nevertheless, NDVI has demonstrated a good correlation with vegetation density [22; 23] and has been widely used for the quantitative assessment of urban greenspace [24; 25]. In this study, all available Sentinel-2 archive data for the period 2016-2020 was used. Maximum NDVI values were calculated for each year and each image pixel representing a 10x10 m area on the land. Since NDVI values change during the year due to phenological changes in vegetation, in the study maximum NDVI values were used representing maximum vegetation density that is reached in a particular image pixel during the year of interest. This approach permitted an assessment of the vegetation status of each image pixel as well as to analyse changes between different years. NDVI values are in the range of 0 to 1 and it is assumed that a value of >0.5 represents an area where vegetation dominates over other land cover types (e.g. buildings, paved surfaces, bare soil). Using the NDVI threshold of >0.5 enabled mapping and calculating vegetation cover percentage on clusters of land parcels.

The clusters of land parcels in the five neighbourhoods included in the NDVI analysis were selected on the basis of the following criteria:

1) Clusters were at least 1000m2 in size to be compatible with recommendations for the calculation of the NDVI;

2) Clusters did not include major roadways, to ensure that NDVI calculations were not negatively biased;

3) Clusters contained only one land use functional zone to enable comparison between the measured NDVI value and the free area greenspace indicator value defined by the Riga Spatial Plan;

4) Clusters did not contain cadastral units zoned greenspace, to avoid introducing a positive bias to the NDVI calculation. If a cluster of land parcels contained land zoned greenspace, the greenspace was excluded from the analysis;

5) Clusters did not include large greenfields zoned development where development had not yet commenced.

Based on these criteria, 14 clusters were selected for analysis. It was not possible to analyse all functional zoning types in each neighbourhood since some neighbourhoods, such as Kundziņsala and Bolderāja, had only two different functional zones that could be analysed.

The proportion of each cluster covered with vegetation was determined using the NDVI methodology. A comparison of NDVI results with the free area greenspace limits set by the Riga Spatial Plan 2030 in each analysed functional zone allowed for the identification of the permitted change in vegetation cover in each functional zone resulting from the implementation of the Riga Spatial Plan 2030.

Territorial Planning Regulatory Framework

In Latvia, in accordance with the national territorial planning regulatory framework, the minimum proportion of greenspace in cities is not determined. Instead, each municipality determines the desired goals and policy in this regard. The Riga Spatial Plan 2030 states that the World Health Organization recommends a minimum of 9 m2 per capita of greenspace (parks, forests, grasslands, gardens, cemeteries). As there are currently 114 m2 of greenspace per capita in Riga (year 2017), increasing the amount of greenspace is not considered necessary [14]. Environmental quality and the provision of ecosystem services is not only dependent on the presence of officially designated public greenspace zones, but also on the presence of greenery on individual land parcels. The Riga Spatial Plan 2030 defines different land use functional zones, and a minimum free area greenspace indicator is defined for each functional zone. The minimum free area greenspace indicator (as a percentage of the total parcel area) defines the proportion of vegetation cover that must be maintained on land parcels. The Riga Spatial Plan 2030 has the following zones: three types of detached house zones, three types of low-rise residential zones, two types of multi-storey residential zones, 8 types of mixed-center zones, an industrial building zone, three types of transport infrastructure zones, two types of technical building zones, four kinds of nature and greenery zones and three types of water zones. The free area greenspace indicator is not defined for transport infrastructure zones, technical building zones and water zones.

The free area greenspace B (m2) formula is B = Z – L1 – L2 – L3 + L4xK (m2), where: Z is area of the land unit; L1 is sum of building areas of all buildings; L2 is area occupied by access roads; L3 is area occupied by parking lots; L4 is the territory that can be partially included in the free area greenspace territory by applying the coefficient K; K is the coefficient applicable to the territory, which can be partially included in the free territory. The elements of green infrastructure that can be included in the free area greenspace with an appropriate coefficient are roof gardens; extensive roof gardens; green walls; newly formed meadow, crop or perennial beds, shrubs; underground covering with greenery; natural meadow with at least 10 species of plants; green rainwater management elements - rain gardens, infiltration site with plants or rubble; preservation of an existing tree; new tree. The revised free are greenspace indicator formula makes it easy to understand the actual area of vegetation cover that must be retained, regardless of the number of storeys, while not requiring greenery at ground level. For example, if the building were to have a roof garden and a rainwater infiltration area with water-permeable material in the car parks, the criteria for free space would be met even without any vegetation cover at ground level. Although green walls, roof gardens and other specific forms of greenery have been proposed as solutions to increase greenery in sustainable, climate-neutral and resilient cities, in Riga they are used as substitute of traditional green elements.

In all functional zones the free area greenspace indicator is not specified for land parcels with individual houses. In all functional zones, except in the mixed centre zone JC3, low-rise and high-rise residential land parcels have free area greenspace indicators of 40-60 %. On education institution land parcels the free area indicator is equivalent to the total floor area. Low-rise residential zones with public building land parcels have a free area greenspace indicator of 40-60 %, but in high-rise residential zones and mixed centre zones (except in the Mežaparks neighbourhood) land parcels with non-residential buildings have a free area greenspace indicator of only 10 %. Although the specific regulation zone TIN14 prescribes a minimum of 50 % free area greenspace, only 11 places in Riga are zoned as such – six parks adjacent to existing health care centres, two greenfield development

TABLE 1

Minimum specifications for free area greenspace indicator in different functional zones in Riga Spatial Plan 2030 [created by author's]

Type of functional zoning	Free area greenspace indicator
Individual home zone DZS1; DZS2; DZS3	No requirement*
Low-rise (up to 3 floors) residential building zone DZM1–DZM4	DZM1 – No requirement for individual residential houses; Other functions** – 40% DZM2 – 60%* DZM3 – 40%* DZM4 – 45%**
High-rise residential building DZD1-DZD2	DZD1 – No requirement for individual residential houses; Other residential buildings – 40%; Other functions* – 10% DZD2 – No requirement for individual residential houses; Other residential buildings – 40%; Educational** and social care institutions – 40%; Other functions – 10%
Specific regulation zone	TIN14 – 50%
Mixed centre zone JC1-JC8	JC1, JC2, JC6 – No requirement for individual residential houses Other residential buildings – 40%, (JC6-30%); Other functions** – 10% JC3, JC4 – 10% JC5 – No requirement for individual residential houses; Other functions – 10% JC7 – No requirement for individual residential houses; Other functions** – 45% JC8 – Specific regulations for Riga city historical centre and its protection zone
Industrial building zone	10%
Nature and greenery zone	Forest park territories – 70% for forest; Parks – 60% for nature; No specifications for squares

* Except for educational institutions – equal to the floor area

** Except for preschool educational institutions – equal to the floor area

sites and two other land parcels.

Only in a few places in detached house functional zones is it stipulated that greenery must cover at least 20 % of the land parcel, whereas elsewhere it is 10 % or not even specified. Furthermore, 15 years ago, forest areas were reclassified as forest parks – previously there were 10 forests and one forest park in Riga, but since 2005 none of the forests in the city are defined as such. Presently, there are 11 forest parks. The increased establishment of recreation and entertainment infrastructure in forest parks is aimed at intensifying their recreational function, which in turn reduces ecosystem services. Additionally, fragments of natural forests are preserved in three protected nature territories of national significance, which are zoned separately.

Focussing on the selected five neighbourhoods, four out of the five neighbourhoods are relatively well endowed and located in close proximity to greenspace functional zones. Two of the three Natura 2000 areas in Riga are located here and one of two protected nature territories of national significance. The national and European protection status afforded to these sites appears to guarantee that they will not be subject to future development pressures. The Riga Freeport (1962 ha land territory) in the vicinity of the five neighbourhoods contains industrial functional zones with a minimum free area greenspace indicator of 10 %, but there are also two protected nature territories (75 ha in total or about 4 % of the Riga Freeport area) and five areas zoned greenspace, each about 2 -10 hectares in size.

Analyzing the residential areas of the neighbourhoods according to the Common European Indicator "greenspace zone is located within 300 m from residences", only in two out of the five neighbourhoods (Daugavgrīva, Kundziņsala) with mixed center functional zones is the criterion regarding proximity to greenspace zone satisfied.

The main function of the mixed centre (JC1 and JC2) functional zones is defined as being the neighborhood center, with commercial, cultural, educational, social and health services functions, as well as well-maintained public outdoor space. The mixed centre functional zone is foreseen only in the central part of the residential neighbourhood of Vecmīlgrāvis, whereas in the neighbourhoods of Daugavgrīva and Bolderāja the mixed centre zone is only designated on the very periphery of the residential area, while the neighbourhoods of Kundziņsala and Mangaļsala do not have mixed centre zones. Significantly, the minimum free area greenspace indicator for mixed centre zones JC1 and JC2 is set at only 10%, which means that relatively little area is foreseen for green public outdoor space near public buildings.

Regulation of greenspace by the Riga Spatial Plan 2030 differs markedly from the current situation in the neighborhoods.

NDVI - The Hidden Value of Greenery on Land Parcels

According to NDVI data between years 2016 and 2020, 25-80 % of the entire area of the five studied neighbourhoods of Riga are green, while 13-56 % of the territory is without vegetation. There is more vegetation in the neighbourhoods with Natura 2000 and national protected nature territories – in Vecdaugava and Mangaļsala (Table 2).

Furthermore, in Vecmīlgrāvis, which have the most developed Riga Freeport infrastructure, the vegetation index data indicates that only 9% of the area is green, which is even less than the 10% free area greenspace minimum specified by planning documents. On the other hand, in the part of Vecmīlgrāvis outside the Riga Freeport area, 54% of the territory is green, which is influenced by the presence of greenspace zones. The lowest permanent vegetation cover is on Kundziņsala, a 555 ha island in the Daugava River. The 35-hectare historic residential area, which is encompassed by the Riga Freeport, since 2021 is mainly zoned as mixed

TABLE 2

Proportion of permanently green and permanently built-up areas in the five neighbourhoods of Riga based on NDVI [created by author's]

Neighbourhood	Areas	Hectares	Permanent greenery (%)	Permanently without vegetation (%)
Daugavgrīva	Total	752	69	19
	Without Riga Freeport	551	72	16
	Port	201	61	25
Bolderāja	Total	726	55	26
	Without Riga Freeport	666	55	26
	Riga Freeport	59	54	26
Mangaļsala	Total	648	80	13
	Without Riga Freeport	546	87	7
	Riga Freeport	101	46	40
Kundziņsala	Total*	555	25	56
	Mixed centre area within it	35	90	7
Vecmīlgrāvis	Total	449	35	48
	Without Riga Freeport	261	54	26
	Riga Freeport	189	9	78
Rīga	Total	26058	64	22
	Without Riga Freeport	24096	65	21
	Riga Freeport	1962	50	37

* all territory of this neighbourhood is within Riga Freeport borders

TABLE 3

Average proportion of vegetation cover in 2016-2020 in selected functional zones in five Riga neighbourhoods [created by author's]

Neighbourhood	Average proportion [%] of vegetation cover in 2016-2020				
	Individual home zone (no minimum free area greenspace required*)	Low-rise (up to 3 floors) residential buildings zone (minimum 40 %*)	High-rise residential buildings (min 40 % for residential buildings, 10 % for others*)	Mixed centre zone (JC1, JC2) (min 10 %*)	Mixed centre zone (JC4, JC5) (min 10 %*)
Mangaļsala	88	n/a	81	n/a	86
Vecmīlgrāvis	83	71	59	x	x
Kundziņsala	n/a	n/a	n/a	n/a	96
Daugavgrīva	n/a	85	65	59	x
Bolderāja	x	73; 77	49	25	x

* – according to the norms of the Building code

n/a – not appropriate as there is not such functional zoning in the neighbourhood

x – not analyzed for this functional zone in the neighbourhood

centre (JC5). Only a few small greenspace zones are present with a combined area of 2-2.5 ha. Throughout the island, outside areas with a greenspace zoning, the Riga Spatial Plan 2030 standard specifies that parcels of land must have a minimum of 10 % free area greenspace.

The data on the amount of vegetation in different functional zones outside the Riga Freeport (Table 3) show that the highest average proportion of vegetation cover is in detached house functional zones, where the regulations do not define the free area greenspace indicator. In low-rise residential building zones, the average share of the green cover is 71-85 %, while in multi-storey residential areas it is 49-66 %. In Bolderāja, for example, the minimum of 40 % free area greenspace specified by regulations in high-rise residential zone is already being approached. In Mangaļsala, the amount of vegetation cover in multi-storey residential zones (81%) is similar to that in detached house zones.

In turn, the greenest mixed centre zones (JC5) in Mangaļsala and Kundziņsala, characterized by historic dwellings with fourth and fifth generation residents, are subject to the greatest development pressures and, consequently, potential changes. They are formally located in the Riga Freeport, where the level of environmental pollution and noise makes the area unsuitable for residential living, and are considered objects for research on gentrification and environmental justice.

Table 3 shows that in all functional zones outside industrial zoning, the current amount of vegetation is higher than the minimum set by planning regulations. There are four important aspects here. Firstly, there is no reason to believe that the amount of vegetation in the analyzed zones will not decrease - there is a lack of parking lots near multi-storey residential buildings, moreover, there are still undeveloped plots of land in residential areas. In turn, in service and industrial functional zones, developers are not interested in leaving more free area greenspace than required. Secondly, all functional zones in Table 3 allow for both residential and non-residential development, which have differing requirements for the greenspace indicator. Thus, it is not possible to determine whether the free area indicator is observed in the area larger than a land parcel. Thirdly, if it were necessary to determine using NDVI whether the free area indicator was observed in each plot, this would be possible only if there was an additional map layer reflecting the function of the building (e.g. educational institution, residential, commercial). In an interview, a representative of the Riga Development Department indicated that such cartographic information is not available and would be resource-intensive to maintain. And fourthly, most of the vegetation is in the residential areas with detached houses, where the minimum free area greenspace is not regulated. Thus, the contribution of the free area greenspace of detached house land parcels to the total greenspace of neighbourhoods is the biggest unknown.

Discussion

According to the research of Cardoso et al on the "Cities we need" [26], nature and greenspace appear as necessary elements in several dimensions of human needs - aesthetic, health and leisure. Sue Stuart-Smith [27], in her study, discusses the deeper and more profound importance of the presence of nature and human-nature interaction for a person's wellbeing and mental health from various aspects. The present study highlights the importance of greenspace in meeting basic human needs, which are undermined by adopted development regulations.

Greenery and greenspaces in the city are a classic common resource [28]. It is to everyone's benefit to have as much as possible, and their abundance depends on three main actors. The municipality determines the location and area of green zones, as well as the minimum free area greenspace in functional zones. Landowners / developers and those responsible for the day-to-day maintenance of greenery each have different interests regarding the amount and types of greenspace. For anyone responsible for a small part of the resource, maintaining greenery requires more or less resources. The fourth actor is the general public, who directly use the urban landscape. The capacity of this latter group to influence the quantity and availability of the common resource greenspace is severely limited. The analysis of greenspace in the five port-side neighbourhoods shows that through the application of city regulations, which require a relatively large greenspace around residential buildings, responsibility for the management of this common resource at the level of land parcels is placed on the shoulders and resources of homeowners. Areas zoned industrial use in particular contribute less to good urban quality because of the low value set for the greenspace indicator, whereas a higher greenspace indicator would contribute to improved air quality, noise reductions and could help to lessen the visual impact of technical buildings.

From the point of view of the common resource theory, the policy chosen by the Riga planning administration not to define the minimum greenspace for the detached house zone is questionable. As the data in Table 3 show, if the proportion of greenery in these zoning areas was reduced to only 10 %, then the decrease in actual vegetation cover would be the greatest of any of the functional zones. In some

of the land parcels of analysed areas with detached houses, the amount of free area vegetation is close to zero. Therefore, it would be informative to identify factors motivating owners in this regard – improving real estate tax rates or perhaps the desire to reduce yard work associated with fallen leaves or regular lawn maintenance. Consequently, the territories with the greatest amount of greenery on land parcels are currently the most vulnerable from the perspective of governance, as free area greenery is largely unregulated and, under the right conditions, vulnerable to dramatic change.

With regard to Riga as a shrinking city, there has been no attempt to adapt to the demographic decline as has been done elsewhere by not building on existing greenspace. The recently approved Riga Spatial Plan 2030 was a great opportunity to rezone undeveloped areas as greenspace, thus potentially improving environmental quality and recreational opportunities. This would have been particularly important for the neighbourhoods near the Riga Freeport, located next to intensive and polluting industrial functions. On the contrary, the creation of territorially large parcels of land (up to 40 ha) in the Riga Freeport and in its immediate vicinity, indicates the policy pursued by the Riga Freeport Authority and approved by municipal decision-makers is to transition from shipping and cargo handling to industrial functions on a scale uncharacteristic of Riga.

The planning of massive industrial zones without intervening greenspace zones and with limited free area greenspace is in opposition to the constructive historical experience of urban development. At one time, both the concepts of the "garden city" and "new urbanism" were the antidote advocated by urban planners and progressive cities to poor urban environmental quality and social conditions caused by concentrating polluting industries in one location and the disregard for the health of residents. The direction chosen by Riga in relation to the definition of free area greenspace is also inconsistent with the concept of resilient and climate neutral cities, as 10% of a land parcel is a critically small area for the creation of gray infrastructure for rainwater management, the reduction of the heat island effect and for linking greenspace into an integrated network.

The study demonstrates that the NDVI is a useful tool inventory and monitor greenspace in urban areas. NDVI is more applicable to the analysis of city blocks or neighbourhoods, but in the case of Riga this level of analysis is not feasible due to the definition of different free area greenspace indicators in one functional zone depending on the function of the building. Greenspace planning and research in Riga is hampered by the fact that the Riga Spatial Plan does not provide relevant quantitative data on changes made in the area and location of greenspace zones.

Conclusions

In addition to the greenspace functional zones defined in the Riga Spatial Plan 2030, a significant proportion of vegetation in the city is found in the yards and courtyards adjacent to buildings. A significant reduction in the area covered with vegetation is permitted through the reduction of the minimum free area greenspace indicator for land parcels. The largest decrease in free area greenspace is allowed in non-residential functional zones - industrial, commercial, services and other similar functional land uses. Furthermore, according to the Riga Spatial Plan 2030, greenspaces, such as forest parks and parks are to be subject to major infrastructure and recreational ammenity upgrades, thus reducing natural areas by as much as by a third. It can be concluded that the ecological, economic and social importance of greenspace is not valued equally with other development priorities.

The application of the NDVI method is well-suited for monitoring the amount and distribution of vegetation cover and for assessing spatial development at the neighbourhood level. However, due to the nature of existing zoning regulations in Riga, which can differ at the level of individual land parcels, the systematic application of the NDVI method in Riga is not presently possible.

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Kopsavilkums
Dabas teritorijas vai zaļās zonas ir termini, ar kuriem latviski vistuvāk var apzīmēt kopējo zaļojošo teritoriju pilsētā. Zaļās zonas ietver gan teritoriju plānojumos īpaši dabai definētas funkcionālās zonas, gan atsevišķus kokus, zālienus, dobes un citus "dabas gabaliņus" starp ēkām. Pēdējie pieminētie ir būtiski iespaidam, cik pilsēta ir zaļa tiešajā nozīmē, un tie ir neaizstājami zaļo koridoru, minidzīvotņu, ekosistēmu pakalpojumu nodrošināšanai, kā arī iedzīvotāju veselībai un mikroklimatam. Pilsētu zaļās zonas platības mērīšana ir metodoģisks izaicinājums.
Pētījuma mērķis bija noteikt starpību starp esošo un plānoto zaļo zonu platību zemes gabalos ar atšķirīgu funkcionālo zonējumu, izmantojot normalizēto diferenciālās veģetācijas indeksa (NDVI) metodi. Pētījums tika veikts piecās Rīgas apkaimēs: Boderājā, Daugavgrīvā, Kundziņsalā, Mangaļsalā un Vecmīlgrāvī. Analīžu rezultāti liecina, ka, ievērojot dažādām funkcionālajām zonām noteikto minimālās brīvās zaļās teritorijas rādītāju, pētītajās apkaimēs var būtiski samazināties zaļās zonas apjoms. Vislielākais apstādījumu samazinājums ir paredzams nedzīvojamās funkcionālajās zonās. Piemēram, meža parkos un parkos, kuros paredzēts veikt ievērojamus atpūtas ērtību uzlabojumus, dabisko platību platība samazināsies pat par vienu trešdaļu. NDVI metodes pielietojums ir labi piemērots pilsētu veģetācijas seguma daudzuma un izplatības uzraudzībai, kā arī telpiskās attīstības novērtēšanai apkaimju līmenī. Tomēr, ņemot vērā esošo zonējuma noteikumu struktūru Rīgā, kas var atšķirties atsevišķu zemes gabalu līmenī, NDVI metodes sistemātiska piemērošana Rīgā pašlaik nebūtu jēgpilna.