Acta Horticulturae et Regiotecturae 2
Nitra, Slovaca Universitas Agriculturae Nitriae, 2020, pp. 60–65

EFFECT OF VEGETATION STRUCTURE ON URBAN CLIMATE MITIGATION

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Vegetation formations are an important component in the urban structure, as they perform a wide range of ecosystem services there. The climate modification to improve the environmental and residential quality of the city is one of the important functions. The paper presents the results of the microclimate assessment in the chosen localities of Nitra town, Slovakia, with an emphasis on the stage and differences in air temperature and relative humidity. The climate elements were measured at 7 spatially different sites (sites A to G), each of them at two comparative sites, vegetation stand and open area. The largest average air temperature difference between the vegetation stand and the non-vegetation area was 1.2 °C at the locality D. The largest air temperature difference in the vegetation stands was measured between the street space (site E) and the city park (F), reaching 2.3–2.5 °C. The relative air humidity reached the highest differences between the park (locality F) and the street space (G) measured at 3:00–8:00. These reached 19.6% to 24.4% with higher relative humidity in the popular city park. The highest differences between the compared habitats were measured at locality G and averaged 9.6% at 04:00 – 07:00 in a preference to a tree canopy. The research results confirmed the importance of the vegetation structures in the process of mitigating the urban climate extremes and the environmental quality improving.

Keywords: urban vegetation structure, climate function assessment, mitigation effect

Currently, 50% of the world's population lives in cities, almost 73% in the European most urbanized regions, and is expected that by 2050 2/3 of the world's population will live in cities. The enormous growth of cities causes complex environmental problems. The environment of the city is influenced by global and local climate changes, pollution load from transport, industry and local heating sources. Current building materials and constructions such as concrete, iron, glass, asphalt, stone paving etc. have started modifying the atmospheric environment and mainly raising the city temperature (Kuttler, 2008).The urban planners, in accordance with the Athens Charter, applied the theory of dividing the urban settlements into functional zones, road traffic and pedestrian paths, together with involving large green areas of public parks and intra-block house vegetation in the urban structure (Supuka, 2002; Bryanet al.2008; Supuka, Feriancová et al., 2008). New trends are also being associated with the urban spaces' density increasing (Vitková, 2008; Supuka and Halajová, 2015). The density of built-up areas, growth of the cities, anthropogenic heat and prevalence of abiotic surfaces over the biologically active ones caused creation of the Urban Heat Islands (UHI). The measured results are known in Thessaloniki city, where the air temperature is by 2 – 2.5 °C higher, compared to the surroundings (Katsioura, Kosmopoulos and Zoras, 2012). Similar data were measured in the Chinese city of Bozhou with the average air temperature differences of 2.5–3.0 °C (Yang et al., 2016). As an example, we will present some results from the measurements in the Slovakian cities and their comparison with the adjacent open country. The city of Bratislava has an elevated average annual temperature of 1.1 °C., approximately the same difference values were also measured in the city of Košice (Lapin, 2007). In Brno city, The Czech Republic, the average differences between the urban spaces and the adjacent country were +4 °C in winter, from +3.6 to +3.8 °C in the other year seasons. An absolute maximum difference in summertime reached from +8 to +15 °C (Dobrovolný et al., 2012). The warming of the urban spaces is directly linked to the increase in the concentration of greenhouse gases in atmosphere. Ecosystem components have shown they are capable of removing the airborne pollutants and greenhouse gases, converting them, utilising and incorporating into the metabolic process. Measurement results in 55 US cities have show the ability of the urban assimilation organs to absorb NO_2, O_3, SO_2, PM_{10} in 2.7–14.5 $g^{-1}.m^{-2}$ leaf area (Nowak and Grane, 2006). It is one of the possible ways to reduce the potential of UHI in the urban spaces. Similar results were published through the research outputs in five Polish cities (Popek, Łukowski and Oleksyn, 2017). A direct mitigation of UHI through the

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shade and cooling effect of vegetation surfaces and the entire city green infrastructure system are the parts of the second form. Green spaces as a part of a green infrastructure complex fulfil multiple ecosystem services and improve the urban environmental and residential quality. The values of the positive effects of green spaces depend on their area, distribution within the urban structure and a share of tree elements. The degree of an effective influence of green spaces on the city environment quality is often expressed using the Green Indices, which express the ratio of the green areas to the built-up area of the city (Zhu et al., 2019). On the other hand, urban green areas are under high pressure from stressors, which inhibit their growth and health (Fornal-Pieniak, Ollik and Schwerk, 2019). Quality maintenance and a management of green spaces are a partial elimination of this factor. The urban vegetation overshadows the solar active surfaces, cools the air by evapotranspiration and reduces air pollutants and wind flow by its structure, which improves the urban environmental quality (Reháčková and Pauditsová, 2006; Keresztesová and Rózová, 2013; Tóth, Halajová and Halaj, 2015). The mitigation and equalization of the urban extreme climate values, due to the vegetation formations, was measured in different cities and reached by 1.5–2.5 °C (Norton et al., 2015), while the higher cooling effect was measured in summertime (leafy trees) and at higher air temperatures. The climate fugal effect of the large urban parks is also proven, up to an adjacent distance by 100–150 m of the built-up area (Supuka, 2002; Bowler et al., 2010). The cooling effect of the urban park vegetation was 2 °C higher on average compared to the open square and 2.5 °C in the street corridor at noon, with a maximum difference of up to 6 °C. Similarly, the relative humidity was by 10% higher in the park in comparison to the other sites (Spangenberg et al., 2008). Different tree species have different effects on the microclimate mitigation; therefore, their properties can be effectively used to improve the thermal comfort of indoor and outdoor urban areas (Tsutsumi, Ishii and Katayama, 2003). Reduction of solar radiation and mean radiation temperature depend on the tree species characteristics such as crown density, size and structure. The best shading effect was shown by massive solitary trees and dense canopy stands (Harbich et al., 2012). The surface temperatures in Fuzhou parks were measured by 4–8 °C lower than the non-green areas. Concerning the green areas greater than 10 hectares, the positive correlation and a good cooling effect was shown (Yu et al., 2018). When evaluating the microclimate factors of the urban vegetation (surface temperature and air humidity) in Nitra town, it was found that the cooling effect is dependent on the canopy shape and a tree crown cover and reaches a differential value of 0.55 °C to 1.83 °C, compared to the streets without any green areas (Klein and Rózová, 2017). The aim of the contribution is to present the microclimatic measurements in Nitra town territory with an emphasis on the differences in the compared areas of the urban green spaces and the open areas without greenery. The accent is put on an assessment of the importance of the green infrastructure elements in the mitigation of the urban thermal island characteristics and improving the urban dwelling environment.

Material and method

For the measurement of the climate characteristics, localities in a different urban structure and with a different share of the green areas in Nitra territory were chosen. We assumed that the different urban-spatial structure of the individual town segments will also be reflected in the different values of the measured climatic traits. The basic climatic elements, namely the air temperature and relative humidity, were measured. The chosen localities for the climate measurements consisted of the street, residential and park spaces. The assessed streets are oriented mostly in the north-south direction:

A/ **Locality A** – housing estate Chrenová with a low share of the built-up land and with 10 m height of the estate in average (4 residential floors). Among the blocks of flats, there are compact green spaces, while almost a size of 35 m^2 of the reserved greenery is available per inhabitant. The settlement is one of the first in the city with a progressive approach to the construction and planting large areas of the green spaces, which thus creates residential and recreational environment in a high quality.

B/ **Locality B** – Jesenského street, a mixed built-up area, a 10 m height of buildings in average, a street with only a two-sided tree alley that leads to the city park.

C/ **Locality C** – Moyzesova street, in the centre of the street, there has been a 8 m wide belt of the green area designed and surrounded by a tree alley. On both sides of the street, there are family houses of one floor height with gardens of a recreational and production character placed.

D/ **Locality D** – Bratislavská street, this street includes a commercial and an industrial part of the city with an average height of the buildings being 8 m. A four lane road runs through the street and leads to the highway. The vegetation elements consist of small grassy strips, which pass into the poplar tree line in the next section.

E/ **Locality E** – Farská street, this forms a part of the historical core of the monument zone of the city, the average height of the built-up area is almost 12 m, the street is only 8 m wide.

F/ **Locality F** – Štúrova street, this forms a relatively long transport corridor with a four lane road with high frequency of transport vehicles. The street width is approximately 30 m. The traffic route is on both sides separated from the pedestrian paths by a 6–8 m wide green belt with a mixed composition of trees, shrubs and grass areas.

G/ **Locality G** – Sihoť City Park, it was founded in the middle of the 19th century and currently its area reaches 20 hectares. Dendrologically, it is very rich. In 2001, a total of 1516 trees were surveyed, resulting in 84 woody species. The proportions of shrubs and flower beds are also quite rich. After the reconstruction in 2000, when playgrounds, ZOO corners, objects of social entertainment and culture were set in the park, it has got a high degree of use by the city inhabitants.

We have used the automatic measurement stations for the climate characteristics, namely TSI Veloci Cale 9565-P type. The measurements were made in 2014 at A–E sites during the summer months in a high pressure anticyclone type of weather at noon and repeated 5 times a month. At each locality, values were measured on two types of plots spaced approx. 50 m apart – both in the vegetation area and a non-vegetation area (Klein, 2017). Other station type AMS-2 was used at F and G sites and measurements were carried out in 2010, also in summertime, in sunny anticyclone weather. The measurement was performed once, but continually for 24 hours in August 20–21st, 2010. This method of measurement was also used on two types of plots, but with different types of surfaces – on the stand under a tree in a shade and on the open grassland, similarly spaced approx. 50 m apart (Jasenka, 2011).

The measured results are presented graphically with a mutual comparison of differences among the localities and areas. The statistical processing was done in STATISTICA 7 environment. One – Way ANOVA, (p <0.05), and the verification test by Tukey Honest Significant Difference (HSD) was used. The data between the monitored localities and the area plots were compared.

Results and discussion

Acquired results of the air temperature and relative humidity measurements at the localities A – E showed differences between the localities and the area sites. These reflect the urban structure of the built-up area as well as the size and the natural level of the vegetation formation, in which the measurement was performed. There was no statistically significant difference concerning the air temperature factor depending on the locality (Fig. 1). The largest average difference in the air temperature between the vegetation stand and the area without vegetation was measured at the locality D (1.2 °C). The median values were close. The lowest average difference in the air temperature was at the locality B (0.6 °C). The average air temperature difference between the vegetation and non-vegetation area at the measured localities was 0.84 °C. Higher air temperature differences (above 2 °C) were almost all recorded in the locality D, which consisted of the dispersed buildings and the industrial part on Bratislavská street. The maximum air temperature difference between the vegetation stand and the stand without any vegetation achieved 4.1 °C and was measured at the locality D. There was no statistically significant difference in the air temperature factor between the monitored area plots at the individual localities (Fig. 1). However, on two plots of D and E locality, the difference between the area with and without vegetation was m_d = 1.6 °C.

There was no statistically significant difference in the relative air humidity factor depending on the location (Fig. 2). The medians between the sites showed minimal differences. The highest average difference in the air humidity between the vegetation and without the vegetation was at the locality D (5.1% only). However, the maximum values are more interesting. The greatest maximum value difference in the air humidity was 15.1%, with the differences above 10% achieved five times – all at the locality D, consisting of the scattered buildings and the industrial part of the city. This may be caused because of the highest airflow values at this locality. In the monitored area, the vegetation was dense, high and shrubby and thus, it eliminates the air flow and keeps the air humidity on the higher level. Concerning the relative air humidity factor, there was a statistically significant difference, which depended on the area at the localities (Fig. 2) p = 0.000297, one-way ANOVA, (p <0.05), (post hocs, p <0.05). The largest difference (d) between the medians (m) of the relative air humidity on the plots was at the locality D – Scattered buildings and the industrial part (m_d = 8.3%), followed by E – Historical compact development (m_d = 6.2%), the third is the locality B – Mixed development (m_d = 4,5%), the fourth is the locality C – Street free development (m_d = 1.1%) and the fifth is the locality A – Settlement area (m_d = 0.6%) (Fig. 2).

In the summary assessment, we compared all the localities, but also the area plots with each other. A statistically significant difference, depending on the localities, was recorded in the surface temperature climate factor, p = 0.000004, one-way ANOVA (p <0.05), (post hocs,

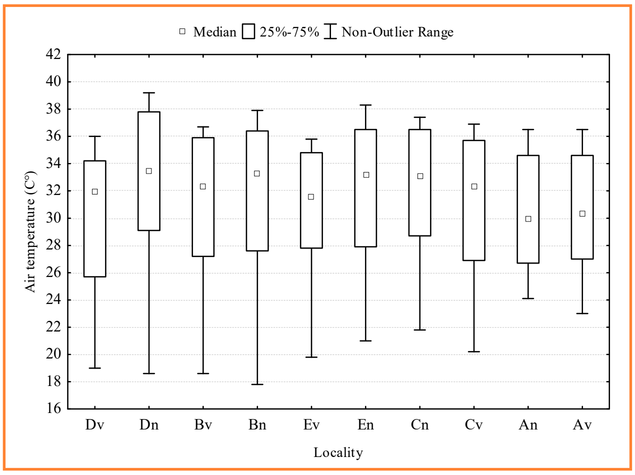

Figure 1 Air temperature at localities
A – E – locality; v – vegetation area, n – non-vegetation area
Source: Klein, 2017

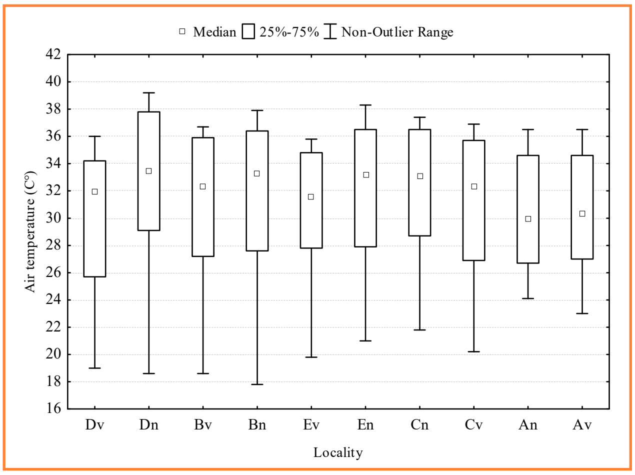

Figure 2 Relative air humidity at localities
A – E – locality; v – vegetation area, n – non-vegetation area
Source: Klein, 2017

Table 1 Median difference comparison of the measured climate characteristics among the studied localities A – E

LOCALITY	$_dF$ ($m^3.s^{-1}$)	$_dAT$ (°C)	$_dH$ (%)	$_dST$ (°C)
A	–	3.80	8.90	4.90
B	0.02	0.60	1.80	1.50
C	0.01	0.75	1.75	4.15
D	0.03	0.90	3.45	6.00
E	0.02	0.50	1.31	6.30

$_dF$ – airflow, $_dAT$ – air temperature, $_dH$ – relative air humidity, $_dST$ – air temperature
Source: Klein, 2017

p <0.05). The largest difference was between the localities A, B and D (Fig. 3). However, the air temperature and the relative humidity did not show a statistically significant difference between the localities. An overview of the median differences (*d*) of all the microclimate factors is given in the Table 1.

The second part of the paper is focused on the evaluation of temperature and the relative air humidity at two localities F and G, where the measurements were performed in a continuous 24-hour regime. At each locality, the climate characteristics were measured at two different habitats, under a tree canopy shade and on the open grassland plot. The presented values are processed from the automatic measuring station AMS, where the readings module was set in 5 minute intervals with a high degree of interpretation accuracy. The aim of the measurements was to obtain information on how the measured characteristics change during the day and night and what are the differences among the localities and also between two different area plots in the studied sites. This methodological approach and the achieved results have a great deal of information value and at the same time they complement and refine the outputs from the daily measurements at the A–E localities. Two distinctly different localities were deliberately chosen in terms of the proportion of the vegetation elements. In addition, the city park is the dominant recreational and cultural space of Nitra town with a high level of attendance by its inhabitants. When evaluating the total sum of the air temperatures, we identified lower values in the park area (the locality G), which in the open area represent a difference of 417.8 °C and under the tree crown shades 413.4 °C, compared to the street space (the locality F), which is significantly warmer. The highest differences in the open grass land were measured between 11:00 and 14:00, when the differences between the street space and the city park reached 2–2.3 °C. An increased value in the air temperature difference was also identified in the time period 18:00–19:00, when it reached more than 2.3 °C. The temperature differences in the tree stands under a tree crown shade are similar to those in the open grass spaces. In the time period from 11:00–14:00, the differences reached 2.2 °C, in the period from 18:00–19:00, up to 2.5 °C. The city park locality G is logically and demonstrably cooler. The temperature differences between the tree stand and the open grassland are also interesting, as in the city park, they reach up to 0.8 °C during the day (the open area is warmer) and 0.6 °C at night (the area under the trees is warmer). The differences in the street space between the tree stand and the open grass area are almost similar (Figs. 4 and 5).

The values of the relative air humidity (RH) were higher in the city park under a tree stand, in which the average 24-hour value reached 72.27%, compared to the street space, where it averaged 64.02%. The highest differences between the city park (the locality G) and the street space (F) were measured from 03:00–08:00 and reached from 19.6% to 24.4% value with a higher RH in the favourable city park. The highest differences between the compared habitats were measured at the locality F and averaged 9.6% in the period from 04: 00–07: 00 in favour of the tree stand. At the locality G, the city park, RH values were previously balanced

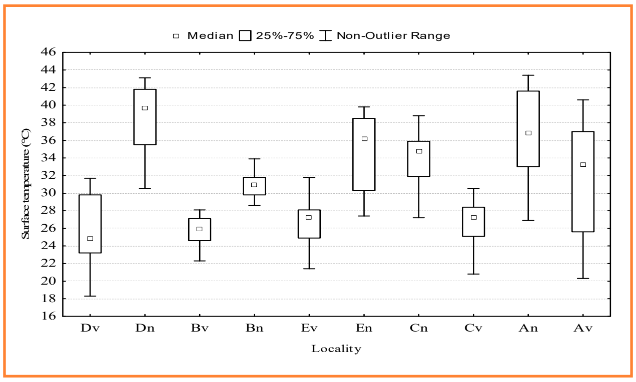

Figure 3 Surface temperature climate factor
A – E – locality; v – vegetation area, n – non-vegetation area
Source: Klein, 2017

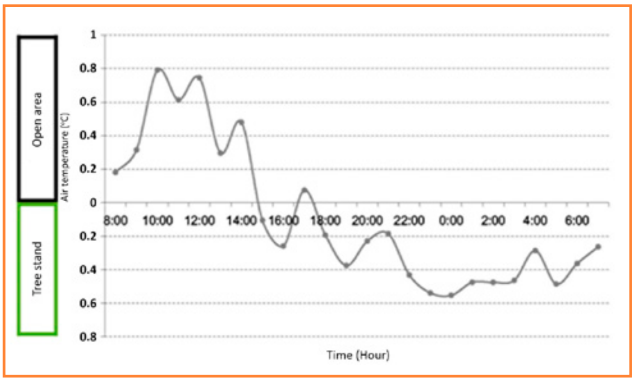

Figure 4 Course of the air temperature differences during 24-hour measurement in Štúrova street (the locality F) according to the area characteristics
Source: Jasenka, 2011

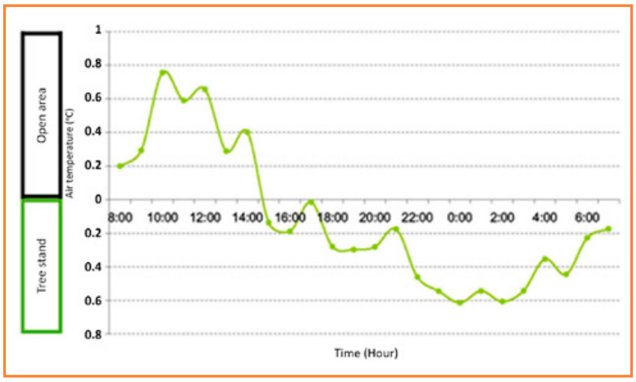

Figure 5 Course of the air temperature differences during 24-hour measurement in the City park (the locality G) according to the area characteristics
Source: Jasenka, 2011

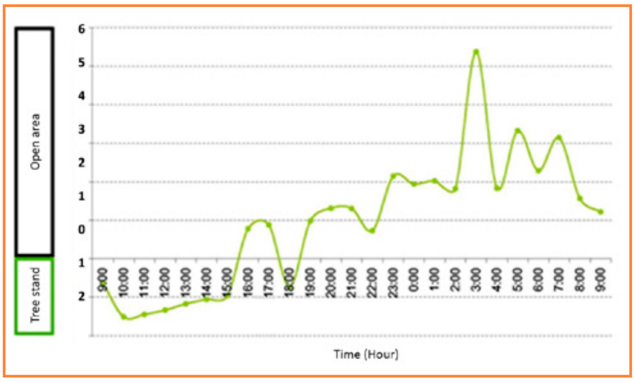

Figure 7 Course of the relative air humidity differences during 24-hour measurement in the City park (the locality G) according to the area characteristics
Source: Jasenka, 2011

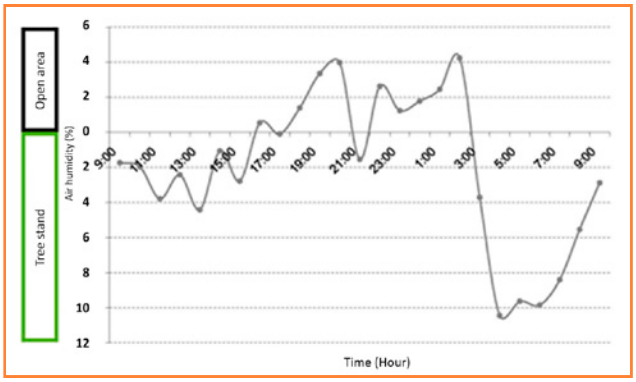

Figure 6 Course of the relative air humidity differences during 24-hour measurement in Štúrova street (the locality F) according to the area characteristics
Source: Jasenka, 2011

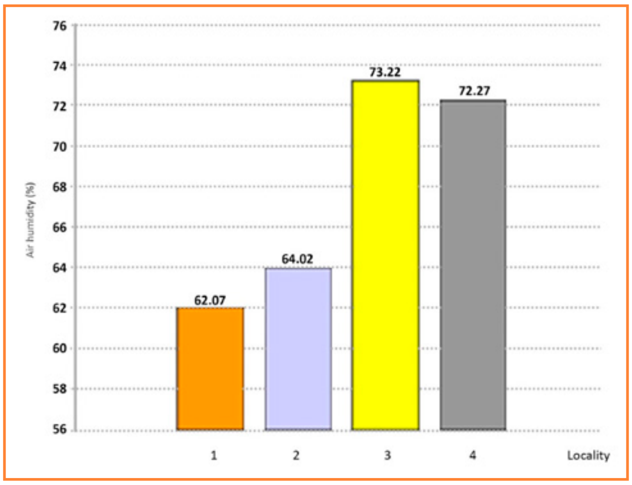

Figure 8 Average values of the relative air humidity during 24-hour measurement at different assessed city localities
Locality: 1 – Štúrova street, an open area, 2 – Štúrova street, a tree stand, 3 – City park, an open area, 4 – City park, a tree stand
Source: Jasenka, 2011

and the differences between the habitats reached 5.4% at 3:00 am, but on the contrary, in favour of the open space (Figs. 6 and 7). Based on the results of the air temperature and the relative humidity measurements among the compared localities, we identified higher climatic comfort in the city park (the locality G) compared to the street space (F). It confirms the achieved average air humidity value differences among the measured localities, too (Fig. 8).

Based on the results of our measurements in the chosen segments of Nitra town, we have found out that the differences in the air temperature and the relative humidity depend on the urban structure of the assessed localities and the proportion and composition of the vegetation areas. The largest average difference in the air temperature between the vegetation and the no-vegetation area was 1.2 °C at the locality D. On the other hand, the largest air temperature difference was measured between the street space (the locality E) and the city park (F), reaching 2.3–2.5 °C. Similarly, Tsutsumi, Ishii and Katayama (2003) show, that the maximum difference in the air temperature between the areas with vegetation and the areas without vegetation is 2 °C. Based on the urban climate investigation, it was discovered that a park, almost like vegetation with an area over 10 ha, is necessary to obtain the air temperature decreasing by 1 °C. On a larger scale, however, the differences are significant in microclimate of hard and soft surfaces, e.g. vegetation surfaces and hard paved surfaces (Gómez, Gil and Jabaloyes, 2004). Many measurements of the city microclimate confirmed that the cooling effect of larger green areas is reflected not only at the lower air temperatures in parks, but also in its adjacent areas (Dobrovolný et al., 2012; Yu et al., 2018). The air temperature is closely correlated with the relative humidity. The highest differences in the relative humidity were measured between F (the open street) and G (the city park), where they reached a difference of 19–24% RH, which represents a significant effect of the vegetation element on the quality of the city residential and recreational environment. In terms of the studied area character, a significant difference in the relative air humidity was also found in the locality D, which corresponds to the differences in the air temperature at the measured locality.

Conclusions

The results of the climatic measurements at the studied localities of Nitra town showed a significant difference in the air temperature and the relative humidity. Also differences between the vegetation areas and the areas without vegetation were found. The results reflect the urban spatial structure, distribution and frequency, as well as the area of the vegetation elements in the city territory. In addition, the results reflect the share of the composition elements and growth forms of woody species in the urban green areas, as well as the share of a tree layer, shrubby composition and grassland. These significantly contribute to the shade proportion and solar insulation and also to the amount of evapotranspiration by the vegetation elements. The above mentioned features contribute to the cooling of the open spaces in the urban structure differently. Among other things, the vegetation elements and their areas significantly contribute to the creation of an aesthetic cultural environment and strengthen the biodiversity of an entire city ecosystem.

Acknowledgement

This study was elaborated thanks to the support of the projects VEGA 1/0044/17, VEGA 1/0706/20, and projects KEGA 011SPU-4/2019, KEGA 003SPU-4/2020.

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Nitra, Slovaca Universitas Agriculturae Nitriae, 2020, pp. 66–70

GREEN INFRASTRUCTURE IMPLEMENTATION PROGRAMMES AT NATIONAL LEVEL: CASE STUDY "NATIONAL PROJECT – SUPPORT OF BIODIVERSITY WITH GREEN INFRASTRUCTURE ELEMENTS IN MUNICIPALITIES OF SLOVAKIA"

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EU-wide strategy promotes the deployment of green infrastructure across Europe. Integrating green infrastructure in spatial planning, policy and strategy development at regional/national levels is the task of each EU member state. The aim of this article is to give an example and evaluate one of the ongoing projects at national level, namely National project – Support of Biodiversity with Green Infrastructure Elements in Municipalities of Slovakia "Green municipalities of Slovakia". The aim of the national project is to implement green infrastructure at local level through vegetation elements in order to maintain and restore biodiversity and ecosystems outside of protected areas Natura 2000. The programme supporting tree planting in rural municipalities is an important tool for the creation of basic elements of green infrastructure throughout Slovakia. As part of the national program, an implementation plan for 6 municipalities in Slovakia in 2020 is proposed. Subsequently, the implementation projects in terms of the use of vegetation in different categories of green spaces, types of vegetation, representation of tree species, including costs and benefits, are proposed. Based on the results, the potential and limits of the programme and specific suggestions for its further use are set. In 6 municipalities, a total of 17 suitable localities were selected for the project, which is an average of 2.83 localities per municipality. A total of 467 woody plants individuals were proposed, representing a total of 19 woody plants species. The total cost of planting is an average of €12,601.10 per municipality, €7,312.05 per ha of area, and €161.90 per single tree. The average number of trees per ha is 45.15 individuals and per each municipality it is 77.83 trees. In the conclusions, a potential risk of the programme regarding the subsequent maintenance of trees, which is not funded under the program, is highlighted.

Keywords: tree, biodiversity, rural municipalities, green spaces

Green infrastructure is a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services such as water purification, air quality and space for recreation and climate mitigation and adaptation (European Commission, 2013). This network of green (land) and blue (water) spaces can improve environmental conditions and therefore citizens' health and quality of life (European Commission, 2013). We can distinguish between conventional and unconventional components of the green infrastructure: the most conventional elements of the urban green infrastructure are public parks and gardens, green squares, street greenery, green spaces at housing estates and other green spaces or greenery elements and the unconventional components, for example rooftop gardens or green roofs; vertical greenery or green walls; or the so-called rain gardens etc. (Tóth, Halajová and Halaj, 2015). On May 6, 2013, the Commission adopted an EU-wide strategy promoting investments in green infrastructure to restore the health of ecosystems, ensure that natural areas remain connected together, and allow species to thrive across their entire natural habitat, so that nature keeps on delivering its many benefits to us. The strategy promotes the deployment of green infrastructure across Europe (European Commission, 2013). Integrating green infrastructure in spatial planning, policy and strategy development at regional/national levels is the task of each EU member state. At the national level of Slovakia, these tasks are currently fulfilled within the Operational Programme Quality of Environment, approved by the European Commission on October 28, 2014. The programme aims to support the achievement of the Europe 2030 strategy objectives for smart, sustainable and inclusive growth in all regions of Slovakia. The main objective is to promote the sustainable and efficient use of natural resources, ensure environmental protection, actively adapt to climate change and promote energy efficiency and low-carbon economy. Within the different priority axes, the Operational Programme Quality of Environment is focused, for example, on the elaboration of documents of regional and local territorial systems of ecological stability, an action plan to address the consequences of drought and water scarcity, and to provide advice on improving the quality of environment. One of the green infrastructure implementation programmes is the programme of the Slovak Environment Agency within the Operational Programme Quality of Environment for the period 2014–2020 (OP QE): National project – Support of Biodiversity with Green Infrastructure Elements in

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Municipalities of Slovakia "Green municipalities of Slovakia," which was chosen as a case study to evaluate national green infrastructure implementation projects.

Material and method

The National project – Support of Biodiversity with Green Infrastructure Elements in Municipalities of Slovakia "Green municipalities of Slovakia" was implemented between 2018 and 2020. The aim of the national project is to implement green infrastructure at a local level through vegetation and with the purpose to maintain and restore biodiversity and ecosystems outside of protected areas Natura 2000. At the local level, this will strengthen the climate, soil conservation, water protection and the landscaping function of ecosystems as well as the environmental function of the urbanized environment. The result of the "Green municipalities of Slovakia" project will be the implementation of vegetation elements at least at 390 eligible sites and the revitalization of natural and semi-natural areas and green areas in urbanized systems (Slovak Environmental Agency, 2019). Eligible users of the programme are municipalities with the designated area in their ownership and located in a currently developed municipal area.

As a part of the national programme, an implementation plan for 6 municipalities in Slovakia in 2020 was proposed. These are five municipalities in the Nitra Self-governing Region (Lužany, Tehla, Štitáre, Modrany, Sľažany) and one municipality in the Banská Bystrica Self-governing Region (Čebovce). The size of municipalities that ranges from 200 to 499 inhabitants is represented by the municipalities of Lužany and Tehla, while the size of municipalities from 1,000 to 1,999 inhabitants is represented by the municipalities of Štitáre, Čebovce, Modrany and Sľažany.

The implementation plan was elaborated on, on the basis of The Methodological Manual for Support of Biodiversity with Green Infrastructure Elements. The implementation project must define the place and method of implementation of the vegetation elements, the extent of the implementation and the type of vegetation elements (Urban et al., 2018). Subsequently, we evaluated the implementation plans in terms of the use of vegetation elements in different categories of green spaces, types of vegetation, representation of tree species, but also costs and benefits. Based on the results, we set the potential and limits of the programme and suggestions for its future development.

Results and discussion

Categories of green spaces

In 6 municipalities, 17 suitable localities were selected for the project, which is an average of 2.83 localities per municipality. The largest number of localities within the municipality was four, namely in three municipalities, in two municipalities only one locality was solved. The decisive criterion in the selection of the site was the ownership of the land, as the solved land must be the sole property of the municipality or under a long-term sublease. This condition is the most limiting factor for municipalities, as many do not have enough land in their ownership and therefore they do not meet the programme conditions or they can only draw funding from the programme to a very limited extent. In rural settlements there are mainly smaller areas of green spaces, so that in order to meet the project objectives, municipalities have chosen several smaller localities in their ownership. However, these green areas are not interconnected, with the exception of the municipality of Tehla (Fig. 1), where the areas will be connected by a tree alley.

In terms of categorization, among the green spaces for the project there were mostly selected semi-public green spaces, which are accessible to the public only to a limited extent, namely 10 localities, which is 59% of the designated localities. The most often represented ones were school grounds (17.64%) and cemeteries (17.64%), followed by sports facilities (11.76%), and wastewater treatment plant areas (11.76%). Areas of public green spaces accounted for 41% of the areas, most often streets (11.76%). Overall, within the 17 objects, 10 different categories of green spaces (Table 1) were proposed.

In the selected municipalities, it was difficult to apply tree planting to public spaces, especially squares, due to the planting of trees in these areas in the recent past under other village renewal programmes. This criterion also significantly affected the resulting representation of green groups in favour of semi-public green spaces. Another problem was the impossibility of planting a tree on the streets, which is limited both by ownership relations and by the restriction of engineering networks in green belts.

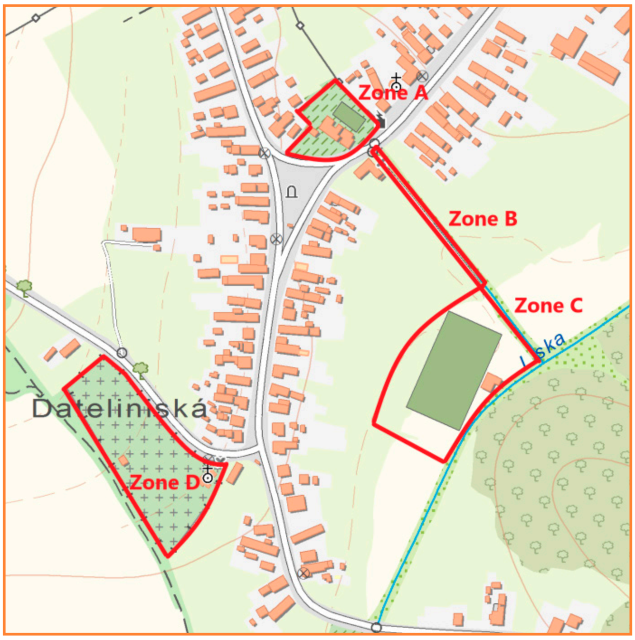

Figure 1 Scheme of functional zones of green spaces in the village Tehla
Zone A – School complex – isolation vegetation on perimeter, Zone B – Road – the tree alley, Zone C – Sports areal – isolation vegetation on perimeter, Zone D – Cemetery – isolation vegetation on perimeter
Map source: ZBGIS

Table 1 Selected green spaces categories

Green spaces categories		Municipalities (by size from smallest)						Total category no. /ha
		Lužany no. /ha	Tehla no. /ha	Štitáre no. /ha	Čebovce no. /ha	Modrany no. /ha	Sľažany no. /ha	
Public green spaces	street					1/0.44	1/0.08	2/0.52
	square	1/0.34						1/0.34
	park, pocket park				1/1.08			1/1.08
	road		1/0.02					1/0.02
	residential zone						1/0.73	1/0.73
	residual green space			1/0.04				1/0.04
Semi-public green spaces	school ground		1/0.30			2/1.04		3/1.34
	sports area		1/1.11	1/0.08				2/1.19
	cemetery		1/1.22			1/2.45	1/0.60	3/ 4.27
	WWTP			1/0.29			1/0.52	2/0.81
Total green spaces per municipality no. /ha		1/0.34	4/ 2.65	3/ 0.41	1/ 1.08	4/ 3.93	4/ 1.93	17/ 10.34

Tree species representation

In order to fulfil the objectives of the programme, the proposed woody plants were to be selected only from a list of precisely defined domestic woody plants species, in total 35 species, of which 29 deciduous and 6 coniferous. The selection of woody plant species was primarily dependent on climatic conditions and potential vegetation. The projects were implemented in an urbanized environment; therefore a significant criterion in the selection of trees was also their aesthetic value and other properties such as toxicity or allergenicity.

A total of 467 woody plants individuals were proposed, representing a total of 19 woody plants species, of which 17 species of deciduous trees and 2 species of coniferous shrubs. The most numerous species were the coniferous shrubs *Taxus baccata* L. (33.40%), and broad-leaved trees *Tilia cordata* Mill. (23.34%), *Crataegus laevigata* (Poir.) DC. (6.85%), *Quercus cerris* L. (6.64%), *Acer platanoides* L. (4.50%) and *Prunus avium* L. (4.07%) (Fig. 2).

All the villages are located in areas with warm climate; therefore, native deciduous trees more resistant to drought (65.53%) were preferred to conifers. The high abundance of *Taxus baccata* L. individuals is due to the fact that it was the only shrub species in the list of recommended plants for this programme. It was necessary for the planting under existing trees (park Čebovce), or for creating evergreen vegetation along the perimeter of the areas (cemetery Sľažany, park Lužany). The use of species *Crataegus laevis* (Poir.) DC., the only smaller tree in the list of recommended plants, was related mainly to the limited space available, but also to its flowering, which played a role in the selection of *Prunus avium* L., too. Both the size of the trees and their attractiveness play a major role in the urbanized environment when it comes to selecting trees.

The biggest shortcoming of the list of recommended plants appeared to be the absence of fruit trees, especially old varieties and shrubs which are needed for the restoration of alleys and small green areas in the countryside. In total, 467 tree species were proposed in 6 municipalities, which are 78 individuals per municipality, and 27 individuals per site. A minimum of 54 individuals was designed in the village of Čebovce, and a maximum of 110 individuals in the village of Sľažany.

From the point of view of the greenery form, woody plants were used mainly in the form of peripheral greenery in 10 localities (58.82%), and in the form of tree alleys in 6 localities (35.29%). The selected forms of greenery were mainly related to the smaller size of the sites, their use, location and shape. For example,

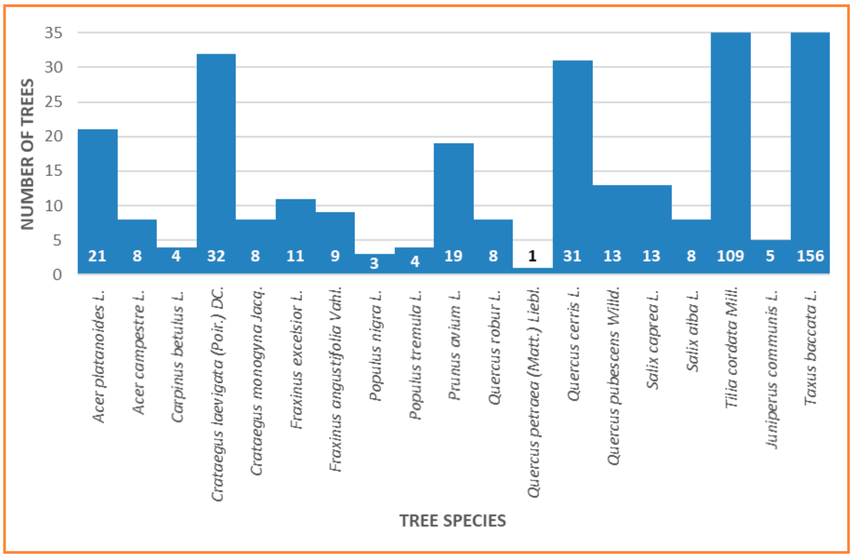

Figure 2 Summary of tree species representation in all municipalities

Table 2 Project costs

Economic indicators	Municipalities (by size starting with the smallest)						Total
	Lužany	Tehla	Štitáre	Čebovce	Modrany	Sľažany	
Number of locations	1	4	3	1	4	4	17
Area (ha)	0.34	2.65	0.41	1.08	3.93	1.93	10.34
Number of trees	59	86	70	54	88	110	467
Cost of plant materials (€)	2,884.14	7,684.26	4,212.00	3,365.35	7,680.58	5,788.28	31,614.61
Planting costs (€)	5,522.40	8,049.60	6,552.00	5,335.20	8,236.80	10,296.00	43,992.00
Total planting costs (€)	8,406.54	15,733.86	10,764.00	8,700.55	15,917.38	16,084.28	75,606.61

Table 3 Summary of economic indicators of the project

	Per municipality	Per locality	Per 1 ha	Per tree
Total planting costs (€)	12,601.10	4,447.44	7,312.05	161.90
Number of trees	78	27	45	-

Table 4 Greenery functions

Greenery functions	Number of locations Municipalities (by size starting with the smallest)						Total
	Lužany	Tehla	Štitáre	Čebovce	Modrany	Sľažany	
Climate	1	4	3	1	4	4	17
Landscape	1	4	2	1	2	2	12
Urban environmental	1	3	1	1	4	2	12
Water protection		2	1			1	4

for school and sports facilities grounds with a building or playground in the middle, it was not possible to use greenery in other forms than at the perimeter of the areas.

Costs and benefits of the project

The project conditions set the minimum value of the project implementation (8,400 € incl. VAT) as well as the maximum value of the project implementation (16,500 € incl. VAT). The total cost of planting and materials together accounted to an average of €12,601.10 per municipality, €7,312.05 per ha of area, and €161.90 per single tree. The average number of trees per ha was 45 individuals, 27 individuals for one locality, and 78 trees for one municipality (Table 2 and Table 3). The total cost included precisely specified plant materials meeting the relevant standards, professional planting and subsequent monitoring of trees during the project period. To evaluate the success of the project, it was necessary to recalculate the costs of tree planting according to the number of survived trees, 3 years after planting.

Naumann et al. (2011) indicated a wide range of per hectare costs for different green infrastructure projects, with capital costs ranging from €250 to almost €1 million per hectare and also indicated some general conclusions: per hectare costs tend to be low for restoration of very extensive habitats, and high for very intensive restoration works targeting small parcels of land. The finding that per hectare costs decline with site size is typical of nature conservation projects. Restoration of urban parks and green spaces tends to have very high costs per ha, especially when this involves working on buildings and gardens. From this point of view, we can classify the project as a relatively less expensive project.

The benefits of green infrastructure can be measured in different ways and at different levels and may be assessed by examining different indicators, for example by ecosystem services (European Commission, 2012). The results of the programme do not yet provide measurable indicators of the benefits of green infrastructure elements. The programme lists the functions whose improvement and fulfilment are expected as a result of the project for each site being solved: to strengthen the climate, soil conservation, water protection and landscape function of ecosystems as well as the urban environmental function. In the selected areas it will be possible to strengthen the climatic function at 100% (17) areas, landscaping function and the environmental function at 70.59% (12) areas and water protection function at 53% (4) of areas (Table 4).

Conclusions

Rural municipalities (2,749) make up 93.92% of municipalities in Slovakia. An essential element of green infrastructure, especially in all conventional green components, is a tree. The design-relevant and health-promotional effects of trees combined together with their ecological and economic importance justify their planting, maintenance, and relational perception (Frohman, 2020). Therefore

The National project – Support of Biodiversity with Green Infrastructure Elements in Municipalities of Slovakia with the aim to promote tree planting in rural municipalities can be considered an important tool for the creation of green infrastructure throughout Slovakia. Another project's positive aspect relates to the development of a professional methodological manual for the benefit of professionally qualified persons. Negative aspects of the programme would be assessed upon completion of the program, after having monitored the trees for a few years. The maintenance of trees in the future is perceived as a potential risk, as it might not be sufficiently financially covered, especially in smaller municipalities with lower budgets. Lack of professional maintenance is already evident after the first few years considering the number of survived trees, and their poor health conditions. Another potential risk of the project may be the aesthetic criterion and the functionality of the proposed trees, as this programme does not deal with concepts such as landscape or village image, village character and identity, but focuses significantly only on improving biodiversity and greenery functions. Some limits of the project include a restricted selection of tree species without the possibility of using, for instance, fruit trees or deciduous shrubs. In the case of project continuation, future implementation should be directed towards the professional maintenance of existing trees, in addition to new tree planting. It would also be appropriate to quantify the benefits of these types of projects, and compare them with the actual costs of the project.

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Acta Horticulturae et Regiotecturae 2
Nitra, Slovaca Universitas Agriculturae Nitriae, 2020, pp. 71–75

RECOGNISING GREEN INFRASTRUCTURE AS A PART OF THE FOURTH NATURE CONCEPT THROUGH UNIVERSITY CAMPUSES

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Every ecosystem on Earth is affected by people as well as has an impact on them. The connection between nature and culture, human knowledge and wisdom of Nature, between us and our environment, is in fact very strong, although sometimes underestimated. It can be promoted by a different way of designing architecture and urban plans – these all should change the quality of our decisions and consequently, once we are acquainted with better options or choices to select, also the quality of our lives will be raised. The Fourth Nature concept is being researched with the goal to identify strategies that create straight connections between culture and Nature, in order to provide humanity with better conditions for living in cities. We are urban beings, living with a current prognosis of being a part of a bigger number of urban dwellers each day. Many different ways the Fourth Nature can be practiced, seen and experienced by in several scales and forms could change our living conglomerates. As valuable places in cities, due to their insertion in the urban tissue and also as coexistence and knowledge development areas, university campuses are here taken to examine this aimed optimal relation between Nature and culture. University campuses have been for centuries an important part of human culture. Creating their own ecosystems, campuses impact on the functioning, sustainability and in the overall also on the appearance of the city, through a blue-green infrastructure implementation and its connections. Within the urban structures, they fulfil their role more significantly and provide important spatial, social, economic, visual and health functions. The area, which is often labelled as public or semi-public space, is thus a part of the blue-green infrastructure and its quality affects also the quality of the surrounding environment. The Fourth Nature is seen as a tool or as a turning point in the current environmental crisis and the university campuses are considered to be the modifiers of the quality of their surrounding environment. The intercrossed analysis of their properties in the current context may bring new ideas and application parameters for the design of the contemporary urban landscape.

Keywords: the fourth nature, a blue-green infrastructure, ecosystem services, urban structures

The population growth, constant and continuous movement of everything around us, social, cultural and technological changes (Hashimshony and Haina, 2006) and urbanization affect the development of urban structures towards suburbs. Automobiles are becoming an essential type of transportation in the 21st century, leading to an increase energy consumption, air pollution, time-consuming, traffic congestion, diseases, dysfunction society and etc. (Rashidi, 2013). The importance of green elements in the densely populated cities and in its developing areas is derived from the attempt to stop the climate change and improve infrastructure, until we modify our well-being status. The study of the Fourth Nature concept deals with all these spheres, since it involves the relation man-nature in time and tries to foresee which way we could go to change our near future (Prochnow and Abreu Filho, 2018). Today, in a busy period and a continual movement of everything around us, the character of the living areas is dynamically changing in a connection with an alternation of mode, art or even opinions. The ambit of changes is seen mainly in the alterations of a functional application of architectural objects and their premises (Čibik et al., 2019). These movements show that we, human beings, are in a continuous evolution and solutions, which fulfil our most updated needs, of both physical and mental health, must with no doubt embrace Nature, as it has been already explored by many authors. As the number of people living in our garden planet approaches seven billion, with a probability to reach nine billion by the middle of the century, the possibility of sustaining a harmonious life in Nature seems even more remote, as Giesek and Jacobs (2012) said in Earth Perfect. The alterations are grand. Today, our urban lives depend most fundamentally on global ecologies and the political economies, which uphold them (Keil, 2003). Architecture and urban design have a main responsibility in this process: the application of ecological approaches in landscape is one of the main steps in creating urban areas without an environmental deterioration and increased financial demands caused by necessary maintenance and sociological effects on new generation (Vaculová and Štěpánková, 2017).

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Theoretical background

The Fourth Nature concept is being defined in research that aims to recognise a new perspective in the relationship man-nature. An updated concept, which takes our consciousness and responsibilities as perceptual subjects into consideration, both influences the perceived object and is influenced by it. Experiencing Nature means to be an observer and a part of it, at the same time. It is with no doubt a two-way path. To consolidate this comprehension, important ideas were found throughout the history, for example, the 'Second Nature' concept, written by Cicero in his book De natura Deorum (41 BC). He already defined the Second Nature as the nature modified by man to serve his purposes and satisfy his basic needs such as food and transport. Hunt (1992) believes, that Cicero's concept would be known by the Italians in the Renaissance, since in 1541, Jacopo Bonfadio wrote about gardens that started to be constructed in a refined way, never seen before. These amazing landscape designs were proposed by other authors, too (such as Bartolomeu Taegio) to be the 'Third Nature' – una Terza Natura – gardens as 'Nature incorporated to artwork'. The main resources of human intelligence and technological skills were invoked to bring these astonishing results, as the search of pleasure from contemplation would overcome the utility purposes. Even though Cicero is not explicit, his words imply the existence of the First Nature, the pristine Nature, untouched by humans. The First Nature would be the kingdom of Gods and also the raw material for the Second Nature (Hunt, 1992).

The important point to consider is that the primitive Nature has been constantly processed for the human consumption and transformed either into the second and then into the third Nature or sometimes directly into the third Nature. This consumption involves the search of conditions for housing, agriculture, transportation, religious beliefs and eventually, leisure or aesthetic pleasure. Whatever the purpose is, the redoing of the primitive Nature makes the physical world milder, more useful, tolerable, pleasant and beautiful, as Hunt describes. The specific emphasis depends on which historical moment the transformation has been set on, together with the place and the social-economic situation. Today's adjectives would also include 'ignored' and 'destroyed', if we look at the majority of our cities. When we realise, in which 'historical moment' we are living now, it is preponderant to perceive that today, we need far more than just a food-transport-contemplation. It is based on our awareness of the importance of designing our places integrated and with a respect for Nature, sine qua non condition for our survival would exist. It is the meaning that the Nature brings to our lives, which enhances its importance.

One of the great myths of our time is about the particular relationship with nature, which we observe within the confined realm of our cities (Girot in Becker and Cachola-Schmal, 2010).

As we will live more and more in cities and cities cause the biggest problems concerning environment, the Fourth Nature concept is focused right on the big cities. However, it is also relevant to see the city not as a problem, but accept it as the solution for our future – this brings a more productive way of thinking. Adli (2017) in his work Stress and the City deals with the question: why do cities make us sick and why are they still good for us? What a great question. The Fourth Nature concept considers that what we need today is to create a dynamic interface between the natural and cultural, in which we will use all the available technology and also takes our real dependence on the natural resources and its benefits into consideration.

It is also a way of sensitising us by reintroducing, enhancing and prioritizing Nature within the cities, so that we reconnect with its cycles and rhythms and live healthier. The main factor of the Fourth Nature may be that it combines a whole spectrum of experiences offered by the presence of Nature in the city with different dimensions of our connection to it, of our perception or awareness by satisfying our body and mind needs. There are many ways, scales, and possibilities of such aim implemented, one of them being the blue-green infrastructure (Prochnow, 2019).

The blue-green infrastructure refers to a network of green building strategies within the cities that connect the existing green features with each other and with the wider landscape that surrounds it (Benedict and McMahon, 2006). University campuses are places where these connections occur strongly, once they become a designed area with open spaces, within or in the borders of the cities and thus, provide an added value to it. This is how this crossed analysis proposal is validated, especially nowadays, when another way of planning comes up by reversing the usual actions as ignoring or destroying into a conscious designing. These consider the importance of an holistic approach for urbanism and architecture, in which Nature is one of the main items in the projects, while not considering the open spaces being the 'unused areas'. Moreover, they are perceived as the most valuable ones and the blue-green infrastructure features as elements, which enhance local characteristics, multiple benefits, less maintenance in a long term view and above all the ones, which connect sites and people.

Material and method

Green infrastructure, as a part of the Fourth Nature concept, is globally considered to be the most effective strategic planning tool to help create a sustainable and resilient urban landscape. It is also an effective measure to mitigate the effects of the climate change, providing a range of ecosystem services as well as social, environmental and economic benefits (Tóth and Feriancová, 2015; Mell, 2016). The university campus is a part of these structures and through the hierarchy of the individual buildings, the campus creates inter-pavilion spaces with a public character, which, in terms of quality and overall visual identity, affect the surrounding environment equally significantly (Čibik and Štěpánková, 2019).

Results and discussion

As a part of the European Concept of the university campuses, university campuses were designed near the city structures in the 1960s and 1980s, and their immediate surroundings became dense as they got gradually urbanised

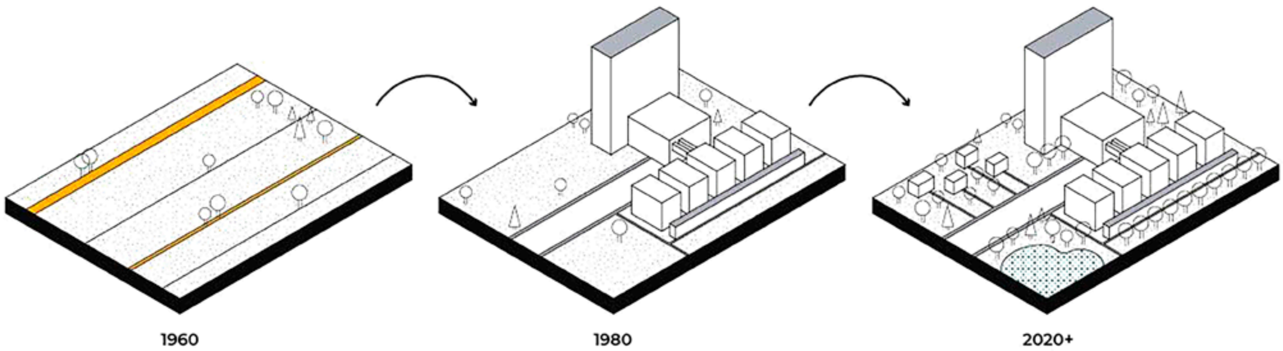

Figure 1 University campuses development. Some university campuses, mostly designed within the European concept and originally designed on the outskirts of cities, are becoming a part of the urban space, due to a massive urbanisation. City campuses are gradually taking up the function of open spaces and their environment significantly influences the surroundings

(Fig. 1). Today, they form important buildings and areas in the city centres and significantly influence their operation. In its in between spaces and buildings (physical matters), as well as by its character (of the intellectual growth of the place, where the new ideas are being developed) and by its constant renewal processes, campuses represent an interesting place to observe and implement the Fourth Nature possibilities – as a blue-green infrastructure. From the big spatial green features as are tree groups and grass relaxing areas, to the most developed strategies of roof and wall greening, different scales of green and water utilization can trigger an effect of interest as well as a result of well-being in its users and visitors. The full interaction among the users, natural/built green backgrounds and the natural phenomena brings the utmost results.

This is why the conceptual thinking within the green infrastructure tools is indispensable not only for the design of the environment, but also for the understanding of the future opportunities and threats. In this aspect – perhaps more than in the past – the process of creation has become a process of identification and exploration, a process of creativity for exploring new spatial possibilities and new methodological approaches.

According to the consequence of suburbanization, the architectural community seeks a solution to reduce the negative effects of a massive urbanization on the culture and economy of the cities and an aim to achieve a sustainable city (Rashidi, 2013). The sustainability of a university campus (Reid, 2008) can be increased through the blue-green infrastructure strategies, once it changes not only its environmental processes but also once it promotes its connection to the city's metabolism as a whole – by improving it. However, regarding to Melková (2014), only an accessible area is justified in the city, as long as it compositionally and urbanistically corresponds to the structure of the city and contributes to its (cultural) enrichment. The well-being of users and social living conditions are therefore the results of the blue-green infrastructure and also serve as an important place-making strategy, since creating high quality open spaces should focus not only on students but also on every citizen. The title 'University Campus' expresses who the space is intended for. People perceive the premises of the campus, but they often have inhibitions to spend time in it. They think that the campus is private, that it belongs to the university and not to everyone and they have respect to the area. The boundaries of the campus must be clearly defined but it is better, when the edges are made up by buildings

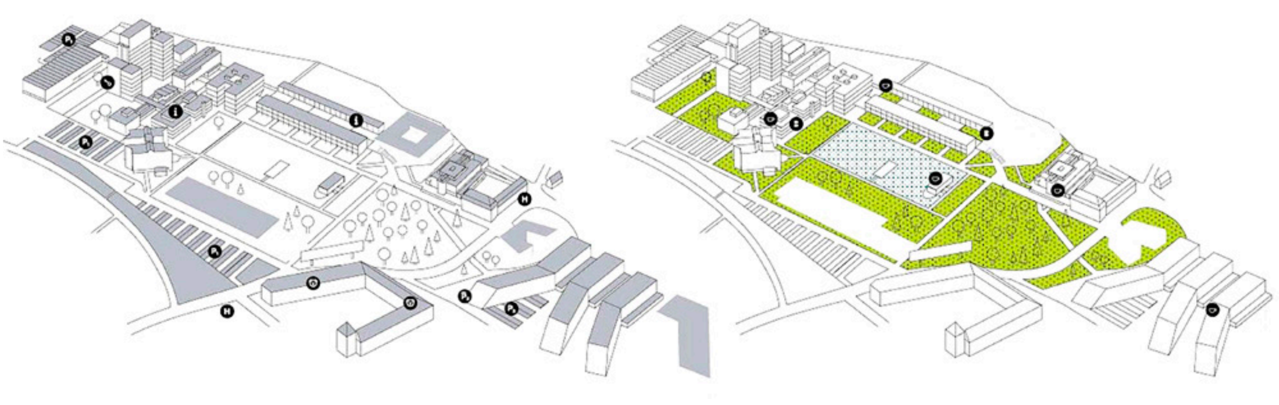

Figure 2 Representation of green spaces, open spaces and community-based services compared to buildings, car parks or areas not accessible to the public. The positive example of JKU – Johanes Kepler University campus in Linz (Austria)
Source: JKU and vectorised by Čibik and Štepánková (2019)

and open spaces than by walls or fencing. Concerning the character of the surrounding development, there are discussions about the semi-public, semi-private or even private space, but the collective space is always the result, which should guarantee comfortable usage for all groups of population, regardless age, social and cultural background and handicap. Green infrastructure tools are one of the many ways for ensuring such aim. Campuses are open and connected with surroundings and not just specific and complementary types of the public spaces. They also offer their territories to everyone, although at a different level. As Rawn (2002) describes, open spaces positively influence the relationships with the city, which include landscape, pavements and urban furniture. The size and number of floors of the individual objects (buildings) of the complex must respect the panorama of the city and their number should correspond with the number of trees and other vegetation (greenery). In order to develop 'city – university campus' relations, the ratio between the greenery and the open spaces within the campus must be roughly equal or even greater than exactly the same ratio, but within the city (Fig. 2).

When talking about the public space quality, it becomes intrinsic to value green spaces and its multidimensional possibilities, in order to enhance cities life quality. According to The United Nations, the world population living in the urban area in 2011 reaches 52.1% (United Nations, 2011). The development of urbanization has therefore big effects on the way people live, related to the natural, physical, social, cultural and economic dimensions. This makes the gaining sustainability an essential authoritative condition to the urban areas (Jenks and Dempsey, 2005). Providing a direct contact with Nature in a reasonable walking distance for every citizen is a basis in visionary urbanism. University Campus can be a provider of green areas in the city. And as these green features offer not only contemplation but also systematic services, they become extremely efficient and thus, the Fourth Nature, green infrastructure and campuses interrelate.

Higher education and more job opportunities in the labour market attract young people to study at universities. University campuses were established as a result of gradually expanding universities. The influx of new students was so great that the individual capacities of the universities were not enough. Today, the university campus is one of the main elements of the city and significantly affects the sustainability of the city and the surrounding environment. Therefore, it is important that there are physical, economic and socio-cultural relationships between the city and the university campus. The university campus positively affects the development of the city and its interconnection with the urban structures and also increases the social activities that lead to the development of the economy and the integration of students with the local inhabitants. According this, the campus affects the city. If the campus becomes sustainable, the city can also become. In these terms, a sustainable campus can be considered one of main concepts of growing sustainability in the cities. In other words, the city can improve its sustainability when having the university campus well located, accessible and planned in sustainable forms. Moreover, for achieving a sustainable university campus, main dimensions of a sustainable university as are natural environment (Melo et al., 2020), social, cultural and economic ones must be considered in the university strategy plan (Lukman and Glavic, 2007). Cultivated squatted urban and peri-urban areas, which undoubtedly the university campuses could be considered as, represent a significant element of the Urban Agriculture (UA) (Tóth and Feriancová, 2015), which, according to Lohrberg (2011) and Lohrberg and Timpe (2012), provides an important contribution to a sustainable and resilient urban development and creation and maintenance of the multifunctional urban landscapes. The UA has been increasingly recognised for the multiple functions, which are supported by it and which the urban society benefits from (Bryant, 2012). Moreover, the university campuses are considered to be large scale green areas in the city borders, too.

Thus, the urban planning is a complex task, which requires multidimensional urban information (spatial, social, economic, etc.) (Kliment et al., 2015). There are some basic standards in the design process, which define the relationship between the user and the university campus at different levels. Surrounding space, dynamic and static motion, safety, visual identity, permeability and etc. are some of these standards. Successful design of the university campus is achieved through a balance between these standards and achievement of the successful urban space, which suits the purpose for which it is established, while meeting the users' needs. Thus, a responsive urban design of the environment and the utilization of this space by humans are both achieved (Rached and Elsharkawy, 2012).

Conclusion

We can consider that the usage of the blue-green infrastructure strategies, as part of the Fourth Nature concept, is a very useful tool towards the achievement of this complex task, once it can embrace several of the desired targets. The campus vegetation for example, meets an important role in the cultural, educational and historical rescue, as well as in the transition from the natural to the built environment. The green areas and their usage as an urban park strengthen the valorisation of the campus. Through the education and research, it is possible to integrate an active learning with a social responsibility and environment by encouraging the construction of sustainable paths, improving the users' contact with Nature, as well as by directing the development of the design towards sustainability and consequently, towards a healthier life, in which people are more conscious of the need of interacting with Nature – as the Fourth Nature concept proposes. Our vision of the future may change our actions in the present. Today's generation is influenced and encouraged by new experiences. Living in an interesting environment, which is also effective in solving structural systems as well as it is a dynamic, livable, multipurposeful and attractive place, is the perspective we are looking for. University campuses can become such desired places within the cities, once we recognise them as innovative and learning places, where the blue-green infrastructure strategies are planned, and the Fourth Nature concept is materialised, and once they reconnect us with the environment and make us perceive, enjoy and take benefits from the presence of Nature in our daily life routine – in a virtuous cycle.

Acknowledgement

The paper is an outcome of national educational and scientific projects of the Ministry of Education, Science, Research and Sport of the Slovak Republic VEGA 1/0371/18, research project KEGA 003SPU-4/2020 and research project KEGA015SPU-4/2020 (UNI-ARCH). The authors would like to express special thanks to VEGA 1/0371/18, KEGA 003SPU-4/2020 and KEGA 015SPU-4/2020 for covering all the expenses.

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Acta Horticulturae et Regiotecturae 2
Nitra, Slovaca Universitas Agriculturae Nitriae, 2020, pp. 76–80

REVITALIZATION OF (POST-) SOVIET NEIGHBOURHOOD WITH NATURE-BASED SOLUTIONS

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The neighbourhoods in the former Soviet Union were after the World War II often planned according to the self-consistent microdistrict concept similar to Clarence Perry's neighbourhood unit. Each residential district was based on the walkable community centre in the middle whereas the area itself was surrounded by arterial streets as the main transport routes with basic services. However, the recent situation of many of those neighbourhoods is rather dim – the bad condition of housing, faded public spaces and unorganised greenery systems are between the most crucial issues. The results of the research made on the case study of the Jubilejny district in the city of Mogilev, Belarus, show that population ageing is the main threat for these areas. Residents are dissatisfied with uncertain housing situation besides inappropriate parking options and lack of opportunities to spend a leisure time outside. Therefore, our proposal to the future development of the Jubilejny district includes short term improvements such as leisure activities within the public spaces or regeneration of green spaces as well as long-term designs regarding a community garden and other nature-based solutions.

Keywords: nature-based solutions, khrushchyevka, microdistrict, urban greenery

After the World War II, the scale of industry has grown rapidly. As a need for housing for industrial workers grew, the former state of the USSR responded by building industrial and prefabricated housing units. The so-called Khrushchyevkas consist of concrete-paneled or brick three- to five-storied apartment buildings built from the late 1950s to the early 1980s, mainly because of their low construction costs (Bohn, 2008). The residential neighbourhoods that consist of Khrushchyevkas were often planned according to the Soviet's microdistrict concept, influenced by Clarence Perry's neighbourhood unit (Perry, 1929). The latter concept, originally developed from Howard's Garden City model (Howard, 1898; Choguill, 2008), was Clarence Perry's vision of a self-contained neighbourhood as a reaction to an increasing motorised transport in the metropolitan areas of capitalist cities (Perry, 1929; Maxim, 2009). The idea of the neighbourhood unit comprises a residential area for up to 6,000–10,000 inhabitants surrounded by arterial streets with retail and services (Perry, 1929). The microdistrict concept might be thus perceived as a Soviet type of the neighbourhood unit sharing the same basic principles (Perry, 1929; Maxim, 2009). As the time went by, Khrushchyevkas were demolished or renovated in many parts of the former Soviet Union. However, in Belarus, and Mogilev in particular, they are still in place and subject to a gradual degradation, both physically and socio-economically. The buildings are in poor condition due to the low-quality construction works and materials and the lack of insulation. In addition, Belarus might be affected by climate changes in the near future. Heat waves and other extreme events (e.g. floods or droughts) are expected to increase, putting urban areas at high risk (Kabisch et al., 2016). The Belarusian economy will be impacted mostly in three sectors – agriculture, forestry and water management (Communication, 2015). For that reason, the adaptation to climate changes is extremely important for the country, especially because 41 % of GDP in Belarus is produced in sectors dependent on weather conditions (Communication, 2015). The Republic of Belarus has already set up different policy programmes and strategies for climate mitigation and adaptation: "The National Programme of Measures to Mitigate the Effects of Climate Change for the Period of 2008–2012 years", "The Strategy for Reducing Emissions and Enhancing Removals of Greenhouse Gases by Sinks in the Republic of Belarus for the period of 2007–2012" and "The National Strategy for Introduction of Integrated Environmental Permits for the period of 2009–2020" aiming to reduce and absorb greenhouse gas emissions and develop the programme of synergic measures for various sectors of the national economy (Zenchanka, 2016). According to Choguill (2008), the concepts of garden cities or neighbourhood units were, albeit unconsciously, based on sustainable solutions. Therefore, the suggestion is to re-establish these concepts and adapt them to the new challenges. Sustainable neighbourhoods include economic, social, technical, and environmental dimensions (Choguill, 2008). Neighbourhoods have to be limited to accessible and walkable areas. Local shops, markets and cafés can be used to expand social opportunities. The number of streets and cars in the neighbourhoods should be reduced to ensure

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safety for children and older members of the society. In addition, parks and other green and open spaces play an important role in common meeting places (Choguill, 2008; IUCN, 2018). Also, the conservation of species diversity is a factor in the sustainability of biotic cycles and, accordingly, the sustainable development of the biosphere (Haliuzhyn et al., 2017). Nonetheless, the development of urban green spaces is a complex process due to the involvement of long-term natural processes including growth and maturation of living elements (McMichael, Woodruff and Hales, 2006). Likewise in other places in Europe, the degradation of urban green spaces has been observed in Mogilev. However, without sufficient political and financial support from national or local authorities, funding agencies or private investors, their further development is not possible (Górniak and Costa, 2008).

Thus, the objectives of the paper are:

- to develop a complex approach to microdistrict space organization using environmentally friendly solutions;
- to optimize the microdistrict concept, taking into account modern approaches in urban planning and the interests of the of the community (youth in particular);
- to examine the prospects for development of microdistrict with Khrushchyevkas without their demolition.

Material and method

The paper is mainly based on the information from primary sources – a non-participative observation and the information collected through interviews with city officials, planners and experienced architects, and questionnaires with the residents of the neighbourhood. The current situation in the study area was analysed using Internet maps Mapy.cz (Fig. 1).

For the purposes of this paper, we have only focused on the space outside the buildings. Generally, the area has lots of unattended green spaces, some of them with the dense growth of trees. Fig. 1 shows all urban green areas in the study area (marked in green), kindergartens and schools (marked in orange). Among the green spaces, few plots have also been developed for playgrounds, which are now rather unkempt and unused.

Most of the urban green spaces are not particularly used by the citizens; however, three spaces were identified as the playgrounds of a decent condition.

Based on the observation, the services available in the area were mapped using The AutoCAD program. The interviews were conducted using an open-ended guided questionnaire while the residents were asked to fill out a structured questionnaire. The structured questionnaires were conducted with youths, adults and older people according to our perception of the respondent's age. This approach covers various perspectives across age groups. A total number of 30 surveys was conducted among the residents in August 2018. The SPSS program was used for analysis of the responses from the residents. It comprises the non-parametric Mann-Whitney and Kruskal-Wallis tests that are appropriate for ordinal data.

Results and discussion

According to the statistical analysis of questionnaires, the residents of the Jubilejny district are generally not satisfied with the housing and parking options in their neighbourhood. On the other hand, they are rather satisfied

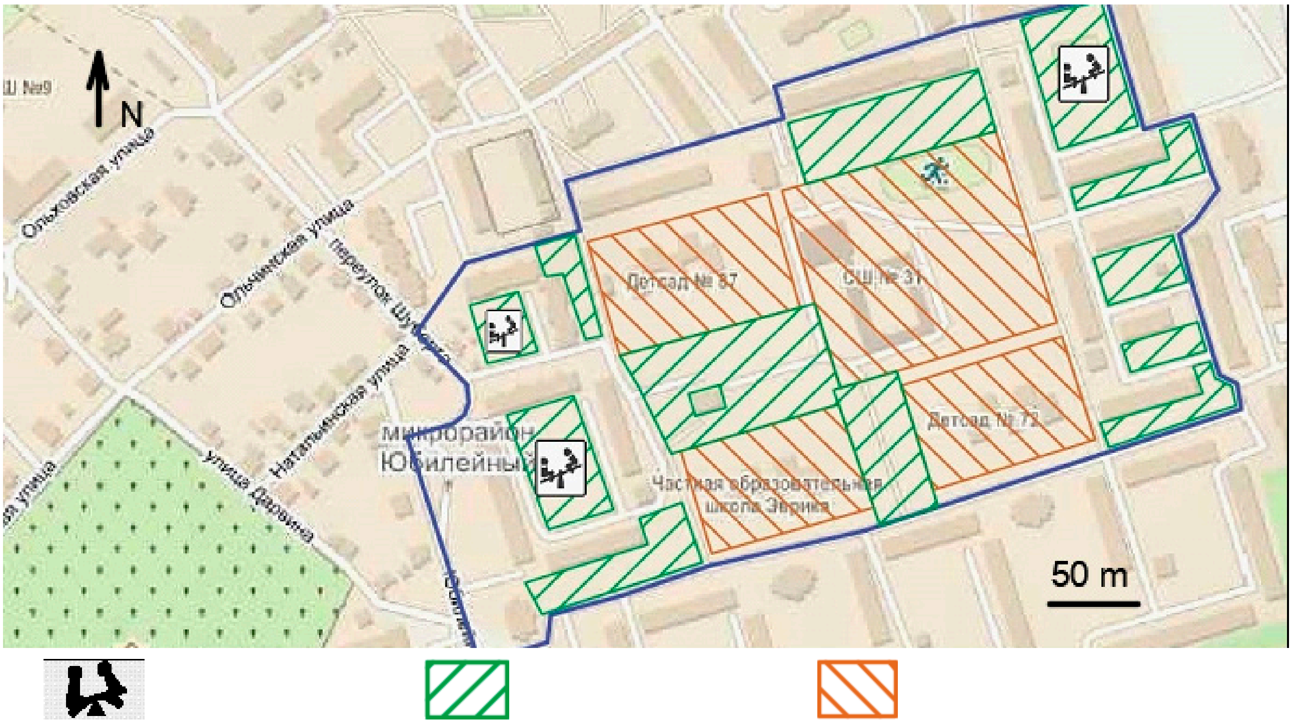

Figure 1 Urban green spaces and playgrounds

Table 1 Satisfaction of residents with housing and neighbourhood

Indicator	Average satisfaction (1–5)	Result
Housing	2.6	weaknesses
Car-parking	2.9	
...	3.0 to 4.0	–
Air quality	4.1	strengths
Public transport	4.1	
Schools	4.1	
Natural environment	4.2	
Grocery stores	4.3	

Table 2 Differences between age groups in residential satisfaction

Tested variable	Used method	Average rank			Sig.
Overal satisfaction	Kruskal-Wallis	18.70	15.60	10.22	0.049
Satisfaction w. neighbors		10.80	16.65	19.05	0.082
W. play-grounds		11.00	17.90	17.60	0.099
Importance of rest./cafes		16.28	18.00	8.83	0.032
Of leisure clubs		17.33	16.20	9.78	0.088
Residential stability		10.39	13.06	17.50	0.061

Table 3 Intentions to move out according to the current housing situation

Tested variable	Used method	Average rank		Sig.
		old	new	
Intention to move out	mann-whitney	11.39	11.39	0.548

with the natural environment, greenery and air quality (Table 1).

However, there are some particular differences in satisfaction with different factors within the age groups – youths, adults and seniors (Table 2). Youths are significantly less satisfied with neighbours and playgrounds than the other groups. The services in the neighbourhood such as restaurants, doctors, leisure clubs and public transport are more important for youths and adults in comparison to seniors. Grocery stores are equally important to everyone. All in all, older people are significantly less satisfied than youths and adults.

Youths and adults plan to move out in the next few years whereas older people will probably stay due to the lack of funds which might cause a further population ageing threat. Nevertheless, the intention to move is not influenced by the age of apartment houses (Table 3). Therefore, the characteristics of the neighbourhood might also play a crucial role in determining the attitude of residents to their future housing plans.

According to the spatial plan which is based on the delimitation of functional zones, the Jubilejny district should stay as a residential area. Urban planning proposals have to adhere to the general master plan of Mogilev and confirmed by the head of

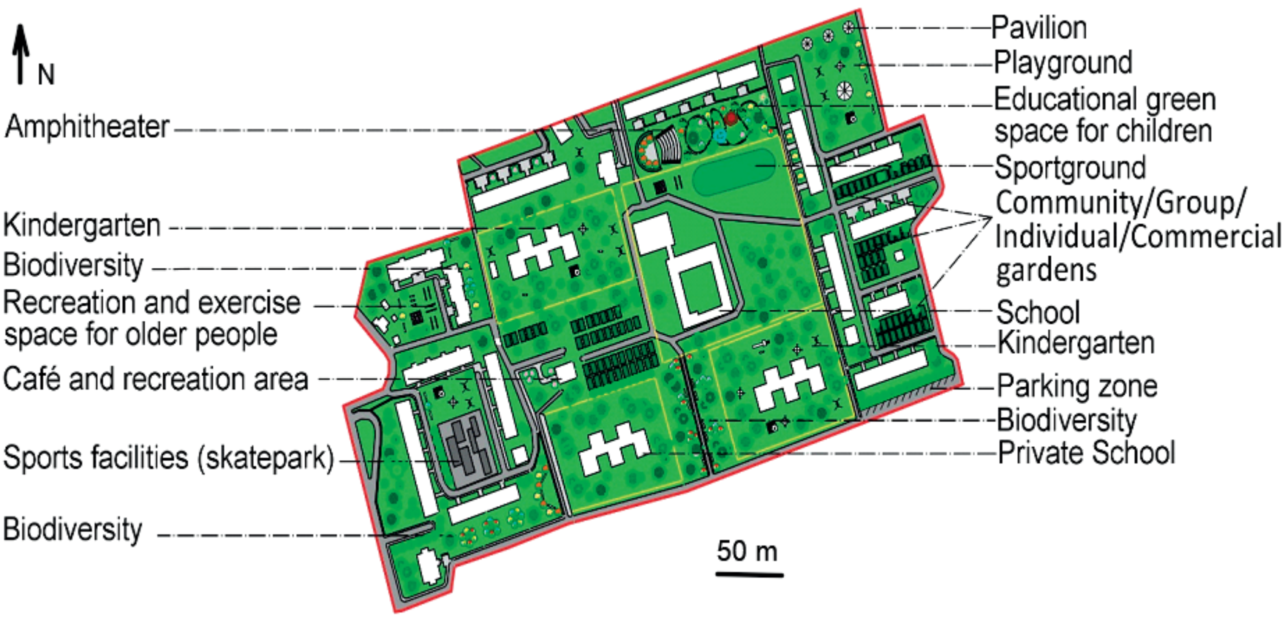

Figure 2 Proposal of implementations in the Jubilejny district

the government. Consequently, it is possible to build new apartment buildings in this area as long as the area keeps its functional zone. However, the local experts are uncertain what happens with the Khrushchyevkas in the future. There are no immediate intentions for their reconstruction or demolition even though there are serious doubts about the concordance of buildings with the requirements of thermal conductivity and fire safety as well as to their overall condition.

Our vision includes the revitalisation of the Jubilejny district by the development of open spaces as per the needs of the local population in a sustainable manner (Fig. 2).

Community/Group/Individual/Commercial gardens

To make better use of the space available, people can be encouraged to grow seasonal food products in urban gardens. Urban agriculture refers to the growing and raising of food crops and animals in an urban setting for the purpose of feeding the local population (Deelstra and Girardet, 2000). It should be noted that there is some lagging behind the advanced countries in the consumption of fruits and vegetables in Belarus (Lobikova, Lobikova and Haliuzhyn, 2017). The cultivation can take place either in large community gardens or in smaller plots allocated to individuals or in commercial gardens. The rental income will benefit the community. A local entrepreneur group could also establish a commercial garden.

Educational green space for children

In the study area, there are two kindergartens and two schools. It is proposed to develop a garden exclusively for the use of school children for an educational purpose. Education for sustainable development is one tool to reconnect populations to green areas and nature. The garden will also develop a sense of belonging to the area and establish a connection to the neighbourhood.

Recreation and exercise space for older people

One of our main target groups is older people because this group stays in the area and spends there a lot of time. It is therefore proposed to address the need of this group on the priority basis and develop recreational and exercise spaces for them to encourage them to spend time outside and being physically active. This will contribute to their health and well-being.

Café and recreation area

It is proposed to have one or two small cafés in the area which people can visit and, thus, the social exchange would be promoted. The products in the café could come from the neighbourhood garden.

Amphitheater

The faded community space of the neighbourhood can be rejuvenated by cultural activities. A small amphitheater is proposed in which the community can gather. The wall of the amphitheater can be used for demonstration of a green wall, which can encourage people to develop vertical gardens or green walls at their own apartments.

Sports facilities

The neighbourhood lacks facilities for outside sports or they are in bad condition. Especially teenagers are very dissatisfied with their playgrounds. Therefore, it is proposed to go beyond the development of urban greenery and also develop special sports facilities. The established playgrounds should be improved, and a new skating park developed.

Safety & Security

Some of the senior people have also expressed safety and security as a concern. While this may not be an issue for the younger residents, it is proposed to develop the security and safety for all by installing solar powered street lights along the neighbourhood streets, pathways and gardens.

Biodiversity

The area already consists of many green spaces. However, a lot of monotonous and invasive species are presently dominating. Therefore, it is proposed to enrich the biodiversity by introducing a variety of local species of vegetation by using a permaculture design.

Car-free zone

The centre of the Jubilejny district is almost without cars. Nevertheless, especially since a lot of people live in the area, it is proposed to make the inner area as a car-free zone. Elderly can then move about without any barriers and children can play on streets without a risk. However, this intervention is costlier, and it should be accepted as a long-term solution. Nevertheless, as residents are rather unsatisfied with parking options in the neighbourhood, it is proposed to develop a small parking area as a compensation for removals of the others.

To implement these nature-based solutions, it is essential to start a dialogue with the local community and the public authorities. Community development will be an essential pillar of the proposal while for some activities, funding from sponsors or public authorities will be important. It is also proposed to invite local entrepreneurs to be a part of this process, thus generating some local jobs and income. To focus on the development of inner areas, it is proposed to reuse the microdistrict concept.

Conclusions

The Jubilejny district in the city of Mogilev, formerly built in concordance with the microdistrict concept in the 1960s, is recently many years after its planned longevity. Nowadays, a number of inhabited apartment buildings, including famous Khruschyevkas, are in almost deteriorated condition with faded public spaces between them. Fortunately, according to the research, the concept of microdistrict and its inner structure persists as the residents have a good access to basic services and public transport.

However, there are several threats besides an uncertain future of Khrushyevkas which might further contribute to a decay of the Jubilejny district. Firstly, the locality is bounded by population ageing since predominantly younger generations have intentions to move out. Therefore, in our proposal, we considered better leisure infrastructures mainly for youths such as the renovation of sports grounds or other outside activities as well as brand new implementations for adult and older people such as an amphitheater or a community garden that may support the active way of life inside the neighbourhood. Secondly, even though the centre of the Jubilejny district is almost without cars and walking belongs to the most used type of transport therein, the residents perceive the parking as one of the main problems of the whole area. Thirdly, the locality enjoys the abundance of greenery; however, trees often consist of monotonous and invasive species and several green spaces are unkempt. Thus, our proposal mainly comprises nature-based solutions which enrich the biodiversity and better utilise the empty green areas. Overall, the Jubilejny district needs to be handled with immediate solutions as well as the long-term visions that consider also potential solutions for apartment buildings and their future development. Since the Jubilejny district is a typical representative of microdistricts in the Post-Soviet region, the research results could be applied in other similar conditions. However, in each individual case, in order to make the most rational use of space, climatic and urban planning features should be taken into account.

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DESIGNING PROTECTIVE ECOTONES TO REDUCE ACOUSTIC LOAD ON THE RAILWAY LINES

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According to the results of the analysis of domestic and foreign literary sources, one of the most innovative ways of ensuring the stability of anthropogenically modified ecosystems is proposed, that is the creation of a system of protective type ecotones, which will allow providing ecological safety on the railways using exclusively natural environmental restoration mechanisms. On the experimental areas, we have described the taxonomic structure of forestry groups and phytocoenotic activity of species in forest grouping. We have also calculated the closeness, viability of the tree-stands, and also the projective shelter. To determine the noise effect, the noise-permeability of forest strips and the scattering of sound-currents from planting action have been analyzed. Based on research and calculations, a zone of sound shadow is determined depending on the size of the obstacle and the length of the sound wave. The acoustic effect of reducing the sound level is determined by such factors as bandwidth, dendrological composition, and design of plantations. The one-factor dispersion analysis allowed confirming that the investigated sections of the tracks of Lviv Railways differ significantly from each other according to these data. The results of the research were also subject to correlation analysis. The coefficients of pair correlation of structural indices of protective type ecotones were calculated with reduction of acoustic load on sections of the tracks of Lviv Railways. Therefore, the interrelation with the distance, the horizontal closure of the tree canopy, the distance between the trees, the height of the shaft and the crown density were reliably established. On this basis, the multiplicity regression equation for complex estimation of acoustic load reduction and prediction of noise reduction with specified parameters of protective type ecotones were calculated.

Keywords: protective type ecotones; forest groupings; closeness; viability; noise-permeability; scattering of sound streams; acoustic effect; coefficient of pair correlation

Road traffic noise is one of the most common environmental problems in the EU, which has negative consequences for society (Aasvang et al., 2011, Alekseev and Kadyskina, 1977; Blidberg, 2011; Croy, Smith and Waye, 2013; Diduh, 1982). Noise pollution affects the quality of human life and is in the second place after the problem of air pollution (de Vos, 2016). At present, according to the World Health Organization (WHO), about 210 million people in the EU are regularly exposed to more than 55 decibels (dBA) of traffic noise, which is at a level when noise has a negative impact on humans.

In this work, it is proposed to evaluate the role of structural parameters of consortive protective ecotones (CPE) in reducing the level of acoustic load on adjacent agrocoenoses and residential areas and derive equations that allow calculating noise abatement on the rail tracks.

Material and method

The study of PFP parameters took place on trial plots (TP). The trees were described by species and viability (VA). The tree tally data were recorded on tally sheets. The measurement of tree diameters was carried out with a caliper. The plantation's height was measured by using the EB-1 hypsometer. The species composition of the vegetation on the trial plots was found during the processing of 60 geobotanical descriptions. The structural and comparative analysis of the floristic composition of the plots was carried out using the biomorph classifications of (I.G. Serebryakov and K. Raunkier 1934), the linear system of living forms of V.M. Golubev, the ecomorph and coenomorph systems of A.L. Belgard.

The determination of the noise effect implies the determination of the noise-penetration of forest strips and the dispersion of sound streams under the action of the stands. The studies were carried out using a noise-level meter spectral analyzer and a portable OCTAVA-110A vibrometer. The measurement error of the noise-level meter in the normal conditions of application for a plane 1,000 Hz frequency wave and a level of 94 dB, which propagates in the reference direction (orthogonal to the plane of the microphone capsule membrane) in a free acoustic field, at the S characteristic, does not exceed 0.7 dBA.

The noise-level meter is installed at a distance of 1 m from the ground taking into account the terrain of the territory. Only flat areas were selected for the study to prevent changes

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in the turbulent regime. The measurements were carried out in the CPE in leafless condition in March and October and in a leafy state in May and August. The measurements were carried out in cloudy weather.

Noise level measurements were taken at different distances from the tracks. The following observation points were established: 2 m from the tracks – point 1; at a distance of 5 m – in front of the forest strip – point 2; point 3, in the strip – at a distance of 50 m from the tracks; point 4, in the strip – at a distance of 100 m from the tracks; point 5, in the strip – at a distance of 150 m and point 6, behind the strip – at a distance of 200 m from the tracks.

In order to analyze the results obtained, the program 110_UTIL-Light was used. The noise level for each type of railway transport on the section of the Lviv-Stryi railway was determined on a 10-km zone where, under normal conditions, the train speed is unchanged. The following sources of acoustic pollution were studied: electric trains, freight and passenger trains. In order to obtain objective results, the condition of the plantings was taken into account, that is, in leafless and leafy states.

Results and discussion

CPE reduces the noise level on railway tracks by attenuating sound vibrations at the moment of their passage through branches, leaves and needle-foliage. Sound, getting into the crown, finds itself as if in another medium, which, having much greater than air acoustic resistance, reflects and dissipates up to 74% and absorbs up to 26% of sound energy. In summer, plantings reduce noise by 7–8 dB, in winter – by 3–4 dB.

The measurement of noise level from electric trains was carried out under conditions of a single noise source, moving at a speed of 60 km.h^{-1}. The study showed that there are insignificant differences in the noise level, depending on the condition of the plantings. The measurement of noise level from passenger trains was carried out under conditions of a single noise source which moves at a speed of 90 km.h^{-1}. The measurement of noise measurement from freight trains was carried out under conditions of a single noise source, moving at a speed of 90 km.h^{-1}. The parallel measurement of the acoustic pollution level at the Lviv-Stryi railway section confirms the hypothesis that the CPE plays the role of a noise pollution filter, cutting down and partially dissipating the noise. The studies have revealed the general tendency towards reduction of noise level from all the investigated sources of noise by 20 dBA, which enhances comfort on the territory adjoining to the rail tracks. In a leafy state, CPE performs the role of a sound waves scatterer better than in a leafless state. Fluctuations in the noise level depending on the state of the plantation is 4–6 dBA, which is an indicator of the greater noise absorbing efficiency of the plantations in a leafy state.

According to the calculation scheme and the value of the specific sound absorption by green plantations, we determine the estimated elements. The distance from the noise source to the crown of the first CPE strip is r_1 = 0.5 + 1.75 = 2.25 m, the width of strips in the CPE is B_1 = 0.5 + 1.5 + 3.5 + 2.5 = 8 m, B_2 = 2.5 + 3.5 + 3.5 + 1.3 + 0.5 = 11.3 m, the width of the gaps between the strips of green plantations A_1 = 4.5 + 0.7 - 2.5 + 1.0 - 2.5 = 1.2 m, A_2 = 1.5 - 0.5 = 1.0 m, the number of rows in the CPE is z = 2 and the specific absorption coefficient of sound energy is β = 0.15. Then, the noise reduction efficiency of this CPE is equal to:

$$L_{e\phi} = 10 \cdot \lg\left(\frac{2.25 + 19.3 + 2.2}{2.25}\right) + 1.5 \cdot 2 + 0.15 \cdot 19.3 = 16.1 \text{ dbA} \quad (1)$$

The sound waves reaching CPE are absorbed by leaves and branches of the trees. The most effective for the absorption of noise pollution are those plants that have thick leaves on thin branches. To obtain a noticeable noise-protection effect, plantings should be thick and have a dense green mass of crowns of the trees and bushes. The acoustic effect of reducing the sound level is determined by factors such as the width of the strip, the dendrological composition and the structure of the stands. Green

Table 1 The results of acoustic pollution measurement on the railway section Lviv – Stryi

Point	Distance from the tracks (m)	Noise level, dBA	
		leafless state	leafy state
		winter (January)	summer (July)
Left side			
1	2	96.2	95.6
2	50	90.4	89.3
3	150	82.9	79.8
4	200	68.5	65.4
Right side			
1	2	97.4	95.1
2	50	91.3	88.0
3	150	83.4	78.6
4	200	69.1	65.7

plantings, formed as special noise protection strips, can have the effect of reducing the noise level by 8 dBA. The high effect is achieved by plantings of 20 m wide consisting of five rows of coniferous trees and two rows of shrubs. However, it is more effective to plant several dense strips of trees at such a distance from each other so that their crowns do not close. In this case, each row of trees acting as a dense hedge reduces noise by 1–2 dB, becoming a new obstacle in the way of its movement, shielding it. The space between the rows covered with grassy vegetation also participates in the absorption of sound waves.

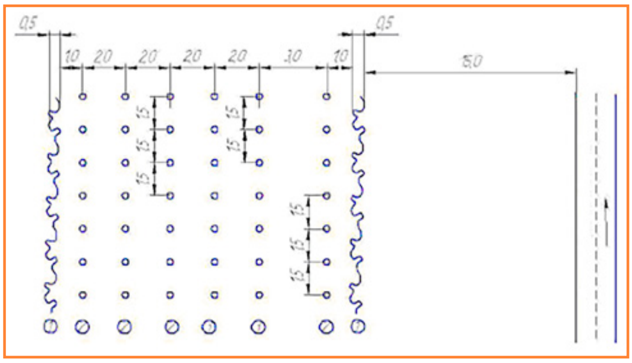
Planting trees in the strip can be in lines or quincunx with a distance between the trees being no more than 4 m and the tree height not less than 5–8 m, and the height of shrubs – 1.5–2 m. It should be noted that quincunx planting is more efficient for noise reduction. Green plantings of conifers are more effective for noise protection than deciduous ones and do not depend on the time of year.

CPE description by structural indicators

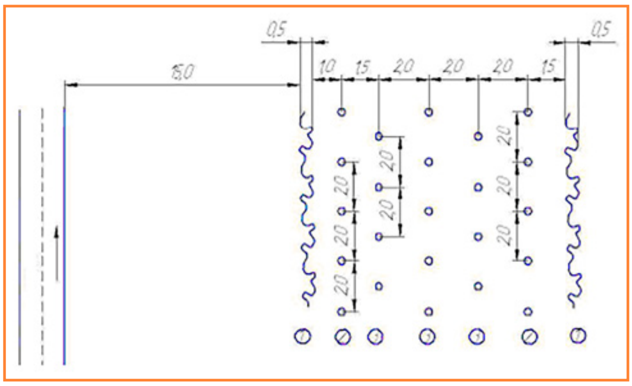
As can be seen from Fig. 1, the level of noise generated on railway tracks penetrates into the depth of CPE differently. For each object under study, it is peculiar. Therefore, to say that noise reduction is associated only with the distance is not wholly true.

For each point of recording the noise level on the Lviv railways, trial plots (TP) were established and a description of the CPE was made according to structural parameters: the stand canopy density, the distance between the trees, the height of the tree trunks, the density of the crown of the trees and bushes (the area occupied by a TP, in percentage). The stand canopy density was taken into account to a certain point on the given TP.

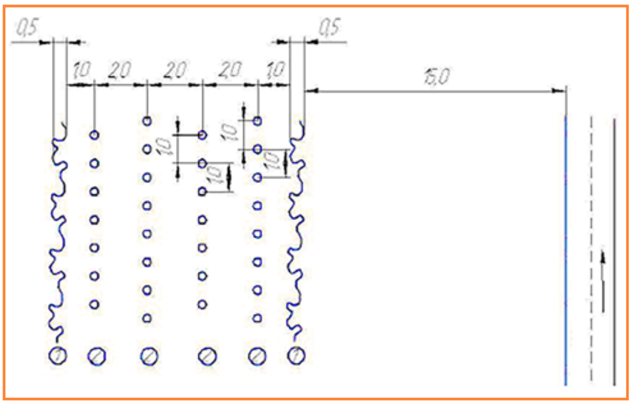
On the railway section Lviv-Sambir (Fig. 1a), predominant are TPs with a half-open type of spatial structure (HOTSS), characterized by stand density of 0.6 to 0.3. The trees are located at a distance of 3.0 m from each other, the height of the trunk is 6.0–7.0 m, and the density of the crown is from 60 to 40%. On the railway section, there are shrubs 0.5–0.7 m high which occupy an insignificant part of the TPs, less than 2%. When describing the structural parameters of the CPE,



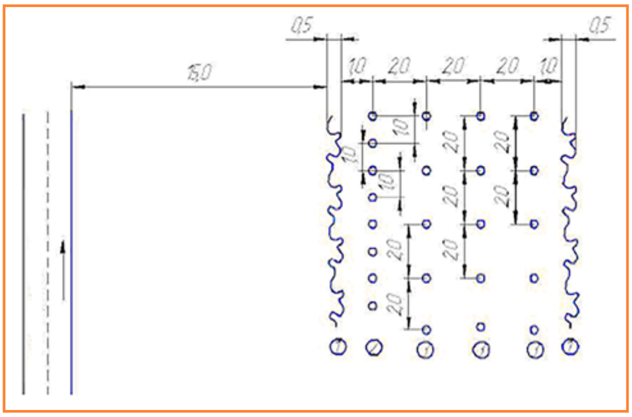
a) The CPE plan of the Lviv-Sambor section of the Lviv railways



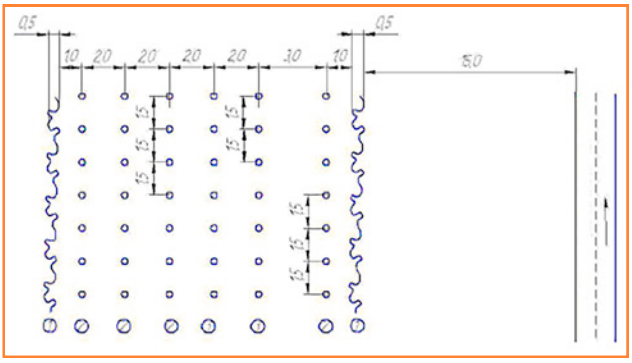
b) The CPE plan of the Lviv-Ivano-Frankivsk section of the Lviv railways



c) The CPE plan of the Lviv- Rava-Ruska section of the Lviv railways



d) The CPE plan of the Lviv-Kovel section of the Lviv railways



e) The CPE plan of the Lviv-Krasne section of the Lviv railways

Figure 1 The CPE plans of the Lviv railways sections they were not taken into account, since they are below the height of the noise measurement.

The Lviv-Iv. Frankivsk railway section (Fig. 1b) is characterized by a TP with a closed type of spatial structure (CTSS) and the stand canopy density being between 0.98 and 0.72. The plant spacing is 4.0 m and 2.8 m, the trunk height being 5.0 m and 8.0 m, and the crown density – 60–70%. Shrubs are not encountered on any TP.

The Lviv – Rava-Ruska railway section (Fig. 1c) is characterized by the presence of shrubs on the territory of the trial plots which cover the under-tree space. The stand canopy density is low: 0.5–0.2, there are also plantations that are characterized by a very low stand canopy density: up to 0.14. According to the height of the trunks and the density of the crown, there can be distinguished two groups:

1. with a distance of 4.0–5.0 m, the height of the trunk of 2.0–3.0 m, and the crown density of 80–70%;
2. the distance is 2.5–3.5 m, the height of the trunk is 3.5-8.0 m, and the crown density is 50–60%.

On the Lviv-Kovel railway section (Fig. 1d), the same as for the Lviv – Rava-Ruska railway section, the test plots have a low stand canopy density: from 0.58 to 0.24. The tree grows in the CPE with a distance of 4.5 m between them, the height of the trunk is 2.0–2.5 m, and crown density is high: 80–90%. On this section of the railway tracks, there are 2 TPs which have shrubs covering the under-tree space.

On the Lviv-Krasne railway section (Fig. 1e), the trial plots are characterized with the stand canopy density of 0.88 to 0.4. According to the height of the trunk and the density of the crown, there can be distiguished two groups: with the plant spacing of 4.0–4.5 m, the height of the trunk being 3.5–4.0 m, and the crown density is 70%; the plant spacing is 3.0–3.5 m, the height of the trunk being 5.0–7.0 m, and the crown density is 60–70%. As on the Lviv-Sambir section, shrubs growing here are 0.5 to 0.9 m high.

To further investigate the influence of CPE structural parameters on the noise level, linearization of the distance data was carried out.

Single-factor variance analysis of the CPE by noise level and structural parameters. In the process of analyzing and generalizing the results obtained, it was found that none of the studied indicators at each railway track section of the Lviv railways had a clear relationship with a decrease in noise level. Using them, it is rather difficult to give with a sufficient degree of reliability an estimate of noise reduction by the

Table 2 Single-factor variance analysis of CPE by noise level and structural parameters.

Source of variations	Sum of squares	Degrees of freedom	Dispersion	Fроз	Probability	Fst	Strength of factor influence
Single-factor variance analysis by noise level							
Between groups	1,057.5	5	211.5	4.19	99.86	2.28	12.80
Inside the groups	7,212.1	143	50.4				
Total	8,269.6	148					
Single-factor variance analysis by crown density							
Between groups	4.37	5	0.87	51.20	99.98	2.28	68.07
Inside the groups	2.05	120	0.02				
Total	6.42	125					
Single-factor variance analysis by distance between trees							
Between groups	57.83	5	11.57	31.27	99.98	2.29	56.58
Inside the groups	44.38	120	0.37				
Total	102.21	125					
Single-factor variance analysis by shrubs							
Between groups	489.39	5	97.88	4.93	99.99	2.29	17.03
Inside the groups	2,383.97	120	19.87				
Total	2,873.36	125					
Single-factor variance analysis by trunk height							
Between groups	431.28	5	86.26	63.77	99.99	2.29	72.66
Inside the groups	162.32	120	1.35				
Total	593.59	125					
Single-factor variance analysis by stand canopy density							
Between groups	12,684.94	5	2,536.99	20.68	99.99	2.29	46.29
Inside the groups	14,719.03	120	122.66				
Total	27,403.97	125					

structural components of CPE, therefore, they could not be recommended for each section of the railway tracks as diagnostic signs when selecting a CPE to reduce the acoustic load on the railway lines of the Lviv railways.

As a result, it was found out that the studied rail track sections of the Lviv railways differ in noise level. To determine the noise reduction values, the difference between the noise along the railway tracks and the point of recording the noise level behind the CPE was found. Therefore, a comprehensive assessment of the noise reduction on all the studied sections of the railway tracks is required in accordance with the significance of each studied indicator.

Correlation analysis of structural parameters of CPE

The results of the study were subjected to a correlation analysis; pair correlation coefficients of structural parameters of CPE with the reduced acoustic loading on the sections of the rail tracks of the Lviv railways were calculated. As can be seen from this analysis, there is a close relationship between the distance, the horizontal closure of the tree canopy, the distance between the trees and the height of the trunk, the density of the crown. When describing the structural parameters on the trial plots, the presence of shrubs is taken into account only at a distance of no more than 105.0 m. When this condition is met, the shrubs are definitely associated with noise reduction.

To calculate the equations of multiple regressions, the most informative were selected, that is, for which the pair-correlation coefficients with a decrease in the acoustic load were reliable (at a significance level of 0.95).

Based on this, for a given set of structural parameters of CPE, multiple regression equations are calculated for a comprehensive assessment of the reduction in acoustic load. The only indicator that was not taken into account is the height of the trunk, since it is closely related to the plant spacing. As shown by the correlation analysis, the effect of shrubs was found only at a distance of 105.0 m; therefore, the coefficients of the multiple regression equation were calculated separately for shrubs as well. As a result, two multiple regression equations were obtained.

The equation for calculating noise reduction takes the form:

$$Y = 5.01 \ln X_1 - 2.84\, X_2 - 1.23\, X_3 + 0.07\, X_4 - 5.07 \qquad (2)$$

where:

Y – the reduction in the level of acoustic load

X_1 – the distance from the noise source to the point of recording the noise level

X_2 – the stand canopy density

X_3 – the distance between trees (m)

X_4 – the crown density (%)

This equation is used only to calculate the reduction in the acoustic load on railway lines at a distance of no more than 200.0 m. The estimates of the coefficients and their reliability are given in Table 3.

The conducted research allowed identifying patterns of noise reduction not only due to the distance, but also structural parameters of CPE. The most significant of them were the canopy closure, the plant spacing, shrubs and the crown density. The equation of multiple regression is calculated, which allows predicting a reduction in the noise level with the given CPE parameters.

Conclusions

On the basis of the investigated system of the spatial structure of CPE, the main principle of the establishment and functioning of PFPs on the railway lines is highlighted.

The correlation analysis of the structural parameters of CPE with a decrease in the noise level showed the following: for all the study objects, the correlation coefficient indicates a close relationship between the distance from the noise source and noise reduction (r = 0.79 × 0.93); on the Lviv-Sambir and the Lviv-Kovel railway sections, the obtained values of the correlation coefficient (r = 0.41 × 0.4) indicate an average relationship between the horizontal closure of the tree canopy and the reduction of noise – the higher the stand canopy density, the greater the noise reduction. The calculated criterion of significance of the correlation coefficient is equal to the theoretical one, which indicates a significant relationship between the investigated characteristics. On the Lviv-Kovel and the Lviv-Iv.Frankivsk railway sections, the correlation between the characteristics is weak (r = -0.18 × 0.13. On the Lviv-Iv. Frankivsk railway section, the resulting r = -0.61, that is, the lower the horizontal closure of the tree canopy, the greater the reduction in noise. This phenomenon is due to the fact that the trial plots located farther from the noise source are characterized by lower canopy density than the trial plots located closer to the noise source; on the Lviv-Sambir, the Lviv – Rava-Ruska, the Lviv – Kovel, the Lviv – Iv.Frankivsk railway sections, the obtained correlation coefficients for distance and noise reduction (r = -0.54 × 0.46) indicate an average relationship between the studied characteristics.

Table 3 Estimation of the values of the coefficients and their reliability for the equation for calculating the reduction in the level of acoustic load on the railway lines

Parameters	Equation coefficients	Standard error	Student's test	Effect of factor (%)
Intercept term	-5.07	1.943	-2.61	–
X_1	5.01	0.358	13.99	54.75
X_2	-2.84	0.487	-5.83	31.04
X_3	-1.23	0.264	-4.68	13.44
X_4	0.07	0.018	3.84	0.77

R^2 = 0.96; F = 438.04; SE = 1.99

The calculated criteria of significance of the correlation coefficient are more theoretical, indicating a significant relationship between the investigated characteristics. It is found out that the smaller the distance between the trees, the greater the reduction in noise. On the Lviv-Iv.Frankivsk railway section, the trial plots have the same distance between the trees. Shrubs are present only on the trial plots of the Lviv-Kovel and the Lviv-Rava-Ruska railway sections. On the Lviv-Kovel railway section, there are only 2 trial plots where shrubs are encountered, so it is difficult to draw conclusions about their impact. The significant impact of shrubs on noise reduction was detected on the Lviv-Rava-Ruska railway section (r = 0.53). On the trial plots with shrubs, noise reduction is much higher than without them; in all the objects studied, a connection was established with the height of the trunk and the level of the acoustic load. On the Lviv-Sambir, the Lviv-Kovel and the Lviv-Rava-Ruska railway sections, using the calculated correlation coefficient (r = 0.6 × 0.54), it was found out that increasing height of the trunk reduces the level of acoustic load to a larger extent. On the Lviv-Iv.Frankivsk and the Lviv-Kovel railway sections, using the correlation coefficient (r = -0.41 × -0.54), it was found out that with a reduction in the trunk height, the level of acoustic load also decreases (r = 0.6 × 0.54) on the trial sites of all sections of the Lviv railways, except the Lviv-Sambir and the Lviv-Ivan Frankivsk sections, it is reliably established that the higher the crown density, the greater the reduction in the acoustic load on the adjacent territory (r = -0.56 × 0.47). On the Lviv-Iv.Frankivsk section, the value of the correlation coefficient is lower than the theoretical value; therefore, the connection is not traced. On the Lviv-Sambir section, the correlation coefficient (r = -0.52) indicates that with a decrease in the crown density, the decrease in the acoustic load is higher. But, just as for the Lviv-Rava-Ruska railway section, when identifying the relationship between the height of the trunk and reducing the acoustic load, for the recording points of the noise level located farther from the noise source, the trial plots are characterized by low crown density. But, if we take the recording points of the acoustic load level approximately at an equal distance from the rail tracks, then the relationship is similar to the other studied railway sections of the Lviv railways.

The studies have revealed patterns of reducing the acoustic load at the expense of not only the distance but also the structural parameters of CPE. The most significant of them turned out to be: the stand canopy closure, the plant spacing, the presence of shrubs and the crown density.

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RE-INTERPRETING THE IMRAHOR VALLEY (ANKARA-TURKEY) IN TERMS OF GREEN INFRASTRUCTURE DIRECTING URBAN AND RURAL DEVELOPMENT

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The earth is rapidly urbanizing. One of the most effective means of dealing with the emergency caused by rapid urbanization is green infrastructure now. Ankara as a metropolitan capital city is also rapidly losing its urban-rural integrity due to rapid urbanization. Although different spatial plans have been made since the declaration of the Republic, the city continued oil-stain expansion and the green area system could not be protected. The Imrahor Valley, which is of ecologically vital importance in the urban-rural integrity, is one of the valuable areas under threat. The valley is an ecotone between the rural and urban ecosystems, southeast of Ankara city center. The valley has come to the point of losing its natural and rural character, especially with the urban transformation practices on the valley floor, slopes and surrounding areas. In this context, the ecological processes to which the Imrahor Valley is connected and dependent and human interventions in these processes are examined in three layers at different levels initially: the province, the city containing the central districts and the basin containing Lake Mogan-Eymir Lake-Imrahor Valley. Then, we focus on the transformation of the Imrahor Valley, one of the most important ecological components of the metropolitan city of Ankara, between 2003–2020. All transformational interventions in the Imrahor Valley affect all natural processes of the Valley irreversibly. It is necessary to re-read and interpret the Imrahor Valley landscape within the framework of the green infrastructure approach in all spatial planning studies and plan changes to be made regarding the metropolitan city.

Keywords: valley landscapes, urban transformations, rural-urban interaction

Globally, more people live in urban areas than in rural areas, with 55% of the world's population residing in urban areas in 2018 and by 2050, 68% of the world's population is projected to be urban (United Nations, 2019). Urban expansion has occurred fast in areas adjacent to biodiversity hotspot on a global scale. This urban expansion will heavily utilize natural resources, including water, and will often consume prime agricultural land, with irreversible damages on biodiversity and ecosystem services elsewhere. On the other hand extensive areas of impermeable surfaces in urban areas result in large volumes of surface-water runoff and increase urban vulnerability to climate-change effects, such as increased frequency and intensity of storm events (Secretariat of the Convention on Biological Diversity, 2012).

As the world continues to urbanize, rethinking of the relationship between urban and rural landscapes radically is needed and the linkages between cities and surrounding rural areas should be strengthened. Global serious problems such as climate change, massive internal and international migrations and Covid-19 pandemic, which we have experienced recently in the global scale, made it necessary to examine the "resilience state" of an urban settlement much more comprehensively. In particular, the Covid-19 pandemic has clearly demonstrated that the rural areas, which feed the city in terms of ecological, economic and socio-cultural dimensions, represent the main factor that keeps safe the fragile urban life.

In this context, Green Infrastructure (GI), which breaks the rigid structure of cities, aims to create multi-functional connections between urban and rural, as well as preserve the existing connections and thus make the city healthier and more resilient, has emerged as a concept of global importance.

According to Benedict and McMahon (2002), GI is a natural life support system that is necessary for the environmental, social and economic sustainability of countries and has an ecological framework.

In the EC Communication, GI is defined as "a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. This definition includes three important aspects: the idea of a network of areas, the component of planning and management, and the concept of ecosystem services. In this sense, GI integrates the notions of ecological connectivity, conservation and multi-functionality of ecosystems" (Liquete et al., 2015).

It is a concept that should be considered at all spatial scales from regional to local-neighbourhood scale, which can be applied to urban sprawl areas connecting with wider rural expansions, as well as large rural areas far beyond the city (Natural England, 2009). They offer regulatory services

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that are highly relevant to cities, such as microclimate regulation, noise reduction or air filtration, while also providing important cultural services such as nature experiences, recreation and promoting social cohesion (Palliwoda, Banzhaf and Priess, 2020).

Ankara as a metropolitan capital city is also rapidly losing its urban-urban fringe-rural integrity due to the rapid urbanization. When Ankara was declared as the capital of the young Republic of Turkey in 1923, it was focused on elimination of post-war destruction, shelter, health and security issues and ensuring the usual production and consumption conditions (Cengizkan, 2004). However, while taking steps to meet these conditions on the one hand, Ankara faced a rapid population increase with the effect of rural-urban migration on the other. This increase has continued steadily (Duman and Coşkun, 2015; Doğan and Bostan, 2019) and the migration rate that Ankara received is 32.27‰ for the 2011-2012 period (AKA 2015). Ankara has become the second largest city in the country (ÇDP, 2017). Having a population of approximately 400,000 in 1927, Ankara reached 5,639,760 people in 2019. While the population of the country reached approximately six times the population of 1927 in 2019, the population of Ankara reached approximately 14 times for the same period (TUİK, 2020).

Ankara is located on a natural threshold zone between the mountain ranges that separates Central Anatolia from the sea and other regions, and located in a "topographic bowl" with an average of 840 m (Buğra, 2006). This bowl also determined the initial development of the city, guiding the potentials or constraints where the urban macroform could expand outwards.

Although different spatial plans have been made for Ankara since the declaration of the Republic, the city has continued oil-stain expansion due to uncontrolled urbanization. This situation is strengthened with the economic model change. As stated in Şahin (2015), Turkey has focused on 'construction-oriented capital accumulation model based on urban rent' recently, thus, its economic growth has become completely urban transformation oriented. In addition to being a metropolitan city under intense urbanization pressure, Ankara is a city that is becoming increasingly fragile due to the challenging conditions of the steppe climate. These conditions bring fundamental changes in landscapes and their ecological conditions, especially for rural areas connected strongly with the city economically and politically.

The Imrahor Valley, an ecotone between the rural and urban ecosystems, southeast of Ankara city center, is of ecologically vital importance in the urban-rural integrity, and is one of the valuable areas under threat. Although the Imrahor Valley is located within the Ankara metropolitan area, it is still an area that keeps distinctly its rural-natural character that makes the valley unique. On the other hand, the geomorphological structure of the valley, consisting of hundreds of small valleys, reinforces this uniqueness. Sınacı Özfındık (2019) stated that the plan revisions, market forces and speculative pressures implemented since the mid-2000s are the main reasons increasing tensions in the valley and pave the way for intense construction.

This study deals with the Imrahor Valley at three-tier spatial approach at the 2003-2020 time interval: the province; the city with the central districts; and the basin containing Lake Mogan-Eymir Lake-Imrahor Valley. Thus, it is revealing the need to rethink and reinterpret the quality and functions of the Valley landscape and propose necessary changes in spatial plans in terms of green infrastructure approach.

Material and method

The focus of the study is the Imrahor Valley located in the southeast of Ankara city center, within the boundaries of the Gölbaşı, Çankaya and Mamak districts. Since the valley, which is approximately 3,500 hectares in size, is hydrologically connected (Karadeniz et al., 2016) with Mogan and Eymir lakes, this study was carried out in the sub-basin that includes Mogan Lake-Eymir Lake-Imrahor Valley (Fig. 1).

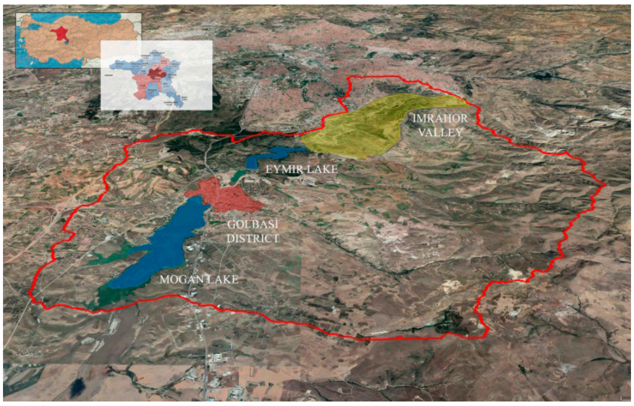

Figure 1 Study area (image retrieved from Google Earth Pro®)

These two shallow lakes interconnected hydrologically with a flow from South (Mogan Lake) to North (Eymir Lake) in the close vicinity of Ankara cover a total of 245 km^2 of the total 971.4 km^2 watershed (Karakoç, Ünlü and Katırcıoğlu, 2003). Gölbaşı Watershed is a river basin that has been subjected to rupture at a depth of 200–250 m in the Quaternary under the effect of the stream processes provided by the İmrahor Stream and its tributaries. Mogan and Eymir Lakes, and the reedfields and mud flats around them; were formed by the accumulation of colluvial materials carried by the side streams on the main valley floor (Kalkan et al., 1992).

The area covering Mogan and Eymir lakes was declared as "Specially Environmental Protection Area" in 1990 (ÇŞB, 2020a). Mogan Lake Key Biodiversity Area (KBA) consists of Mogan and Eymir Lakes and is an important breeding, nesting and wintering areas for herons, predators and duck species. There is a lesser kestrel (*Falco naumanni*) overnight area of approximately 200–300 individuals. The number of white-headed duck (*Oxyura leucocepahala*) – classified as 'endangered' in the IUCN Red List of Threatened Species (Gürsoy Ergen, 2019) – has decreased due to reed harvesting and construction activities around Mogan Lake (Kılıç and Kıraç, 2006). Mogan Lake is one of 122 Important Plant Areas (IPA) in Turkey. *Centaurea tchihatcheffi* Fisch.

and Mey. – critically endangered plant species – grows only on limited scale in the vicinity of Ankara-Gölbaşı-Mogan-Eymir Lakes, at a distance of 20 km from Ankara (Okay and Demir, 2010). Tarıkahya Hacıoğlu, Erik and Mutlu (2011) studied Ankara urban flora and indicated a total of 2,389 taxa and endemism rate of 15%. The city, located in the Irano-Turanian phytogeographical region, is greatly influenced naturally by the steppe flora surrounding it. 48% of the total number of taxa, that is a half, are also found in the urban area. The rate of plant taxa specific to the city is 6% and this indicates the existence of untouched microclimate areas in the city. A research conducted by Altınözlü and Vural (2000), shows that 30 of the 387 taxa detected in the Imrahor Valley are endemic and the endemism rate is 8.8%. Besides its floristic richness, the valley has exceptional other assets such as habitat for species, migration corridor and has unique features in terms of geomorphological properties.

The prevailing wind direction is northeast and north in Ankara. The circulation channels of the winds into and from the city are formed by the valley systems (ABB, 2017). In this context, of the Imrahor Valley, its location and the direction of its slopes support the air flow inside and outside the city. Thus, the valley has the feature of being an air corridor which is of great importance for Ankara in terms of air pollution and climate stabilization (Buğra, 2006).

The carbon sequestration amount of the Imrahor Valley is higher than the city center due to the still untouched steppe cover and it has a very high value in terms of habitat provision ecosystem service (ES). Besides these ESs, the Imrahor valley has very high values in terms of local climate regulation, air cleaning, flood prevention, carbon capture and habitat provision ecosystem services to make the city resilient (Çağlayan Demirbaş et al., 2020).

In the spatial plans for Ankara until 2013, the dominant approach has been to preserve the natural character of all valleys in the city and its periphery, perceive the valleys as a part of the green belt and wind corridors as well as to create new green areas by protecting the stream beds and water

Figure 2 Güneypark urban development and transformation project at the upper part of the Imrahor Valley (2014)
Photo: retrieved from ABB (2006) website

Figure 3 The constructions rising on the valley floor, slopes and upper parts of the valley destroy all ecological functions of the valley in the form of concrete walls (2019)

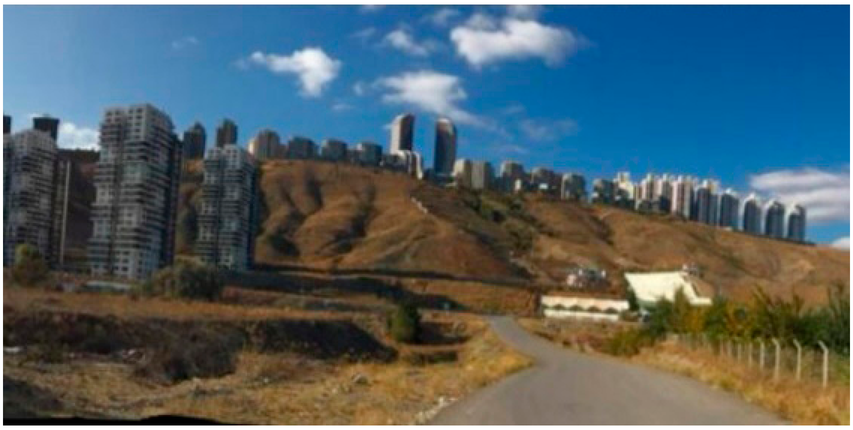

Figure 4 The unique geomorphological structure of the valley is destroyed resulting in small valleys that feed the Imrahor stream losing their functions. At the same time, the air corridor function of the valley is damaged

The latest construction in the valley is the first phase of the Imrahor Valley Millet Bahçesi – national garden in Turkish – a project carried out by the Housing Development Administration (TOKI). The project includes recreation facilities, city gardens, ponds, sports fields, cafeterias, social facilities and a museum (Sınacı Özfındık, 2019). "Millet Bahçeleri" are built to meet the public's needs for recreation, active life and socialization, to be symbolic green areas of the cities in which it is located and to be used as disaster gathering areas when necessary (ÇŞB, 2020b). However, because they are not designed to increase green areas, the expectation of rent comes to the forefront, they include functions out of purpose, the local is ignored and participation is not included (Duru, 2020), they are far from providing the expected ecologic and social benefits. High density construction by creating a 'new' but a 'concrete' landscape in an upper part of the valley without any traces of either natural vegetation, natural terrain characteristic or natural drainage pattern has resulted in the change of the terrain's whole ecological processes and characteristics. The topography is irreversibly degraded, the surface soil is scraped off, and more importantly, the waterways – consisting of small valleys – that led the runoff to the valley floor are destroyed (Figs 2, 3 and 4).

As the initial step we applied Drivers, Pressures, States, Impacts, Responses (DPSIR) to determine the main driving force that changes and transforms the valley landscape and see the current state of the landscape. This will guide our approaches of how we want the landscape to be shaped in the future regarding to the interrelation with the metropolitan city.

GI components were determined using the European Environment Agency (EEA, 2011) and Pedrazzini (2017) as a three-tier spatial approach: the province; the city with the central districts; and the basin containing Lake Mogan-Eymir Lake-Imrahor Valley (Table 1).

For the first two scales, green-blue-gray infrastructure components were determined by using CORINE 2018 data and Google Earth Pro© image (Fig. 5 and Fig. 6).

In order to better understand the distinctive aspects of the Imrahor Valley and its dense transformation in a short

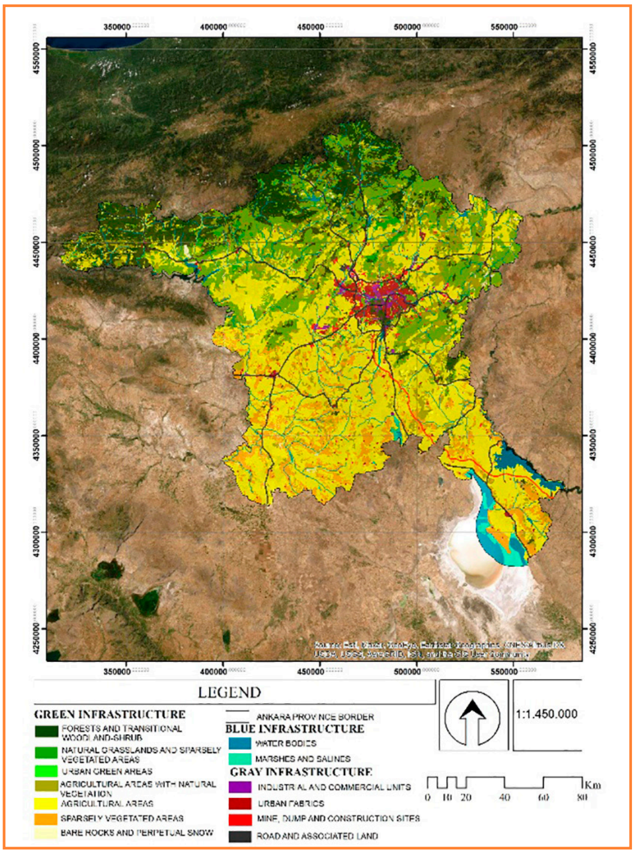

Figure 5 GI components for Ankara province

Table 1 Components of the green infrastructure system at three different scales

Scale / Components	Provincial	Central district	Imrahor Valley and its surroundings scale
	– sparsely vegetated areas	– sparsely vegetated areas	– sparsely vegetated areas
	– natural grasslands and sparsely vegetated areas	– forests	– densely vegetated areas
	– forests and transitional woodland-shrub	– recreational areas	– woodlands
	– agricultural areas	– urban green spaces	– opend lands
	– urban green spaces	– agricultural areas with natural vegetation	– cemeteries and religious bulding gardens
	– bare rock	– agricultural areas	– pocket parks
	– water bodies	– streams	– institutional gardens
	– marshes and salines	– marshes	– school gardens
		– water bodies (lakes, ponds and dams)	– playgrounds
			– lakes
			– marshes
			– streams

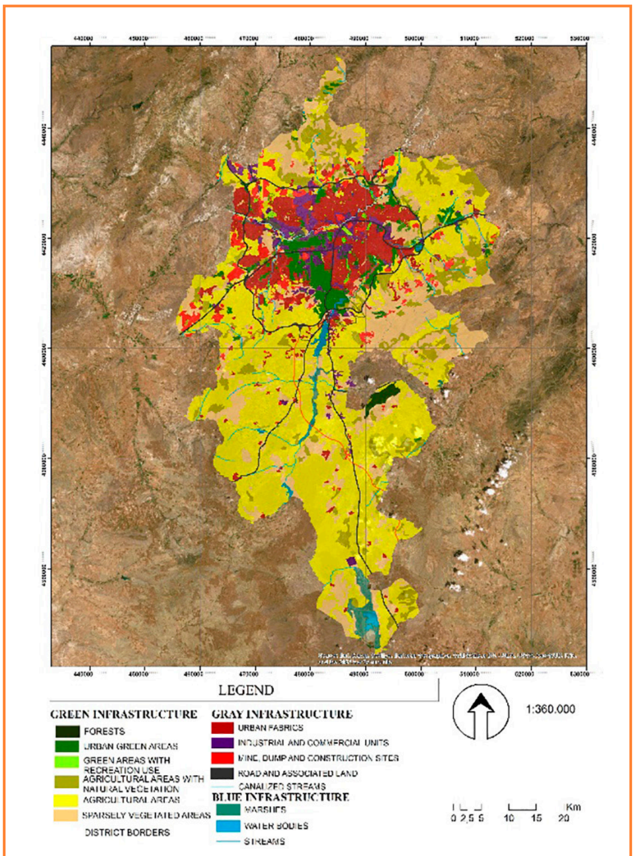

Figure 6 GI components for the central district level

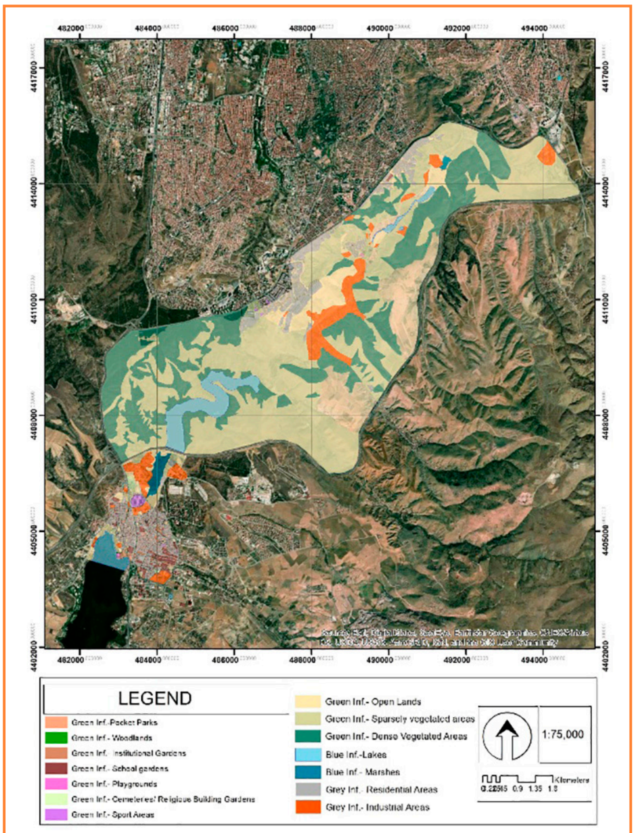

Figure 7 GI components in the Imrahor Valley

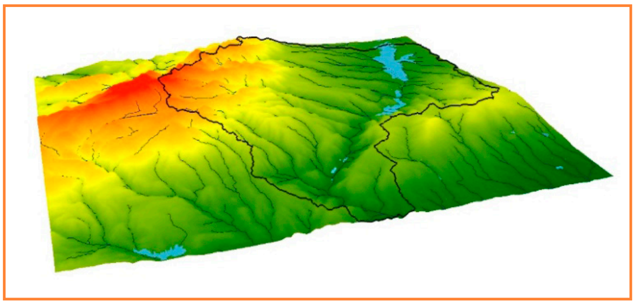

Figure 8 Watershed boundary Mogan – Eymir Lakes and the Imrahor Valley

time vertically and horizontally, GI components were determined in the Imrahor Valley as the last scale using Google Earth Pro© (2020) image (Fig. 7).

In order to read the different aspects of the relationship between the Imrahor Valley and Ankara city in terms of green infrastructure, a watershed boundary covering Mogan-Eymir Lakes and Imrador Valley, hydrologically dependent on each other, was determined by using the 1 : 25,000 scale geomorphology map (Erol et al., 1980), ArcScene 3D topography map and DEM data (Fig. 8).

Change analyses were made within this watershed boundary using presence of surface waters, geomorphologic structure and land cover parameters. A score scale between 2 and -2 was used when looking at the change in each analysis (0 – excluded).

Permeability, permanent streams and seasonal streams feeding them were used for analysing the surface water change. Zoning was carried out by examining the expansion, shrinkage, deviation, untraceability and transformation of surface waters into impermeable surfaces between 2003 and 2020.

Using the 2006–2018 CORINE land cover data, the change in green infrastructure components was discussed in terms of the transformation of permeable surfaces into impermeable surfaces. The analysis of the geomorphological structure change was made using the geomorphological units, CORINE data and the land sections taken on Google Earth Pro 2004–2020 showing the location of the urban transformation project areas initiated since 2005.

These three layers are overlapped to understand the change in green infrastructure. As a result, they are characterized as areas where green infrastructure maintains its current status, green infrastructure is supported, green infrastructure is weakened and green infrastructure has transformed into gray infrastructure.

Results and discussion

The urban transformation-oriented economic development model that affects the whole country (Şahin, 2015) is the main driving force that causes the transformation of the Imrahor Valley landscape (Fig. 9). Consequently, the area is under dense construction pressure. On the other hand, constructing a concrete canal by taking the Imrahor Stream underground is another important source of pressure. Ignoring the fact that the Imrahor stream and its tributaries are the main 'landscape-pattern-maker' of today's Gölbaşı

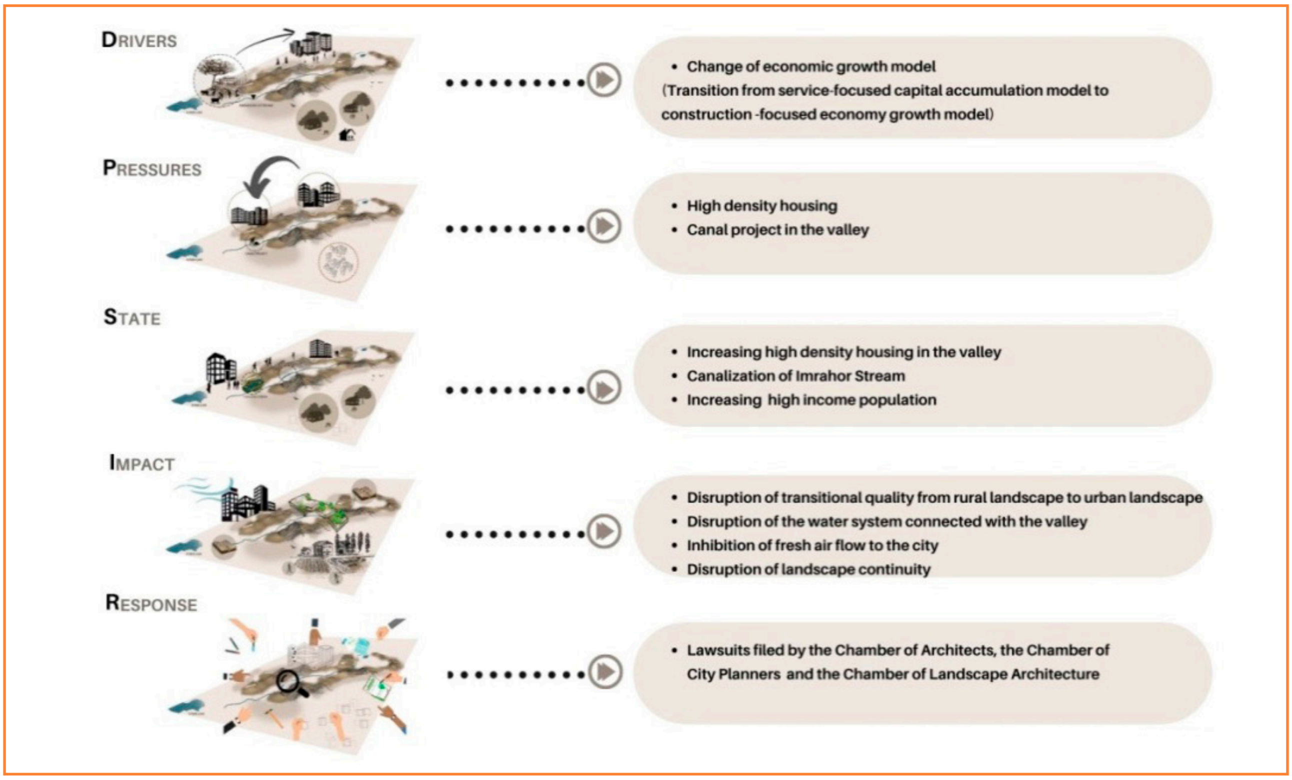

Figure 9 Drivers-Pressures-State-Impacts-Responses (DPSIR)
Source: authors. Illustrator: Inci Saray

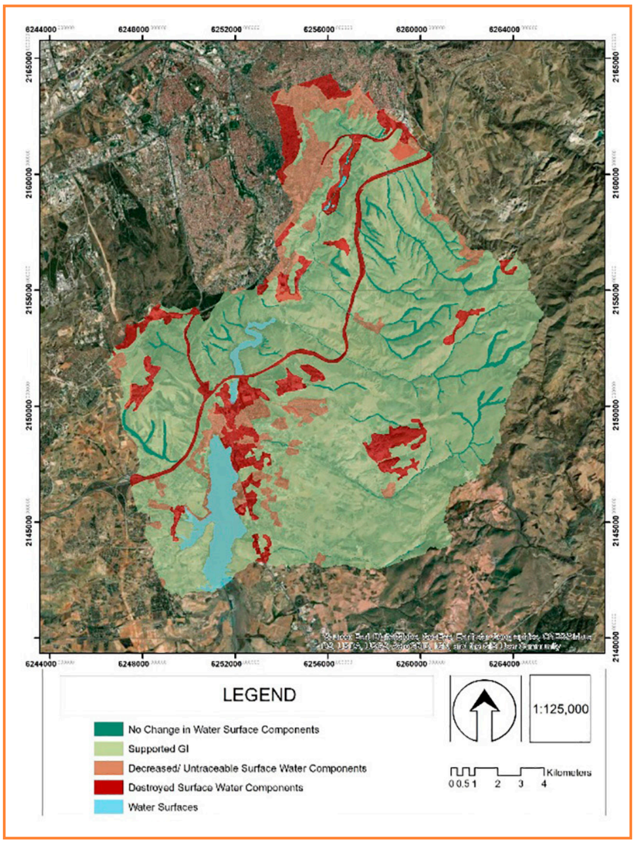

Figure 10 Transformation in surface waters

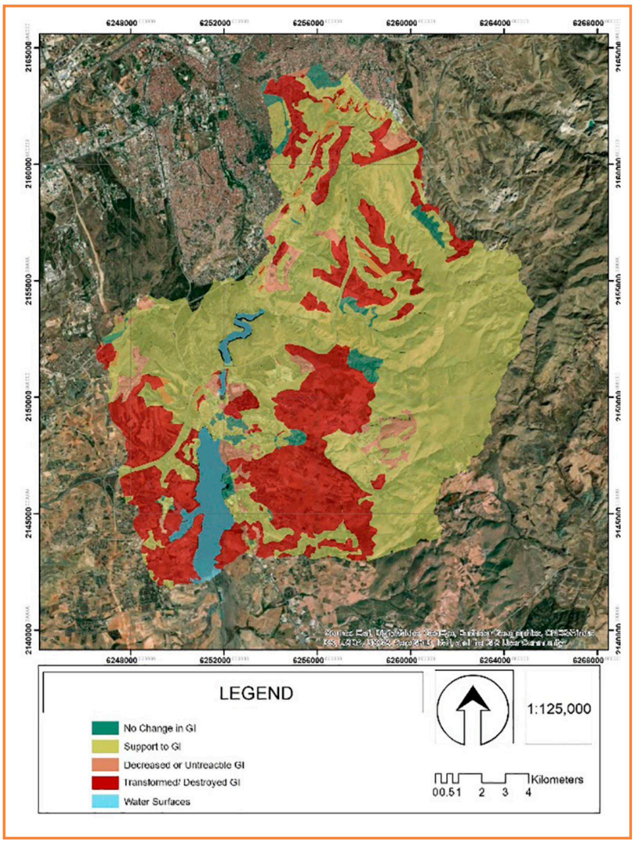

Figure 11 Land cover change in Mogan Lake-Eymir Lake-Imrahor Valley watershed

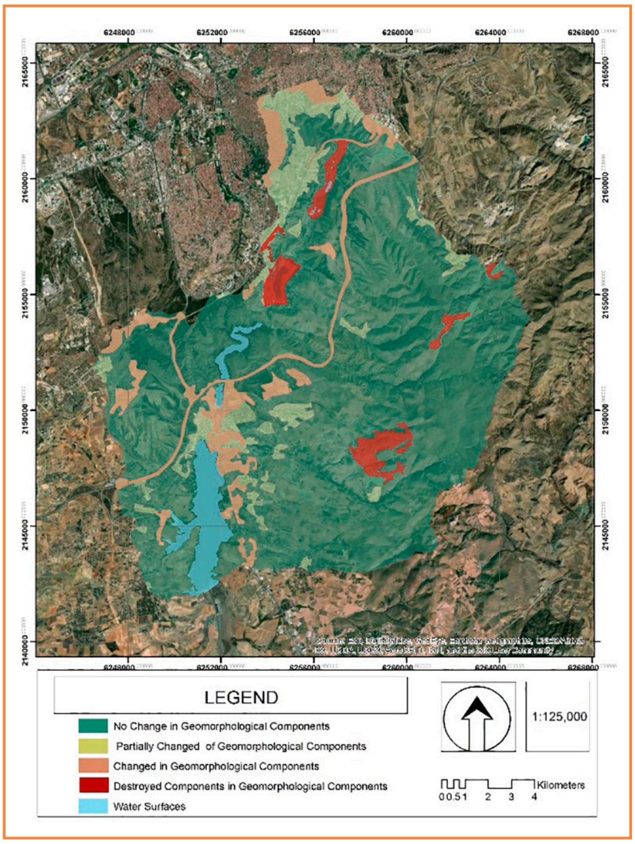

Figure 12 Geomorphological components change in Mogan Lake-Eymir Lake-Imrahor Valley watershed

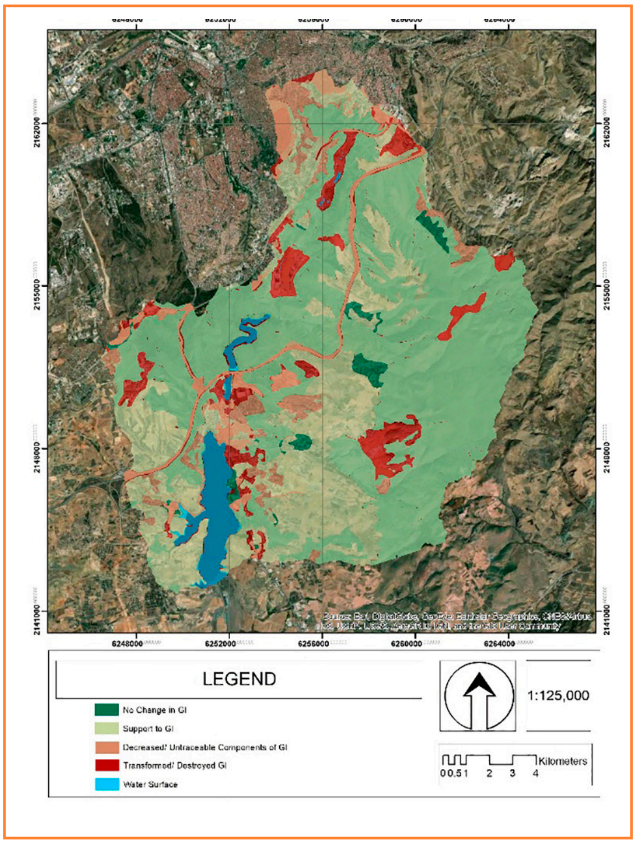

Figure 13 GI transformation in Mogan Lake-Eymir Lake-Imrahor Valley watershed

basin (MTA, 1992) creates irreversible effects on hydrological system and breaks the landscape continuity.

The effects created by the main driving force have been tried to be understood with the observed changes in surface waters, land cover and geomorphological structure.

The main reasons of surface water change within the watershed (Fig. 10) were identified as road fragmentation, loss of surface water due to urban transformation and canal projects. The eastern part of the watershed generally preserves its hydrological structure. Gölbaşı settlement between Mogan and Eymir Lakes has expanded further over the years. However, the biggest change in vertical and horizontal perspective has occurred in the Imrahor Valley. The construction projects initiated at the base of the valley and towards the slopes completely changed the land morphology. The surface runoff collection areas on the east facing slopes of the valley have been replaced by high density settlements and impermeable surfaces. The degradation of the hydrological network within the basin boundaries will also disrupt the flood prevention function of the Imrahor Valley. However, considering the research results of EEA (2019), which reveal that floods will increase due to local precipitation in small basins and one of the critical problems of the city of Ankara, it is once again revealed that the Imrahor Valley should be handled in hydrological integrity.

According to the analysis of change in land cover (Fig. 11), the recreational potential of Lake Mogan has triggered the development around the lake, the increase in grey infrastructure and the transformation of the rural texture towards the urban fabric. This situation has caused green infrastructure components to transform, change or disappear. Similarly, the green infrastructure components of the Imrahor Valley have also decreased or disappeared.

According to the analysis of the geomorphological structure change (Fig. 12), the most intense change in the basin occurred in the east-facing slopes and valley floor of the Imrahor Valley, then in the mining areas to the north of the basin and around Lake Mogan. Changes in the valley will increase the risk of landslides on the east-facing slopes of the valley, adversely affect the clean air supply function of it, and increase the likelihood of flooding due to changes in surface flow directions.

Overlapping of these three layers shows that while the areas where green infrastructure is not changed are located predominantly at the southeast and east part of the basin; the areas completely disturbed are located at the north of the basin, around Lake Mogan and the north eastern part of the basin (Fig. 13). The areas where green infrastructure is not changed indicate the existence of rural areas around the city.

Conclusion

Urban areas are currently facing severe challenges including not only shortages of water, more frequent and severe floods, storms, heat waves, demographic and social changes associated with urbanization and management, but also smart management tools for transition to a more sustainable future (Secretariat of the Convention on Biological Diversity, 2012).

When the Covid-19 pandemic began, scientists stated that the main cause of it was the extermination of barriers between humans and animals that must be protected so that both sides can live in healthy conditions. Similarly, it should be understood that the barriers that exist between urban and rural areas and human beings, which are necessary for the healthy living of all parties, should not be ignored. Only in this way, urban and rural areas become more resilient and safe for all kind of livings.

These indicate the need for comprehensive, integrated, and multi-scale approach which should go beyond imitating nature inside the city. Considering the globally threatening challenges, green infrastructure gains importance as a necessary mechanism in ensuring this kind of approach.

Through a comprehensive green infrastructure approach that understands and describes all components and aspects of natural-rural-urban processes, the challenges that intensive urbanization will bring to the city and the rural can be dealt with.

As stated in EEA (2014), ecosystem multifunctionality and biodiversity conservation and functional connectivity need to be included in all kinds of spatial plans. All plans should illustrate the fragility and be respectful to ecological borders and limits of the ecologic systems of the Valley. Since the Imrahor Valley is connected with two important wetland habitats, GI integrity should be ensured by considering the relationship between core habitats and migration corridors in urban, semi-urban and natural areas. Continuity should be taken as a basis in terms of landscape integrity covering primarily hydrological and geomorphological patterns. In this context, the most urgent step should be to restore the stream starting from the outlet of Mogan Lake to the end of the Imrahor Valley in a way that it will fulfil its multiple functions. Here, it is vital to allow the natural flow of water and remove the concrete surfaces that cover the valley floor. In order to adapt to the natural process, the support of natural wetland plants should be provided at the riparian zone.

Another urgent step is to restore the damaged east facing slopes in order to gain their natural functions. Small rain/runoff collection areas should be created on the eastern slopes of the valley at different heights supporting each other. Thus, the healthy relationship between the stream and runoff waters should be re-established. *Astralagus* sp., *Amygdalus orientalis*, *Cotoneaster* sp, *Creatagus* sp., *Rosa canina*, *Tamarix* sp. (Akaydın and Erik, 2002) found in the flora of Ankara are prominent species of steppe vegetation and can be used primarily to repair damaged areas. The west-facing slopes are the least affected part of the valley and preserve its rural character. The large grasslands in this part should be protected as they are important components of GI, and introducing the scattered woody vegetation including natural species in these areas is needed.

The dramatic effects of urban transformation, which leads the main multiple functions of the natural system into a single function, can be neutralized with the green infrastructure process. Increasing food security and generating income for fragile urban households is possible by protecting agriculture in the urban and surrounding areas, which is one of the main components of GI. The damages caused by urban transformation projects to the distinctive characteristics of the peri-urban areas can be rehabilitated with green infrastructure approaches. The Imrahor Valley should be taken into consideration as 'avoidance zones' in the spatial plans for illustrating the fragility and vulnerability of the urban-rural relationships in terms of creating a resilient city.

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Acta Horticulturae et Regiotecturae 2
Nitra, Slovaca Universitas Agriculturae Nitriae, 2020, pp. 96–100

GREENING NYANGA: DEVELOPING A COMMUNITY PARK IN A COMPLEX URBAN ENVIRONMENT IN CAPE TOWN, SOUTH AFRICA

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Green, recreational spaces are lacking in most low-income urban areas of Cape Town, South Africa. Public open spaces that do exist are often considered nuisance plots, as they attract anti-social behaviour. Thus, there is a dire need to create green, recreational spaces in such areas to provide the benefits of parks to the community members who live there. Nuisance plots are unsafe and should be developed into safe, convivial, and beautiful spaces for local communities to utilise. Using the development of a community park in the Cape Town township of Nyanga as a case study, this paper demonstrates the communality and contestations involved in the planning and implementation of green infrastructure in an urban landscape marred by socioeconomic inequalities. Sourcing data from nine months of ethnographic fieldwork, this paper aims to i) show the importance of inclusive planning and decision-making through participation of all stakeholders in urban design and spatial planning projects; ii) to highlight the complexities and social contestations of such projects, and the need to consider the social relations of an area during the planning and implementation phases; and iii) to emphasise the importance of incorporating sense of place and belonging in design and planning decisions.

Keywords: community park, inclusive governance, green infrastructure, socioeconomic inequality, place-making

The inequitable patterns of and access to green spaces within many cities are concerning in the sustainability debate. Recently, Venter et al. (2020) argue that studies from different world regions have shown that lower income urban residential areas are more likely to have the least access to green infrastructure in the form of green spaces or street trees. In particular, cities in the global South are commonly faced with challenges associated with natural resource threats, the inequitable distribution of wealth, informality, and poor infrastructure (Parnell and Robinson, 2012). Such challenges are attuned to rapid urbanisation happening in Southern cities. Parnell and Walawege (2011) argue that Africa's rapidly expanding urban areas are likely to experience the biggest impact of global environmental change over the next thirty to fifty years because of population growth and weak capacity and infrastructure of nation-states to manage urbanisation and environmental change in cities. More specifically, in Cape Town, the complex intersections between urban history and planning legacies (colonial segregation followed by apartheid), socio-cultural diversities, and socio-spatial differences in vulnerability, resilience, and coping capacity to environmental change will massively impact its poor and marginalised citizens (UN-Habitat, 2014).

A city renowned for its natural assets and cultural diversity, Cape Town is often referred to as 'Africa's most liveable city' (UN-Habitat, 2014), but is also widely known to be one of the most unequal cities in the world. Cape Town's inequality is felt across an array of areas, including social (for example, access to water, Wilson and Pereira, 2012), spatial (including perpetuation of the apartheid city layout and its consequences, McFarlane, 2018), institutional (in terms of constraints in which participatory governance is designed and implemented, Lemanski, 2017), economic (for example, high poverty and unemployment levels, Brown-Luthango, Reyes and Gubevu, 2017) and environmental (regarding environmentally degraded spaces, for example, Arendse and Patel, 2014). The city is grappling with the challenge of how to prioritize pressing development needs and challenges with making choices that ensure medium and long-term sustainability (UN-Habitat, 2014).

Cape Town's urban periphery and the city itself today are like the two oceans surrounding Cape Town's coastline: they converge but do not meet. They portray a dichotomous image, where green spaces on the periphery are still poorly maintained compared to those in the city and suburbs. In many township areas, such as Nyanga, formal recreational and green spaces are rare, poorly maintained, and often avoided for fear of crime (Cocks et al., 2016). A seemingly low appreciation of green spaces is reflected in the general impression of Nyanga as a result of cuts in the municipality's maintenance budgets of these urban regions, for example (Chiesura, 2004).

Nyanga is located within the Cape Flats (see Fig. 1), which connects the False Bay coastline to the townships, and is characterised by a sandy landscape of sparsely vegetated dunes, the severe south-easterly winds (predominantly in summer), and periodic flooding (predominantly in winter)

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Figure 1 Map showing the location of Nyanga within the context of the city of Cape Town and South Africa

(Awotona, Japha and Prinsloo, 1995). Nyanga is the second oldest black African township in Cape Town after Langa. This formerly racially-segregated neighbourhood was established in 1946 (Fast, 1995) as a result of addressing the overcrowded conditions in Langa, caused by the influx of (mainly) black African men who came to Cape Town to find employment (Field, 2007). Despite the socio-economic challenges in Nyanga, such as unemployment and crime, that portray impressions of a neglected township, local residents and community organisations are "spreading the story of how the forgotten structure could manifest a new kind of beauty" (Aalto and Ernstson, 2016). Everyday sustainability is manifest and portrayed in various activities that enliven the landscape with gardens, community parks, and the hustle and bustle of informal trading. In this paper, the development of a community park is used as a case study to show how an urban green infrastructure (GI) project was established through collaboration between the local municipality, a local non-governmental organisation (NGO), and the local community. The GI project was identified during the fieldwork phase of my PhD, when I was able to engage with all stakeholders in the planning and implementation phases of the project. The methodology of the ways in which this research was conducted will be discussed next.

Material and method

Ethnography was used in this study to understand the ways of life of the local people of Nyanga in the context of their everyday, lived experiences during the development of the community park. Ethnographic data were gathered using the following methods: participation and observation, by spending time in Nyanga, walking around the area, and taking part in community activities, including community meetings; taking photographs; conducting 20 semi-structured interviews and an estimated 40 to 50 conversational encounters; and keeping a personal diary to record each day's encounters. Participants in the study were selected based on their engagement with the development of the community park. Most of the participants from the local community were not employed, either because of retirement or because of not finding work, and the ages of the participants ranged broadly between 24 and 65 years.

The community-driven NGO involved in the project, called Etafeni, encompassed a multitude of programmes that focused on prominent development issues in Nyanga, including greening projects. The Greening Nyanga Programme's projects encouraged community members to keep the environment clean and green, plant trees, and establish home vegetable gardens. Its main objective was to transform nuisance plots (a term used by Etafeni's Greening Nyanga Programme) into beautiful, convivial, and safe spaces for the community to enjoy. My observation and participation at Etafeni included attending regular management meetings and team-building events, and the community meetings that revolved around the development of the community park. Upon my arrival at Etafeni, a plot had already been identified as being the next park to develop (see Figs. 2 and 3 showing the before and after pictures of the plot). I was able to participate in the design of the park with the community and Etafeni, and assist in the procurement of the resources to go into the park. I observed the conflict that arose between community members and the fence company that erected the fence around the plot, and then I observed the resolution of the conflict at a street committee meeting. Both these important events will be discussed in the next section of this paper.

Results and deiscussion

The community park that was initiated by Etafeni in partnership with the surrounding local community and the local municipality that owned the land ultimately demonstrated the potential to blend space, people, nature, memory, and imagination. It was implemented as a result of a socio-ecological design process in response to current urban social and environmental challenges in the township. The environmental transformation of the park resonated with Gandy's (2006) idea of New Urbanism, which was influenced by sustainability and nature-based formations in urban design processes. His notion of urban design being an extension of beauty in nature by being reflected in "the geometric arrangement of space or the embellishment of urban life through gardens" (Gandy, 2006).

Figure 2 and **Figure 3** Before (April 2016) and after (September 2017) images of the park

At one of the monthly community meetings I was introduced to the committee members, who allowed me to sit in on the meeting. The agenda included the project to build a community park in the section of road opposite Etafeni. It was at this moment that I realised that there were different communities within Nyanga. Portrayed as a socially divided and dichotomous township, gang violence and violent crime made this particular area one of the most dangerous areas of the township, yet it was an area where communities played an active role in managing it. This particular part of Nyanga in the vicinity of Etafeni consisted of various street committees. Performing as a type of governance structure, they met regularly on behalf of all residents living in the individual streets to discuss neighbourhood concerns. Decisions were made by the committee and relayed to the Ward Councillor of Nyanga to formally address and implement them at a Municipal level. These meetings were important for the communities as platforms for community members to voice their opinions and ideas.

The development of the park was a multi-stakeholder project, but the needs of the community were at the forefront of the design and implementation processes. Across the road from Etafeni, a derelict piece of land that was usually used for anti-social behaviour, such as illegal dumping of waste and gatherings for criminal activities, was identified by all parties (Municipal officials, Etafeni, and the local Street Committee) as the space for the new park to accommodate the elderly in the area. The plan was, thus, to recover and revitalise the land for the new park and design it according to the needs of the elderly. A partnership agreement was finalised by the parties, and the fundraising process by Etafeni began. The Municipal officials said upfront that their budget could only provide plants and trees. The first and most important item that the Street Committee requested from Etafeni was a palisade fence. Crime in the area dictated that a fence be erected to protect the various components that would make up the park, on which I will elaborate shortly.

During the erection of the fence by an external company, conflict arose from local community members. The community was adamant that it should be involved in the work generated by the erection of the fence, rather than employees from an external to the neighbourhood company. The scale of this contestation was aligned to sense of place attachment and place meaning. According to Kil, Holland and Stein (2014), empirical research suggests that place attachment and meanings influence environmental concerns such as the acceptability of recreation settings (over housing developments, for example), which was indicative of this community park project. This community had come to an agreement to develop the space into a community park, and therefore, had shown interest and attachment to the imagined space. In addition, the high rate of unemployment in Nyanga placed some people in a position to seize upon work opportunities when they arose. Community members saw that outsiders (employees of the fence company) were making money from the green space, a place that they were protecting and uplifting for the sake of their community. Thus, the meaning behind the erection of the fence extended beyond place protection, but also an opportunity for temporary employment.

Moreover, such place-protective behaviour represented social exclusion and was symbolised by the fence. The fence was not only represented as a physical barrier to unwanted people, but also an emotional one. It evoked hostile emotions on the day that it was supposed to be erected. It was also a significant feature in the planning phase of the project, where the Street Committee requested that it be placed around the park. The concern of criminal activity and undesirable people in the park by the committee meant that it became a feature that was impossible to ignore. The practices of everyday life that were place-protective in the form of erecting a fence, for example, demonstrated adaptiveness and inventiveness in planning and transforming current situations, such as criminal activity. In this case, erecting the fence meant a safer space that people could use and perform other practices, such as socialising and playing, and one of opportunity for employment.

At this juncture in the development process I was awakened to the idea that this park was for the community, by the community. The tension alleviated through engagements between the stakeholders and the assurance that the community would be involved in all processes of


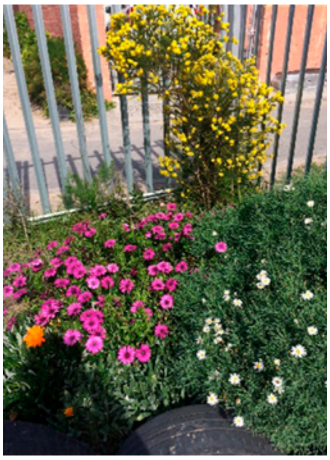


Figure 4, Figure 5 and **Figure 6** Flowers in bloom and the labyrinth

the development of the space going forward. I learnt that one of the community members, Whitey (male, late 30s), guarded the fence overnight for fear that parts of the half-built fence would be stolen. He expressed:

"The people who steal are on Tik (a local version of methamphetamine) and don't care about the park. They and their children will use it, but they will steal from it. They don't understand the importance of it."

Whitey demonstrated the community commitment to a common cause in Nyanga of building a place that would become meaningful to the people living in the area. In addition to the emotional connection to a place, increased knowledge about a place increased the likelihood that individuals would demonstrate place-protective behaviours (Halpenny, 2010). Thus, residents with higher levels of neighbourhood attachment were more likely to fight against attempts to negatively change the social and physical nature of their neighbourhood.

The duration of the work done to complete the park spanned a period of 18 months. During this time, noteworthy interactions emerged. The commitment of a community member (male, early 50s) working in the park during the planting phase culminated with his commitment to planting a garden at his home. He explained to me that he learnt so much from working in the park and wished to replicate the practice at home. Similarly, a female (early 40s) community member walking past the park echoed the desire to make a garden of her own at home. As the plants started to flower (see Figs. 4 and 5), more community members showed an interest in the park. A male individual (early 40s) visited the park one day to specifically ask about the name of a ground covering plant that had pink flowers. He explained that he wished to buy such plants to grow in his own garden. The characteristics of practice, such as desire and imagination, and knowledge and meaning, were evident in these examples of interactions with community members and culminated in the practice of gardening in other contexts.

A design feature of the park that Etafeni introduced to the community to add to the calming nature of the park using hard forms of landscaping with pebbles and recycled bricks was the labyrinth, which piqued a lot of interest, where some people knew how to walk it and others didn't (see Fig. 6 for the image of the labyrinth). I realised that it may be because the bricks hadn't been laid correctly, and caused dead ends in certain places. I saw this as a unique characteristic of the park that was symbolic of Nyanga, where people would come across dead ends in their lives, but would continue to persevere in life, sometimes on different trajectories, with commitment and support from others.

However, commitment towards completing the park at times was absent. Interestingly, all stakeholders played a role in this lack of commitment. At times members of the community who agreed to work in the park failed to arrive. Over time it seemed that the interest in the park by the Street Committee faded. At a Street Committee meeting I was told that people had other concerns to deal with, such as leaking roofs that needed attention after a storm. An elderly male individual suggested that the community was "in denial" and that people "lack motivation to want to improve their lives." He blamed the rampant use of drugs in the area for making it unsafe and explained, "People in the area are robbing their own facilities and resources from their own people." I was also told that some people see parks as crime hotspots, so people don't like them. The ambiguity and tension of place-making was evident in this encounter where the space of the park was one that represented belonging and alienation, intimacy and violence, and desire and fear.

On a different note, the park was seen as a meeting place for people to initiate positive interventions. Where once community events and ceremonies, such as funerals, had no physical home, the park became one of civic and community importance. When the park was viewed as an extension of home, as a place of sanctuary, the fence, then, became a structure that was used to secure the park from potential criminal activity for the women and elderly who might feel vulnerable using it. Viewed by some as a safe and beautiful space, the park became a landmark as a meeting point for social gatherings. Enabling a sense of place and identity that facilitated positive place-making and the celebration of important social activities, saw the original social tensions subside. Thus, the park was not only an environmental asset that provided a home to various species of fauna and flora, but the park was also an important social and homely feature in the turbulent township setting.

Conclusions

The urban green infrastructure project implemented by Etafeni showed that such projects connect people to nature, people to people, and also people to urban places. However, such communality was not without the social contestations that come with everyday life. This study has shown that people's choices to use a community park, or not, are influenced by their fear of crime, which, in this case, influenced the way in which the park was designed. Thus, people are seen and heard to be entangled in the ambiguity of their relationships with their communities. Although parks are developed in township areas, such as Nyanga, to address the environmental and social injustices of the past and the present, crime dictates the way parks are designed, which in turn, produces social exclusion. Therefore, in Nyanga, parks provide for social interaction and cohesion, but they are also fenced off to undesirable people.

This case study demonstrates that the complex nature of social relations, and how they are produced and modified by processes of change, such as in times of unemployment and crime, matter in the way people view the environment. It highlights the intricate relationship between the GI approach of creating socio-ecological connectedness and justice, and the reality of everyday challenges. The complexity of everyday urban issues means that the messiness of the socioeconomic and environmental challenges that characterise Nyanga, require different forms of expertise and knowledge that are contributed and influenced by different disciplines, temporalities, participants, and communities. Ultimately, this research highlights the importance of inclusive planning, decision-making, and implementation of such urban design projects through participation of all stakeholders because of the context specific complexities and social contestations associated with Nyanga. Furthermore, it provides evidence that place-making and sense of belonging are crucial components to the thinking behind urban green infrastructure and the implementation of such projects in order to attain permanent, or at least long-lasting, results in the transformation to sustainable urban communities.

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Acta Horticulturae et Regiotecturae 2
Nitra, Slovaca Universitas Agriculturae Nitriae, 2020, pp. 101–107

IMPROVING COMMUNITY HEALTH AND WELLBEING THROUGH MULTI-FUNCTIONAL GREEN INFRASTRUCTURE IN CITIES UNDERGOING DENSIFICATION

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Evidence shows that maintaining a relationship with nature is essential for human health and wellbeing. This is of great importance when migration to urban areas is increasing globally and the need for nature as well as green and blue spaces as a source of recreation and relaxation is highly regarded for the health and wellbeing of local communities. Sustainable urban development and alternative design solutions to address urban compactness and densification are becoming increasingly important tools to counteract the adverse effects of urban sprawl. In the context of the highly compact bicultural capital city of Wellington, Aotearoa-New Zealand, this paper examines the effects of urban densification and compact city development in urban green spaces. It explores how architecture and landscape architecture can transform urban environments into desirable places to live and capitalise on the potentials of interstitial spaces, outdated zoning and changing land-use. To achieve that, it looks at green and blue infrastructure design solutions and opportunities that foster sustainable intensification and by offering new views for health and wellbeing that improve the social, cultural and environmental health of the city.

Keywords: green and blue infrastructure, compact cities, culture, health and wellbeing

With the number of urban dwellers expected to rise from 54 to 69% by 2050, or 6.3 billion people (United Nations, 2018), the pressure in urban areas and populations is increasingly critical. Individual and community ill-health and loss of wellbeing of city residents is escalating with rapid urbanisation. Forecast increases in urban population are similar both globally and locally in Wellington, Aotearoa-New Zealand. The next 30 years will see a 10–15% increase (United Nations, 2018) in people living in cities around the world and in Wellington, the city's population is projected to increase by approximately 20–36% over the next thirty years (Wellington City Council, 2020).

As places become more urbanised, the compact urban forms compete with green space. Urban green spaces are generally characterised by small, isolated, or unevenly distributed lots, appearing in different shapes and sizes. Intensification associated with urbanisation destroys natural landscapes and devastates rich indigenous ecologies (Kamiryo, Sakashita and Matsumoto, 2011). The juxtaposition of housing and related built infrastructure with minimal interstitial space can also pose a significant threat to biodiversity and human health.

In the face of rapid densification in urban areas, the need for multi-functional green spaces, and the associated services derived from them, is critical. These green spaces play a vital role in supporting the human-nature interaction (Kim and Coseo, 2018; Kim and Miller, 2019; Kim, Miller and Nowak, 2015), urban sustainability, environmental quality and human health and wellbeing (Kaplan, Kaplan and Ryan, 1998). Research demonstrates a positive relationship between access to nature and natural processes and human health and wellbeing (Hartig et al., 2014; Kuo, 2015; Seligman, 2002) as well as the role of nature in restoring cognitive processes in people (Kaplan and Rogers, 2003; Kaplan, Kaplan and Ryan, 1998). Biophysical attributes such as water and greenery are seen as highly restorative to our health and wellbeing and contribute to how we experience a place (Kuo, Bacaicoa and Sullivan, 1998). A strong sense of place increases place attachment and develops a stronger sense of use and care, contributing to an enhanced sense of community (Marques, McIntosh and Campays, 2018). Similarly, many studies report comparable results on the positive effects that blue spaces, such as rivers, lakes or the sea, have in the health and wellbeing of individuals both through views and sounds of water (De Vries et al., 2016; Grellier et al., 2017; Nutsford et al., 2016; Voelker and Kistemann, 2013; Wheeler et al., 2012).

However, Green Infrastructure (GI) is more than just 'greening' urban environments via creating open spaces and green corridors. Implementation of green infrastructure in urban environments provides significant social and cultural benefits by bringing together people and nature (Buizer et al., 2016). Cultural regeneration is generally associated with green infrastructure as it connects places with people through creating nurturing cities, vital custodianship and wellbeing (Menzies, Renata and Whaanga-Schollum, 2016). Healthy ecosystems hereby have the capacity to provide a comprehensive range of services (Costanza et al., 1998; Lu and Li, 2003).

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In the context of compact cities, GI is a critical framework for designers and planners to identify under-utilised interstitial spaces as opportunities to provide amenities to individuals and communities (Chanse et al., 2017; Nikologianni, Moore and Larkham, 2019). Compared with many countries internationally, Aotearoa-New Zealand is not the first to come to mind when thinking about compact cities. However, due to the rugged and steep topography, the geography of Wellington had led to a highly compact urban form (Marques et al., 2019). The city is characterised by an amphitheatre of hills that lead to the waterfront. The city's urban form has also developed by broader policies of containment and compact suburban development.

The aim of this paper is to discuss opportunities and potential consequences of the green and blue infrastructure approach in the context of the compact city with particular focus on the socio-cultural dimensions of the human-nature interaction. This paper draws from design research projects in Wellington, Aotearoa-New Zealand to examine the role of green infrastructure as a design strategy and a framework to improve community health and wellbeing in urban areas. GI provides an array of solutions that bring together natural and semi-natural areas and elements in rural and urban areas, while providing a wide range of ecosystem services and functions to cope with unforeseen challenges (Barthel et al. 2015; Elmqvist et al. 2013; Folke, 2006; Gallopín, 2006; Kim and Miller, 2019; Tóth, Halajová and Halaj, 2015; Vierikko et al., 2016). The concept of GI comprises both the quantity and the quality of urban, suburban and rural green spaces (Rudlin and Falk, 2009; Tzoulas et al. 2007), their multifaceted roles (Sandström, 2002) and the interconnectedness of habitats (Van der Ryn and Cowan, 2013). A carefully planned GI has the potential to boost urban development as it provides a coherent framework for economic growth, nature conservation and public health promotion (Schrijnen, 2000; Walmsley, 2006).

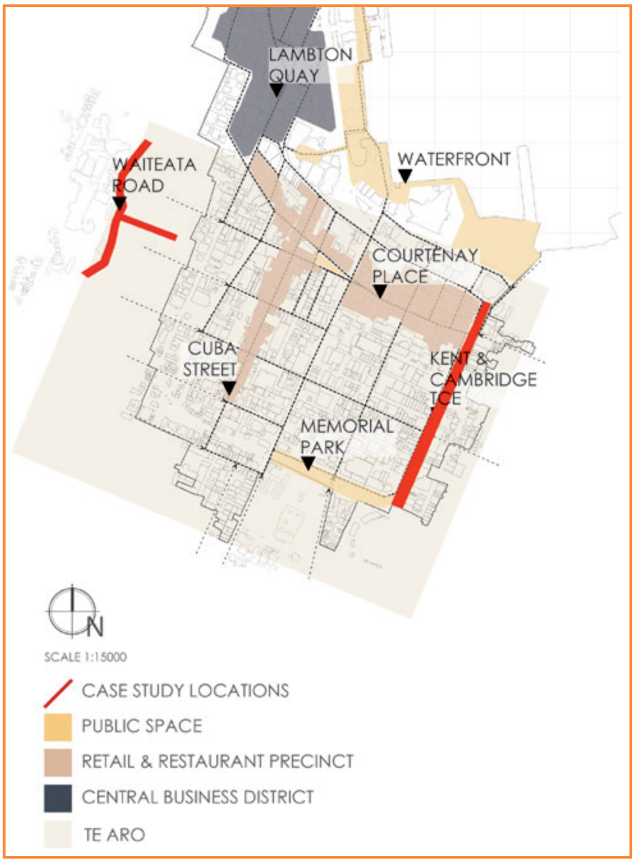

Figure 1 Map of Te Aro downtown suburb in Wellington, showing the location of Kent and Cambridge Terrace (case study 1) and Waiteata Road (case study 2)

Material and method

This paper examines two green infrastructure propositions which adopted a 'research through design' methodology, where both context and phenomenon were investigated conjointly through the positioning of theory with case studies (Lehman and Nelson, 2014). The two contrasting studies, one dealing with horizontal space in Kent and Cambridge Terrace and the other engaging with vertical green space near Waiteata Road, are both situated in the compact capital city of Wellington, Aotearoa-New Zealand, and explore the human-nature relationship as well as the socio-cultural regenerative forces within green-blue infrastructure. One study addressed the importance of green and blue infrastructure in relation to ecosystem services, while the other looks at the importance of green infrastructure in relation to human mental health and wellbeing.

Case Studies

In both studies, following literature review and case study analysis, key themes were identified as design performance criteria for improving community health and wellbeing in urban areas. The extracted super-ordinate themes were: green and blue infrastructure, ecosystem services, and human health and wellbeing.

Wellington has been defined as a compact city due to its containment by steep topography and extensive waterfront, despite its relatively low population compared with the highly urbanised compact cities internationally. Both case studies are located in the extreme ends of the central downtown suburb of Te Aro: Kent and Cambridge Terrace and Waiteata Road (Figure 1). With the increased densification of the inner city, and the subsequent increased transportation through the centre, both the existing and the potential for new or improved green infrastructure are placed in jeopardy.

Te Aro takes up the majority of Wellington's central urban area. It is filled with busy cafes, bars, restaurants, commercial and some light industrial uses as well as high and medium density housing and a few remnants of low-density housing. It has a young and dynamic demographic as it supports a large percentage of students and young professionals due to its proximity to two universities, governmental agencies and a large creative sector. As urban growth puts pressure on the inner city green space and while resources are limited, opportunities arise for landscape architecture to provide innovative nature-based solutions to balance the stress-inducing noise and growing sea of concrete and asphalt.

Green and blue infrastructure and the importance of ecosystem services: the case of Kent and Cambridge Terrace

The first case-study is situated between Cambridge and Kent Terrace, two large north-south arterial roads that run parallel to the edge of the city zone area, connecting the southern suburbs to Wellington City. These roads provide the main state highway connection to the international airport and as such are essential transport routes which have developed into fast-moving transport corridors. Increasingly, they create a substantive pedestrian barrier which has divided neighbourhoods and hindered a people-centric development of this area.

Beneath this busy urban corridor runs Waitangi Stream, which begins in Mt Cook, travels north under the Basin Reserve and finishes at Waitangi Park. Urbanisation pressures have resulted in the culverting of Waitangi Stream 5 meters below Kent and Cambridge Terrace where it collects the stormwater for the adjacent suburbs of Mount Victoria and Mount Cook as well as part of Te Aro. This stream corridor is the key to flood management and the harbour water quality in Te Aro. Yet, it has been disregarded and replaced by roading infrastructure like many other urban streams.

Much research has reported on the link between green and blue infrastructure, ecosystems health and ecosystem services (De Vries et al., 2016; Elmqvist et al., 2013; Grellier et al., 2017; Pedersen Zari and Hecht, 2020; Rapport, Costanza and McMichael, 1998). Research finds that opportunity lies in re-instating habitats and species that benefit urban biodiversity as well as contributing to human wellbeing (Tilman, Isbell and Cowles, 2014). Researchers also note the close and beneficial relationship between ecosystem health and ecosystem services, for delivering, providing, protecting and maintaining goods and benefits that derive from nature for the betterment of humans (Bolund and Hunhammar, 1999; De Groot, Wilson and Boumans, 2002). Therefore, spaces that are designed and adopt Green and Blue Infrastructure solutions can contribute to ecosystem health and public health, respectively.

The proposed approach to this site looks at the importance of green infrastructure as providing ecosystem services that enable the re-activation of urban areas, and also at the social dimensions of space as a way to reconnect communities with nature. From an analysis of the existing pedestrian and public space structure of neighbourhood and the barriers to pedestrian flow, the research re-forges the broken link down the Kent and Cambridge corridor in a way that facilitates pedestrian thoroughfare, increases public space and restores natural systems. It achieves this through raised pedestrian corridors, daylighting the stream corridor to both address urban drainage and flood management and local ecologies as well as provide a much needed new urban space for recreation and leisure. In this way, green infrastructure

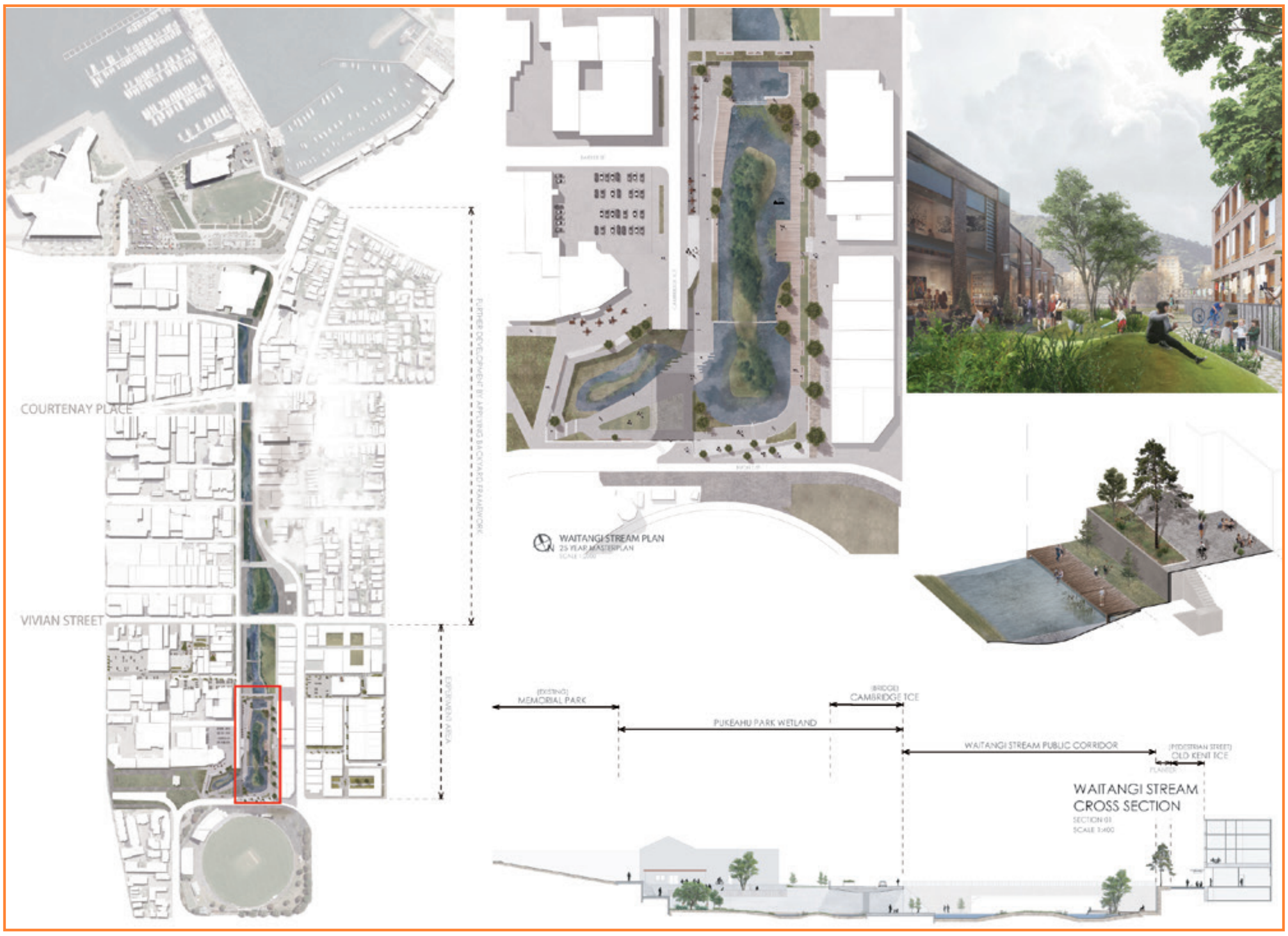

Figure 2 Design-led research exploration for Kent and Cambridge Terrace: masterplan, section, axonometric detail, and render

supports the physical, mental, emotional and socio-economic benefit to individuals and the community offering substantially increased amenity.

In this first case study, the design (Figure 2) explores opportunities for reclaiming nature for people while strengthening and renewing the natural systems. The design includes many essential ecosystem functions and services that tap into the biological, physical, aesthetic, recreational and cultural spheres of this innercity suburb. In doing so, it also reduces the dependence on purely grey infrastructure solutions, which tend to be more expensive and less sustainable if compared to nature-based solutions. In this case study, the green infrastructure solutions adopted offer an alternative to obsolete built stormwater infrastructures by lowering the costs of stormwater management as well as reducing the heat island effect, while maintaining protection from floods and drought. But perhaps most importantly, it reunites the suburb, providing a thoroughfare to enhance social interaction and a psychological and cultural refuge for users as they engage with the restored ecosystems and nature.

Green infrastructure and human health and wellbeing: the case of Waiteata Road

The second case study is situated on one of the steep hillsides that contain and densify the city core. Here the rugged topography defines the layout of the extensive urban road and infrastructure network. This proposition is located on the south-west face, strategically situated between Victoria University of Wellington's main campus and the Central Business District (CBD). In this case, vertical topography creates a movement barrier rather than a horizontal arterial roadway. The design explores how architecture can play an essential role in transforming a neglected hillside to an environment conducive to pedestrian flow and improve health and wellbeing.

Rather than creating a hard connecting infrastructure of asphalt switchbacks down the hillside, this research proposition employs a central pedestrian spine which supports a variety of multi-sensorial options and student-driven spaces, fostering social encounters and opportunities for quiet reflection. The proposed architectural scheme has a minimal impact on the natural setting. It emulates its surroundings through the augmentation of the existing ecological network as a means of alleviating the ecological impacts of habitat fragmentation. The scheme follows an environmental practice that suggests that an interconnected network of natural areas and open spaces as well as technologies and practices that use natural systems or engineered systems. Such approach mimics natural processes to enhance environmental qualities that can conserve ecosystem functions and natural capital, sustain clean air and water, and provide social and economic benefits to people and communities (Allen III, 2012).

The research through design approach requires the development of ideas, followed by critical reflection and testing to ensure that they meet with performance criteria. In this case study, the initial ideas (Figure 3) proved visually exciting to a design review panel of international scholars and practitioners; however, on reflection the design failed to sufficiently meet objectives for vision, navigation and scale. Further iterations developed the main ideas further leading to a final developed design that achieved all of the goals of the research.

Figure 3 Early design iteration

This scheme acknowledges the stress of university students and the high rates of poor mental health as it seeks to slow the progression from town and possible residence to classroom and vice versa. The creation of pause moments, adjacent health-related facilities and lookouts all contained in an immersive green infrastructure can aid in both feelings of wellbeing, but also improve mental health. The use of green infrastructure in architecture can hereby offer a forward-thinking alternative to mainstream ideas improving life in different ways through its environmental, social and economic dimensions (Fig. 4). Looking at the architectural object as part of the green infrastructure allows to maintain the integrity of habitat systems and may provide the physical basis for ecological networks while contributing to benefit the user from the connection to nature (Tzoulas et al., 2007). This integrated approach between architecture and landscape architecture offers many opportunities for connection between urban development, nature conservation and public health promotion. Ecological and working landscapes are linked to human communities acknowledging that they are inextricability linked and that healthy landscapes are essential to human health, vitality and quality of life (Allen III, 2012).

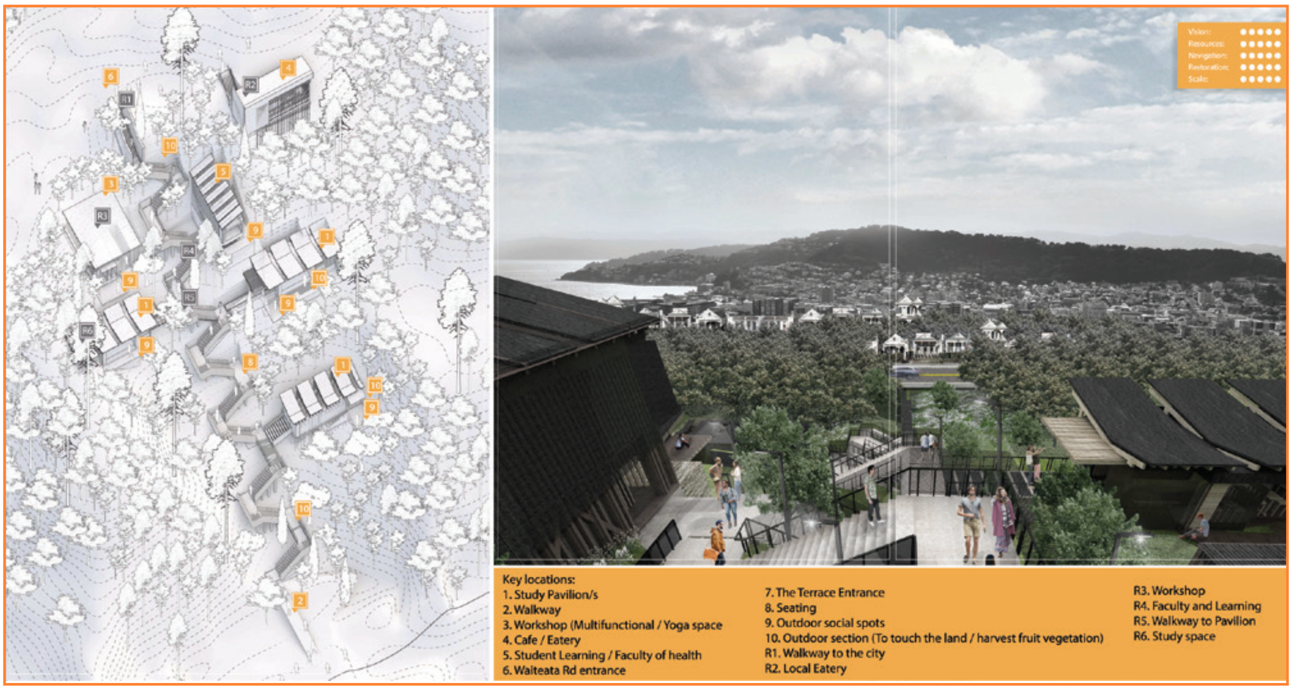

Figure 4 Final design proposal for Waiteata Road and view towards Wellington downtown

Results and discussion

This research examines two design-led research projects in the Wellington downtown suburb of Te Aro. Comparing and contrasting a horizontal landscape architecture exploration with a vertical architectural proposition, including landscape architectural elements, it shows two ways that innovative GI can be reinserted into a compact city. Both case studies looked at interventions that adopt blue and green infrastructure solutions to create a more permeable suburb. These studies contribute to the discourse on the compact city and the increased importance of GI for human health and wellbeing. Such interventions can also help to rebuild and strengthen communities by offering more opportunities for social interaction, 'community' projects and gatherings.

Through the juxtaposition of public and private spaces, green-orientated 'focal points' such as those in the case studies, can also foster a stronger sense of community and give individuals a place to relax, reflect, meet and play. As such they become extensions of our own private living premises when we choose to appropriate them, and in other times they are simply a thoroughfare. This flexibility provides users with the opportunity to define their spatial boundaries and actively engage with the urban ecosystem at large, with choice. Therefore, it makes sense that these 'focal points', the places in which we gather and engage in activity with others, should help to support our fondness for landscape. As the community strengthens, more social activities will occur and subsequently allow for people to manifest in these spaces.

The properties of an ecosystem can be seen as complex, open, ordered and self-organising. As a system, the different parts work together to produce emerging properties, where all components interact directly or indirectly, within defined boundaries (Lovett et al., 2005). The scale of such systems is highly dependent on their function. However, a holistic understanding is necessary (Menzies, Renata and Whaanga-Schollum, 2016). In the context of Aotearoa-New Zealand, our understanding must acknowledge the social and cultural uniqueness of place and connect with our assumptions and our deeper beliefs, values and behaviours (Collins, 2005; Hampden-Turner and Trompenaars, 2011).

Belief systems are a set of values resulting from collective and cumulative experience. Nature has cultural, social, health and spiritual meaning to many people, especially for New Zealand Māori (Clarkson and Kirby, 2016). In Aotearoa-New Zealand, our bicultural stance opens new opportunities for a deeper appreciation of the role of nature in the urban setting. For Māori, the Indigenous people of New Zealand, humans and nature are part of an intertwined ecosystem seen as a cycle and an energy. From this energy comes the production, consumption and decomposition of landscape as part of a cycle. In this way, the breadth of qualities beyond the visual are key to an urban restoration that tries to reconnect people with nature. In both case studies, such approach to urban restoration aimed to enhance habitats, reconnect spaces with the integration of blue and green corridors, and extend green space to incorporate qualities such as health, socialisation and recreation within the urban realm.

In this way, urban restoration through green and blue infrastructure solutions contributes to ecological, social, and cultural health in various holistic and interconnected ways (Hes and du Plessis, 2014; Mang and Reed, 2012; Pedersen Zari and Hecht, 2020). It does this by safeguarding the ecological and biological aspects of our unique native flora and fauna, while still filling our urban landscapes with life and meaningful experiences. Human bodily motions and experiences are vital to reintegrating and reconnecting with our natural surroundings and with other individual beings. To know the inclusive outlook between us and nature and the differences of inclusive and separatist views seems highly important to gaining a successful urban restoration outcome that incorporates humans experiencing natural spaces in infinite ways; from simply affection to intimate spiritual connections with nature that imposes bodily experiences, and through discoveries and memories rather than just 'making' urban restoration.

Conclusion

Green infrastructure provides opportunities for urban design investigations at architectural and landscape scales that can explore strategies fully linked to individual and community health. This is particularly important in the face of increased urbanisation. As a concept, GI encapsulates a complex multi-layered system which brings together natural and semi-natural elements. In the context of urban environments, it provides a wide range of ecosystem services, including mental health benefits and public health benefits.

An examination of two design projects demonstrates the transformative aspects of developing a multi-layered, multi-functional application of GI that contribute to individual and community health. By analysing and experimenting through design-led research and considering green and blue infrastructure approaches at architectural and landscape architectural scales, a re-framing of these urban structures and landscapes can provide new perspectives for health and wellbeing in a way that contributes to improved social, cultural and environmental health. These case studies demonstrate the opportunities and advantages of GI to offset some of the pressures from increased densification and urbanisation in Wellington, Aotearoa-New Zealand.

In conclusion, urban planners and decision-makers need to investigate how to move beyond generic approaches to 'greening' in the form of open space design, e.g. parks, rooftop gardens, green walls, greenways or restored natural areas, such as streams or rivers, and instead, envision an urban GI strategy that incorporates individual and community health benefits through design details and design strategies. Part of the aim of this paper was to demonstrate the value of landscape in crafting new design solutions to green and blue infrastructure, but more importantly, to re-shape the mindset of governmental agencies and associated stakeholders. As more residents relocate to urban areas, this need becomes increasingly critical.

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DOI: 10.2478/ahr-2020-0021

Acta Horticulturae et Regiotecturae 2
Nitra, Slovaca Universitas Agriculturae Nitriae, 2020, pp. 108–116

INFLUENCE OF DEFENSIVE WORK ON CITY LANDSCAPE SHAPING – WARSAW FORTRESS SYSTEM CASE STUDY

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The following article presents the results of analyses of source materials regarding the presence of a defense work in the city space and the results of one case – the Warsaw Fortress System. Information on the characteristics of the fortified landscape was presented, with particular reference to one of the types of fortifications – the ring fortress. A very important element was to trace the history of this object and its changes in the last 150 years. Individual objects characterized by interesting architecture, terrain and interesting vegetation perform different functions in the city landscape. These functions result primarily from the different use of objects. It is also evident that these objects in the future may also develop as a result of adaptation to new purposes or use. They have a very large spatial and natural potential.

Keywords: fortified landscape, citadel, military cultural tourism, the Warsaw Fortress System

The city landscape is the result of many factors; it is a sum of many smaller landscapes. At present, these elements are particularly appreciated, and they are in a sense a showcase of a place; they are unique in a special way. Such uniqueness is characteristic for a fortified landscape.

The term fortified landscape was introduced into the Polish literature by Bogdanowski (1996). This concept is designated as a comprehensive form of coverage and terrain adapted for defense purposes. Such a landscape, in addition to combat objects, also includes non-military structures, such as engineering, logistics, barracks, road, railway structures, fire connections – currently interpreted as view links and communication links with accompanying avenue trees.

Due to the very specific spatial structure, functional and spatial solutions characteristic of it, also in the field of greenery, the remains of which are easy to read to this day, are very important elements of the natural system of cities, as well as their spatial composition (Clark and Glazer, 2004).

The aim of this article is to indicate the impact of defensive work presence on the city landscape shape during functional and economic changes. The example object is the case of the Warsaw Fortress System. The article is focused on the three main topics:

- the changing position of the forts and other remnants of the defense system,
- the value of and challenges and problems related to the preservation and maintenance of the elements of the fortification system,
- the potential and threats of urban development on and around the forts.

Material and method

The methodology of the study is based on the SWOT method and the analysis and criticism of the literature as well as the systematic review. Elements of criticism of the sources were also made. A very important part of the source materials were historical iconographic materials – photographs, engravings, sketches, paintings. Historical iconographic materials (photographs and maps) were compared with the current state of preservation of the fortresses in terms of the preservation of architectural material, communication and viewing connections, and the share of vegetation.

Inventory fieldwork was also carried out, which included the implementation of photographic documentation, which was then analyzed and confronted with written and iconographic source materials. It was also crucial to analyze the place of particular elements of this defensive work in the current structure of the city.

Results and discussion

This defensive work is an example of a ring fortress. Its citadel elements consist of a citadel, surrounded by rings of forts, mostly bastion ones, and other fortress objects. The system of the ring fortress was associated with a much larger area in which the defensive work was carried out. Unfortunately, as history has shown, this form was not tactically effective. That is why few ring strongholds have survived to this day (Fig. 1).

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After the defeat in the Crimean war in the mid-nineteenth century, rivalry between Russia and Prussia began for the advantage in Europe. The line of confrontation ran through the territory of the Kingdom of Poland, which is why Russia decided to build a number of fortresses from its means, which constituted a barrier against the German Empire and a base for the Russian army in a possible war against Germany. The construction of the Citadel began after the defeat of the November Uprising (1832–1934). The construction costs (11 million rubles = 8.5 tons of gold) covered the Congress Kingdom in its entirety, it was a punishment for rebelling against Russia, at that time Poland did not exist on the map, and this part of it was under the rule of Russia (Królikowski, 2002). In the years 1847-1965, the Citadel was surrounded by six forts. In 1883, the construction of a large ring fortress was started, first implementing the outer ring of forts around the city (Pałubska, 2006). The last stage of the expansion of the fortress falls in the years 1889–1992.

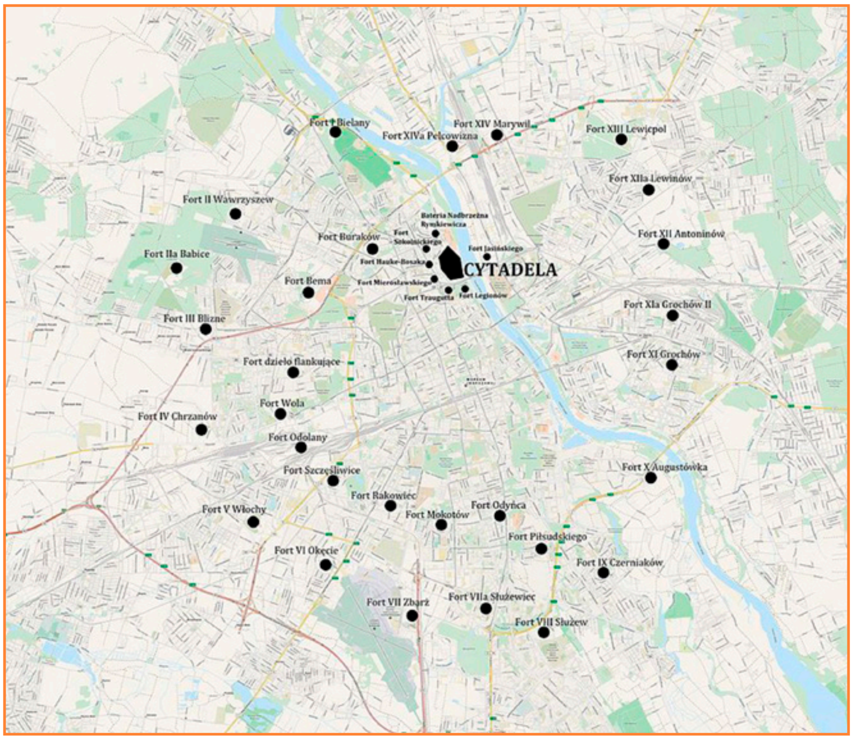

Figure 1 The Warsaw Fortress System
Source: htps://pl.wikipedia.org/wiki/Twierdza_Warszawa#/media/File:Forty_Warszawa.jpg Forty Twierdzy Warszawa, author Sznmka, access 30. 6. 2016

Figure 2 The Warsaw Fotress System – existing elements
Source: https://www.google.pl/maps/search/fort+8/@52.1666541,21.0387566,17z/data=!3m1!4b1, access 20. 9. 2028

The outer ring was composed of 15 brick-and-earth artillery and infantry forts (Fig. 1). The inner ring, on the other hand, consisted of five brick-and-earth forts. From 1890 to 1894, earth embankments and resistance points were built. The network of paved military roads connected all defense constructions. There were outlines along the rings – the perimeter roads, which were connected by main exit routes from Warsaw. In addition, the roads ran radially from the center of the Citadel to each fort. To this day, this communication system is very important in the functioning of the city. The Regional Railway Line provided food stores and barracks. At the end of the 1890s, the forts were modernized, and brick and concrete buildings were replaced. The work ended in 1907.

In 1915, Russian troops left Warsaw without major fights, and as a result, the fortress was built without a huge cost. That same year, on August 5, German troops entered Warsaw. The occupation began, which lasted until November 11, 1918 (Pałubska, 2009).

In April 1916, permission was granted for almost a three-fold enlargement of the Warsaw area. As a result of this management, the city crossed its administrative borders and entered the fortress areas, which eventually ended the fortress city stage. The Germans used the barracks, warehouses and other objects of the fortress, but they were little interested in the forts. After Poland regained its independence, the forts remained the property of the army. Later there was a process of transferring fortress areas to other ministries and allocating them for development (Pałubska, 2008). Liquidation of the fortress at the same time enabled the territorial development of the city.

The fortress belt consisted of two rings: an internal one with a storage function and an external one with a combat function. The main site of the Warsaw Fortress was the Warsaw Citadel. The forts are located in 10 districts of Warsaw (Fig. 2). The Warsaw fortress created a star-band layout of the city, which is still visible

Figure 3 The Warsaw Fortress System, Changing the coverage and surroundings in case of The Parysów Fort in 1945 and 2013
Source: http://www.forty.waw.pl/index.php/warszawa/twierdza-warszawa/352-twierdza-fortowa, access 10.11.2017, current status 2013 (Google Earth)

today. The border adopted from 1770 was an acute border that could not be crossed. A large increase in the population from about 70 thousand up to about one million before World War I caused a huge spatial restriction. The closure of the city in strictly defined limits contributed to the narrowness, the introduction of high buildings as well as the reduction of sanitary conditions. On the other hand, the necessity to establish communication between the forts was decisive for the expansion of roads, city canalization, introduction of electricity, telegraph and telephone network (Królikowski, 2002).

The urbanization process took place – areas with multi-family housing appeared. Agricultural land changed its destination mainly to the development areas and areas of allotments gardens. Previously unpaved communication routes were changed to asphalt roadways (Figs. 3 and 4).

Due to the restructuring of the army as a result of system changes (1989), the Warsaw forts were transferred to the Military Property Agency and the Military University of Technology. Then, according to the law, a part of the forts was put up for auctions. Nine forts have been nationalized or privatized. Ignorance about the values and possibilities of using the Warsaw Fortress contributes to the degradation of the valuable relic of the Russian fortifications from the 19th and the beginning of the 19th century.

Loss of the military function of the fortress does not mean that the fortress did not play later and currently does not play an important function.

The fortress had a significant impact on the city's physiognomy. The spatial structure of Warsaw was significantly shaped by the fortress. Until 1911, in the area of the esplanade, investments related to the erection of brick and wooden buildings were significantly limited. In this way, the natural spatial development of the capital was stopped. The direct effects of the slowdown were: an increase in population density, space deformation, increased concentration of buildings, and thus a widespread lack of housing. The demand for investment land increased. Intermediate effects can be attributed to the dynamic development of the town, which were located outside the wide fortress belt. The abolition of these restrictions in 1911 resulted in a three-fold administrative enlargement of Warsaw in 1916 and the incorporation of fortress structures into the city's structures. Another problem was the connection of all post-construction areas with the central part of the city.

In 1918, the post-industrial areas changed their ownership status. Although the earlier owner – the State Treasury (in Polish law represents the Polish state acting in the field of civil law relations in which it is treated as an equal partner to private entities as opposed to the sphere of public law relations in which the State represented by public authorities decides unilaterally on the legal situation of individuals) – sold the objects of the former fortress at a very low price or transferred free of charge, the poor communication of these areas from the city center resulted

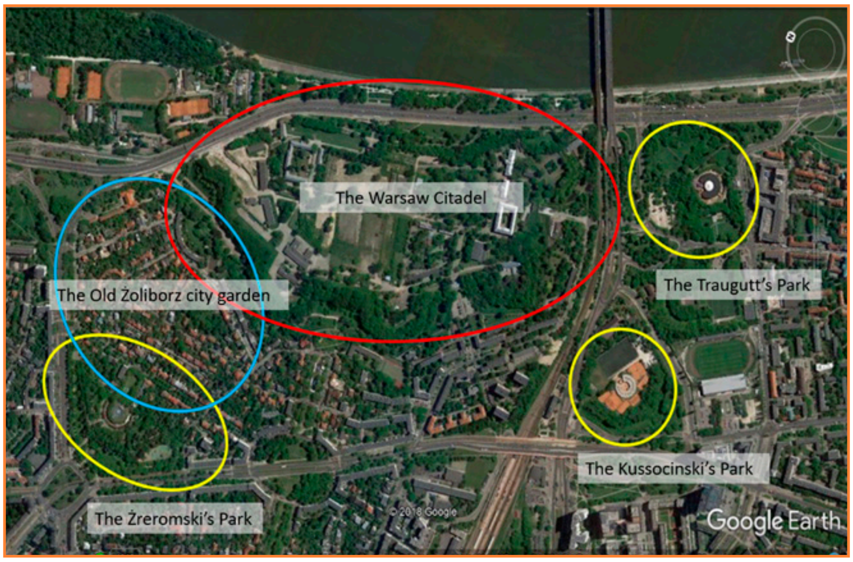

Figure 4 Contemporary land use of the Warsaw Citadel and its surviving forts : Red mark – The Warsaw Citadel, yellow marks – parks with citadel's forts, blue mark – city garden Żoliborz Oficerski
Source: Zaraś Januszkiewicz, map Google Earth, 2018

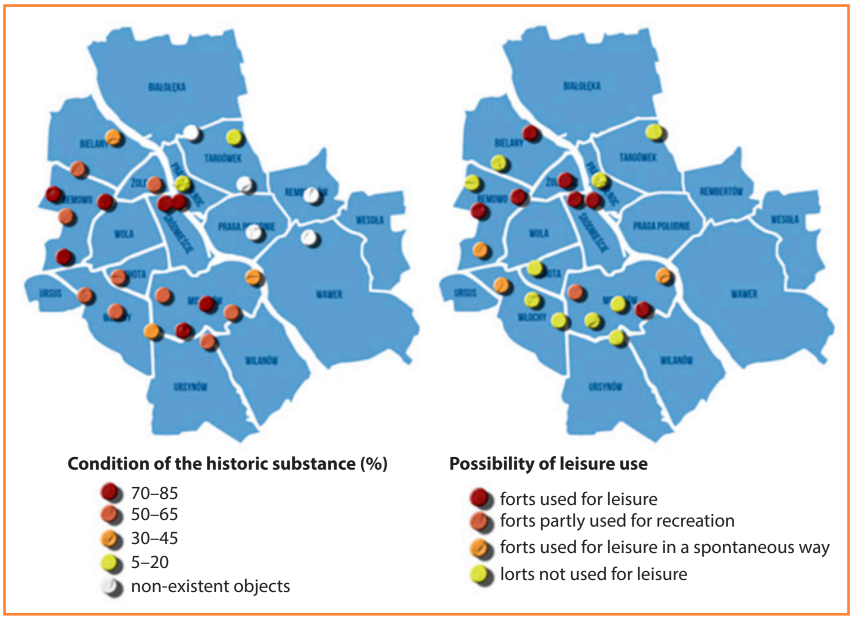

Figure 5 The condition of historic substance and possibility of using as leisure elements of the Warsaw Fortress System
Soruce: Karpińska, 2007

in little interest in the purchase of these areas. In connection with this, it was decided to use the idea of Ebenezer Howard (Golińska, Herman and Przybyłowska, 2015). In this way, numerous villa settlements were created (including Żoliborz Oficerski, the city – Czerniaków garden, and the city – Włochy garden), which concentrated around the forts. Thanks to this, Warsaw became a system of smaller city-garden units. There were also new parks around the forts (including the Żeromski Park, the Dreszer Park, the Sowiński Park) (Fig. 4).

During the inter-war period, the idea of allotment gardens was extremely popular. Some of these gardens in Warsaw were also built around the forts. This was the beginning of the implementation of the so-called the Great Warsaw (Różańska and Krogulec, 2007). Unfortunately, these plans were not implemented due to World War II.

Unfortunately, after the World War II, previously developed urban planning guidelines were not binding. The departure from the urban plans of the Great Warsaw has squandered the chance for a cohesive development of the capital. The fortress areas passed into the hands of the army. During the socialist period new estates were created in the area of the fortress esplanade, diversified urban and architectural landscape for each of the districts (including the Przyjaźń estate, the Jelonki estate, the Ksawerów estate). However, it was an incoherent process, without a comprehensive urban concept. Unfortunately, the disharmonious landscape of Warsaw was created in this way.

Currently, the area of the former fortress (nearly 250 ha, without protection zones), due to the size of the spatial foundation, architecture, earth structures distinguished by the terrain on the background of the city landscape, is a very attractive element in the capital tissue, which should be used in development projects (Fig. 5).

The main source of the fortress's problems was the abolition of its most important function – a defensive function. Both the protection and management of these residues in the capital city is a significant problem. The area occupied by the fortifications is 250 ha, which already in 1995 represented more than 1% of the invested areas, as well as nearly 17% of all areas of services, administration and central functions of the capital (Molski, 1996).

To this day, from the 19^{th} century fortification system, in addition to the Warsaw Citadel, 21 forts and 5 defense points have been preserved. The network of fortified roads was partially obliterated, and only the residual amount of secondary plantings remained from fortress greenery. Urbanization processes have led to a blurring of the layout of the nineteenth century Warsaw Fortress (Królikowski, 2002).

Based on the analyzed material regarding the condition of the historic forts of the Warsaw Fortress, it was found that the districts where brick structures were best preserved were: the Bemowo, Mokotów and

Table 1 Development and use of the Warsaw fortress facilities

Localisation	Fort name	Use	Degree of coverage with woody vegetation (%)	Area (ha)	Degree of preservation of a historic substance (%)
The Warsaw Citadel		– a museum and park facility, partly used by the army – visual dominant of the city	40 to 50	36	90
Citadel Forts	Siergiej	– the Żeromski Park, in the buildings of a cultural and gastronomic establishment	11 to 40	2	60
	Aleksiej	– the Kussociński Park, sport facilities	1 to 10	2	85
	Władimir	– in 1999, the fort was taken over by the Military Property Agency and in 2000 sold to a private catering company. The fort together with part of the underground corridors is open to visitors with a guide. A fragment of the Traugutt Park	1 to 10	2	85
	Śliwicki Fort	– in 2001, in the immediate vicinity of the fort, a housing estate for police officers with buildings on the esplanade and partly in the courtyard of the fort was created. Although there are still individual buildings of the fort, this construction was carried out without taking into account the principles of protection of monuments and care for the urban order of the city. This meant a permanent breach of this valuable monument and its layout. It should be emphasized here that there were projects and works in which the fort was to be included in the layout of the newly planned housing estate as a park and recreation area	11to 40	8	20
Inner ring of forts	P – Parysów Fort	– the whole area is an area for cycling, hiking and running. For more extreme crosscountry cycling or running accents, we can use the same fortifications and embankments (located in the very center of the fort).	11 o 40	8	80
	Szcze-Szczęśliwice Fort	– currently, the fort area is partially occupied by allotment gardens, but you can easily visit the barracks and find out the ruins of the caponier; homeless	1 to 11	7	50
	M – Mokotów Fort	– after the World War II, from 1961 to the end of the 1980s, the fort housed television and radio broadcasting equipment. Currently, the fort is surrounded by residential buildings, and it is used as the seat of companies and clubs	40 to 60	7	65
	Cze – Czerniaków Forts	– in 2007, the fort left the army, the facility is accessible and deprived of supervision. Allotment gardens in the fort were almost completely devastated. The area of the fort is overgrown with trees and the outline of the original fortifications is difficult to see; to this day, large sections of the old forts have been preserved. Currently, the investment area Fort CZE – apartments estate	40 to 60	7	70
External ring of forts	I Bielany	– currently, the area of the fort is used for sports purposes, forest park	11 to 40	8	35
	II Wawrzyszew	– currently, the fort's area is divided into parts. In the neck there are workshops and warehouses, and in the front part – a recreation center. The moat of the fort is one of the cleaner water reservoirs of this part of Warsaw	40 to 60	6	65
	A Babice	– from the end of the war to the present day, the fort is occupied by units of the Polish Army, and therefore it is unavailable	60	5	70
	III Blizne	– the fort is in the hands of a private owner who has not undertaken any work there yet. It is still surrounded by a picturesque moat. Around are garden plots and new housing buildings, group events	11 to 40	5	60
	IV Chrzanów	– paintball, apartments estate	40 to 60	5	80

Continuation of the table 1

Localisation	Fort name	Use	Degree of coverage with woody vegetation (%)	Area (ha)	Degree of preservation of a historic substance (%)
External ring of forts	V Włochy	– institute of Nuclear Chemistry, cross-cycling; to this day, the fort has been in good condition. The post-mortem area in its neck and on the esplanade (in front of the forehead) is occupied by the cemetery. There are barracks preserved in very good condition, poterna barracks on the axis and ruins of the caponier and blown-up traditor. The very clear layout of the fort, including the embankment and esplanade, has been devastated and seized in recent years. In the outline of the embankments, there is a playground, tennis courts and recreation areas for the residents of the district	11 to 40	5	65
	VI Okęcie	– warehouse area, parking; since the end of World War II, the Okęcie Fort area belonged to the Polish Army. From 1999, the army moved out of the fort. Currently, the object is preserved in about 50%: the remaining neck barracks without a frontal wall and the powerful ruins of the main caponier (anti-cloak). The dry fortress ditch has been re-flooded with water, through which moisture penetrates into the neck barracks. Fortunately, several modern objects have been created in the fort, effectively blurring the readability of the object	1 to 10	5	50
	VII Zbarż	– currently, the surrounding of the fort is used as garden plots. The fort itself, located in a state of ruin, is owned by the State Treasury, the State Enterprise "Porty Lotnicze" and several other investors. The structure of the building was partly affected by the construction of the S79 expressway. There are two reservoirs in the fort – one of them is a moat on the shore of which one of the few concrete caponier of the mountain pine was erected in Warsaw, whose powerful ruins still exist today. The second is in the flooded courtyard and is used for diving; the maximum visibility recorded was up to 4–5 meters. The maximum logged depth within the fort's courtyard is a little over 4.5 meters	40 to 60	5	40
	VIIA Służewiec	– film production company,,Czołówka", apartments estate	60	3	70
	VIII Służew	– apartments estate	11 to 40	7	65
	IX Czerniaków	– a walking park and a museum of the Polish Army. After the war, through the eastern part of the fortification, the street was pierced and in the eastern part of the fort a park was created, while the western one until the 1990s was occupied by the army. Since the early 90s, there was an inaccessible warehouse of equipment collected by the Polish Army Museum, and at the end of the 1990s, the Museum of Polish Military Technology was opened	1 to 10	7	50
	X Augustówka	– currently, there are organized: modeling, shooting (sport carabiners) and archery competitions. There is also an earth track with obstacles for cyclists. There is an interesting cycling route around the fort		5	30
	XIII Lewiepol	– used by the army. In the surrounding forest there are traces of the western embankment (on its foreland a slight curvature of the moat), the trace of the northern embankment of the fort (traversed by a WWII shooting ditch) and characteristic alternate embankments and depressions – traces of the barracks	40 to 60	5	5

Soruce: Zaraś and Januszkiewicz, basing on Głuszek (1995), Karpińska (2007)

Śródmieście districts. The situation of forts located on the right side of the Vistula is much worse, where most of them have not been preserved. The general Bem's Fort was characterized by the highest degree of preservation of the historic substance.

A significant part of the forts included in the building with the best preserved historic substance is at the same time used for leisure. Three of the seven best-preserved forts (Fort Bema and two forts of the Warsaw Citadel – Forts Alexey and Vladimir) are at the same time forts used for leisure (Boguszewski, 2004; Karpińska, 2007).

A comparative table of the Warsaw Fortress forts is showed (Table 1). On its basis, one can get an idea of the access possibilities, the method of use, the size of the trees, the surface, the degree of preservation of the historic substance and the usefulness of the fort in servicing the leisure traffic.

As you can see in each case, the fortress buildings enter the system of urban green areas due to the vegetation and, above all, the high proportion of trees and shrubs. They differ in availability. They are partially excluded from urban use due to their military functions. Their availability is also limited. The reasons for this limitation are: museum functions, housing functions – fort buildings are part of estate greenery within apartment buildings or due to lack of access and difficult accessibility. However, a significant part of these facilities has been absorbed into urban tissues and adopted for modern purposes (Figs. 6 and 7).

However, you can also see that the potential of these objects is not fully used. First of all because of the city landscape shaping. Their mutual connection is not fully utilized, which from the end of the 19th century shaped the spatial order of Warsaw, as well as the areas suburban at the time, and today included in the city's administrative boundaries.

As a result of the SWOT analysis, the following was identified:

S (Strengths):

- very interesting architecture,
- interesting forms of terrain,
- the most common mature vegetation, mainly in the layer of trees and shrubs, but also in the herbaceous layer,
- a clear spatial composition of the objects themselves, as well as their mutual relationship in space,
- easy access for visitors.

W (Weaknesses):

- bad technical condition of the infrastructure,
- limited access as a result of the management method,
- disturbed spatial relations with the environment typical of a defensive work by, for example, building the foreground.

O (Opportunities):

- easy access to each object allowing to create a clear system of objects of decorated urban greenery, harmonizing with the urban nature system,
- development of military tourism,
- social activation.

T (Threats):

- location attractive for developers,
- no management programme for the entire facility,
- no clear instructions to protect the facilities,
- no information system about the facility,
- individual objects have different owners.

Recently, due to the location of fortification objects (within the city), their market price increases. The lack of free areas for investments in Warsaw creates a great opportunity for the Warsaw Fortress. On the other hand, investments also pose a danger, resulting primarily from ignorance of the advantages and opportunities of using areas. Therefore, you should change the user structure at the beginning to enter only those investments that will be appropriate to historical values. For example, a significant threat is the idea of using forts for garden plots. An interesting solution, however, turns out to be the inclusion of fort objects in the spaces

Figure 6 Visualization of the project adaptation Fort Służew – apartment-estate
Source: http://www.forty.waw.pl/index.php/twierdza-warszawa/zewnetrzny-pierscien-fortow/348-fort-viii-sluzew#gallerya37ab0dbf1-7, access 10. 2. 2019

Figure 7 Visualization of the project adaptation Fort Służew – apartment-estate

of new neighbourhood investments as parts of estate parks (Figs. 6 and 7).

One should also outline the problem of illegibility of the layout of the Warsaw Fortress in the city space. There is no integration of the functional and spatial layout of the city with the fortification, which is why it is very important to legalize the entire former layout of the fortress. The rings of the fortress, the location of buildings along the main exit roads should be exposed to the shaped agglomeration of Warsaw – concentric-band. It should also be aimed at perceiving individual objects as elements of the system. The historical and scientific values resulting from the complexity of the functional and spatial system of the fortress are not legible and fixed in the urban tissue.

Changing owners, previous functions, provisional use, insufficient budget, ignoring conservation conditions contribute to the destruction of objects. A prerequisite is the adoption of adaptation and investment measures that will contribute to the conservation and conservation coopers of the entire fortress system (Głuszek, 1995).

It is necessary to work on a coherent concept of development of all objects of the former fortress, emphasize the value of objects as historical objects. In the Warsaw Fortress, despite conservation restrictions, high-standard, modern functional solutions can be introduced. At the same time, the fortress can be preserved as a monument of military architecture and as a valuable spatial foundation. The fortification areas can play an active role in the spatial layout as well as the natural layout of Warsaw (Molski, 1996).

All actions that are currently insufficient should aim at giving a contemporary form and function that honors all their values, ranging from military and historical values, spatially – architectural, nature and landscape.

Contemporary tourist attraction should refer to the so-called 3xE rules (entertainment, excitement, education), which has supplanted the previously existing 3xS rule (sun, sea, sand) (Richards, 2005). Under the new rule, new ways of development form a coherent educational and entertainment programme.

The developed ways of developing the fragment of the outer ring of the Warsaw Fortress for the needs of military and cultural tourism were also based on the relational structure of the tourist attraction. At the beginning, the tourist presents the attraction of the so-called marker (e.g. guide, information boards). During the visit, the marker is converted into a real view. Below is the relationship between tourists, views and markers (view information) (McCannell, 2002) tourist + marker/view = attraction

Conclusion

1. Defensive work The Warsaw Fortress is a unique object with a very high cultural and historical value. This object has a large impact on the city's physiognomy due to the current network of streets, which is a continuation of the system of fortress roads of various ranks. Part of the defensive structures has become important park elements or centers around which garden-style estates developed.

2. Currently, one of the compositional dominants of the city is the Warsaw Citadel. The remaining forts constitute existing local dominants, especially those located in the city center. Other undeveloped objects, due to the very interesting architecture and terrain, resulting from the characteristics of the defense works, constitute potentially valuable elements shaping the city space. The condition is to observe the rules of shaping the space around the defense work.
3. In the area of study, military-cultural tourism was not developed at a satisfactory level; full use is not made of tourist facilities belonging to the 19th century Warsaw Fortress for its development. In the area covered by the study, there is no tourist and educational programme. The functioning of forts as tourist attractions is assessed at a very low level.
4. The historical spatial layout of the work is now illegible. Forts are perceived as independent objects, not as objects that are part of a larger system. The main reasons for this condition include improper maintenance, inappropriate way of managing the facilities, as well as inadequate forest management.
5. The ring system of the fortress can be exposed.
6. The objects covered by the study are well communicated – both from the center of Warsaw as well as suburban towns. This applies to collective and individual transport.
7. In the area adjoining the site, there are historic objects that increase the attractiveness of the route connecting the forts.
8. Access to facilities is difficult, primarily through a highly fragmented ownership.
9. Preserved historical elements are often neglected; no adequate measures are taken to secure them.

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DOI: 10.2478/ahr-2020-0022

Acta Horticulturae et Regiotecturae 2
Nitra, Slovaca Universitas Agriculturae Nitriae, 2020, pp. 117–119

CROP YEAR EFFECTS ON THE QUALITY AND QUANTITY OF WINTER WHEAT VARIETIES

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Crop year impacts have been studied in a long-term trial of the Nagygombos experiments of the Szent István University, Gödöllő, Hungary. The present paper is intended to give an overview of 18 winter wheat *Triticum aestivum* L. varieties tested during the time range between 1996 and 2018. All of the varieties were studied under similar agronomic conditions, each of them for min 3 years in a series of a polyfactorial replicated field trials. The 120 kg.ha^{-1} N plant nutrition applications of the respective crop years were processed in the evaluation. Amount of grain yield, protein (%), wet gluten and farinographic values of the varieties examined were compared. The results obtained suggest that most of the varieties had a rather high variation concerning yield figures, however protein, and farinographic indicators proved to be more stable characteristics. Wet gluten values were influenced mainly by the crop year. The study supports an evidence that *Fusarium graminearum* infection of the trials was in accordance with the pre-harvest moisture conditions of a crop year. The study may support a conclusion that certain varieties have shown a higher stability in quality manifestation regardless to the amount of their grain yield. Alföld 90, Jubilejnaja 50, Mv Magdaléna and Mv Toldi varieties proved to be the best quality varieties in this research series.

Keywords: Long term trial, winter wheat, quality, quantity

Crop quality and quantity performance is affected by environmental conditions in general. Grain yield and yield quality of winter wheat *Triticum aestivum* L. is highly influenced by the meteorological conditions of the given crop year, especially the amount and distribution of precipitation and the actual temperature (Grimwade et al., 1996; Győri 2008; Pepó, 2010). Crop yield and grain quality can also be influenced by agronomic applications. Plant nutrition in general and N topdressing in particular should be considered as the most effective treatments within the technologies of winter wheat production. The amount of nitrogen and the timing and distribution of the application have an impact on wheat quality, especially on the protein production of the crop (Pepó, 2010). Wheat varieties may have different responses to agro-ecological impacts (Mesterházy, 2019). Varietal differences are to be evaluated in long term trials to reduce the impact of variable crop year effects (Kismányoky and Ragasits, 2003). The aim of the series of trials was to evaluate quality and quantity of the grain yield of certain wheat varieties.

Material and method

Winter wheat *Triticum aestivum* L. varieties were examined under identical agronomic conditions in a long-term field trial. The small plot trials were run at the Nagygombos experimental field of the Szent István University, Crop Production Institute, Hungary. Soil type of the experimental field is chernozem (calciustoll). Annual precipitation of the experimental site belongs to the 550–600 mm belt of the Northern edges of the Hungarian Great Plain. Experiments were conducted in a split-plot design with four replications. The size of each plot was 10 m^2. Plots were sown and harvested by plot machines (standard Wintersteiger cereal specific experimental plot machinery series). Various identical agronomic treatments were applied to plots. Plant nutrition applications were done in single and combined treatments. N topdressing variants were applied by single and repeated topdressings representing 6 levels: 0, 80, 80 + 40, 120, 120 + 40 and 160 kg.ha^{-1} N in single and split applications. All plots were sown with identical series of wheat varieties for studying their performance in relation with agronomic impacts. The present paper is intended to give an overview of 18 winter wheat *Triticum aestivum* L. varieties tested during the time range between 1996 and 2018. All of the varieties were studied under similar agronomic conditions, each of them for at least 3 years in a series of a polyfactorial replicated field trial. The 120 kg.ha^{-1} N plant nutrition applications of the respective crop years were processed in the evaluation for both yield and quality parameters. Wheat grain quality parameters: protein and wet gluten contents were determined from grain samples, as well as quality characteristics

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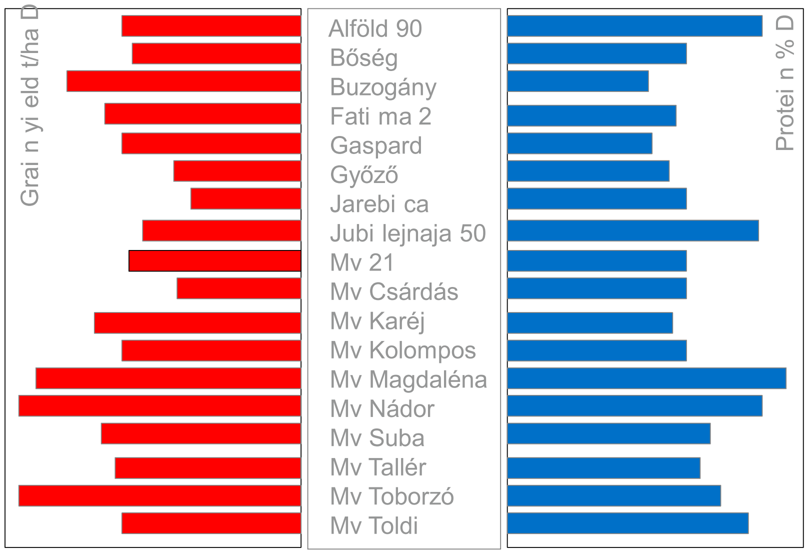

Figure 1 Grain yield and protein content of wheat varieties Nagygombos, 1996–2018

	Wet gluten content	Baking quality
Alföld 90	28-38 %	A1 – B1
Bőség	21-27 %	B2 – C1
Buzogány	22-27 %	B1 – C1
Fati ma 2	25-29 %	A2 – B2
Gaspard	21-26 %	B1 – C1
Győző	22-25 %	B2 – C2
Jarebi ca	23-28 %	B1 – C1
Jubi lejnaja 50	26-35 %	A1 – B2
Mv 21	26-32 %	A2 – B2
Mv Csárdás	25-32 %	A2 – B2
Mv Karéj	23-33 %	A2 – C1
Mv Kolompos	25-31 %	B1 – C1
Mv Magdaléna	26-38 %	A1 – B2
Mv Nádor	26-35 %	A2 – B1
Mv Suba	23-30 %	B1 – B2
Mv Tallér	24-30 %	B1 – B2
Mv Toborzó	25-37 %	A2 – C1
Mv Toldi	25-38 %	A1 – B2

Figure 2 Wet gluten content and baking quality ranking of wheat varieties Nagygombos, 1996–2018

at the Research Laboratory of the SIU Crop Production Institute, and RET Regional Knowledge Centre laboratories according to Hungarian and EU standards (MSZ, 1998; EK 2000; Horváth, 2014). During the examined period, levels of fusarium (*Fusarium graminearum*) infection was detected in the wheat trials.

Results

Many varieties were studied in the trials during the 22 years of the experimental series (Jolánkai et al., 2018). In this paper only those 18 cultivars are introduced which were tested for at least 3 years at the Nagygombos site. Amount of grain yield, protein (%), wet gluten and farinographic values of the varieties examined were compared. The results obtained suggest that most of the varieties had a rather high variation concerning yield figures, however, protein and farinographic indicators proved to be more stable characteristics. Wet gluten values were influenced mainly by the crop year.

Fig. 1 provides information on grain yield and protein content of the varieties. Buzogány, Mv Magdalena, Mv Nádor, Mv Toborzó were the highest yielding varieties during the examined years.

The study may support a conclusion that certain varieties have shown a higher stability in quality manifestation regardless to the amount of their grain yield. Fig. 2 presents information on the quality ranges of the varieties summarising the wet gluten content and the baking quality groups. Alföld 90, Jubilejnaja 50, Mv Magdaléna and Mv Toldi varieties proved to be the best quality varieties in this research series.

During the examined period fusarium infection was monitored in all years.

According to the data presented in Fig. 3 it can be stated, that except for few extreme years, the Nagygombos experimental site was not exposed to severe fusarium infections. There were two peaks with high infection: 1997 to 1999 was a strong infection period followed by an almost 10 years' free period of *Fusarium graminearum*. The next peak occurred in 2010. Both high infections were escorted by extreme weather conditions – such as water flood during the pre-harvest vegetation period.

Discussion and conclusion

According to the results obtained it should be emphasized that the quantity and quality parameters of any crop varieties are to be examined in polyfactorial long term trials that may provide the researcher with identical conditions to exclude unfavourable factors and buffer the crop year effects.

The authors are sorry to inform the reader that in 2018 year the Nagygombos experimental site of the SIU Crop Production Institute had to

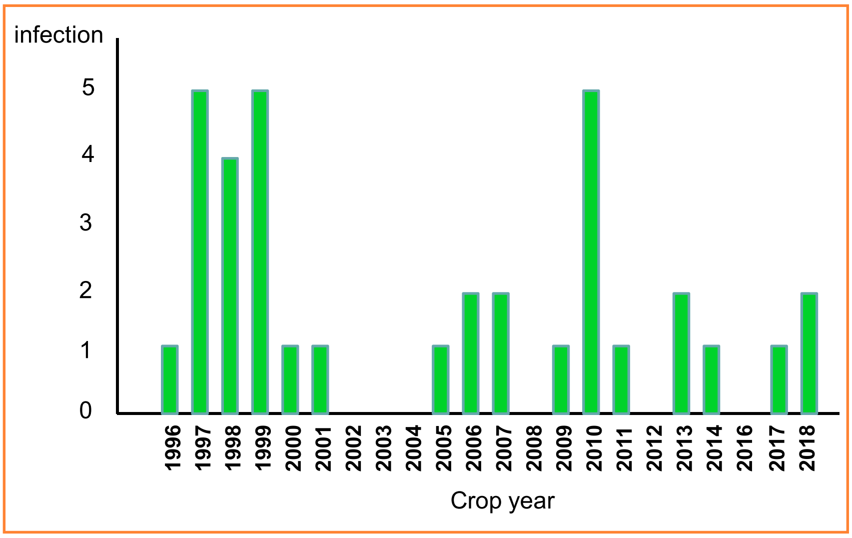

Figure 3 Occurence of fusarium (*Fusarium graminearum*) infection in wheat trials, Nagygombos, 1996–2018

be terminated. We do hope to preserve the main blocks of the experimental design, once the trial can be restarted again.

Acknowledgement

The authors are indebted to earlier OMFB, OTKA, NKFP, TEMPUS, COPERNICUS, VKSZ fundings as well as that of the present NVKP 16-1-2016-0016 project.

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