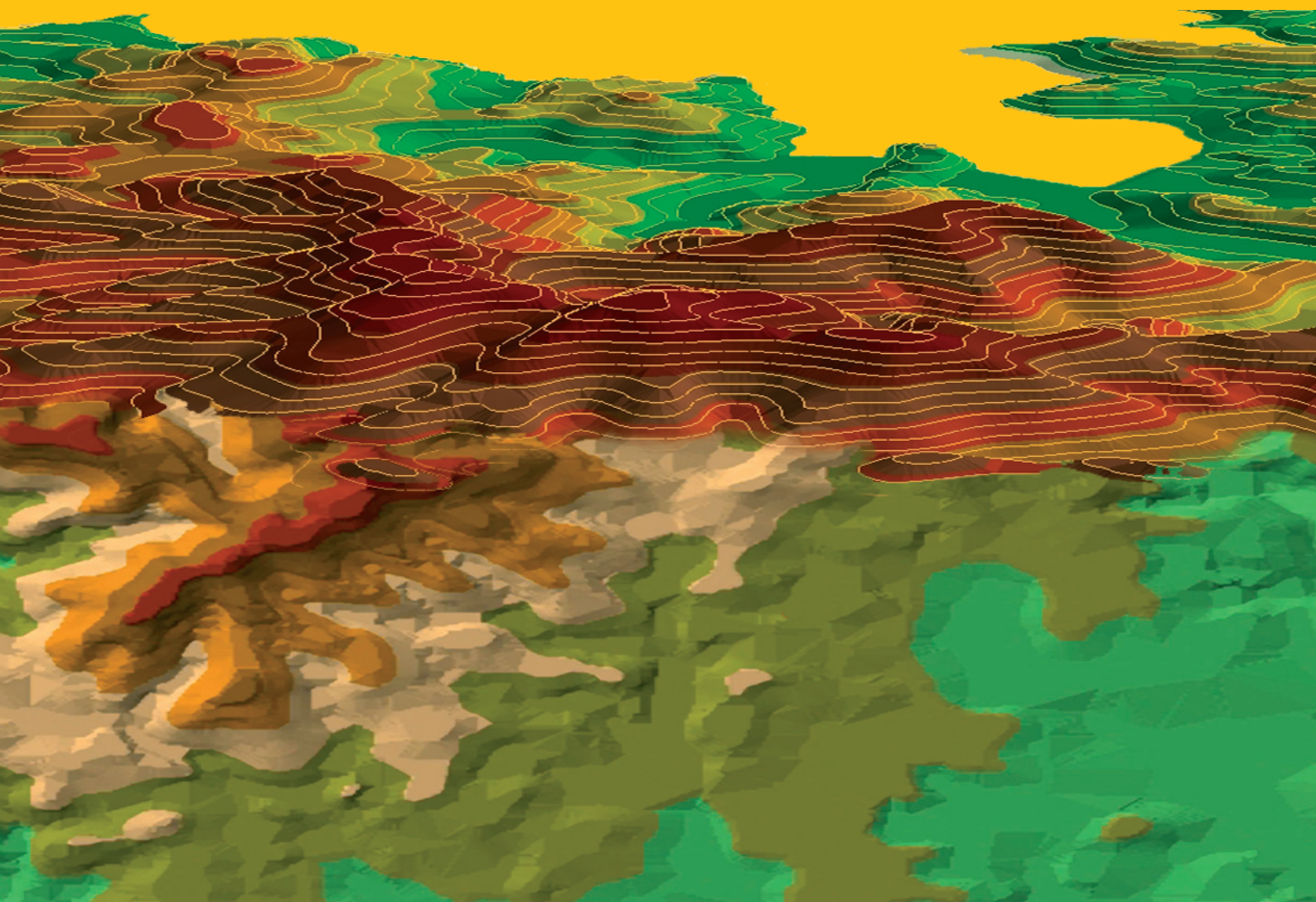


Vol. 32/2024

No. 1

MORAVIAN GEOGRAPHICAL REPORTS



MORAVIAN GEOGRAPHICAL REPORTS

Review paper:

- 2 | Grzegorz SMULEK
NIMBY or YIMBY? Understanding the complex relationships between foreign military bases and host societies

Research papers:

- 14 | Tomasz GRZYB
Recreational use of the urban riverscape: What brings people to the river?
- 26 | Hendrik SIELAFF, Lukas BUNDSCHUH, Lena MORITZ, Clarissa TAUBMANN, Joanne BADACK, Klara WEINHOLD, Marcus HÜBSCHER
COVID-19 pandemic and urban green spaces: Shifting usage behaviours and perceptions in Leipzig (Germany)?
- 37 | Cristiana VÎLCEA, Liliana POPESCU, Amalia NIȚĂ
Urban revitalisation within the historical quarter: A comprehensive analysis of a medium sized city in Romania
- 51 | Maria BOROWSKA-STEFAŃSKA, Krzysztof GONIEWICZ, Vasile GRAMA, Marcel HORŇÁK, Edyta MASIEREK, Cezar MORAR, János PÉNZES, Alena ROCHOVSKÁ, Filip TUROBOŠ, Szymon WIŚNIEWSKI
Spatial mobility of the inhabitants of the countries of NATO's eastern flank in the event of a military conflict
- 66 | Rok CIGLIČ, Anže GLUŠIČ, Lenart ŠTAUT, Luka ČEHOVIN ZAJC
Towards the deep learning recognition of cultivated terraces based on Lidar data: The case of Slovenia

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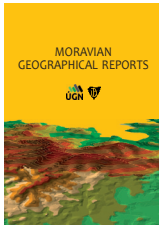
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REVIEW PAPER

NIMBY or YIMBY? Understanding the complex relationships between foreign military bases and host societies

Grzegorz SMUŁEK^{a*} 

Abstract

Based on a scoping review of English-language scientific literature for the period of 1990–2022, the article presents a synthetic outline of previous research, focusing on factors influencing the specifics of foreign military bases (FMBs) as examples of facilities that mostly generate negative attitudes known as ‘Not In My Backyard’ (NIMBY). The specific characteristics of different categories of objects that generate various social attitudes are also presented. The results of the analyses include a classification of factors and aspects related to the local impacts of foreign military bases, which have not been analysed before.

Keywords: Foreign military bases; NIMBY attitudes; social, economic, environmental factors; local community effects; extraterritorial facilities

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1. Introduction

Since the end of the Cold War, Foreign Military Bases (hereinafter FMB) have become an increasingly frequent subject of contentious debate in the scientific and political world, especially in host countries (Calder, 2007; Harkavy, 1989, 2007). FMBs can be defined as land or sea areas outside the jurisdiction of a sovereign state, in which a certain number of armed forces conducting military activities are stationed, with infrastructure, and military facilities (Harkavy, 2007). FMBs are a symbol of a sphere of influence that strengthens national interests in economic, political, cultural, and security areas (Sun & Zoubir, 2011). The analysis of the functioning network and factors that determine the location of FMBs are the basis for understanding the sphere of influence and the balance of power in the world (Dos Santos & Simao, 2014), as well as the strategic goals of specific countries (Lutz, 2009). The stationing of foreign soldiers abroad also enables an analysis of relations between the sending and hosting country and a determination of the impact of extraterritorial military bases on national security architecture (Koga, 2017). On a local scale, however, opinions and attitudes towards military installations, and especially FMBs, may significantly differ from national or international scales.

The main aim of this study is to explain the specificity of FMBs as analysed by scholars between 1989 and 2022, with a focus on their association with ‘Not In My Backyard’ (NIMBY) attitudes. The study also aims to examine whether and to what extent FMBs generate positive attitudes, known as ‘Yes In My Backyard’

(YIMBY). Another objective is to identify and analyse knowledge gaps. The obtained results can serve as a precursor to a systematic review, highlighting research aspects that require more attention and scientific analysis.

In the following sections, I will present arguments that, in combination with selected theories and research approaches, as well as examples of other objects generating negative social attitudes, will address the two research questions: which factors influence the specificity and uniqueness of an FMB as a NIMBY object? Can FMBs generate YIMBY attitudes?

In the first part of this work, the research project, methods, and stages of research activities are presented. In the second part, the issue of civil-military relations and the process of militarisation, crucial for understanding the research problem, is emphasised. Then, theories concerning NIMBY objects were concisely described. Next, the focus shifted to the analysis of literature data regarding the effects of FMB impact, which were divided into three spheres: social, economic, and environmental. The last part of the article includes a discussion and a summary of the conducted research along with guidelines for future considerations.

2. Research design

To summarise the vast topic related to foreign military presence, a scoping review was considered the most appropriate method. Utilising the Scopus and Google Scholar research engines, open-

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access materials in the English language were gathered, resulting in the collection of 67 articles and studies directly referring to Foreign Military Bases (FMBs). The search employed the following keywords: “foreign military bases,” “military bases abroad,” “foreign military presence,” “foreign military base impact,” and “foreign military base attitudes”. In the process of reviewing and selecting source materials, efforts were made to eliminate repetitive content.

Consideration was given to articles on foreign military presence, including articles, book chapters, conference papers, reports, theses, and reviews. Exclusion criteria were applied to non-reviewed studies, books, and monographs. Given the diversity of military installations and the characteristics of foreign military presence worldwide, the permanent or periodic presence of troops representing official states operating outside their home territory and stationed in identifiable infrastructure facilities was considered as FMB. This encompasses the stationing of troops on the territory of another state or a dependent territory with a population from a different ethnic group, as part of international agreements between sending and host states, or national military missions abroad. The data was extracted and analysed using MAXQDA software. The selected articles were also analysed using the Narrative Framework Policy (NFP) theory and model (see [Appendix 1](#)). Attention was given to the context in which the analysis is presented, the actors involved, the plot of the research paper, and the moral, i.e. suggestions for solving the problem or conclusions. The stages of the research procedure are shown in Figure 1.

To comprehensively analyse FMBs in terms of their impact on host societies, it is crucial to both classify and explain the NIMBY phenomenon on one hand, and to present the concepts of civil-military relations and militarisation on the other.

3. Relations between civilians and the military

Interactions and impact effects resulting from the installation of military facilities are part of the research regarding civil-military relations, which combine considerations associated with e.g. psychology, sociology, economics, history, or geography. The basic assumption of these studies is the difference in the existing values, attitudes, goals, characteristics of community leaders as well as civilian and military institutions (Welch, 1985). According to Pion-Berlin and Dudley (2020), among the many approaches to civil-military research there are four important ones: beliefs, context (historical and political), institutions and agency.

In democratic states, civilian control over the military is one of the fundamentals of internal politics. Civilian control is made easier when there is a military belief in political obedience (Pion-Berlin & Dudley, 2020). Thus, the armed forces will not intervene if they believe in the principle of civilian supremacy (Finer, 1962).

The political context is embedded in Huntington’s concept of objective control (1957), according to which military institutions become increasingly subordinate to civilian authority when left to themselves to modernise, professionalise, and, in this regard, become politically neutral. The historical context can refer to

national cohesion. The level of polarisation within the nation between competing parties, factions, and groups creates instability that can lead to military intervention (Dudley, 2016).

Institutions define power relationships and hierarchies, empowering some actors while closing channels of power to others (Croissant et al., 2013). They can either define barriers by limiting the military’s influence on politics or create space for intervention by soldiers who would attempt to unduly influence their governments. The military’s behaviour is thus subject to laws, rules, and procedures embedded in the institutional space that regulate its influence.

Agency refers to the difference that individuals make as they operate within contexts and institutions, but the range of options available to the decision-maker to effect changes in the armed forces is constrained by her unique environment. Achieving civilian control involves a process of reducing military contestation and prerogatives (Stepan, 1988).

The above examples show that differences in values, structure, or objectives on both the military and civilian sides can lead to different dysfunctions. They are mostly visible on a local scale, as a hierarchical and specific institution such as the army can easily transfer or even impose its models of behaviour, attitudes, functioning systems, etc. (Brooks, 2008).

A specific example of civil-military relations, however, is the presence of troops in an area dominated by another country’s population or ethnically or culturally distinct, as in the case of the FMB. In that context, the majority of studies concern the American presence in Europe and Asia, but attention has also been paid to other areas, such as Sub-Saharan Africa (Dahir, 2019) or Central America (Lindsay-Poland, 2005). Extraterritorial military bases of the Russian Federation (Olech & Rogozińska, 2020; Gorenburg, 2020), the People’s Republic of China (Cabestan, 2021; Kardon, 2022), France (Sun & Zoubir, 2011), Great Britain (Stergiou, 2015), Turkey (Quamar, 2017) and other countries in East Africa (Melvin, 2019; Dahir, 2019), have also been described.

Geyer (1989) describes militarisation as “a contradictory and tense social process in which civil society organises itself to produce violence.” Militarisation can also be defined as a process of normalisation and self-discipline in which military ideas, behaviours, language, and objects enter the intellectual, emotional, and physical spheres of human lives. Thus, they interfere with what is commonly regarded as non-military areas (Eichler, 2011; Sjoberg & Via, 2010; Hohn & Moon, 2010). Militarisation also shapes racial, gender, and dichotomous beliefs regarding normality and citizenship, it militarises social relationships and changes the perception of security and protection (Gerson, 2009). It influences ideas, behaviours and aspects that are not usually associated with the military and thus transforms the everyday life of local communities. This process is carried out by to the formation of military landscapes, which, as a time and spatial framework, allow to determine both positive and negative effects of military activity (Rech et al., 2015). Military bases also possess a symbolic and psychological dimension.

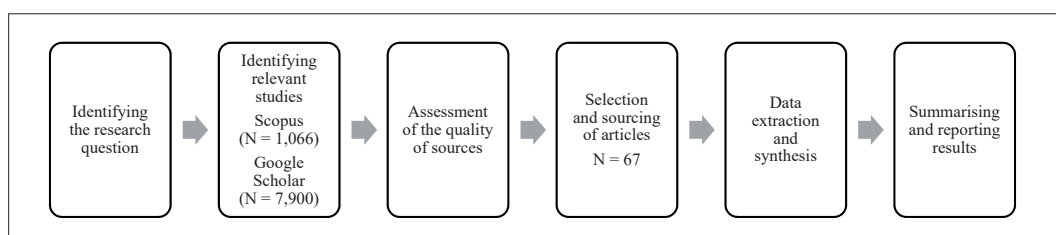


Fig. 1: Stages of the scoping review of FMBs literature
Source: author’s design based on Arksey and O’Malley (2005)

According to Enloe (2000), militarisation should be treated as a gradual process in which a given element or sphere of life is controlled by, dependent on or derives value from the military as the closest superior institution. Control of space through the use of armed forces or the police can lead to the use of violence as one of the main tools of internal control by governments.

As such, militarisation is a powerful intellectual and ideological tool. By combining the concept of militarisation with “colonisation for strategic purposes” or otherwise “military colonialism”, Gerson (2009) shows its two sides: visible (hard) such as military bases, infrastructure and equipment, and less visible (soft) – e.g. food, cultural tastes, markets and military ideology, which plays a fundamental role in the way society and space are governed.

The process of militarisation is therefore directly related to FMBs, which, apart from conventional forces and nuclear arsenal, constitute the most important part of the military structures of a given state (Vine, 2009, 2015). The scale and dynamics of the militarisation process are influenced by spatial location factors (Hikotani et al., 2023), i.e. geographical conditions and spatial factors that affect the functioning and range of FMB impact (e.g. Calder, 2007; Cooley, 2005; Yara, 2012; Yeo, 2011; Vine, 2015, 2019).

4. NIMBY: typologies and classifications

The main distinguishing feature of a NIMBY object is the widespread acceptance of the need for a given type of facility, with simultaneous opposition to the location in the immediate vicinity (Pol & Di Masso, 2006). In the study of social attitudes towards NIMBY, the aforementioned geographical or spatial context is particularly important, because it is the proximity of a given investment that determines the scale and intensity of negative social phenomena. Dear (1992) identifies three major conflict-related threats that may arise from the emergence of NIMBY, including:

- i. Decrease of real estate value;
- ii. Personal security issues; and
- iii. Deterioration of quality of the environment.

Devine-Wright (2007) identifies several planes for determining the impact of these specific objects:

- i. Personal factors: Socio-demographic characteristics such as age, gender and social class.
- ii. Psychological factors, including (a) Level of awareness and understanding, (b) Political beliefs, (c) Beliefs and concerns regarding the natural environment, (d) Perceived honesty and levels of trust, (e) Contextual factors.
- iii. Technological factors: type of facility and scope of activity.
- iv. Institutional factors: ownership structures, benefit sharing, and the use of a participatory approach to public involvement.
- v. Spatial factors: regional and local context, spatial proximity, and “NIMBYism”.

This classification presented above indicates that NIMBY objects generate conflicts on sociological, political, ethical, economic or environmental grounds. In their work regarding the psychological impact parameters of NIMBY facilities, Pol and Masso (2006) present a typology of these investments, which include, among others, sanitary, industrial (including energy or mining), communication, technical infrastructure, or specific types of service facilities.

Coleby et al. (2009) analysed social attitudes towards wind turbines and indicated the aspect of changes in the landscape in the immediate vicinity, by emphasising the differences in the perception of investments at the supra-local level as opposed to the local level - personal, constant contact with a given facility.

After examining hazardous waste facilities or solid waste management facilities, Groothuis and Miller (1994) emphasise that the monetary and psychological costs of a harmful object are borne locally by the neighbourhood around the object, while the benefits of the harmful object are distributed globally throughout the economy. Krause et al. (2013) refer to the geographical proximity of carbon storages and their public acceptance, in case of which there is also a discrepancy between the general opinion about the facility and personal experiences associated with its presence. What is important, the authors note that the attitudes towards NIMBY facilities are often based on personal concepts and ideas, and not on reliable information or situations that can be referred to. To solve the issue of inefficiency and locate the malicious target safely, those who receive the benefits must compensate the neighbourhood around the target for the external cost of the target (O’Hare, 1977 and Kunreuther et al., 1987). At the same time, there is an individual aspect of the resident, whose appropriate features (general knowledge, awareness, tolerance, and higher social position) may influence the opinions and acceptance of a given object in space. Research carried out by Rahardyan et al. (2004), regarding the attitude of residents towards solid waste management facilities, showed that the concerns of local communities related mainly to health issues, including environmental pollution, which determines nuisance in everyday functioning and an increase in living costs.

Farkas (1999) accurately describes the opposition of local communities to the proximity of prisons and correctional facilities, citing Popper’s (1981) term LULU (locally unwanted land use). Although criminals are theoretically confined behind walls, there is a high level of concern in communities living around prisons associated with an increase in the crime rate in the area, the emergence of drug trafficking, a decrease in land and property values, a decrease in the attractiveness of the area and the quality of life. It is common to accept these types of facilities and, above all, the need for order and security, although crime is downplayed (habit) in some areas (Bradley, et al., 2011). Farkas (1999) notes that this case perfectly shows that from the very beginning of the NIMBY design stage, the priority should be to build appropriate relationships with the local community and organise social consultation groups. In addition, local leaders should be involved in the process of creating such a site, and communication paths should be established. Research regarding social attitudes towards psychiatric hospitals (Jena et al., 2021) shows more links and analogies with prisons than other healthcare facilities, especially among the populations living in rural areas, which emphasises the importance of education as a factor that shapes attitudes.

Differences between individual social groups and the quality of space lead to conflicts that are difficult to resolve (Beraldo et al., 2023). This is particularly evident in the case of a sudden influx of people from ethnic or cultural groups which are distinctly different compared to the local groups. Hainmueller and Hopkins (2014) show that the economic aspect, when the local community fears the loss of jobs, and thus the deterioration of living conditions, finds no empirical support. Thus, they emphasise that the current fear and anxiety shaping social attitudes result from the lack of knowledge or a low level of education in local communities.

Based on the given examples, the lack of appropriate education and knowledge of the local community becomes clearly visible, along with the marginalisation of these factors in the process of locating NIMBY facilities. In addition, there is a clear difference in the perception of these installations depending on the proximity of the phenomenon or the scale of its occurrence. There is also a question regarding the scope/nature of a given object (local, supra-local, regional, state), which may also affect its perception.

5. Foreign Military Bases and their impacts on host communities

The data obtained from the analysed scientific reports regarding the effects of Foreign Military Bases (FMBs) and social attitudes toward them were divided into three parts. The first part concerns social issues, the second is focused on economic impacts, and the last aspect is related to environmental and landscape issues.

5.1 Social aspects

Definitions of what constitutes an overseas ‘base,’ rather than a ‘facility,’ also typically require a cession of territorial sovereignty by the host, providing the user nation with high levels of discretion over the use of the site (Rossiter & Cannon, 2019). This can be one of the factors that impact both dialogues at the international level and the social attitudes of host societies. The question of the usefulness of U.S. military bases in the territory and their legal status is also relevant in the context of the rights and sovereignty of host communities (Roznitti, 2008). Nevertheless, the benefits resulting from FMBs may guarantee stability and security, while the disadvantages, on the contrary, may lead to social imbalance and hostility among the political actors (Simon, 2008). They can also be treated as entities that play a secondary role, i.e. they do not participate in international negotiations between states and governments (Takahashi et al., 2019).

The analysed literature reports show that the presence of foreign troops affects important life spheres of residents – economy, education, health, or transport (Willis, 2019). The impact on youth is a unique example, which can generate extremely nationalistic attitudes under the influence of military presence (Rassbach, 2010).

The social effects of FMB impacts depend on personal relationships between soldiers and residents. They may differ from those observed in the case of factories, hospitals, power plants, or other objects that are the subject of NIMBY’s attitudes. This is related to the specific nature of the army as an institution, i.e. identification with violence, militarism, war, and danger (Wright, 2015). The range and intensity of impacts may be affected by the size of the base, type of army and tasks performed, location in relation to current conflicts and crises (Ušiak et al., 2021), and historical conditions and experiences with militarism (Rassbach, 2010). Lutz (2015) also elucidates internal factors, e.g. the form of accommodation for soldiers (in the base or outside). The issues of in-depth personal relationships are a unique aspect of the functioning of FMBs (Ingimundarson, 2004). An extreme case illustrating the negative impact of FMBs concerning intimate contact is the phenomenon of trafficking for sex workers, which has occurred primarily in East Asia (Yea, 2006).

In the reviewed literature reports, studies regarding the negative and harmful social impact of FMBs are predominant. This is confirmed by the global network of various social initiatives defined as anti-base movements (ABMs). The origins of these movements were limited to a specific base or country, but gradually began to expand their activities. Media publicity has influenced the installation of new FMBs or the enlargement of existing ones, as exemplified by the “*Ne základnám*” (“No to military bases”) initiative in the Czech Republic (Steiger, 2008) or the initiatives of *Presidio Permanente* and *Autonomus Geographies* in Italy (Fois, Paragano, 2011). ABMs activities often grew to a national scale starting from a single event, e.g. an accidental death caused by a foreign military (Kern, 2005) or the destruction of civilian infrastructure by military equipment (O’Shea, 2018), which indicates the diffusion of attitudes from local to national (Yeo, 2006).

ABMs refer to environmental (Colgan, 2018), economic (Willis, 2019), or legal issues regulating the presence and activity of foreign troops in their own country (Lutz, 2015). The security

aspect is addressed by Alexander (2016), who comments that FMBs bring the opposite effect to ensuring security – they are primarily a war infrastructure, that is, they enable war and bring the threat of attack to the communities that are around it. Moreover, this author points out that even in times of peace, bases deny sovereignty and self-determination, ignore human rights, and threaten the culture, values, and resources of host communities. This is confirmed by research carried out by Davis et al. (2007), which describes the negative attitudes of Puerto Ricans towards the American base Vieques. They indicate that a military base may negatively affect the structure of society in the long term. An additional aspect in many countries is the increased number of terrorist attacks on FMB-related military installations, in case of which the local population also suffers (Mizobuchi, 2020).

The nature of these protests and their fitting into a specific framework may be the main factor determining the effectiveness of their actions (Yeo, 2011). According to Willis (2019), they may take the form of anti-state, anti-war, anti-imperialist, anti-nuclear, anti-arms economic violence, exclusion, land rights, and concerns for the natural environment, injustice, and legal issues. They may arise spontaneously, be organised by NGOs or by associations with various ideological bases (Biberman & Ocakli, 2015), they may remain open, or only concern a specific social group (Holmes, 2014).

The occurrence of ABMs may be characterised by a different scale, e.g. in the Czech Republic, the anti-base campaign was co-created by over 50 organisations (Steiger, 2008), and in Ireland, the opposition against the use of the airport in Shannon by the American army covered the whole country (Rassbach, 2010). In addition to the geographical scale, the time scale is also important – according to Lutz (2015), the feeling that FMBs impose a huge burden on local communities and the nation is common in countries where FMBs are most ubiquitous and have existed for the longest period.

Vine (2019) indicates that the activities of ABM movements were effective and influenced government decisions and the location of FMB, even though the government administration was in a difficult position – between the party sending the army, political elites, and corporations counting on profits from the presence of a foreign army. Yeo (2006, 2011, 2017) refers to the issue of the effectiveness and efficiency of ABM movements, claiming that it depends on finding a balance between the local and national levels, which over time may change the arguments, purpose, and framework of action. Without cooperation in several various fields, however, the movement has lower chances of success. At the same time, this author highlights the limited communication between leaders at the national and local levels, emphasising the lack of respect for the democratic rights of local communities by state governments (Yeo, 2018). Kawato (2017) argues that the most important factor in the effectiveness of ABM protests is the understanding of the arguments by all parties associated with the conflict. Kovner (2016), in the Japanese case, shows that national governments worked together to insulate the host society, making it easier for Japanese men and women to tolerate the bases and for U.S. servicemen to live within them.

In the mid-1990s, local ABMs attempted to form a broader coalition (Yeo, 2011), but despite some success, most ABMs continued to focus on local issues. In March 2007, an international conference was held in Quito (Ecuador), which gathered over 400 activists from 40 countries associated with ABMs (Fitz-Henry, 2011). Fitz-Henry (2011) states that despite great hopes for the globalisation of such activities, an important problem emerged during this conference – the lack of understanding in the perception of the issue by activists at the national and local levels. ABMs can therefore represent opinions at the national level, regardless of the challenges faced by local communities living in

the vicinity of FMBs. This highlights the issues associated with the scale and distance in social phenomena and research into social attitudes towards NIMBY objects.

5.2 Economic aspects

The proper functioning of an FMB on the territory of the hosting state requires the provision of goods and services to the stationed troops. Some countries, such as Japan, allocate over \$1 billion a year to US bases within their borders (Lutz, 2015), which accounts for most necessary costs. Williams (2013) argues that acceptance of the FMB can be a result of the historical and persistent postwar socioeconomic conditions, leading to a path dependency that favours forces in favour of the military base. It is worth noting, however, that some of these costs go to local contractors working for the American side, or through the expenses of soldiers and their families in local enterprises (Allen et al., 2020). Moore et al. (2014) point out that in some cases the host country receives funds for the development of infrastructure, education, communication, or energy together with the military presence. In exchange for making a location available for FMBs, countries also try to obtain funds for infrastructure development (Ušiak et al., 2021) or additional revenues for the budgets of neighbouring cities (Rogozińska & Olech, 2020). The amount of funding depends on the state of economic development of the host country, however.

Maintenance of FMBs is expensive, therefore the states that send troops abroad are looking for ways to share costs (Tanter, 2013). Depending on the concluded agreement (e.g. SOFA or HNS regulations), the host countries also provide employees to operate the base, supply of utilities, expansion of the military or administrative infrastructure, refund of accommodation costs, compensation for damage to the local community, organisation of security systems or repairs and renovations. These forms of contribution to the operation of the base are direct. Indirect forms include customs duties, trade and revenue taxes, fees for rent and use of services, transport fees, personnel costs (Lostumbo et al., 2013), or integration of telecommunications and satellite networks (Tanter, 2013).

Local communities seek economic benefits associated with FMB (Martin, 2018a, 2018b), which is used by political actors. As a result, FMBs are presented as both an institution that increases prosperity and a guardian of regional security and protection against external threats (Alexander, 2015).

Many cities and regions around the world are economically dependent on FMBs, hence the withdrawal of troops would have a significant impact on the local and national economy (Sharp, 1990; Masaaki, 2000). Military bases are considered by many decision-makers and local community leaders as catalysts for regional development, and the withdrawal of the military could cause an economic recession in the region, mainly due to job losses. There are also counter-examples when the liquidation or reduction of a military base provides development opportunities and opens up new perspectives or has no major impact on local and regional economic growth (Andersson et al., 2007).

An increase in the income of the inhabitants of a given area, both due to foreign investment and direct spending of money by soldiers in local shops and premises can be a direct or indirect effect of the presence of foreign armed forces. This may result in higher expenses for the local community on housing, services, or trade (Kriesel & Gilbreath, 1994). At the same time, one of the effects of the functioning of FMBs is the gentrification process, which leads to an increase in housing prices (Davis et al., 2007) and partly offsets the increased purchasing power generated by the presence of the base. Property prices can also increase due to inflated rents for foreign workers/soldiers. This may also apply to

other services or products, which also affects the competitiveness between enterprises and suppliers from countries sending their troops abroad. The presence of foreign troops can also be treated as a tourist attraction and promote less wealthy areas (Simon, 2008).

FMB is a specific “company” that requires qualified employees. Despite many jobs guaranteed for local residents (Ingimundarson, 2004), if the base is located in peripheral areas, most of the employees may come from outside of this area. In addition, with a low level of development of the local economy, supplies of goods and services will also come from other places in the host country (Alexander, 2013). As a result, leakage effects are significant, and local multipliers are small.

Moore et al. (2014) claim that even the best preparation of the army and planning activities for serving abroad may break down due to the lack of recognition of local conditions – the social and cultural characteristics of the local community. The area in which an FMB is located is subjected to a type of “drainage” of local resources and services, which may lead to a change in the model of the local economy based on one branch of the economy, or even to an economic recession.

For the sending country, the FMBs are also elements of “soft power”, creating an appropriate image and attitudes towards this country. The army can become the main taxpayer and source of income for local governments, and create its image through cultural events for residents, such as picnics and festivals. In the face of a difficult financial situation, residents see the army as a safe place of employment and a source of income (Alexander, 2016), especially in the event of land loss for the construction of FMBs, which may refer to an economical relationship called the Dutch Disease (Ebrahim-Zadeh, 2003). The opposite example of soft power is China’s military strategy in Africa, which embraces ‘civil-military integration,’ focusing on building dual-purpose civil-military infrastructure that local residents can use (Sun & Zoubir, 2021).

Moore et al. (2014) suggest that it may be necessary to create special economic zones that can offer duty-free import of goods, appropriate infrastructure, and an increase of job offers. Simon (2008) notes that local entrepreneurs as well as local authorities should be introduced to the process of establishing agreements and contracts, which will allow for the development of appropriate strategies and economic programs using local resources and opportunities. It is therefore important to thoroughly analyse the micro- and macroeconomic factors of the creation of FMB objects from both sides and to plan several partnerships between governments, business, private, and non-governmental organisations.

5.3 Environmental aspects

Harris (2015) argues that environmental concerns are often used as a “greenwash” to divert attention from the negative aspects of militarism, including environmental degradation, the mistreatment of individuals, and the perpetuation of colonial governance. Despite high ecological standards and transparency of operations in many armies of the world, the natural environment is still an element that is directly and negatively affected by the military bases. Two types of factors should be taken into account in order to determine the level of degradation of the natural environment as a result of military operations – external and internal. The external factors include the type and characteristics of natural ecosystems that are inside or adjacent to a given base, i.e. forest cover, hydrographic network, mesoclimate, land cover, and others. The internal factors primarily include the nature of the military presence (permanent, periodic, rotational), type of unit, size of the unit, and type and number of used equipment.

To date, studies regarding the impact of FMBs have mainly focused on two issues – the emission of toxic liquids and gases that were dangerous to the natural environment, and changes in the landscape. Currently, the monitoring and conducting of analyses regarding the level, scale, and type of pollution released into the environment as a result of military activity is a standard in well-developed and organised armed forces. In the report of Davis et al. (2007) regarding the activities of the American military base in Puerto Rico, the author points to the denial of the negative effects of the US Army's activities on nature and the falsification of the results of mandatory environmental tests (including the presence of heavy metals in the soil) by the army. This type of conduct by the US armed forces is particularly negatively perceived by local communities. In addition, the inhabitants of the island pointed to the aspect of the location of the base about the prevailing winds, which regularly carried harmful substances suspended in the air during military exercises.

Due to the intensity of operations involving FMBs, the US presence in the Middle East is a significant source of data regarding their negative environmental impact. In addition to the emission of petroleum substances and the release of uranium into the environment by heavy military equipment, research indicates that the emission of thorium (which is poisonous to humans) by the military, to which local communities were exposed as a result of burning garbage in the open air. In the case of exposure to thorium and uranium, analyses indicate that anomalies in children in the Nasiriyah region, in whom increased concentration of this element was detected, depended on the distance of residence of the respondents from the American military base (Savabieasfahani et al., 2019). In Asia, one of the main arguments used by movements opposing the presence of the US military also concerns the negative impact on the natural environment. Contaminations of watercourses have been reported in Japan, as faulty infrastructure and inadequate fuel storage at an American air base have led to the introduction of harmful and poisonous substances into the municipal hydrotechnical network, which negatively affected individual users as well as local businesses and enterprises (Wright, 2015). In the case of air bases, noise pollution is also extremely burdensome for local communities (Lutz, 2015).

The impact of military activities carried out in the framework of FMBs on the environment is particularly noticeable by its opponents because, despite external state support in the security architecture, environmental degradation is an effect that is extremely easy to identify. In areas of training or stationing under allied agreements such changes are noticeable with lower intensity, but they still negatively affect both flora and fauna in the immediate area impact and also impact human functioning.

Colgan (2015) points to the conclusions of the FMB policy in the context of environmental changes. It highlights the sites of storage of radioactive materials in the Pacific during the Cold War, where currently rising sea levels may result in the release of hazardous materials into the environment. The author cites the example of the "Iceworm" project (military bases in Greenland) as an example that a single military base may contain, among others, over 20,000 liters of hazardous chemical waste. The landscape of an area abandoned by the armed forces is another issue. On the example of the base in Vieques Davis et al. (2007) highlight issues such as the disappearance of residential areas, areas of existence of indigenous tribes, craters and destruction caused by artillery fire or bombing (training ground), leaving of unexploded ordnance or pollution of beaches and coastal waters. The image of changing space, which is left in chaos, and its partial destruction is clearly shaped in the case of reports regarding specific bases as well as in general studies (Lutz, 2015), which directly affects the health and life of living organisms.

The link between base policy and climate change presented by Colgan (2018) is the final aspect of environmental change and FMBs that uniquely sheds light on international security architecture and international relations. The author forms predictions by analysing the ongoing processes and phenomena of climate warming and their possible impact on the functioning of military bases in an environmental context. He notes that, to date, only direct effects for FMBs related to the cost of remediation or offsetting the effects of climate change have been indicated, but in a broader perspective – he presents a cause-and-effect relationship between climate change, problems with the functioning of military infrastructure and international policy. The author (Colgan, 2018) highlights the impact of climate warming on FMBs laws and regulations, local migrations, and environmental changes as well as unpredictable consequences in time and space, especially on a local scale, which may currently occur, but are marginalised by military and civilian authorities. In the final paragraph of this section, it is important to emphasise that positive effects of FMB impacts on the natural environment are rarely found, thus indicating that this aspect is an important argument in civil-military relations, which affects the social attitudes of the local community and remains crucial to build relations between the host country and the sending country.

6. Synthesis of results and discussion

Using the theoretical framework of NFP, a classification and characterisation of the factors and domains through which foreign military bases (FMBs) influence the local environment were carried out, encompassing the social, economic, and environmental dimensions. Given the subject of the analysis, the author explored, for example, the topic of the base policy, i.e. the interaction between sending countries and host countries in relation to the operation of foreign and local military facilities within the host nations, as proposed by Gresh (2015). In this regard, the studies were focused on, e.g. shaping the base policy during the period of political reforms. (Cooley & Hopkin, 2007; Takahashi et al., 2019), the influence of political dynamics and national conditions (Mizobuchi, 2020; Calder, 2007), the structure and vertical dimension of the base policy (Kawato, 2017), relations between the local and national level (Kawana & Takahashi, 2020) and factors that influence the decision to establish bases and their functioning (Calder, 2007).

In the context of local development, studies that analyse the anti-base movements phenomena are predominant. Moore et al. (2014) indicates that understanding the contemporary dynamics of the functioning of areas at the local level is a crucial element which impacts the proper functioning of the armed forces. The impact of FMBs on employment (Alexander, 2016), dispossession (Martin, 2018b), environmental degradation (Davis et al., 2007), infrastructure development, shaping local security (Holmes, 2014), as well as health and living conditions (Savabieasfahani et al., 2020) has been investigated. Allen and his team (2020) conducted analyses regarding the impact of the American presence in the context of social capital and economic interests. It is also worth quoting the analysis of Lostumbo et al. (2013), which extensively describes the costs incurred by the host countries and their economic contribution to the functioning of the FMBs. Phenomena and processes that occur after the closure or reduction of FMBs were also analysed (Calla et al., 2020). The analysed literature as well as the main issues which were the focus of the developed studies are summarised in Table 1.

The reports mostly include interdisciplinary research, but there is a clear predominance of the trend describing basic politics, geopolitics, and social movements against a foreign military presence. The analysed issues were visible in the literature, especially in the first years of the 21st century. The qualitative analysis of the content shows that, regardless of the research

approaches and trends, the functioning of FMBs generates several negative phenomena and processes affecting local societies and their social attitudes, which is characteristic of NIMBY facilities.

One of the more significant and simultaneously challenging issues is identifying how authors define the military stationed outside their home country. In most cases, they are referred to as ‘bases,’ ‘presence,’ and ‘facilities,’ but the number of terms, especially related to space and location, is much larger (Tab. 2). This complicates the determination of the relationship between the scale of the object generating NIMBY or YIMBY attitudes and the areas subject to influence.

Among the selected 67 publications, only nine of them (Tab. 3) directly refer to the NIMBY phenomenon, of which only the study by Williams (2013) also addresses YIMBY. Eight of them, which are related to negative public attitudes and issues such as identity or territory, deal with U.S. military bases in the Pacific area – South Korea, Okinawa, or Guam. Only the work of Vine (2019), whose framework deals with military expansion, has a global dimension, covering different parts of the world, but cases from this part of the globe are one of the most important aspects of it.

Dividing the selected literature by location is challenging since the subject of analysis often encompasses more than one country or dependent territory. Figure 2 shows the prevalence of FMBs analyses in the European area and Southeast Asia. Additionally, there is a significant proportion of general studies with a global focus.

The analysed literature indicates a high intensity of FMBs impact on local communities, in social, economic, and environmental terms. Thus, in each of these spheres, the militarisation process is a major or one of the key factors in shaping the environment affecting the dynamics and intensity of the effects of FMBs’ activities. These findings are in agreement with the planes of influence on social attitudes indicated by Devine-Wright (2007) and the main NIMBY threats defined by Dear (1992), as well as four civil-military frameworks in the four approaches to civil-military relations listed by Pion-Berlin and Dudley (2020). Even though the local population cannot be able to control military forces, civil society organisations (CSOs) can impact decisions regarding foreign military presence on a local or even national scale.

A common feature of all the NIMBY facilities mentioned in the study is mainly negative social attitudes towards the new

Main approach	References
Anti-base movements and protests	Alexander, 2011; Bieberman & Ocakal, 2015; Fitz-Henry, 2011; Ikeda, 2018; Imai, 2020; Kawato, 2017; Kern, 2005; Kovner, 2016; Rassbach, 2010; Steiger, 2008; Vine, 2019; Willis, 2019; Wright, 2015; Yeo, 2006, 2011, 2018;
Base policy and geopolitics	Bitar, 2015; Cooley, 2005; Cooley & Hopkin, 2010; Cooley & Marten, 2006; Fields, 2004; Kardon, 2022; Kawato, 2017; Kim, 2017; Lindsay-Poland, 2005; Lutz, 2015; Lostumbo et al., 2013; Melvin, 2019; Mizobuchi, 2020; Moore et al., 2014; O’Shea, 2015; Quamar, 2017; Rogozińska & Olech, 2020; Rossiter, 2019; Stergiou, 2015; Sun & Zoubir, 2018, 2021; Vine, 2009, Yeo, 2006, 2017;
Economy	Allen et al. 2020; Cooley & Marten, 2006; Lostumbo et al., 2013; Hikotani et al., 2023;
Environment and health issues	Colgan, 2008; Davis et al., 2007; Harris, 2015; Savabieasfahani et al., 2020;
Gender	Alexander, 2016; Ingimundarson, 2014;
Law	Ronzitti, 2008;
Local relations and development	Calia et al., 2020; Hikotani et al., 2023; Martin, 2018a, 2018b; Simon, 2008; Williams, 2013; Yara, 2012;
Militarisation and identity	Alexander, 2013; Gerson, 2009;
Politics and international relations	Bitar, 2015; Cabestan, 2019; Dahir, 2019; Dos Santos & Simao, 2014; Fields, 2004; Gorenburg, 2021; Uściak et al., 2021; Lutz, 2015; Petursson, 2020; Simon, 2008; Strosin, 2012; Tanfer, 2013;
Public opinion and social attitudes	Allen et al. 2020; Holmes, 2014;
Security implications	Akkaya, 2009; Peterson, 2008;
Space and territory	Alexander, 2016; Fois & Paragano, 2011; Takahashi et al., 2019;

Tab. 1: Main approaches in the analysed literature
Source: author’s elaboration

Terms related to places and objects	Terms not related to places and objects	Terms related to the characteristics of the object
Camp	Military activity	Complex
Campdown	Military component	Dual-base
Military area	Military contingent	Formal base
Military base	Military deployment	Hub
Military depot	Military force	Land-base facility
Military facility	Military personnel	Port
Military footprint	Military presence	Quasi-base
Military infrastructure	Military unit	Smallbase
Military installation		Training facility
Military outpost		
Military polygon		
Military site		
Military station		
Operating location		
Sovereign base area		

Tab. 2: Terms describing the presence of foreign military used in the analysed literature
Source: author’s elaboration

Topic	Publications
NIMBY (9)	Alexander, 2011, 2013; Hikotani et al., 2023; Vine, 2019; Williams 2013; Yara, 2012; Yeo, 2006, 2011, 2018;
YIMBY (1)	Williams, 2013

Tab. 3: Publications that address the topic of NIMBY or YIMBY
Source: author’s elaboration

investment in the neighbourhood, which differ depending on the scale at which they occur. In addition to the selected features presented in Table 4, there are also other negative and positive effects of the functioning of FMBs that appear in many studies (Tab. 5). The only example in the reviewed literature of an FMB's impact described directly as YIMBY is Williams' (2013) analysis of Henoko village in Okinawa.

Despite the benefits achieved as a result of the presence of a foreign army, which may indicate the presence of YIMBY attitudes, the authors point out the predominance of negative impact effects, as both already existing and potentially occurring

threats. The prevalence of negative impact effects is mainly due to the lack of a long-term strategy for the joint functioning of local communities and a foreign military unit. Therefore, the lack of dialogue based on social, cultural, and economic aspects, including basic values such as security, social inclusion, ethical issues, aesthetic aspects, solidarity, or quality of life is a significant problem (Horlings, 2015).

Based on the above lists and the conducted analysis, however, some unique conditions related to FMB emerge, influencing social attitudes and interaction outcomes. Notably, the studies analysed reveal a lack of sufficient spatial analysis and a geographical

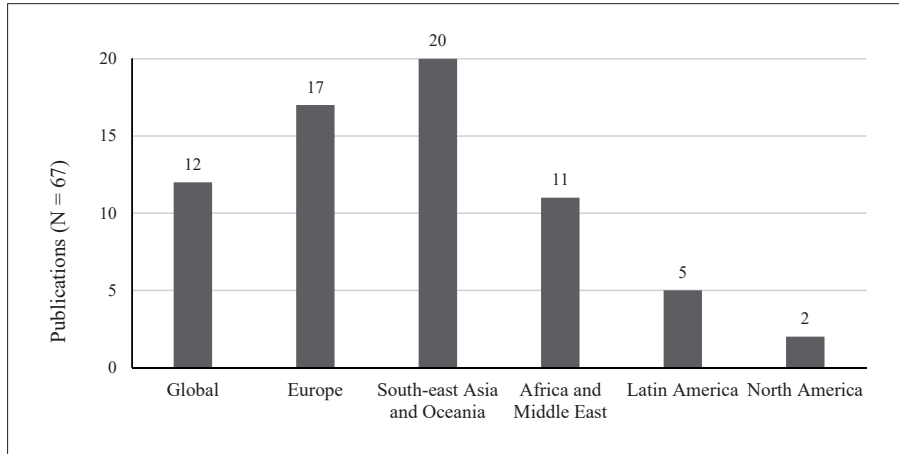


Fig. 2: Number of publications according to the research area
Source: author's elaboration

NIMBY objects	Selected object features	Features of FMB objects as NIMBY
Wind turbines (Coleby et al. 2009)	<ul style="list-style-type: none"> Reluctance to live in close proximity 	<ul style="list-style-type: none"> Fear and constraints regarding living near military installations, e.g. due to the potential target of the attack
Hazardous waste facilities (Groothuis & Miller, 1994, O'Hare 1977, Kunreuther et al. 1987).	<ul style="list-style-type: none"> Negative economic and psychological effects on a local scale Benefits on a supra-local and national scale The need to compensate residents 	<ul style="list-style-type: none"> Inhibition of economic development due to restrictions related to military areas An important element of the security architecture on a national scale Loss or decrease in land value and real estate
Solid waste management facilities (Rahardyan et al., 2004)	<ul style="list-style-type: none"> Harmful effects on human health Environmental pollution 	<ul style="list-style-type: none"> Negative impact of heavy military equipment on people and the environment
Carbon storages (Krause et al. 2013)	<ul style="list-style-type: none"> Positive general public opinion Change of attitude on a local scale – uncertainties and doubts 	<ul style="list-style-type: none"> FMBs perceived as factors that strengthen the role of the state and its defense capabilities Change of attitude in the situation of FMB proximity
Crime facilities and frequency (Bradley et al., 2011, Farkas, 1999)	<ul style="list-style-type: none"> Social reluctance despite the closed nature of the facility (limited outside activities) Lack of appropriate prior dialogue and cooperation strategy with the local community 	<ul style="list-style-type: none"> Negative attitudes towards the closed or semi-closed nature of the facility Local governments and people omitted in the process of FMB construction or determination of the operating conditions
Emigrants and refugees (Hainmueller & Hopkins, 2014)	<ul style="list-style-type: none"> Fear based on stereotypes regarding people from other cultural and ethnic groups Increase in social inequalities and crime 	<ul style="list-style-type: none"> Stereotypes regarding soldiers (as a specific group) and the ethnic/cultural groups they represent Crimes and incidents caused by soldiers
Psychiatric hospitals (Jena et al., 2021)	<ul style="list-style-type: none"> Difference in attitudes between inhabitants of rural and urban areas Education as a factor that shapes attitudes 	<ul style="list-style-type: none"> Location of heavier equipment and operational units in rural or peripheral areas rather than in cities Knowledge regarding the military activity which conditions social attitudes

Tab. 4: Comparison of selected features of NIMBY objects with FMB features
Source: author's elaboration

Negative (NIMBY)	Positive (YIMBY)
<ul style="list-style-type: none"> Excessive traffic in the local transport network Excessive costs of FMB maintenance and operation incurred by local and regional governments Dependence on one type of economy/workplace Social imbalance 	<ul style="list-style-type: none"> Investments in local infrastructure Inflow of funds for education and culture Increased revenues of local entrepreneurs Increased number of jobs Increased attractiveness of the region to tourist

Tab. 5: Other effects of FMB interactions are described in the analysed literature reports
Source: author's elaboration

approach to the phenomenon of FMBs. Below, I have listed features and factors that, in my opinion, are not as common in other NIMBY sites or have not been analysed in detail. Taking them into consideration, further scientific research could expand the state of knowledge and unveil new mechanisms and processes occurring around FMBs.

6.1 Social dimension (internal)

FMBs result in the influx of a specific social group with a specific hierarchy. This group has a set of specific formalised behaviours, habits, and rules which are not found otherwise. Moreover – particularly in the case of the global network of American FMBs – these communities consist of people from many ethnic and cultural groups, differing in the intensity of connections, applicable norms, and forms of communication. The emergence of such a group (especially in a culturally or ethnically homogeneous peripheral area) can easily lead to many conflicts on various levels. At the same time, along with the length of experiencing the presence of FMBs, local communities may adopt specific behaviours and attitudes. New cultural patterns, unique to a particular area where foreign troops are stationed, may also be developed. The nature of the military associated with the widespread acceptance of violence, aggression, a sense of threat, and weapons as a symbol is an additional aspect.

6.2 Social dimension (external)

The intensity and scale of the FMB impacts also depend on the characteristic factors of the area in which it is located. In the case of civil-military relations, these include the strategy of action adopted by individual local governments, the level of knowledge of foreign languages by the local community, the level of education, the involvement of local cultural institutions, and, in a broader view, the characteristics and type of commune, distance from a large urban centre or the degree of industrialisation of a given area. Most military bases are located in rural or peripheral areas, in which communities can be more conservative and require a longer time to accept a new social group. Although these issues are equally important in the case of other NIMBY facilities, in combination with the internal social dimension, it is an extremely important and difficult issue in the context of civil-military relations and acceptance of a new investment in the neighbourhood, such as a FMB.

6.3 Spatial dimension (horizontal scale)

Due to their unique purpose, military facilities (especially those of foreign troops) are restricted objects or are only partially accessible. Despite this, the range and scale of impact in terms of space can significantly affect the daily life of residents in the short and long term. The direction of interaction is two-way. Services that satisfy the functioning of the base and the social desire to meet “new neighbours” can be directed from the ‘outside’. From the ‘inside’, there may be a desire to assimilate and get to know the environment.

6.4 Spatial dimension (vertical scale)

The area under the influence of an FMB object can be treated as a place of contact between actors representing a global scale (soldiers of international alliances and global political and economic networks) and actors assigned to a local scale (e.g. inhabitants of peripheral areas, excluded) without regional or supra-regional structures. The aforementioned adoption of attitudes or the creation of cultural patterns may lead to a change like the surrounding area (or locality), which may display features typical for large cities and agglomerations in the settlement hierarchy. This also applies to various types of services which should meet the needs of foreign soldiers, cultural and educational facilities, or enterprises, the existence of which would not be possible or would be very difficult without FMBs.

6.5 Military dimension

In addition to the social factor, the military dimension should also be added to the internal conditions. It concerns e.g. the type of military unit stationed in the base (e.g. used equipment, characteristics and area of operation, frequency of exercises), the size of the military unit stationed in the base, characteristics of the military unit/military base commander.

Even though most military areas can be classified as a military base, the characteristics of the unit that is stationed in or uses the area are important. A unit with heavy wheeled or tracked equipment will affect the environment to a different extent than an air or navy unit. The figure of the commander as the main military actor is also important. Depending on his vision of the functioning of the unit under his command, he can influence the intensity of contacts between subordinates and representatives of the local community and regulate the possibility of influencing the local economy with the private money of stationed soldiers. It can also affect the form and formation of relations with the cultural environment.

6.6 Time dimension

The majority of the reviewed studies concerned FMBs with a permanent characteristic. These bases, in addition to the infrastructure intended for the everyday functioning of soldiers, also include accommodation and education facilities for the families of soldiers, an increased number of civilian personnel, a well-developed service and commercial network, properly organised space as well as medical and transport infrastructures. A soldier stationed in such a base indirectly becomes a “resident” of a given area, and the base becomes a separate area with urban characteristics. In this case, the possibilities of cooperation with the surrounding area are high, and its proper establishment is important for the stationed army.

The situation is completely different when the military base is rotating, and the unit stationed there regularly changes. In such cases, there are cyclic processes of adaptation, shaping cooperation, establishing rules and norms in civil-military relations between the inhabitants and the army. For local governments, this can be a unique challenge in managing their area and embracing an appropriate development strategy.

The intensity and impact of the given factors on the neighbouring area and the community that inhabits it depends to a large extent on historical and geographical conditions. This may result in a single or a few dominant individual features. Nevertheless, it is difficult to find other objects in the literature reports that would have a set of such operating conditions that influence the environment.

7. Conclusion

This article presents a review of previous research on social attitudes towards Foreign Military Bases and the effects of their impact in the light of selected NIMBY theories and the processes of militarisation of space. FMBs can be treated as both NIMBY and YIMBY objects or change from an initial YIMBY associated with hopes for development into a NIMBY. The positive or negative attitudes will depend on the location of the object.

Factors indicating that FMBs are specific and special forms of objects in space were also described. Their uniqueness, however, depends on internal (military) factors – the characteristics of the military unit – as well as external (geographical) factors – socio-economic and environmental conditions of the areas in which these objects are located.

In the future, it is worth expanding the analyses by exploring the latter aspect, such as the dynamics of changes in social attitudes and the effects of spatial impacts based on socio-demographic

factors. It is also important to elucidate the activities of local governments in the face of the emergence of an FMB object in their area. Another issue worth developing in future analyses is the narrative of FMBs that refers to the authors' country of origin, as well as the impact of FMBs on local societies, depending on the level of democratisation in the country. In the context of the ongoing militarisation of space and social radicalisation, conducting research at the local level is therefore desirable.

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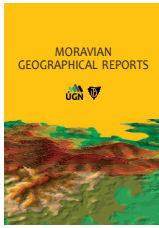
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Recreational use of the urban riverscape: What brings people to the river?

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Abstract

Visiting urban green and blue spaces improves the quality of life in cities as it helps to preserve human-nature bonds. In this context, the role of urban parks and forests has been well-recognised; however, much less is known about the landscapes of inland water bodies. To fill this gap, the study aimed to identify spatiotemporal patterns of recreational activities in the urban riverscape in relation to the visitors' residential proximity. Also, survey results were combined with spatial and remote sensing data to determine how the spatial characteristics of the riverscape affect its recreational use. The case of Warsaw, Poland, was used. The results indicated that the riverscape serves as a local park for the neighbouring communities, while it is rather a warm-weekend attraction for far-living ones. Visitors concentrate in the city centre, and spread out along the communication paths; however, spatial patterns of the magnitude of particular activities also show interbank differences. Spatial error models of drivers of riverscape recreation revealed (1) the multifaceted role of trees in densely visited areas and (2) the importance of physical availability for contact with the urban river. These findings expand knowledge on the recreational use of urban rivers by exploring its place-related motivations.

Keywords: urban riverscape, recreation, PPGIS, spatiotemporal patterns, spatial drivers, Warsaw, Poland

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1. Introduction

Urban green and blue spaces positively contribute to the quality of life in cities with multiple ecosystem services they provide. These spaces support air purification, heat reduction, water retention, and habitat/biodiversity maintenance (McPhearson et al., 2014). They are also significant providers of cultural ecosystem services (CES), namely non-material benefits to people's well-being arising from human-nature interactions (Chan et al., 2012). As a prominent reason for spending time outdoors, nature-related recreation is regarded as a key link between people and nature in urban areas (Bolund & Hunhammar, 1999). At the same time, urban growth leads to the increased demand for recreational use of urban nature (Chen et al., 2019). Therefore, the adequate provision of accessible, multifunctional, and inclusive green and blue spaces in cities should be of particular importance for urban planners as a part of the implementation of Sustainable Development Goals (United Nations, 2015). These spaces need to be created and managed in a way that balances their increased use intensity with the robustness of the recreational opportunities they provide. In this respect, it is essential to identify drivers of recreation, including which characteristics of green and blue spaces attract people depending on the purpose of their visits (Hegetschweiler et al., 2017).

This paper concerns the recreation within the urban riverscape, one of the key types of urban green and blue spaces. The results of a citywide participatory mapping survey were used to identify

spatially explicit information about people's recreational activities along the river. Survey data were combined with spatial and remote sensing data to provide answers for the following questions:

1. To what extent the residential proximity to the urban riverscape influences the seasonal/intraweek patterns of recreational activities?;
2. What are the spatial patterns of urban riverscape activities?; and
3. How do urban riverscape characteristics influence its recreational use?

The problem was addressed by taking the example of the Vistula River in Warsaw, Poland. By linking spatiotemporal patterns of recreational activities with urban riverscape features, insights from the study can be applied in the context of spatial planning in riverine cities of the temperate zone in general, and management of recreation in particular.

2. Theoretical background

Previous studies have explored links between the recreational activities of city dwellers and the spatial characteristics of urban green and blue spaces. Changes in recreational preferences were identified along the urban-periurban gradient (Rall et al., 2017; Riechers et al., 2019). Differences were also found while comparing various settings, such as parks and brownfields (Paliwoda & Priess,

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2021), or parks and forests (Pinto et al., 2021). The size of the area (Bertram & Rehdanz, 2015), its shape (Brown et al., 2014), and connectivity to other green spaces (Wang et al., 2022) proved to be of particular importance for some users, such as cyclists or dog walkers. The relationship between actual or perceived distance from home and the visited places has been explored, with a general preference for regular visits to nearby green and blue spaces (Priess et al., 2021). Zhang and Zhou (2018) found an association between the accessibility of urban parks with public transport and visitation rates. Referring to the site characteristics, biodiversity level (Bertram & Rehdanz, 2015), land cover (Dade et al., 2020; Pinto et al., 2021), landscape diversity (Chang & Olafsson, 2022) and density of vegetation (Bjerke et al., 2006) were found to explain how people use these spaces. Recreation is also fostered by the presence of man-made amenities, such as paths, benches, gastronomy, and sports equipment (McCormack et al., 2010; Palliwoda & Priess, 2021), with the specific needs of visitors for different activities (Krellenberg et al., 2021).

The above findings are mostly related to urban parks and forests, as their recreational role has been studied most extensively (Hegetschweiler et al., 2017; Browning et al., 2022). Much less attention has been paid to urban blue spaces, however, including rivers and streams (Veerkamp et al., 2021). With adjacent areas, rivers in cities form urban riverscapes. The character and physiognomy of riverscapes have evolved as a mutual effect of natural processes and man-made transformations; as a result, they consist of a variety of formal and informal green spaces along with various types of man-made riverfronts (Duran-Vian et al., 2021). Due to this heterogeneity, urban riverscapes provide multiple recreational opportunities to city dwellers, related to the use of riverbanks and the corridor itself (Stepniewska & Sobczak, 2017). Flowing water supports relaxation and contemplation by attracting multiple senses (Völker & Kistemann, 2013). The suitability of the riverscape for physical activities is stimulated by its linear shape; walking, cycling, or jogging can be performed on more or less landscaped shores, while water-based activities (e.g. kayaking, cruising) along the river corridor (Stepniewska & Sobczak, 2017). Apart from recreation, the paths along urban streams are aesthetically pleasing and evoke a sense of place (Kicić et al., 2022). Rivers are also perceived as highly natural compared to other types of urban green and blue spaces, which may attract people trying to isolate themselves from the urban rush (Kaplan & Kaplan, 1989).

Studies on recreational use of urban blue spaces have focused so far on exploring the spectrum of activities (Stepniewska & Sobczak, 2017) and identifying user-related determinants of recreational preferences (Hossu et al., 2019). At the same time, they sparsely addressed the temporal variability of the use of blue spaces (Vierikko & Yli-Pelkonen, 2019), and rarely explored the spatial patterns and drivers of the activities (Scott Schafer et al., 2013).

3. Materials and methods

3.1 The study area

Warsaw, a 2-million Polish metropolis, is located in the central part of the country, on both banks of the Vistula River (Fig. 1). Comparable to Berlin (51%) and Vienna (44%), nearly half of the city area (47%) is covered with green and blue spaces (European Environment Agency, 2022). The Vistula is a key element of the ecological system of the city, serving as main aeration corridor, supporting urban heat reduction, and connecting urban and suburban green spaces. It is also protected under the Natura 2000 programme as a corridor for migratory birds. Riverbed regulation processes have not advanced, with the construction of groynes and regular river dredging as the main interventions of the river flow (Degórska & Degórski, 2017). Warsaw's riverscape was used

as a case study as it represents multiple types of riverfronts that can be found in other riverine cities in the temperate zone. In the city centre, a sequence of concrete boulevards has formed on the western bank (Fig. 1, photo A). Similar constructions that join flood prevention and urban promenade functions have been built in numerous cities and studied in terms of benefits from experiencing the river (Völker & Kistemann, 2013), typical and nontypical use of recreational facilities (Miaux & Garneau, 2016), or the impact of infrastructural changes on people's perception and use of promenade (Vert et al., 2019). On the opposite shore, the quasi-natural riparian zone is covered with trees and grass (Fig. 1, photo B). Outside the city centre, the original shape of the middle-course valley was greatly preserved (Fig. 1, photo C); similar landscapes can be found in Bratislava, Slovakia, or Novi Sad, Serbia.

In 2018, 73% of Warsaw residents visited the river (Warsaw City Hall, 2019). Similar to other riverine cities, typical visitors are young or middle-aged, and spend time on the boulevards for leisure and taking walks (Warsaw City Hall, 2020; Bąkowska-Waldmann, 2022).

3.2 Survey participants and questionnaire design

Data on recreational activities was collected as a part of the broader participatory mapping survey on how urban residents use and perceive the riverscape. The online map-based questionnaire was designed using Maptionnaire (Mapita, www.maptionnaire.com). This way of data collection was chosen for several reasons. First, mapping in selected locations within the riverscape can narrow the scope of the research to the preferences of visitors only met in these places; the online distribution of the survey broadened the spatial extent of the obtained results. Also, online PPGIS surveys are relatively easy to conduct both in terms of survey distribution and filling them by the respondents (Brown & Kyttä, 2014). Ultimately, the online form was preferred due to the sanitary conditions as the number of cases of COVID-19 in Poland increased when the survey was conducted (autumn 2021).

The bottom-up approach was followed in this study as it was aimed at the members of all local communities across the city of Warsaw. To invite the participants, the questionnaire was sent to ca. 200 local communities (neighbourhoods, housing estates, housing cooperatives) using Facebook groups gathering members of these communities. It was additionally submitted to several district and sport-related groups (e.g. cyclists, kayakers, ice swimmers, fishers). As a result, 246 groups were addressed with the survey (Supplementary Material S1). The survey was active between 29 November and 22 December 2021. 7, 14, and 21 days after the first publication, the link to the questionnaire was republished in order to attract new participants.

Overall, the survey was comprised of six sections grouping 24 questions; the sections that were used in this paper can be found in Supplementary Material S2. The key part of the survey was questions related to the mapping results. Participants were asked to mark up to three places and three routes they preferred to visit within the study area. The city and district boundaries, as well as the extent of the study area, were presented on the background map. For each of the marks, the respondents indicated the frequency of visits, seasonal and weekly preferences, and preferred activities. Survey participants could choose up to three activities from the predefined list, including the option to provide their own answer using the open question. The answers from both sources were then grouped into nine bunches:

- Recreational walks (taking walks);
- Routine necessities (walking a dog; spending time with a child);
- Land sports (riding a bicycle; practising yoga; using open-air gym and workout zone; running);



Fig. 1: The study area (red line)

Notes: The boundary of Warsaw is marked with the blue line. In the box, the path/trail network was marked with the white lines
Source: National Geoportal (2023), modified by the author; photographs by the author

- Contact with nature (observing nature; feeding animals);
- Water sports (kayaking, sailing; cruising; fishing; bathing);
- Social life and entertainment (spend time in bars, restaurants, cafes; take part in cultural events, e.g. outdoor cinema, festivals, fairs; drinking alcohol);
- Relax (relax/do nothing - sit on a blanket/grass, rest, sunbathe);
- Taking photographs; and
- Transit (moving through on the way to other places).

3.3 Data analysis

3.3.1 Temporal patterns of urban riverscape recreation

The associations between the temporal preferences of visitors and recreational activities were assessed in relation to their place of residence. The received questionnaires were grouped into two sets regarding residential proximity to the riverscape. Close-living visitors (inside the 1-km buffer around the study area) and far-living visitors (the remaining of the surveyed) were compared in terms of their seasonal and weekday-weekend recreational preferences. Seasonal patterns were identified using the percentages of users who declared they undertake the particular activity in a season in relation to all close-living or far-living survey participants visiting the riverscape in this season. For intraweek preferences, percentages of users were calculated separately for each activity in relation to the number of close-living or far-living respondents who declared they undertake this activity.

3.3.2 Spatial patterns of urban riverscape recreation

The marks were initially pre-processed by excluding points and routes drawn outside the study area. Additionally, all routes were checked for evident spatial biases arising from imprecise marking; if necessary, they were generally adjusted to the nearest possible route (e.g. to the nearest bridge). The spatial distribution of the riverscape activities was analysed using a fishnet with a cell side length of 100 meters. On a cell level, the magnitude of the recreational activity was measured in order to balance the absolute and relative importance of each activity across space. It was calculated using the following formula:

$$M_x = \frac{n_x}{n_{all}} \times \sqrt{n_x}$$

where n_x means the number of marks representing activity x in a cell, and n_{all} means the number of all marks in this cell. The results were then plotted as a series of maps in order to identify how the magnitude of the particular activity varies within the riverscape, and to compare spatial patterns of the activities.

3.3.3 Spatial drivers of riverscape recreation

The demand for riverscape recreation may vary spatially, as influenced by the landscape characteristics that attract visitors or amenities that enable them to undertake particular activities. To identify these links, eight variables were tested as potential spatial

drivers of riverscape recreation (Tab. 1). The catalogue of variables aimed to encompass multiple aspects of the functioning of the riverscape as a recreational space, including the spatial variation of its accessibility, land cover, management level, and spaciousness. To allow the replicability of the study, the variables were built using publicly available data. Using the rasterised network of pedestrian and cycling paths of the study area, Cost Distance tool from Spatial Analyst toolbox was applied to generate raster datasets of path distance to the nearest entrance/exit point, public transport stop, recreational amenity, or gastronomy object. The datasets were vectorised, and spatially joined to the fishnet to calculate the mean distance per cell. Path distance was preferred over Euclidean distance as it takes into account the actual accessibility of the riverscape; for example, the distance between locations situated on the opposite banks of the river was calculated assuming the use of the nearest bridge. Near tool from the Analysis toolbox was used to calculate the shortest Euclidean distance from the centroids of the fishnet's cells to the shoreline. Viewshed tool from the Spatial Analyst toolbox was used to generate viewsheds from the centroids of the cells. All spatial analyses were conducted using ArcMap 10.8 (Esri, 2020).

Spatial drivers of riverscape recreation were analysed on a cell level, with the same fishnet as used to identify spatial distribution of the activities undertaken along the river; only cells where the particular activity was reported were taken into analysis. The magnitude of activity (M_x) was set as a dependent variable. The explanatory variables were z-scored to facilitate the interpretation of the models. The collinearity of explanatory variables was checked using the Variation Inflation Index (VIF), with the criterion of variable exclusion of $VIF > 4$; as a result, the variable Distance to riverine gastronomy was excluded from all models. Next, for each activity, a 3-nearest neighbour queen contiguity spatial matrix was created. The distance of 300–400 meters from the cell centroid (up to 5 minutes walking distance) was used both to identify the spatial dependence of the variables and to overcome potential respondent mapping bias. The matrices were then applied to the OLS regression models of riverscape activities in order to diagnose spatial dependence with Global Moran's I of residuals and Lagrange Multiplier (lag and error tests). Spatial Error Models (SEM) were eventually performed for all activities as

the results of Robust Lagrange Multiplier (*error*) for sports, relax, and contact with water were significant, and for the other activities the significant value of Robust Lagrange Multiplier (*error*) was higher than the significant value of Robust Lagrange Multiplier (*lag*). The results of the OLS and SEM models were reported with coefficients and significance levels. The goodness-of-fit of the models was reported with the AIC value and R-squared. Statistical analyses were conducted using GEODA software (v.1.20.0.36).

4. Results

4.1 Survey sample and general recreational preferences

462 completely-filled questionnaires were returned by Warsaw residents. The sample consisted of a majority of women (61.9%) over men (35.3%); 4.8% of the surveyed did not specify their gender or refused to answer. The participants were mostly middle-aged (75.3%), highly educated (83.4%), and had a full-time job (81.2%). The median age was 39 (Standard Deviation = 10.5).

193 out of 462 survey participants (41.8%) lived in a 1-km buffer around the study area; 269 of them lived further away (58.2%). Close-living respondents visited the riverscape far more often than the far-living ones; 49.2% of them appeared along the river at least once a week (vs. 22.3% of far-living), while only one of the nine close-living respondents preferred rare visits, i.e. less often than once a month (vs. 39.4% of far-living). Close-living respondents predominantly reached the riverscape by foot (89.6%) or by bike (35.8%); fewer of them used public transport (16.6%) or private cars (13%). Transport preferences of far-living visitors were more balanced, with the descending willingness for using public transport (49.4%), bikes (48.3%), private cars (41.6%) and walking (37.2%).

439 of 462 respondents contributed with 998 marks related to their visits to the riverscape that intersect the study area (597 points and 401 routes); close-living visitors provided 2.39 marks per capita, while far-living ones 2.12 per capita. Regarding the activities they undertook, more than half of the survey participants declared recreational walks along the river (64.9%), social life and entertainment (52.3%), contact with nature (50.9%), and land sports (50.9%). Four of ten visitors preferred routine necessities

Variable	Description	Spatial extent	Measure unit	Source of data	Reference
Distance to entrance/exit points	Mean path distance from the cell to the nearest physical location where the border of the study area can be crossed: path/trail/stairs that enable to reach the path on the top of the embankments; crossings, tunnels, footbridges of the multilane roads; locations where pedestrian/bike paths cross the border	Study area	metres	Open Street Map (OSM), fieldwork	Sikorska et al., 2019
Distance to public transport stops	Mean path distance from the cell to the nearest public transport stop (bus, tram, train, metro)	Study area and 300 m buffer	metres	OSM, National Database of Topographic Objects (NDTO)	Zhang and Zhou, 2018
Distance to recreational amenities	Mean path distance from the cell to the nearest bench, picnic site, playground, bonfire place, dog park or outdoor gym	Study area and 50 m buffer	metres	OSM	McCormack et al., 2010
Distance to riverine gastronomy	Mean path distance from the cell to the nearest restaurant, bar, pub or café	Study area and 50 m buffer	metres	OSM	Kraemer and Kabisch, 2021
Distance to shoreline	Shortest Euclidean distance from the centroid of the cell to the shoreline	Study area	metres	NDTO	Chang and Olafsson, 2022
Path density	Total length of the pedestrian and bicycle paths per cell	Study area	metres	OSM	Kraemer and Kabisch, 2021
Tree canopy intensity	The proportion between number of LAS points representing high vegetation (2 meters and above) and the total area of the cell	Study area	continuous	National Geoportal	Chang and Olafsson, 2022
Riverscape openness	The ln-transformed area of the viewshed from the centroid of the cell	Study area	squared metres	National Geoportal	Van Berkel et al., 2018

Tab. 1: Overview of the variables
Source: author's elaboration

(39%), while relax and taking photographs were declared by 34.6% and 33.8% of the respondents, respectively. Riverscape was used as a transit corridor by 22.7% of the survey participants, while activities related to water sports were indicated by 22.1% of them. Other activities (e.g. playing music, reading books, skiing) were mentioned by a small group of visitors (5.2%).

Close-living and far-living visitors differed in terms of their recreational preferences (Fig. 2). The former were especially more willing to spend time in the riverscape on routine necessities (+ 21.2 pp), contact with nature (+ 7 pp) and recreational walks (+ 5.9 pp) than the latter. Conversely, social life and entertainment and relax were the activities relatively more popular among far-living visitors (+ 10.8 pp and + 7.9 pp, respectively).

4.2 Urban riverscape recreation: temporal patterns

4.2.1 Seasonal preferences

The survey results suggest that the Vistula in Warsaw attracts a comparable share of visitors in summer (91.7% of close-living visitors, 94.4% of far-living visitors) and spring (91.2% of close-living visitors, 84% of far-living visitors). The other seasons, however, are notably more popular among close-living visitors, with 85.5% of them spending time along the river in autumn (vs. 68% of far-living ones) and 69.4% in winter (vs. 40.9%).

Regarding seasonal differences in demand for particular activities, recreational walks, contact with nature, taking photographs, and transit were found to attract a similar share of visitors regardless of the season; this pattern was observed for both groups of survey participants (Fig. 3). The demand for social life and entertainment and relax was generally higher in spring and summer, while the relative interest in visiting the riverscape for routine necessities slightly increased in winter for both groups. The higher share of close-living visitors did land sports in spring and summer than in the case of those spending time along the river in the other seasons; it was more balanced for far-living survey participants. Water sports peaked among close-living visitors in the summer.

4.2.2 Intraweek preferences

The majority of those surveyed preferred to spend time in the riverscape all week (81.9% of close-living and 64.7% of far-living). Nearly one-third (30.9% of the latter declared only-weekend visits (vs. 11.4% of close-living respondents), while only a few survey participants appear along the river only-weekdays (3.1% of close-living and 1.5 of far-living).

The general pattern is reflected on the activity level (Fig. 4). For all of them, the share of only-weekend visitors is much higher among far-living visitors than among close-living ones; it is about tripled for routine necessities, social life and entertainment, and

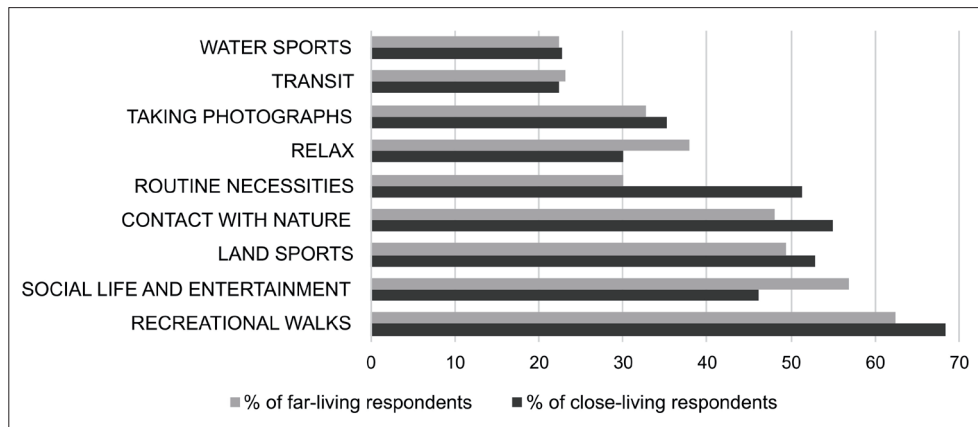


Fig. 2: The comparison of recreational preferences of close-living and far-living riverscape visitors
Source: author's elaboration

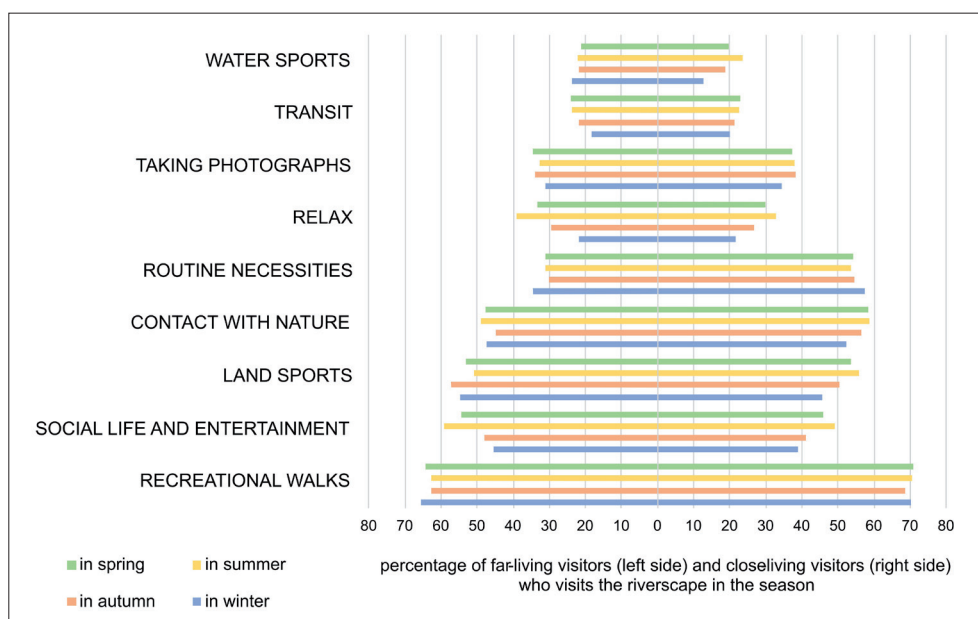


Fig. 3: Riverscape activities by seasonal preferences of close-living and far-living riverscape visitors
Source: author's elaboration

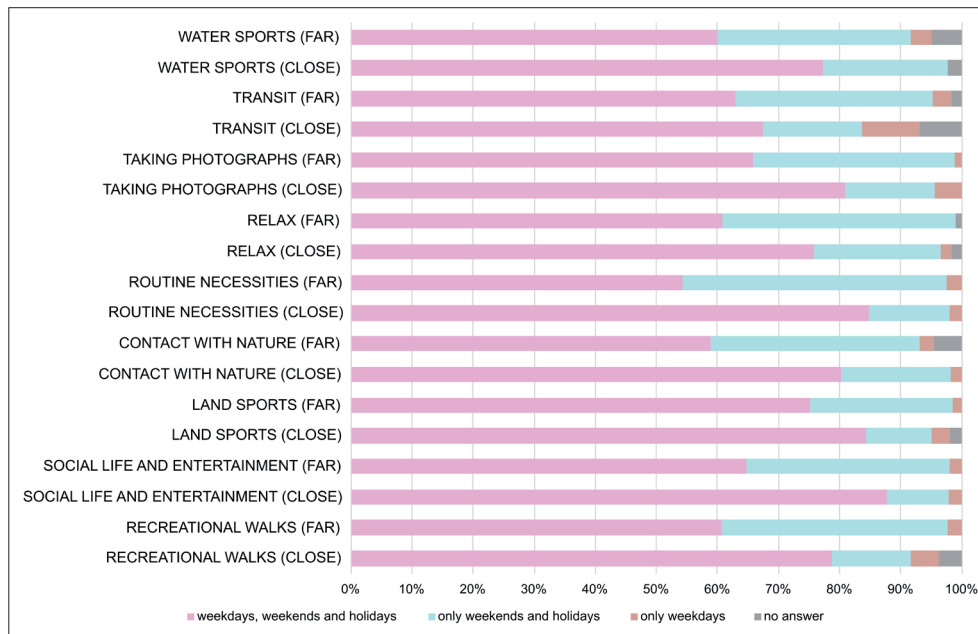


Fig. 4. Riverscape activities by intraweek preferences of close-living and far-living riverscape visitors
Source: author's elaboration

recreational walks. Regarding the shares of all-week visitors, the most temporally universal activities are social life and entertainment, routine necessities and land sports (close-living survey participants), and land sports, taking photographs and social life and entertainment (the far-living ones). The highest share of only-weekday visitors was noted among close-living visitors who declared use of riverscape for transit purposes.

4.3 Urban riverscape recreation: spatial patterns

The results indicated that survey participants were generally more likely to spend time in the city centre, on both sides of the river (Fig. 5). The magnitude of activities (M_x) decreased towards the city peripheries; however, there were differences between banks regarding the extent of the areas with the highest magnitudes. In the case of recreational walks, social life and entertainment, and transit, elongated clusters of high magnitudes have formed along the boulevards on the western bank, while on the opposite shore the agglomerations have formed around the popular urban beaches. Land sports and contact with nature represent the opposite pattern as the visitors concentrated along main communication paths on the eastern bank, with a smaller extent of boulevard hotspot. Routine necessities play the significant role on the boulevards, but they are also prominent on the peripheries, in mixed forests (north) and grasslands (centre-south, south). A unique pattern has formed for water sports, notably related to the riverbed. On-water routes associated multiple activities, however, including land sports, contact with nature, social life and entertainment, and even transit to some extent. Relax was mostly linked to the boulevards in the city core; however, small hotspots of high magnitude can be also found in the southern part of the study area. In the city centre, taking photographs is of high importance on both sides of the river, with the strong role of viewpoints on the Warsaw Old Town; on the peripheries, the magnitude grows on paths on the tops of embankments.

4.4 Spatial drivers of the recreational use of the riverscape

The results of OLS regression suggest low to moderate explanatory power of the used variables as R-squared values did not exceed 0.3 in any case (Tab. 2). The problem of spatial dependence was also found as the distribution of residuals was autocorrelated for all models (Moran's I significant at the 0.05 level), and the Robust Lagrange Multiplier (error) was significant at the same level.

Distance to the entrance/exit points negatively influenced the magnitudes of all activities except contact with nature and water sports. The longer the distance to the public transport stops, the more visitors for routine necessities and taking photographs; the opposite pattern for recreational walks, social life and entertainment and land sports underscored the role of buses, trams, and metro for main riverscape activities. Except for land sports, people's activity was generally interlinked with the proximity to recreational amenities. The closer the shoreline, the higher the magnitude of recreational walks, social life and entertainment, contact with nature and transit; however, the opposite pattern was observed for taking photographs. The key role of paths was manifested in the general positive association between path density and the magnitudes of all riverbank activities. The more intensive tree canopy, the more visitors seek contact with nature; the opposite pattern was noted for social life and entertainment, transit, and water sports. Riverscape openness was in general negatively associated with magnitudes of activities; a positive relationship was found only for water sports as related to the broad viewsheds from the water level.

Spatial error models are considerably better fitted than OLS models as lower AIC values were noted for all activities (Tab. 3). Models also differ in terms of regression equations as coefficient values and significance levels changed in several cases. High spatial dependence is reflected through highly significant Lambda values that vary between 0.73 (water sports) and 0.85 (recreational walks).

When spatial dependence was taken into account, the role of distance to entrance/exit points changed as their proximity only kept stimulating relax, but for recreational walks the coefficient changed its sign. Social life and entertainment, relax and water sports turned out to be more popular closer to public transport stops, while demand for taking photographs kept growing along with the distance. Proximity to recreational amenities significantly stimulated all activities except social life and entertainment, land sports, and water sports. Compared to OLS models, only demand for social life and entertainment remained negatively associated with growing distance to the shoreline, while for the rest of riverbank activities (except transit) the opposite pattern was found. Path density kept stimulating the activities, except water sports. Tree canopy intensity positively

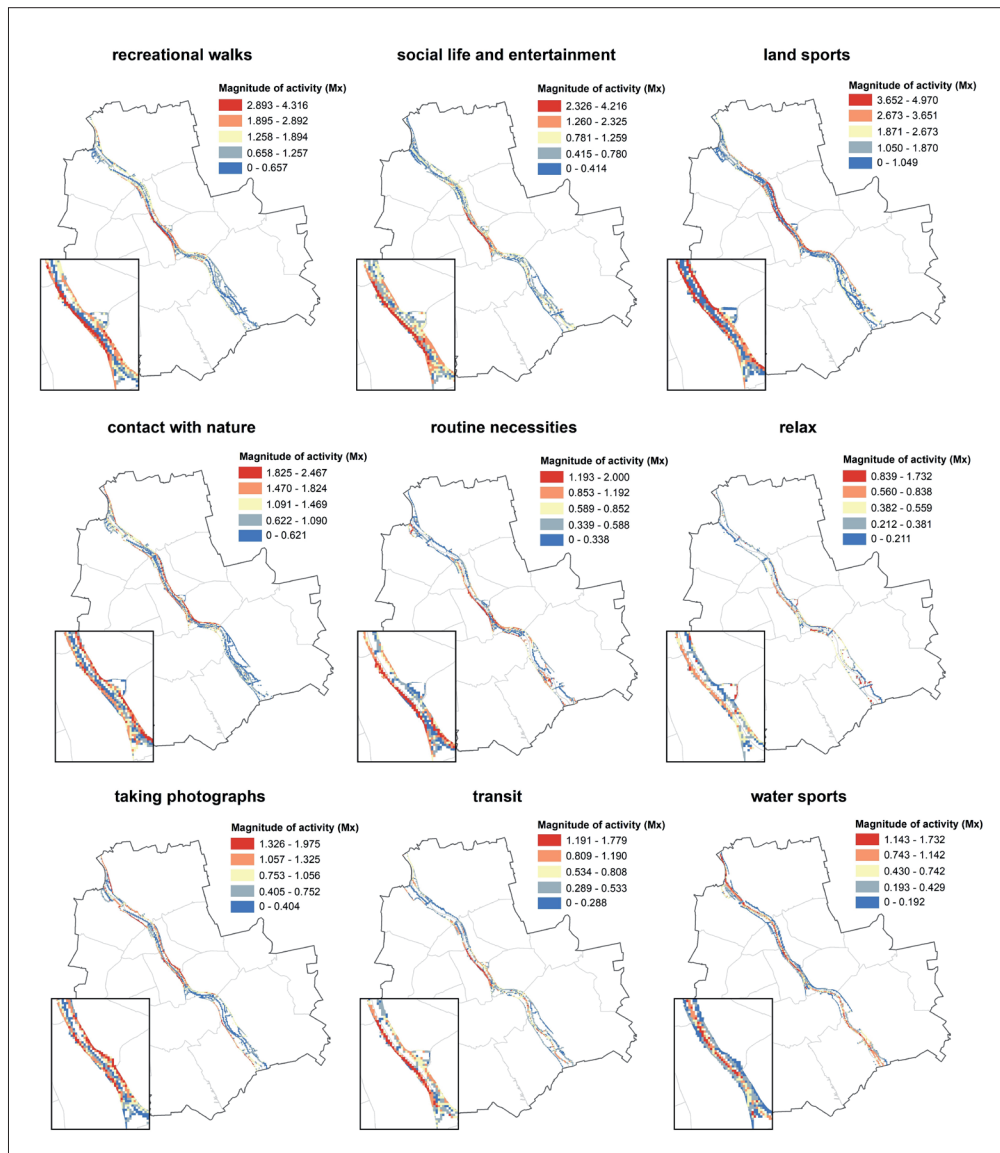


Fig. 5: The magnitudes of the riverscape activities
Source: author's elaboration

influenced recreational walks, land sports, contact with nature, routine necessities and taking photographs, while, compared to OLS models, it turned out to be insignificant for social life and entertainment. The role of riverscape openness narrowed to a positive influence on water sports, and the opposite pattern was found for recreational walks.

5. Discussion

The study revealed that recreational walks, social life and entertainment and, to a lesser extent, land sports and contact with nature were the most prominent activities among the riverscape visitors. This catalogue corresponds to the results of previous studies on urban greenery in Europe (Rall et al., 2019; Fisher et al., 2018; Bertram & Rehdanz, 2015) and blue spaces in particular (Stepniewska & Sobczak, 2017; Hossu et al., 2019). Furthermore, nearly 25% of the survey participants declared water-based activities in the past year. In contrast, the in situ survey of Stepniewska & Sobczak (2017) on the Warta River in Poznań, Poland, revealed that only a few percent of the surveyed declared boating, canoeing, or angling. The high number of water-oriented visitors can be linked to the method of recruitment of participants (the snowballing effect in the most engaged communities, e.g. kayakers).

5.1 When by the urban river? Citywide and local perspectives

The results suggest that the way recreational needs are fulfilled by the urban riverscape is related to the residential proximity of its users. Close-living visitors treat the riverscape as one of the neighbourhood parks. It is visited regardless of the season (and at least once a week by a half of those surveyed), popular both on weekdays and weekends, predominantly accessed by foot, and mostly used for walking (the dog), nature contemplation, and physical activity. From the perspective of far-living visitors, it is rather perceived as a seasonal attraction; visits along the river take place several times a year, preferably in the warm season and with a notable share of only-weekend (cf. Elbakidze et al., 2022). Summer peaks are in line with the other studies on urban blue spaces (Vierikko & Yli-Pelkonen, 2019; Grzyb & Kulczyk, 2023). The set of the most popular activities is similar regardless of the place of residence; however, the role of the Vistula as a place of relaxation and social interactions is much more prominent for the far-living visitors. Also, their slight off-summer preference for sports can be linked to the optimal ambient temperatures for best performances: 10–17.5 °C for running (Valenzuela et al., 2022) and 10–25 °C for cycling (Mantzios et al., 2021). The differences in shares of only-weekend visitors are consistent with insights from previous studies. Bertram et al. (2017) found that Berlin residents

	Recreational walks	Social life and entertainment	Land sports	Contact with nature	Routine necessities	Relax	Taking photographs	Transit	Water sports
Distance to entrance/exit points	-0.053**	-0.054***	-0.067**	-0.018	-0.063***	-0.0041***	-0.030**	-0.054***	0.012
Distance to public transport stops	-0.041*	-0.097***	-0.07**	-0.021	0.021*	0.004	0.106***	-0.030***	-0.044***
Distance to recreational amenities	-0.047**	-0.083*	0.111***	-0.128***	-0.047***	0.003	-0.071***	-0.060***	-0.059***
Distance to shoreline	-0.071***	-0.140***	-0.002	-0.057***	0.002	0.008	0.043***	-0.039***	-0.076***
Path density	0.336***	0.222***	0.502***	0.156***	0.075***	-0.003	0.114***	0.065***	-0.115***
Tree canopy intensity	-0.013	-0.071***	-0.025	0.046**	-0.049	-0.004	-0.009	-0.034***	-0.035**
Riverscape openness	-0.130***	-0.017	-0.129***	-0.054***	-0.021	0.001	-0.061***	0.017	0.113***
Constant	1.104***	0.693***	1.614***	0.917***	0.564***	0.392***	0.697***	0.513***	0.443***
AIC	3,997.67	2,942.20	5,877.11	2,579.26	1,165.02	-34.30	1,628.51	514.04	963.65
R-squared	0.27	0.28	0.28	0.20	0.11	0.06	0.17	0.22	0.40
Number of cells	1,957	2,080	2,159	1,960	1,587	1,237	1,708	1,554	1,560
Moran's I (error)	0.278***	0.274***	0.205***	0.272***	0.366***	0.267***	0.364***	0.266***	0.186***
Lagrange Multiplier (lag)	1,251.037***	1,334.547***	621.188***	1,104.244***	1,516.904***	461.097***	1,559.209***	722.484***	270.348***
Robust LM (lag)	73.161***	74.488***	1.118	14.447***	12.365***	1.969	11.541***	31.343***	0.168
Lagrange Multiplier (error)	1,488.103***	1,659.525***	1,009.325***	1,490.121***	1,714.517***	566.668***	1,896.665***	815.896***	500.612***
Robust LM (error)	310.228***	399.466**	388.255***	400.324**	209.978***	107.541***	349.017***	124.755***	230.431***
LM (SARMA)	1,561.264***	1,734.013***	1,009.443***	1,504.568***	1,726.882***	568.637***	1,908.225***	847.238***	500.780***

Tab. 2: OLS regression models of spatial drivers of urban riverscape recreation. Significance level is marked with asterisks * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Source: author's calculations

	Recreational walks	Social life and entertainment	Land sports	Contact with nature	Routine necessities	Relax	Taking photographs	Transit	Water sports
Distance to entrance/exit points	0.067**	-0.015	0.058	0.005	-0.008	-0.029*	0.015	-0.0184	-0.028*
Distance to public transport stops	0.064*	-0.117***	-0.015	0.004	0.001	-0.045**	0.090***	0.024	-0.086***
Distance to recreational amenities	-0.104**	-0.018	0.072	-0.103***	-0.090***	-0.044*	-0.068**	-0.107***	-0.005
Distance to shoreline	0.157***	-0.102***	0.309***	0.069**	0.040*	0.034*	0.128***	-0.025	-0.192***
Path density	0.268***	0.170***	0.472***	0.159***	0.058***	0.003	0.106***	0.055***	-0.102***
Tree canopy intensity	0.101***	0.001	0.132***	0.066**	0.023*	-0.011	0.024*	-0.011	-0.081***
Riverscape openness	-0.053**	0.005	-0.026	-0.003	-0.016	0.008	-0.005	0.003	0.046***
Constant	1.127***	0.733***	1.634***	0.893***	0.582***	0.418***	0.709***	0.518***	0.392***
LAMBDA	0.846***	0.818***	0.823***	0.821***	0.804***	0.726***	0.819***	0.740***	0.734***
AIC	3,345.43	2,343.38	5,396.04	2,011.27	545.405	-329.29	943.72	134.60	694.76
R-squared	0.51	0.49	0.45	0.43	0.44	0.31	0.48	0.43	0.52
Number of cells	1,957	2,080	2,159	1,960	1,587	1,237	1,708	1,554	1,560

Tab. 3: Spatial error models of spatial drivers of urban riverscape recreation. Significance level is marked with asterisks * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Source: author's calculations

were more likely to contact nature and play sports during the week, while walking and social interactions played a more significant role at the end of the week.

5.2 Where by the urban river?

Survey participants clearly pointed out their preference for spending time along the river in the densely populated city core rather than in the peripheries, and the tendency was observed regardless of the preferred activity. Previous studies found significant links between the density of population in the park neighbourhood and the frequency of visits (Riechers et al., 2019) or social media activity (Hamstead et al., 2018). Analysis for the particular activities, however, provided a more nuanced image. To some extent, the results correspond with the work of Rall et al. (2017) and Riechers et al. (2019), both conducted in Berlin, and Warsaw's study of Bąkowska-Waldmann (2022): social life and entertainment and recreational walks were more important for city centre visitors. According to Pinto et al. (2021), sociodemographic diversity and the multifunctionality of urban nature account for the preference for social interactions. In this case, it applies to the most visited locations along the river; centrally located boulevards with bars and restaurants along them, and to the urban beaches on both shores (Warsaw City Hall, 2020). Since land sports and contact with nature were expected to be prominent in the city's outskirts, however, the results only partially confirmed this assumption. It is probably due to the presence of a quasi-natural riparian zone in the city centre, on the eastern bank of the river, both intensively used as a recreational space and admired from the boulevards on the opposite shore. Conversely, Rall et al. (2017) found in Berlin inner city clusters of sports, while nature experiences, spending time with family, and dog walking were more dispersed.

5.3 Spatial drivers of urban riverscape recreation

There are two major findings concerning how spatial drivers influence riverscape recreation. First, the attractiveness of riverine nature is multifaceted. Spatial error models revealed significant links between tree canopy intensity and a set of movement-related activities (recreational walks, land sports, routine necessities). These links specifically refer to the peripheral part of the riverscape, with paths and trails through the riparian forests and meadows as the main communication corridors. The results also suggest that tree-covered areas are valued both due to their recreational potential and the calming effect they provide, supporting previous studies that underscored the positive role of shade provision for recreational preferences at meso- (lower temperatures in the riparian forests) and microscale (shade provided by one or a couple of trees) (Ayala-Azcarraga et al., 2017; Krellenberg et al., 2021). OLS models proved the negative impact of tree canopy intensity on demand for social life and entertainment, but it turned out to be insignificant when spatial dependence was taken into account. On the other hand, this was the only non-water activity positively stimulated by the proximity of shoreline according to SEM; it is linked to the use of city-centre boulevards and riverine beaches where social life and entertainment strongly clustered. Here, visual contact with flowing water can be the key aspect of experiencing nature; for many, the river is probably treated as a nice background for social interactions rather than the main purpose of visits (Völker & Kistemann, 2013). OLS models also revealed negative associations between riverscape openness and people's activity that could be linked to limited access to shores outside the city core in both physical (wetlands, natural reserves) and visual (main paths are separated from the river by willow-poplar forest) terms. This effect remained significant only for recreational walks in SEM, however.

Second, it is all about accessibility. The study revealed that riverscape visitors stick to the paths regardless of the activity, which is in line with previous studies (Paliwoda & Priess, 2021).

Routes drawn by survey participants accounted for 40.4% of all the marks, and some point locations represented places where people decide to stop their routes for various reasons: to rest, to enjoy the view. However, the crowded paths and trails can reduce the tranquillity effect (Åberg and Tapsell, 2013) or generate conflicts between different visitors, such as cyclists and dog walkers (Smith et al., 2022). In terms of reaching the riverscape from the outside, the effects were more nuanced. SEM revealed that demand for predominantly city-core activities (social life and entertainment, relax) was associated with the availability of public transport as the river serves as a citywide attraction (Riechers et al., 2019). Demand for relax grows with the distance to the entrance/exit points and to public transport stops, which may indicate that people seek a calming refuge from the urban buzz (Kaplan & Kaplan, 1989). The lack of importance of public transport availability for recreational walks and land sports can be related to the use of riverscape as neighbourhood green spaces that are mostly reached by foot (Zwierzchowska et al., 2018). Nevertheless, for more distant spaces, insufficient connections were previously raised in relation to the less frequent visits (Elbakidze et al., 2022).

5.4 Methodological considerations

Online PPGIS surveys are a robust source of information on people's attitudes and preferences towards urban green spaces (Brown & Kyttä, 2014). They enable the researcher to broaden the scope of participants through multiple forms of survey distribution (e.g. flyers with QR code, social media posts, mailing lists). This study followed the bottom-up approach by aiming to reach all local communities across the city; in this respect, the questionnaire was submitted to more than 200 communities gathering the members of neighbourhoods, housing estates, and housing cooperatives, supplemented by several district and sport-related groups. This approach succeeded in providing the information on recreational patterns of Warsaw residents based on their residential proximity to the river. The way the questionnaire was distributed, however, also posed a challenge to demographically balance the sample. As a result, its composition was biased towards women and middle-aged people. Therefore, the results cannot be strictly referred to the city population. The recreational preferences of underrepresented groups require more attention as previous studies revealed age-led differences in attitudes towards and use of urban green spaces (see Ode Sang et al., 2016; Paliwoda & Priess, 2021; Hegetschweiler et al., 2022).

As the survey was conducted in late autumn, the participants were asked to synthesise their riverscape activity during the passing year. They marked usually visited locations and indicated seasonal and weekday-weekend preferences for them. Due to the long temporal scope of the research, the preferred time of day was not addressed. As it can vary seasonally, a panel survey conducted every three months could be conducted to get into detail about riverscape preferences in a day-night rhythm.

The study workflow may be easily implemented in management practice in the spectrum of riverine cities of the temperate zone due to the universality of the case study used. The value of online PPGIS surveys lies in their efficiency, convenient distribution, and respondent-friendly interfaces. Their advantage for monitoring urban outdoor recreation is the ability to obtain information about the entire area of interest at once, including locations that are rarely visited and may be difficult to monitor in other ways. Surveys can be conducted in a regular manner to provide information about the temporal patterns of people's recreational preferences, or standalone (e.g. to consult local management changes). Combined with data from other sources (e.g. interviews, field observations), spatially explicit recreational data can help the managers make data-driven decisions for sustainable management of the riverscape.

6. Conclusions and management and policy implications

In this paper, spatial, remote sensing, and survey data were combined to model spatial drivers of the recreational activities in the urban riverscape. Recreational walks, social life and entertainment, and contact with nature were found the most prominent activities along the urban river. Close-living visitors seem to treat the riverscape as a neighbourhood green space, while for those living further away it is rather an occasional attraction to visit on warm weekends. The central part of the city is a core of riverscape activity that spreads outwards along the paths and trails. OLS regression and spatial error models predicting spatial drivers of riverscape recreation showed the multifaceted role of riverine nature and underscored the role of riverscape accessibility. These findings shed new light on the motivations of riverscape visitors and provide knowledge that can support the sustainable planning and management of urban rivers as recreational spaces.

The obtained results indicated three main challenges for the spatial planning in riverine cities in general as well as the recreational policies towards the urban riverscape in particular. First, as dominated by outdoor activities, riverine recreation in the temperate zone is affected by seasonal changes; the off-season decrease of demand for visiting the riverscape is especially the highest in the case of visitors living more distantly from the river. The results underscored that the recreational potential of the riverscape is scalable, what requires the managers to consider both local and citywide perspectives in the preparation of recreational policies. Therefore, one of the solutions to overcome interseason disparities could be further development of the under-roof recreational opportunities taking place in autumn and winter (e.g. organising cultural events on barges tied to the boulevards). Previous studies underscored that the presence of amenities is correlated with the number of urban park users (Cohen et al., 2013), and they are valued regardless of the season (Vierikko & Yli-Pelkonen, 2019).

The other challenge in urban riverscape management is to balance conservation principles with the demand for recreational spaces. The Warsaw study results underscored the influence of centrality as well as the role of paths and amenities in the creation of recreational 'honeypots'. The term originates from conservation studies and defines (intentionally created) sites that attract a larger number of visitors than their surroundings (Williams et al., 2000). Honeypots are mostly used in protected areas to reduce human pressure by directing the flow of visitors to particular amenities or through selected paths and trails. In Warsaw, the central part of the riverscape on both sides functions as a multifunctional recreational honeypot, while outwards from the city centre the traffic is channelised using sequences of delineated paths, mostly led on the tops of embankments. As they are mostly hardened, they are suitable for walking and cycling; it attracts a significant number of visitors, at the same time reducing the direct pressure on the riparian zone. Nevertheless, the domination of the central part of the riverscape as free time destinations remains evident and requires further attempts in order to responsively spread out the recreational demand for the river. In this respect, new recreational amenities outside the central part of the riverscape should be aimed to minimise human impact on the riparian zone (e.g. dog parks, outdoor gyms). The spatial preferences of visitors can be also managed with the creation of the image of an urban riverscape using social media feeds by the local authorities. With knowledge of the patterns of riverscape recreation, specific places can be promoted as attractive to visit in general or for undertaking the particular activity in detail. On the other hand, the change of behaviour that is somewhere unwanted due to the management policies can be persuaded using social media posts that can be viewed by thousands of city residents.

Nature protection principles can also pose a challenge to provide the city residents with physical access to the river. The results indicated that the recreational use of the riverscape increases with distance from the shoreline; also, landscape openness was negatively associated with magnitudes of activities in OLS models. To address this challenge, more viewpoints on the river could be provided beyond the boulevards, with basic recreational infrastructure encouraging visitors to stay a while (e.g. log benches) if possible. To facilitate the access, both new and existing viewpoints should be properly signed. On the other hand, to reduce the human pressure on the riparian zone, some desire paths can be blocked using fallen branches. These insights may guide both the management of relatively natural areas and the planning processes of restoration of river valleys, where recreation is regarded as an important driver (Zingraff-Hamed et al., 2018).

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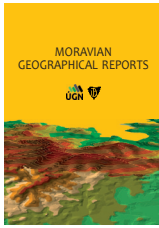
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COVID-19 pandemic and urban green spaces: Shifting usage behaviours and perceptions in Leipzig (Germany)?

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Abstract

Crises such as the COVID-19 pandemic challenge some established human-landscape interactions notably. In this article, we analyse whether the pandemic had an impact on the perception of urban green spaces (UGS) and usage behaviours in Leipzig, Germany. We use a quantitative survey to understand people's attitudes. Our study is novel in that it firstly explores the relationship between UGS and visitors during the final phase of the COVID-19 pandemic (winter 2022/2023), contrary to the vast majority of already existing studies that relied on digitally distributed surveys due to the lockdown protocols. Secondly our study does not apply exclusively online methods to reach out to the participants. The survey results show that about 40% (of the 115 participants) use parks more frequently during the final phase of the COVID-19 pandemic compared to before 2020. Characteristics such as proximity to home, naturalness and cleanliness have become the most relevant. We see a notable increase in the demand for secure public green spaces, particularly among female visitors. Every second respondent confirmed experiencing considerable difficulties when accessing UGS, revealing the existing (spatial) deficits in environmental justice. These results should be considered by urban planners to adapt UGS to the changing demands of the citizens.

Keywords: Urban green spaces (UGS), COVID-19, usage behaviour, ecosystem services, environmental justice, Leipzig, Germany

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1. Introduction

In March 2020, the World Health Organization declared COVID-19 a global health emergency (WHO, 2020). Consequently, governments around the globe imposed social and mobility restrictions. To stop the spread of COVID-19, the population was called upon to stay at home and to avoid social encounters for several weeks, such as for example during the lockdown protocols in Germany (German federal government, 2020).

The pandemic, but also the imposed restrictions, had a strong impact on various aspects of our everyday life. The use and perception of urban green spaces (UGS) is one of these aspects, where notable changes due to the pandemic are discussed. Several studies identified the regular usage of UGS as an effective strategy to cope with the challenges imposed by the pandemic. For example, lockdown protocols and other restrictions provoked psychological distress among people, particularly in densely populated urban areas (Xiong et al., 2020; Passavanti et al., 2021). The closure of UGS mainly affected low-income citizens because they often live in quarters with the least green space (Astell-Burt et al., 2014) and were not able to compensate with private green spaces (Geary et al., 2021). Hence, it is not surprising that even at an early stage

of the pandemic, researchers started to discuss the changing relationship between society and (public green) space (Honey-Rosés et al., 2020; Yamazaki et al., 2021).

One of the main questions now is how this changing relationship is manifesting itself and to what extent it represents a reconfiguration of established habits. According to Schot (2020), COVID-19 has indeed a certain potential to induce profound changes, referred to as “deep transition”. Such profound changes are becoming visible in the shift in everyday practices, e.g. new and different user behaviours in UGS, which have been documented in different case studies (Grima et al., 2020; Yap et al., 2022). The question remains, however, as to whether this change will also persist in the final phase of the pandemic.

2. Theoretical background

2.1 Urban green spaces and (cultural) ecosystem services

Analysing (the changing) patterns of green space usage has been the subject of research prior to COVID-19. Since the 1990s, the discussion was fuelled by establishing ecosystem services as a new concept that describes services provided by nature and

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used by humans (in an active or passive way; Mager et al., 2021). This concept allows for ecological aspects and their values to be considered in society during planning processes (Spyra et al., 2019). Hence, the transparent assessment of such services, and the communication with citizens and stakeholders about it, is regarded as a basis for a more participative planning approach (Mager et al., 2021, p. 41).

There are different types of ecosystem services, such as providing food and water or regulating natural systems (Huerta, 2022). In this study, we will focus on non-material benefits, labelled as cultural ecosystem services (CES). CES provide space for recreational activities and enhancement of well-being (MEA, 2005), both physical and mental (Ihlebaek et al., 2018). These services are difficult to quantify, and comparatively less studied, such as the differences in the usage of UGS around the world, which depend on cultural background and environmental influences (Fish et al., 2016). In addition, “CES are outcomes of the dynamic, complex, physical or spiritual relationships between ecosystems and humans, across landscapes, and often over long time periods” (Hirons et al., 2016).

Crises can reshape or renegotiate such long-established relationships, making CES a compelling object of study in crisis contexts. For example, ecosystem services in general have been shown to contribute to overall well-being by promoting mental health and reducing stress levels (Kabisch & van den Bosch, 2017, p. 208 f.; Bratman et al., 2019; Samuelsson et al., 2020). With growing spatial polarisation due to gentrification (Pearsall & Eller, 2020), however, or short-term rental induced touristification (Hübscher & Kallert, 2022), access to such services is not distributed equally throughout urban spaces. On the contrary, UGS have become a decisive factor in revaluation and speculation in local housing markets and often lead to rising prices (Schwarz et al., 2021, p. 10).

From an environmental justice perspective, this raises the question of how the COVID-19 pandemic affected everyday practices of the city's residents with regard to CES in urban green spaces. On the one hand, the importance of UGS during the lockdown protocols is undoubted, as they “allowed residents to perform physical activities, enjoy natural landscapes, and relax while socially distancing, thus making them a highly effective public health tool” (Huerta, 2022). On the other hand, Huerta (2022) rightly observes that there is a growing number of studies that reveal how low-income neighbourhoods are usually disadvantaged when it comes to the distribution of and access to UGS in cities. This is particularly relevant, as we know from previous studies that socially disadvantaged neighbourhoods have higher health burdens and were more vulnerable during the pandemic (Wade, 2020; Sharifi et al., 2021). Using environmental justice as a lens helps to unravel such (spatial) inequalities.

2.2 Research gap and objectives

There are different observations regarding the use of UGS during COVID-19. Some studies report an increase, others a decrease, depending on the geographical region and the time period (Jay et al., 2022). The same applies to attitudes towards environmental issues in general, where rather divergent results are observed (Marais-Potgieter & Thatcher, 2022). What is beyond any doubt is that pandemics are seen as critical moments where lifestyles change, and thus how UGS are being used and by whom (Yamazaki et al., 2021). On that basis, we identify two main research gaps in the relationship between UGS and citizens.

Firstly, most of the existing studies have focused on the immediate effects of the pandemic, comparing a shift in perceptions and behaviours with pre-COVID-19 settings. Accordingly, the question if this shift is persistent, even during the final phase of the pandemic, remains unanswered.

Secondly, during the pandemic, most of the researchers relied exclusively on online methods to reach out to their participants. For example, Cheng et al. (2021) analysed posts on social media platforms to assess the use and perception of UGS. Others make use of online surveys distributed on the internet (Lopez et al., 2021; Poortinga et al., 2021; Noszczyk et al., 2022). Online tools were certainly a valuable approach, particularly in times of restrictions due to the pandemic. At the same time, such methods exclude certain social groups from participating, for example those who are less media-savvy or less present on social media platforms.

In our study, we address both of the aforementioned gaps. Firstly, our study is novel, as it takes place during the final phase of the pandemic. With large parts of the (German) population vaccinated and a decreasing number of infections during winter 2022/2023, a “top German virologist says COVID-19 pandemic is over” (Deutsche Welle, 2022). Hence, the aim of this paper is to find out whether COVID-19 has changed the reasons for visiting UGS, compared to before the pandemic. We also want to find out to what extent this change is becoming permanent (Honey-Rosés et al., 2020), and we seek to understand which characteristics of urban green spaces and CES are important to meet the needs of their users and ensure environmental justice.

Secondly, our objective is to address a broad audience. Here, we will combine both online and offline approaches. This will help us to reach out to our potential participants, even during the winter season, but also to include a wide variety of people.

We choose Leipzig, Germany, as a case to study for several reasons. With 25 public parks and one city forest, Leipzig has the sixth highest green space density among large German cities, which amounts to approximately 17.15 m² per resident, or a total of 9.98 km² (Stadt Leipzig, 2023a; Keller, 2023). There is a diversity of UGS in Leipzig that encompasses both designed green spaces, but also an inner-city floodplain forest, which is the second largest of its kind in Germany (Kasperidus & Scholz, 2011). Unlike other cities (Huerta, 2022), the city administration in Leipzig provides public data about the distribution, characteristics, and area of UGS (Stadt Leipzig, 2023a), which makes it easier to conduct research about this topic.

With currently 616,000 residents, Leipzig has been Germany's fastest growing city over the last decade and has grown by about 100,000 residents since 2010 (Stadt Leipzig, 2023b). This strong growth has changed the framework of urban development in the city completely. The vacancy rate on the housing market dropped from 9.7% in 2010 to only 2.5% in 2021 (Statista, 2022). Simultaneously, displacement pressure is becoming stronger due to inner-city suburbanisation (Koumparelou et al., 2023), green gentrification (Ali et al., 2020) and commercial gentrification (Hübscher et al., 2020). Exploring the changing use of UGS in this setting is particularly compelling. Considering the abovementioned data, we presuppose an increasing pressure on UGS in Leipzig due to the sheer growth of 100,000 potential new users within the last 10 years.

We also see Leipzig as an interesting case to study with regard to the COVID-19 restrictions and their impacts. Germany faced several (strict) lockdown phases that included different measures, e.g. closed schools, limitation of social contacts in public space, and even a curfew (for an overview see Federal Ministry of Health, 2023). Compared to other countries, Germany's restrictions were rather moderate (Hale et al., 2021). Within Germany, Saxony (which is the German federal state or Bundesland where Leipzig is located), saw the second highest lethality rate, indicating the relationship between the number of deaths and the number of infections (Siekmann & RKI, 2023). This means that Leipzig is a city where the pandemic was particularly visible, within the German context.

On this basis, we structured our paper as follows: Section three describes the methods and data collection. In section four, we present the results. Section five discusses the findings and puts them into context with the current state of research. Section six draws a conclusion.

3. Methods

3.1 Study design

We conducted an online survey using a quantitative questionnaire (see [supplemental material](#)). Our aim was to explore the changes in behaviour and perception of people using UGS in Leipzig. Due to the high degree of standardisation, we were able to directly compare responses and draw conclusions (Mayer, 2013; Kromrey et al., 2016).

We decided to carry out the survey online via the LimeSurvey platform and created a link and a QR code which we distributed among UGS visitors on site in December 2022 and January 2023. This decision was influenced by the cold and wet weather conditions during these winter months in Germany. Conducting the survey online was one way to ensure a high level of participation, because it allows participants to complete the questionnaire from their homes and without the influence of the instructors (Mayer, 2013). By distributing the QR codes in the UGS, we ensured that we were reaching out to current park users. By means of a pre-test, we confirmed the functionality of both the process and the survey. If a person was interested in participating, but did not feel comfortable doing the survey online, we would do it together on site using an end device such as a mobile phone. We designed the questions in such a way that they offer as little scope for interpretation as possible. Additionally, all participants answered the questions in the same order and form. This guarantees a high degree of reliability and comparability of the study (Moosbrugger & Kelava, 2020).

Our survey was structured in thematic sections (Mayer, 2013; see Tab. 1). At the end, we asked some demographic questions, which we used to analyse the results of the different user groups. Between each section, we provided a short transition sentence that briefly explained the next subtopic. We used closed questions with predefined answer options, which we based on a previous field observation and categories found in other studies (e.g. Walter, 2015) in order to ensure data comparability. Participants were able to give their own answers in some cases, however, within the category “other”. We also used filtering questions to sort out those aspects that were not relevant to the participants. Thus, we gave our participants the opportunity to complete the questionnaire even if they could not answer some questions (Döring & Bortz, 2016).

There are multiple techniques to operationalise CES. In accordance with the classification of methods presented by Hiron et al. (2016), we mainly apply scaling methods. Hence, the response format for some of the questions was a rating scale (e.g. “Please specify whether the following park characteristics have become more or less important to you as a result of the COVID-19 pandemic”). A rating scale is easy to tick off and provides interval-scaled data that can be analysed statistically. We decided to use an odd number of levels, namely a five-point scale that ranged from “+ 2” (more important) to “– 2” (less important). This gave participants the possibility to choose a neutral option. Apart from a descriptive statistical analysis, we also performed one and two-sample t-tests and ANOVA.

3.2 Choice of urban green spaces

In order to choose appropriate case studies (meaning the locations where to approach the participants), the first step was to identify all UGS in Leipzig, based on the town hall’s online database (Stadt Leipzig, 2023a) and desktop research. On that basis, we chose four parks that were as different as possible according to criteria such as location, size, amenities, and socio-economic factors. In doing so, our aim is to reach a representative sample of UGS visitors in Leipzig, rather than comparing different parks with each other.

We have chosen Robert-Koch-Park, Lene-Voigt-Park, Rosental and Lennéanlage (see Tab. 2 and Fig. 1) as case studies, because these spaces display a certain diversity within the city of Leipzig (larger and smaller parks; central and peripheral locations, different degrees of naturalness). Embedded within a highly dynamic urban context, these UGS have been shaped and designed by society to varying degrees. Due to this variety of green spaces, we apply the broad concept of urban green spaces (UGS) in this paper. UGS encompass publicly accessible spaces “with a high degree of cover by vegetation” of either natural or designed origin (Schipperijn et al., 2013, p. 110). Simultaneously, our four selected cases are also labelled as parks by Leipzig’s town hall (Stadt Leipzig, 2023a), which is why in our paper we will use both terms.

Rosental is one of the largest UGS in Leipzig with extensive grass areas. We have chosen the Lene-Voigt-Park because of the numerous amenities it provides in an emerging neighbourhood with a very low average age of residents (Stadt Leipzig, 2023b). Robert-Koch-Park is situated in Grünau, a district of Leipzig with the highest unemployment rate (Stadt Leipzig, 2023c) and the lowest income (Stadt Leipzig, 2023d) in the city. In addition, we started to conduct the survey in Oberer/Unterer Park in the city centre. We decided to change the park for reasons of personal safety, however, as we were worried about the high level of crime

Part	Aspects
A/ Introduction	<ul style="list-style-type: none"> • Place of residence in Leipzig (neighbourhood) • Time living in Leipzig
B/ Current use of UGS	<ul style="list-style-type: none"> • Frequency • Purpose
C/ Change of usage	<ul style="list-style-type: none"> • Compare the current usage behaviour to the pre-COVID-19 context (with regard to activities, frequency, etc.) • Is the change (if any) persistent (probability)?
D/ Characteristics of UGS	<ul style="list-style-type: none"> • Assessment of the perceived characteristics of UGS, their importance and how they changed due to the pandemic
E/ Most frequently used UGS	<ul style="list-style-type: none"> • Designation of the personally most frequently used UGS in Leipzig and assessment whether this preference has changed due to the pandemic • Time taken and means of transportation to reach this UGS
F/ Demographic questions	<ul style="list-style-type: none"> • Age, gender, profession • Household income • Opinion about the current restrictions due to the pandemic

Tab. 1: Topics and aspects in the survey
Source: authors’ elaboration

Parks	Robert-Koch-Park	Lene-Voigt-Park	Rosental	Lennéanlage	
Size (ha)	25	11	70–118	3.3	
Amenities	Playground, many trees and greenery	Many amenities (sports facilities, playground, barbecue), less green	Café, playground, extensive green spaces	Seating, several trees	
Location	Adjacent to a hospital in a peripheral neighbourhood	Located in a dynamic and emerging neighbourhood	Adjacent to the zoo, close to the city centre	City centre	
Neighbourhoods	Grünau-Ost	Reudnitz-Thonberg	Zentrum-Nordwest	Zentrum	City of Leipzig
Population in 2022	7,775	23,293	11,042	1,901	624,689
Recreational area [ha] per resident (in 2020)*	0.0012	0.0010	0.018	0.0026	0.0055
Population growth 2012-2022 [%]	5.9	24.4	11.7	11.6	18.2
Average age in 2022 [years]	51.5	36.5	39.5	44.2	42.2
Net income in 2021 [€ per month]	1,400	1,700	2,200	2,000	1,592
Share of foreigners in 2022 [%]	14.3	14.0	10.4	30.7	13.4
Unemployment rate in 2022 [%]	7.2	4.4	2.9	4.0	5.1

Tab. 2: Selected UGS in Leipzig and their respective neighbourhoods

Note: *There is no public data available on the amount of green spaces per neighbourhood in Leipzig. The statistic on recreational area includes green spaces, but also entails other recreational spaces that are not regarded as green spaces.

Source: authors' elaboration based on Stadt Leipzig (2023a–d)



Fig. 1: Green spaces and the selected study areas in Leipzig

Source: authors' elaboration based on Open Street Map and Geofabrik GmbH (2022)

and did not feel safe during certain hours. Instead, we changed to Lennéanlage. Both parks have similar characteristics, particularly in terms of location (in the city centre) and size.

To conduct our online survey, we decided to provide QR codes. These codes were distributed in the four selected parks during different time slots (7–9 am, 12–2 pm, 3–5 pm, 6–8 pm), on several weekdays and weekends. In addition, the survey was carried out in common areas of each park, such as the entrances, and every third person or group of people was approached. This ensured the objectivity of the study and guaranteed that the sample was not biased towards a particular type of user (Moosbrugger & Kelava, 2020, p. 18). Within one month (14th of December 2022 to 14th of January 2023) we covered all time slots in each UGS.

3.3 Statistical Analysis

We distributed 439 QR codes in the chosen parks in Leipzig. In total, 142 individuals commenced the survey, and 115 completed it (response rate: 26.2%, completion rate: 81.0%). To analyse the sample, we started with a descriptive analysis of each question. We were particularly interested in the questions about changes in usage behaviour which were Likert-scaled. For better

interpretations in further steps, we conducted a one-sample t-test to check if the mean differs significantly from the midpoint (0) of the scale (Bortz & Schuster, 2011).

In addition, we used an independent sample t-test for one and two groups and analysis of variance (ANOVA) for more than two groups (Völkle & Erdfelder, 2010, p. 456) to analyse mean differences between groups (e.g. students, non-students, etc.) for certain factors (categories such as well-being and social interaction). Several textbooks mention that a normal distribution is required in order to use these tests. As a result, we examined the distribution visually and decided to use the t-test because we did not identify severe deviations from a normal distribution. Some more recent publications argue that t-tests are robust to violations of the normal distribution with sample sizes greater than 30 anyway (Herzog et al., 2019; Rasch et al., 2011; Pagano, 2011). This is also the reason why we decided to not dig deeper into this analysis.

One major objective was to compare income groups, different occupations and age groups with each other for certain factors simultaneously using an ANOVA. The ANOVA did not yield significant results, however, as the group sizes were too small (Bortz & Schuster, 2011, p. 481). Instead, we only identified

some tendencies in the results (Section 4). We are also not able to make significant statements about groups such as pensioners, unemployed persons or people identifying themselves as non-binary, due to small group sizes. Using independent t-tests, however, allowed us to identify some significant differences between groups, which we present in the results.

4. Results

4.1 Participants

We expected that the winter months and the associated weather conditions would make it more difficult to find participants in the parks. Still, we received 115 fully completed questionnaires for analysis. According to Slovin’s 1960 formula (Tejada & Punzalan, 2012), this is enough participants to have an alpha error tolerance of less than 10%, meaning that we are willing to accept a 10% chance of false rejection of our H_0 hypothesis when it is actually true. Still during the summertime, people use UGS more often and for different activities than in the winter. That is why we asked for activities and behaviours during summer months or days with good weather conditions, rather than winter months.

By conducting an online survey and distributing QR codes in the chosen parks, our aim was to address a broad variety of park users, which previous studies had difficulties with based on the lockdown protocols. Indeed, we reached a slightly higher proportion of participants aged 66 or older (4.3%) compared to other studies

(3.5%; Noszczyk et al., 2022). The majority of codes were circulated in Lene-Voigt-Park (43.3%), followed by Lennéanlage (25.9%) and Rosental (23.2%). The fewest codes were distributed in Robert-Koch-Park (7.5%). Approximately one fifth of the participants live in Reudnitz-Thonberg, which is the neighbourhood surrounding Lene-Voigt-Park, and this also reflects the QR code distribution named above. With the exception of Reudnitz-Thonberg, the distribution of participants throughout the city was relatively even. People from 38 out of 63 neighbourhoods in Leipzig participated. Table 3 shows some demographic and socio-economic characteristics of the participants.

4.2 General park usage behaviour

The results show that the vast majority of participants indicated feeling generally little affected or not affected at all by COVID-19 (94.1%, in winter 2022/23). Three quarters of all participants confirmed that they used UGS in the summer or on days with good weather at least once a week. To analyse this in more detail, we asked the participants about their activities in UGS. Based on “physical and intellectual interactions” provided by CES (Hirons et al., 2016, p. 549), we predefined the following six categories, which we based on a previous field observation and categories found in other studies (Walter, 2015) (transit, walking the dog, well-being, social interaction, sports, and education). The most frequent use of parks by participants was for transit routes (Fig. 2). Two thirds pointed out that they used parks for personal well-being on a weekly basis. The categories of walking the dog and education were the two least frequent usage categories.

Gender	Frequency	%	Age group	Frequency	%
Female	56	48.7	18–24	37	32.2
Male	58	50.4	25–40	55	47.8
Non-binary	1	0.9	41–65	18	15.7
Total	115	100.0	66+	5	4.3
Total	115	100.0	Total	115	100.0
Occupation	Frequency	%	Household income (€)	Frequency	%
Pupil	2	1.7	1,249 or lower	47	40.9
University student	45	39.1	1,250–1,749	13	11.3
Employee	50	43.5	1,750–2,499	19	16.5
Self-employed	8	7.0	2,500–3,499	13	11.3
Unemployed	2	1.7	3,500–4,999	10	8.7
Retired	5	4.3	5,000 or higher	13	11.3
Others	3	2.6			
Total	115	100.0	Total	115	100.0

Tab. 3: Demographic and socioeconomic characteristics of the sample
Source: authors’ elaboration

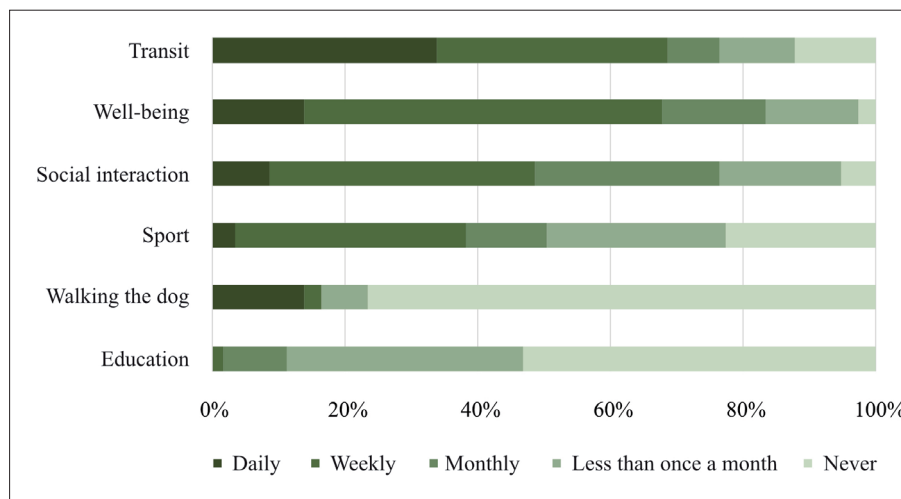


Fig. 2: Frequency and purpose of UGS usage
Source: authors’ elaboration

In the survey we asked, “Do you currently use parks more often compared to the winter months before the COVID-19 pandemic?”, which was confirmed by nearly 40% of the participants. In addition, 26.9% reported a change in their usage behaviour in terms of what they did in parks and their use of parks for new activities. We analysed this result to see if students showed a different behaviour compared to other groups, such as employees. Here we compared the mean values of both groups with a two-sample t-test, to identify significant differences between the groups. For this t-test the H_0 hypothesis was that students do not use parks significantly more often for new activities than employees. The analysis showed that we can reject this hypothesis with a 5% probability of error and therefore argue that the students tried more new activities than the other groups.

The results of the survey also show that more than half of those who use parks for new activities since the start of the pandemic use them for social interactions and personal well-being. Sports also play an important role in this regard. Looking at the general change in usage behaviour, rather than only new activities, the descriptive statistics show that the mean of all categories is above “0”. The question arises if this is a significant effect. The one-sample t-test indicates a significant difference from “0” in park usage with respect to well-being, social interaction, transit, and sports as demonstrated in Table 4. Their means are positive which indicates an increase in usage for these four categories.

On a rating scale, we asked the participants if they practised a certain use with higher (+2) or with lower frequency (-2) compared to before the pandemic. 0 meant there was no change, so an average higher than 0 would indicate an increase in usage. Here, “well-being” reached the highest average score (0.74), while “social interaction” came second (0.57; Fig. 3). Also, the uses

“transit” and “sports” reached higher frequencies. Contrary to that, “walking the dog” and “education” scored only 0.07 and 0.05 respectively, which were the only categories without a significant increase ($p > 0.05$). Still, the statistical tests have shown significant differences between the categories, with the social and personal functions of the UGS being those uses that increased most during the pandemic.

Compared to their pre-COVID-19 usage behaviour, 59.1% of the participants said they did not use parks more often at the time they were asked. In contrast, the distribution by category gives a different picture (Fig. 3). According to this distribution, at least 45% of them use the parks more frequently. In addition, almost 85% of participants stated that their changing usage behaviour is more likely or very likely to be permanent, even in a post-COVID-19 setting.

4.3 Characteristics of parks

The importance of characteristics of UGS depends on the needs of their visitors. In this questionnaire, we asked for the changing importance of several characteristics since the beginning of the COVID-19 pandemic (size, proximity to home, naturalness, sports grounds, playgrounds, security, infection protection, places to sit and cleanliness of a park).

Figure 4 illustrates that all these characteristics are, on average, more important to participants today compared to before the pandemic. Again, a one-sample t-test was used to test whether the means of these characteristics differed from the scale midpoint (0, no change). The test revealed a significant difference to the scale midpoint ($p < 0.05$) for all characteristics, except for playgrounds. The characteristic with the highest growth in importance for the participants since the beginning of COVID-19 is the location

	Mean*	Standard deviation	T	Df**	One-tailed p	Two-tailed p
Well-being	.74	.839	9.452	114	< .000	< .000
Social interaction	.57	.928	6.634	114	< .000	< .000
Sports	.29	.710	4.332	114	< .000	< .000
Transit	.27	.717	4.030	114	< .000	< .000
Education	.06	.566	1.152	114	.126	.252
Walking the dog	.05	.510	1.096	114	.138	.275

Tab. 4: T-test of changes in usage behaviour

Notes: *All items used a response scale of -2 (less use) to +2 (more use). One-sample t-tests were used to examine whether means differ from the midpoint of 0; **Degrees of freedom

Source: authors' elaboration

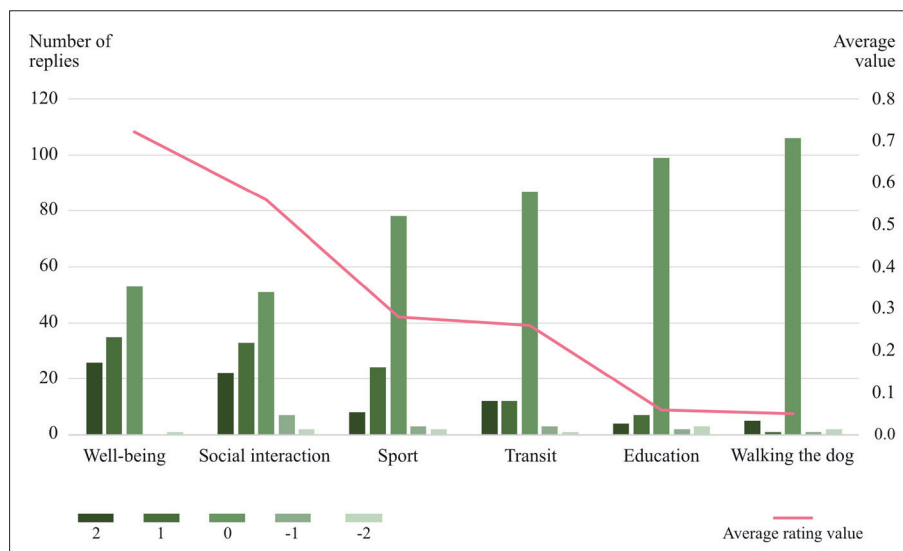


Fig. 3: Change in park usage since COVID-19 from higher frequencies (+2) to lower frequencies (-2)

Source: authors' elaboration

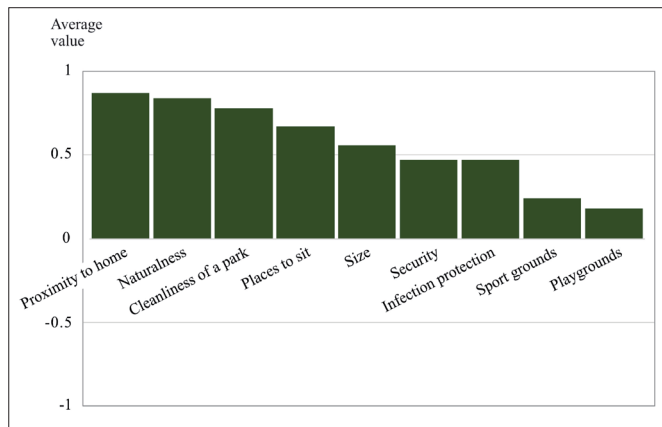


Fig. 4: Changing importance of characteristics in UGS since the beginning of the COVID-19 pandemic from strong increase (+2) to strong decrease (−2) in importance
Source: authors' elaboration

relative to their homes, with an average value of 0.98 (on a scale from +2 to −2). The second and third highest growth in importance was for cleanliness and naturalness of the parks with average values of 0.90 and 0.87 respectively.

Furthermore, security in public green spaces seems to be a matter of gender. We analysed this aspect in more detail since we suspected that it would be more important for women than for men (Madan & Nalla, 2016). The one-sided t-test shows that the importance of security in UGS is significantly higher ($p < 0.05$) for women than for men with values of 0.78 for women and 0.28 for men (on a scale from +2 to −2). We also analysed the survey regarding differences in income, occupation and age. For that we can identify differences in the means, but they do not reach the required level of significance (5%). This means that we cannot make any significant statements about them but can only point to certain trends. Nevertheless, our survey shows that the importance of sports facilities seems to have increased more for people with lower incomes than for those with higher incomes. This is also observable for the attribute of places to sit and the naturalness of the park, as well as for the activities of transit, well-being and social interaction. In terms of age, our survey shows that it is mainly younger people (under 25) and people over 65 who have changed their habits and perceptions of parks the most compared to pre-COVID-19. Although explanations and conclusions may seem obvious for some of these results, we cannot provide or draw on them due to lack of significance. They suggest possibilities for further research, however, and could be further explored in a later and larger study.

We found that about 30% of the participants need more than 14 minutes to get to their most frequently used park (by walking, cycling, car or public transport). Since most of the participants prefer to have a park nearby, we also wanted to know if people changed their most frequently visited UGS because of the pandemic, which was the case with 22.6% of the participants. Only two people, however, explicitly stated that COVID-19 was the reason for this change. The participants were sensitive with regard to physical obstacles when going to their preferred UGS: Almost one in two reported traffic problems (such as busy roads without traffic lights, etc.) or even safety concerns.

5. Discussion

This study has focused on the users' perspective on UGS, referring to other researchers' calls to activate and explore local knowledge about ecosystem services (Spyra et al., 2019, p. 1733). We understand cultural ecosystem services as a set of services that highly relate to human values and "do not exist *per se*, but are socially constructed" (Bernaud & Antona, 2014, p. 114). As such, they are the results

of a constant (re)negotiation and adaptation of practices. Hence, understanding how current crises reshape the perception of CES will contribute to strengthening the resilience of residents. In this sense, Hirons et al. rightly ask how to "widen the range of people, values, and cultural ecosystem services considered in ecosystem valuations?" (2016, p. 566). Here, our study does not give a final answer. Analysing user behaviour and perceptions, however, is one way to understand ecosystem services, and we have shown how to systematically assess these items in a post-COVID-19 setting.

We conducted a standardised survey which implied several limitations. We will briefly list them before we discuss our findings. Firstly, conducting a questionnaire online may provoke a certain technical barrier, particularly for less media-savvy people. This is a limitation that several studies have faced (see for example Noszczyk et al., 2022; Lopez et al., 2021). Secondly, the questionnaire was written exclusively in German, which creates a language barrier. Thirdly, it is also possible that the results are slightly distorted due to changing the park once, as described in Section 3.2. We still decided to keep the 15 questionnaires from Oberer/Unterer Park because the distributed QR codes could not be filtered out afterwards. Fourthly, we also decided not to include cyclists out of safety concerns in the winter weather conditions. We focused only on actual park users as we conducted the survey only in UGS. Hence, we neglected the perspective of residents who at this moment did not use UGS regularly for whatever reason. Fifthly, another distortion might occur due to the ex-post observation. Participants were supposed to assess their behaviour compared to before the pandemic, which could create a recency bias.

5.1 UGS as places of well-being and social interaction

One of our main findings is that in winter 2022/23, the majority of our participants did not perceive the pandemic as having a large impact upon their everyday life. Exploring our dataset on the use of UGS in Leipzig in more detail, however, we indeed see considerable changes in usage behaviour, which might indicate how the shifting preferences are becoming permanent.

Our study found that almost 40% of the participants in Leipzig used UGS more often than before the pandemic. This value is smaller than in other studies, such as Neumann et al. (2022), who reported a figure of 65% in a representative sample in Germany. This study was conducted in autumn 2020. With the pandemic developing and residents adapting to the changing situations, the lower value in our study may indicate a slow return to pre-pandemic habits. Although 94% of our participants confirmed that they would likely or very likely maintain their (new) habits, further studies are necessary to analyse the permanent character of the observed changes in the following years.

Figure 3 shows that a clear majority of participants changed their frequency of using UGS, with the highest increases being for social interactions, well-being, and sports. This is not surprising given that the lockdown protocols particularly affected these functions and activities. It also shows that parks were important places to maintain mental health, supporting the assumption that city residents have developed a higher awareness of CES functions. In this sense, urban green spaces have benefitted from the shift of these functions from other spaces that were shut down during lockdowns (such as fitness clubs, gastronomy, social and cultural infrastructure, libraries). From an urban design perspective, this means that UGS should provide a large variety of structures (to facilitate the access to different CES and uses such as sports, social gatherings, picnics, or barbecuing), given that the diversity of desired functions in UGS comes with different expectations and perceptions (Kühl, 2019).

We interpret this awareness of different social groups' preferences as a question of interactional justice. This includes asking which social groups are being considered, and which are not, and if UGS

enable random encounters between park visitors (Low, 2013). One way to ensure the inclusion of multiple necessities is to let residents participate in park design and development, improving the procedural dimension of justice (Anguelovski et al., 2020) in UGS development. The observed growing importance of UGS also poses the question of who has access to such spaces, and who does not (distributive justice; Soja, 2010, p. 9). For example, residents in neighbourhoods without sufficient access to green infrastructure experienced less opportunities to shift their activities to UGS compared to residents in greener districts and are probably neglected in our study because they are less present in the parks.

The opportunity to visit UGS becomes a question of the socio-spatial conditions in which the residents live, highlighting how environmental injustice and structural inequalities are related to each other. Cole et al. (2021, p. 72) discuss how the pandemic has not only revealed, but also intensified, already existing inequalities and injustices. For example, Jay et al. (2022) found that in neighbourhoods in the U.S. with higher shares of white and a wealthy population, there was a larger rebound effect of using UGS after the first lockdown protocols (from March to April 2020). During the pandemic, we were also able to see how different job profiles faced different levels of exposure to the virus, such as comparing blue to white-collar workers. Working from home is not possible in every sector, and it is particularly common among the households with the highest incomes and university degrees (Neumann et al., 2022). This shift of the workplace to the home has contributed to the growing importance of UGS in residential areas, while also exposing existing injustices.

Apart from that, we would like to highlight the particular role of university students, as they were one of the largest groups in our data sample (39.1%), although they represent only 6.6% of Leipzig's population (Stadt Leipzig, 2023d). The high share of students might be due to the location of the chosen parks in neighbourhoods where many students live (Lene-Voigt-Park in Reudnitz-Thonberg) or study (Lennéanlage, which is near the city centre and the University of Leipzig). Also, students might be more willing to participate in surveys than other groups and prefer online questionnaires (Król & Hernik, 2020).

The personal living conditions of students could be a further explanation for this high share of university students in our sample. On the one hand, some university students might have a more flexible timetable consisting of lectures and self-learning phases. Other authors document that UGS provide a “safe arena” for students to “maintain social contact with friends outdoors, or to escape their home environment” (Collins et al., 2022, p. 1). Our study confirms this argument, as we find that, relatively speaking, students (0.93) increased park usage more for the purposes of well-being compared to other groups (0.62) in our sample.

5.2 Ensuring access to (safe) parks

The changing relationship between UGS and visitors during and after the pandemic is also a question of who has access, and who has not (distributive justice). In our study, we see at least four relevant dimensions to this question, starting with “distance”.

The survey results indicate that the importance of park characteristics has changed, with proximity to home, cleanliness, and naturalness gaining the most in importance. This is in line with what other studies have documented, namely an increase in the popularity of parks perceived as “natural” or “nature-like” during the pandemic (Yap et al., 2022). Proximity to home is even the most important characteristic of parks. Yet, 26.9% of participants have to go or choose to go to a park that is not close to their home (> 14 minutes' distance). This could be due to a different perception of distance, or due to a simple lack of UGS within a reasonable walking distance. As accessibility is a dimension of environmental justice (Mohai et al., 2009), close access to parks is of crucial

importance, especially for (families with) children and the elderly due to potential mobility limitations. During pandemics in general, close access becomes even more relevant, “as most urban residents globally experienced mobility restrictions that limit their ability to access distant spaces” (Huerta, 2022, p. 2).

Apart from distance, age seems to be a second factor in determining who has access to CES in urban green spaces. In Leipzig, almost a quarter of all residents are aged 66 or older, which is considerably more than the 4.3% of participants in this age group in our study. The share of this age group is lower compared to other research (which relied completely on online tools; 7% in Lopez et al., 2021; 12% in Crossley & Russo, 2022). Still, this does not mean that our combined online/offline approach was not successful in reaching a wide variety of social groups. It may also show that UGS in Leipzig are generally used to a lesser extent by this age group. “Will the elderly be more likely to stay at home?” (Honey-Rosés et al., 2020, p. 3) due to the pandemic, and afterwards, is hence a question that remains topical.

A third relevant aspect that our study has revealed is safe access to UGS. We examined the perceived safety in UGS as a question of gender and found that participants who identified themselves as female felt less safe in parks compared to the male participants, which is in line with comparable studies (Ugolini et al., 2022, p. 6). In Leipzig, the importance of safety has even increased to a significantly higher level for women than for men when comparing the pre- and post-COVID-19 settings. Safety is therefore a fundamental prerequisite: Without (perceived) safety, people will not use the UGS (Lopez et al., 2021). In order to address this, policy makers and urban designers might consider measures such as installing emergency hubs or improving the lighting concept (Federal Ministry for the Environment, 2017; Tandogan & İlhan, 2016). A lightning concept must be carefully deliberated, considering the negative impact of light pollution on animals and insects (Eisenbeis & Hänel, 2009). Apart from that, ensuring distributive justice does not only imply providing safe (urban green) spaces, but also safe access to them. Given that half of the participants in our study have concerns about traffic problems and safety, planners should also aim for a better access for pedestrians and cyclists. This is particularly relevant as “public spaces are often the only recreational outdoor spaces for low-income residents and provide relief from cramped living conditions.” (Honey-Rosés et al., 2020, p. 10), and are “essential for physical and mental health” (Poortinga et al., 2021, p. 9).

A fourth aspect related to distributive justice is that UGS (under market conditions) are distributed unequally in a city (Kabisch & Haase, 2014). This is because UGS might provoke higher housing prices in surrounding neighbourhoods, as Wüstemann and Kolbe (2017) show in the case of Berlin. Now, with the COVID-19-induced re-evaluation of CES provided by urban green spaces which we observed in our study, we also expect a certain reflection of that in (growing) housing prices. These trends might be overlapped by a growing demand to live in less dense suburban spaces or small and mid-sized cities (Neumann et al., 2022), which would decrease the pressure on inner-city housing markets.

6. Conclusions

The extent to which COVID-19 leads to a (long-term) transformation in the use and perception of urban public (green) spaces is the key question (Honey-Rosés et al., 2020) – and our paper provides some further insights into the early post-COVID-19 phase. Contrary to previous studies which had to rely completely on reaching out to participants online (such as Lopez et al., 2021; Poortinga et al., 2021; Noszczyk et al., 2022), we aimed to explore the users' perspective of green spaces on the ground and achieve a higher representativity. Our most important findings are the following:

- Firstly, despite a strict strategy of approaching potential participants in UGS (weekdays and weekends at different times of the day, addressing every third person met), our sample had a strong bias towards university students (39.1% of the sample). Contrary to that, persons aged 66 or older are underrepresented (4.3%), compared to Leipzig's general demographic structure. This shows who currently predominantly uses UGS spaces and who does not.
- Secondly, an overwhelming majority (94.1%) stated that they did not feel strongly affected by the pandemic anymore with regard to everyday practices. We see this as further indication of a beginning post-pandemic phase.
- Thirdly, it is surprising to see how park visitors still confirm shifts in their behaviour compared to before the pandemic, with 85.2% stating that their new patterns are likely or very likely to become permanent. CES that influence personal "well-being" and "social interaction" were the two aspects that document the highest increase in re-evaluation in our survey. Also, the perception of relevant UGS characteristics has changed, with "proximity to home", "cleanliness" and "naturalness" showing the strongest growth in importance for the participants.

The pandemic is expected to have "positively readjusted the human-nature nexus" (Marais-Potgieter & Thatcher, 2022, p. 101), meaning that the awareness connected to UGS has increased, and our study reaffirms this. We also see how this raises new questions with regard to spatial justice. While this increased consciousness of CES comes with positive impacts for health and well-being for its users, it will also put pressure on the neighbourhoods close to UGS. Although researchers observed a reversed gentrification process during the initial phase of the pandemic (with wealthy urban residents fleeing the overcrowded city centres of Paris or Madrid; Cole et al., 2021), the question now is: How will gentrifiers behave in the long run? With the importance of having UGS nearby growing, we can also expect a certain reflection in urban housing markets, with green gentrification and disparities between green and non-green neighbourhoods. Hence, the growing importance of UGS must be kept in mind when arguing about potential displacement pressures.

Planners and policy makers are well advised to integrate the changing patterns into the design and provision of UGS. For example, to keep current park visitors as users, UGS need to develop according to their needs. At the same time, the needs of potential users who currently do not want to or cannot spend time in UGS should not be neglected. This goes particularly for groups with special needs, such as the elderly or women, for example.

In order to address growing inequality, politicians and urban planners should ensure that every resident has access to UGS in their future planning. In this sense, Huerta (2022) recommends identifying priority areas within the city where action is most needed and we endorse this recommendation. Integrating ecosystem services into planning at different planning levels, to ensure and develop green spaces, can be a valuable approach in doing so (Deppisch et al., 2021).

Based on our study, future research might focus on the following two aspects:

- Firstly, COVID-19 was a turning point that triggered changes in the behaviour and perceptions of park users (Addas & Maghrab, 2022), and our study offers further insights here. The pandemic adds to a larger set of overlapping crises, currently being discussed as a polycrisis (Lawrence et al., 2022). While there have already been several studies on these phenomena during the pandemic, it remains rather unclear which role UGS play during the polycrisis.
- Secondly, we call for larger samples and more comparative research designs. In our study, we addressed park visitors in situ, which is an approach that was not feasible during lockdown protocols. Our method was more labour-intensive and yielded a smaller number of participants compared to surveys conducted exclusively online, however. Further studies that manage to reach out to a larger sample on the ground would be highly desirable in order to achieve an even more representative sample. In addition, a more exploratory qualitative design would help to get to the bottom of some of the patterns which we have discovered. Understanding the strong increase in the demand for safety could be one of the objectives of such qualitative approaches.

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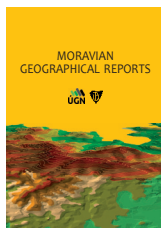
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Urban revitalisation within the historical quarter: A comprehensive analysis of a medium sized city in Romania

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Abstract

The public space environment is one of the critical influential factors for strengthening local identity and communities' sense of belonging, while enhancing city life quality. This study focuses on the use of heritage buildings as a catalyst for reactivating public spaces and aims to explore to what extent the revitalization project for the historical centre of Craiova, a medium-sized post-socialist city, has succeeded. The three dimensions of revitalisation – physical, economic and social – were analysed using a mixed approach, including participant observation, field investigation, and a residents' survey. Physical changes within the study area, improved accessibility, functional changes and economic restructuring were analysed, as well residents' perceptions and use of the area (perceived changes, use of the place, types of places used by the residents, frequency, times spent). The results point to the fact that not all the three dimensions of the revitalization project were equally successful, proving once again that not all the actions are effective in delivering the best outcomes. The main beneficiaries are discussed and the outcome of the revitalisation project is analysed against similar projects in other countries.

Keywords: heritage conservation, urban revitalization, functionality changes, residents' survey, Craiova, Romania

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1. Introduction

City centres are public urban spaces, open to all citizens, which cause pride for the residents and allow public interaction (Giddings et al., 2011). Within the urban context, public spaces worldwide have always faced "transformations, revitalisation, overlapping, or reconfiguration [...] since the urban change is a necessary process, resulting in newly created hybrid landscapes" (Ilovan et al., 2018, p. 419).

Historical quarters, often located in central areas, give a city's charm and appeal and hence have become protected and preserved, but are nonetheless in dire need of revitalisation as functioning parts of their cities, either through the regeneration of traditional activities or the restructuring of the quarter's economic base (Heath et al., 2013).

Towards the end of the 20th century, due to the peculiarities of the urban development and housing policies of the European socialist governments that led to almost five decades of 'more than benign neglect' (Scott & Kühn, 2012) (housing stock was generally under state ownership, state authorities had total control over all public policies, including housing), cities from the European communist countries were quite different from those in Western Europe. As most of the older buildings that were confiscated and nationalised by the government were assigned to various social classes paying low rents, they gradually decayed following the neglect of both

state authorities and tenants. These old decaying buildings were found throughout the inner cities in former socialist countries (Tosics, 2005). In the early 1990s, the restitution of buildings taken abusively by the governments was seen as an element of de-communisation (Stan, 2006).

Although the socialist regime fell, in Romania and some of the neighbouring countries, the great urban operations for historical city centres destruction that took place during the former period continued for another two decades in most of the Romanian cities, even if the conditions were completely different; this left a bizarre footprint on the urban realities of cities, which is difficult to control (Gheorghiu, 2017b). This period, termed the Wild West of urban management (Stanilov, 2007), was marked by poor or no enforcement of regulations and lack of social responsibility.

In most Romanian cities, historical areas were severely devalued due to lack of investments and under use of land (Bürkner & Totelecan, 2018) that spread well into the 2000s, as a result of a "primitive accumulation process" (Chelcea, 2006) due to a "new social class, including renters, real estate entrepreneurs, corrupt clerks" that had not so much financial capital, but rather social capital – a vast network of liaisons with state institutions that managed the dwelling fond (Nitulescu, 2006). These dramatic outcomes spread throughout the historical parts of the cities

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caused spatial shifts as well as divergent interventions regarding policies and programs aiming for the regeneration of the urban space (Pavel & Jucu, 2020; Vesalon & Crețan, 2019).

The geopolitical changes in the Central and Eastern European countries in the early 1990s, triggering both economic and social transformations, rendered many public spaces especially in the central areas of the cities quite vulnerable, either directly through neglect and abandonment or indirectly through the "abusive taking of the public space", called "Balkanizing" (Radoslav et al., 2013), that 'starts with temporal, legal or illegal, constructions, which afterwards tend to become permanent' many cases, for more than two decades, the historical areas of the Romanian cities were left to drift towards decay.

For most Romanian cities, the historical heritage in the urban core is made up by dwellings, small commercial areas and workshops (Light et al., 2020; Nistor, 2006). These urban areas that "contain and mirror histories and long standing traditions, old organisations and statutes, various mentalities as well as tangible values that could still be capitalised today" are in dire need of protection, a fact which causes a major problem for local authorities, governments and Romanian professionals (Gheorghiu, 2017a, p. 7).

The current paper aims to examine the strategy chosen by the local authorities of Craiova (Romania), a medium sized city according to the European classification, to revitalise part of its historic quarters which was partially derelict for several decades. For this purpose, the three main directions of revitalisation identified following a thorough literature review were analysed, focusing on the major changes that took place from the physical, economic and social point of view. The main research questions this paper tries to answer are:

- Q1: What type of changes took place following the revitalisation of the historic quarter in Craiova? Were there significant economic and social changes, or only physical changes?
- Q2: Who are the main beneficiaries of the revitalisation process? Did anyone lose out in this process?
- Q3: To what extent the revitalisation strategy chosen by the local authorities is similar to the ones adopted by their counterparts in other European countries?

The paper begins with a brief description of the context of the historical centres in the former socialist cities, followed by a review of the concept of urban revitalisation and its dimensions, before turning to the case study. The third part of the paper presents the main characteristics of the study area, as well as the research design and methods used for data collection and analysis. In the fourth part, the main results of the revitalisation project are presented, focusing on three main aspects: a physical upgrading of urban spaces through architectural restoration and adaptive re-use of buildings; an economic capitalisation of urban spaces; and the social use of public spaces. The last part of the paper reviews the significance of results and raises issues related to the beneficiaries of the project and similarities with other revitalisation projects in Europe.

2. Theoretical background

When reading about urban redevelopment policies and strategies regarding urban decline, one of the main issues that is quickly evident stems from the lack of agreement on the right concepts and definitions regarding urban revitalisation (Balsas, 2007; Grazuleviciute-Vileniske & Urbonas, 2014; Roberts & Skyes, 2000). Although changes have always affected city centres which are distinctive, multifunctional places, probably none compare to the ones that took place during the last decades (Balsas, 2007), hence the concepts, definitions and theories related

to urban regeneration have evolved (Roberts & Skyes, 2000), moving 'reconstruction in the 1950s to revitalisation in the 1960s, renewal in the 1970s, redevelopment in the 1980s and regeneration in the 1990s' (Balsas, 2007, p. 233). Moreover, the concept has had different meanings, depending on time, place and agenda (Grodach & Ehrenfeucht, 2016), inner-city revitalisation being seen as a "slippery concept", sometimes associated with gentrification, at other times with the alleviation of poverty (Zielenbach, 2000).

City centre revitalisation, defined as "the general process of redevelopment in central city neighbourhoods" (Schwab, 1981, p. 16), refers to "the physical redevelopment of blighted areas, the creation of additional jobs, the improvement of local infrastructure, and/or the elimination of undesirable individuals and businesses" (Zielenbach, 2000, p. 24). Similarly, Grodach and Ehrenfeucht (2016, p. 4) use revitalisation to refer to "a rebirth or revival in the conditions and character of a place that has endured a period of decline", identifying six main dimensions, namely: human capital, social-cultural equity, built environment, place attractiveness, economic competitiveness and environmental sustainability.

Drawing upon the lessons and observations of numerous case studies regarding the revitalisation of historic urban quarters from North America and Europe, Heath et al. (2013) conclude that a successful revitalisation must manifest itself in three main directions, i.e., physical, economic and social. These three dimensions are considered complementary to each other for a successful revitalisation of the historic urban centres (Vehbi & Hoşkara, 2009).

From a physical point of view, city centre revitalisation mainly refers to, but is not limited only to the restoration of old architecture, the upgrading of housing and retail. It also entails pedestrianisation, new street furniture, public art, as well as improved accessibility and safety, targetted at increasing the aesthetics of the overall area and strengthening local identity (Balsas, 2007; Radoslav et al., 2013; Smagacz-Poziemska, 2008). Parts of the investments regarding the upgrading of buildings are closely related to their obsolescence, be it physical/ structural or functional which resulted in decreasing the competitiveness of a given area (Doratli, 2005). Hence, conversion or adaptive reuse of heritage buildings must take place. International instances of best practices point to the adaptive reuse of heritage buildings (Beretić & Talu, 2020; Boeri et al., 2016; Lei & Zhou, 2022; Mısırlısoy & Günçe, 2016; Nedućin et al., 2019) throughout the world, this process leading sometimes to gentrification (Larsen, 2005; Nedućin et al., 2019). If revitalisation is limited only to the physical component, however, it is only a short-term strategy that cannot ensure sustainability (Doratli, 2005; Heath et al., 2013; Vehbi & Hoşkara, 2009).

The second component of revitalisation is related to the economic aspects and for the long term, it is of utmost importance, providing the productive utilisation of space that pays for the maintenance of the public realm (Heath et al., 2013). Programs have focused on creating new consumption spaces (Raco, 2003) to attract both investors and other beneficiaries, to bring people and business back to the neighbourhood and thus increase property values and boost economic activities. Functional diversification or, on the contrary, functional restructuring, as well as functional regeneration (still the same occupations, which are nevertheless operating more efficiently or profitably) (Heath et al., 2013; Tiesdell et al., 2016) are the main strategic approaches to economic revitalisation. Among the economic indicators for a sustainable economic regeneration, researchers list development costs (maintenance cost, land value, infrastructure), as well as tourism facilities in the area and financial indicators (property and rent prices compared to the income level, ratio of locally owned businesses) (Vehbi & Hoşkara, 2009).

The revitalisation process also entails a general improvement of public spaces and functional spaces, as well as the diversification of spatial functions so as to meet the needs of individuals and social groups related to living, leisure and work (Smagacz-Poziemska, 2008). This is no easy feature considering the complex interaction among institutions, actors and resources of both the public and private sectors (Sutton, 2008), not to mention the private space and different property owners it encompasses, sometimes with conflicting interests (Balsas, 2007). Most of the times, owners want to maximise the potential of their properties and are not necessarily keen on their historical structures, which often involves higher costs to maintain or preserve (Ilovan et al., 2018). It is precisely these multiple interests from various actors that make the process of revitalisation so complex (Rich & Tsitsos, 2016) and the economic revitalisation the most challenging.

One of the strains of the revitalisation policy has emphasised the importance of ‘human renewal’ (Sutton, 2008) or social revitalisation, which is closely connected to the attractive ambience. As Heath et al. (2013) argue, the public realm must be animated by people, and such animation can be planned, thus spaces becoming places through their use by people. Consequently, revitalisation has resurfaced as an important topic and policy as all stakeholders gradually understood that a proper planning of commercial activities and good city centre management help maintain liveable cities (Balsas, 2000).

Historical quarters as “public spaces are shaped not only by claims” (who uses the space, for what categories of residents it is an iconic place), “but also by the absence of claims and withdrawal from the public sphere [...] which is reflected in neglect and decline, poor maintenance or lack of care and attention” (Madanipour, 2010, p. 238). These incivilities, be they social or physical, trigger problems related to the fear of crime, no matter the level of actual crime (Day et al., 2007). Hence, since the 1980s, urban regeneration projects have focused on measures to ensure that places are not only safe, but perceived as safe (Day et al., 2007; Raco, 2003; Rhodes, 2016; Wiig, 2018), minimising the opportunities for criminal behaviour. It is clear that urban perceptions and their representations occupy an important role when creating enjoyable urban spaces that should be taken into consideration in the urban revitalisation and regeneration processes (Niță, 2021).

The adaptive re-use of buildings and infrastructure by keeping the historical area and preserving its heritage while fostering the sense of community cultural identity (Throsby, 2016) has been acknowledged to support the economic and social revival of historical areas of cities worldwide (Arbaci & Tapada-Berteli, 2012; Rousseau, 2009; Throsby, 2016). Since city centre revitalisation was tagged as a “trendy objective in political discourses” at the beginning of the 21st century (Balsas, 2007), there are numerous well-detailed revitalisation proposals for world-famous projects, but mainly for the largest cities and not so much regarding medium-sized cities as several researchers have already pointed out (Dokmeci et al., 2007; Doratli, 2005; Horbliuk & Dehtiarova, 2021; Polanska, 2008). Moreover, the majority of the published papers dwell with cultural projects for the urban regeneration of Western cities (Grodach & Loukaitou-Sideris, 2007) and more recently, on some of the largest cities from the former socialist countries (Sagan & Grabkowska, 2012), but to a much lesser extent on the medium cities in Central and Eastern Europe (CEE). This paper therefore aims to fill this research gap by providing an analysis of the recent city centre revitalisation intervention in a medium size city in Romania, offering an Eastern European perspective to the debates about urban revitalisation strategies. Moreover, while most of the existing literature on revitalisation stems from case studies related to well-established tourism destinations, the current study brings to focus a medium city trying to assert itself as a destination for cultural tourism on an already extremely competitive and diverse tourism market.

3. Material and methods

3.1 Study area – the historical quarter in Craiova

Craiova is one of the many Romanian cities that only partially conserve the historic morpho-structures (Gheorghiu, 2017a), despite its rich history and former architectural heritage. With some 300,000 inhabitants, it is one of the largest Romanian cities. It lies in the south-western part of Romania (see Fig. 1), in a large agricultural domain, being the de facto administrative centre of Oltenia region for some 500 years. Consequently, it was the home of many rich boyars and great landowners that left numerous architectural masterpieces, many of them included on the list of

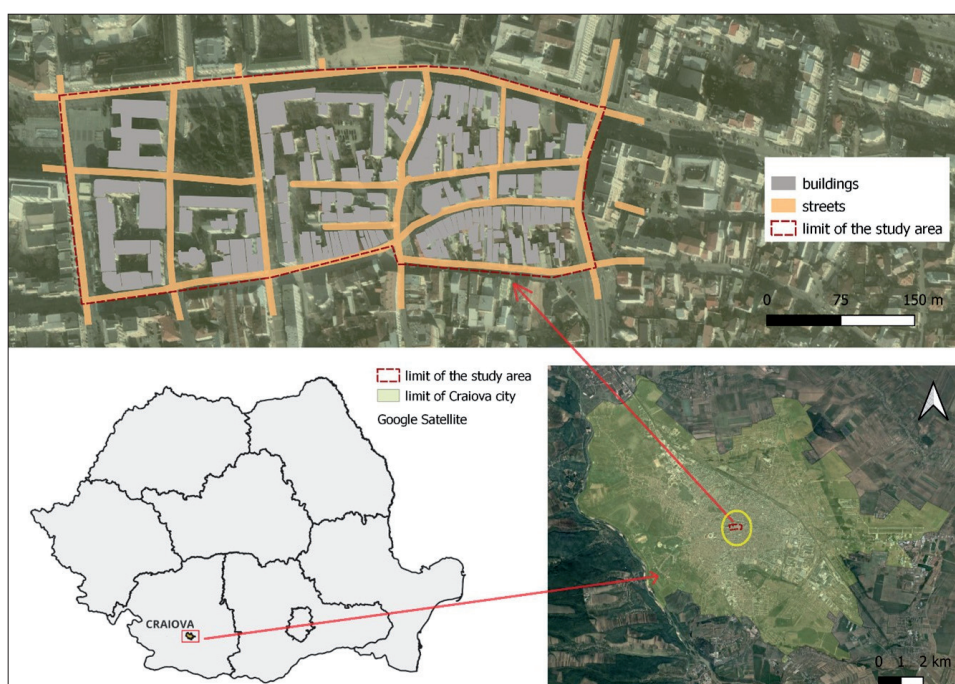


Fig. 1: Location of the study area
Source: authors' elaboration

built heritage. During the socialist period, two major government strategies impacted this area: first, nationalisation of buildings and later on large scale demolitions and reconstruction in many parts of the city. This caused significant transformation of the urban landscape in the city centre: part of the old buildings, which hardly underwent any renovation or conservation since they were built, were demolished to make room for new residential collective buildings beginning with the 70s until the late 80s, while others were scheduled for demolishing just before the fall of communism, thus causing some lasting problems and subsequent degradation. Hence, the former historical quarter of the city is a mixture of areas that still preserve pre-war buildings and areas with new collective buildings. Beginning with 1990, there followed two more decades of neglect and decay of the central area, which further affected commercial development as well as the appeal of the area to its residents, not to mention the quality of the buildings. All the buildings built prior to 1960 (accounting for as much as 80% of them), were in very bad technical condition and some of them were derelict for some time. Generally, ground floors housed shops, workshops or small businesses catering to the needs of students, while apartments were on the upper floors, just like before the Second World War. The inner courtyards and small alleys which were originally private gardens were usually dark, filthy and full of all sorts of junk materials.

In the early 2000s, the area was an intricate mix of small shops (many of them thrift stores), dozens of stalls (many of them illegal), dwellings, public services on the ground floor of some three hundred decaying buildings. It was also a very congested area due to the car traffic and abusive parking, leaving almost no sidewalk for pedestrians. Some of the streets were only culs-de-sac due to abusive constructions of some of the residents (car garages, warehouses, sheds etc.). The area faced a "serious image problem, being perceived as an ugly, dirty and decaying area, with no major attraction points, with a rather high crime rate" (GEA, 2009, p. 23).

In 2010 the city council approved a project proposal addressing the decline of part of the historical area, which was approved for financing in June 2012 and started in October 2013. It totalled 16.7 mil. EUR, with a major contribution (79%) from the European Union within the REGIO 2007–2013 program. The area included in the project, centrally located, covered only 5% of the city area (Fig. 1), comprising buildings dating from the end of the 19th century/early 20th century, mainly dwellings and shops, but also hotels, administrative and financial institutions. The Commission of Urbanism within the City Hall identified the part of the old heartland that would be included in the project, considering the buildings still preserving clearly defined architectural characteristics that could render the image of the old urban settlement, while updating their functionality and use. The main target was to draw selectively on the past to strengthen the identity of the city, while also favouring the economic and social development of the area (Popescu et al., 2020). The local administration also rezoned this particular plot of land so as not to allow further construction of dwellings within the area: only commercial, cultural or other tertiary activities are allowed.

3.2 Research design

Participant observation was the initial technique used by the authors in the early stages (2012–2015), first and foremost as lifelong residents of the city and subsequently as researchers, which gave us the opportunity to document changes to the study area. Later on, a thorough review of the official planning documents followed by fieldwork (2018–2022) allowed us to further identify and map urban changes.

Although there are numerous studies depicting revitalisation projects for various cities, mostly from the developed North, but also from developing countries, we did not find any standardised

methodology for assessing the strengths and weaknesses of any particular strategy or its success. The literature review, however, yielded three main components of revitalisation that must be taken into consideration when discussing revitalisation, namely physical, economic and social revitalisation. Consequently, we based our analysis on these three major components, using a variety of research methods (Fig. 2).

3.3 Data collection and analysis

A crucial approach to depict the dominant features within a study area involves conducting an examination of the physical characteristics of the respective space. For the physical revitalisation, we carried site investigations and applied observational techniques to gather information on the physical conditions of the study area. GIS techniques were used for the elaboration of connectivity maps and the spatial representation of physical changes within the study area.

Spatial behavioural analysis seldom employs mixed methods, yet their incorporation is crucial for converging insights derived from the urban fabric and human experiences. This study uses two methods (the residents' survey and space syntax) to investigate the effects of urban revitalisation on enhancing social and economic activities. Accessibility is a quality of travel and occurs both at the community and individual level to provide access to various land uses. Accessibility focuses on travel time, travel cost, travel options, comfort, and risk while addressing the needs within the community. The authors did not use common methods to assess spatial accessibility like isochrones or Euclidian distance, instead the study uses the space syntax method to show the accessibility through space connectivity and integration. This spatial analysis method that focuses on understanding the relationships between spatial configurations, such as streets and buildings, and human behaviour is used to investigate society-space relation based on graphic representation (Rashid, 2019; Şahin Körmeçli, 2023; van Nes & Yamu, 2021; Yamu et al., 2021; Yunitsyna & Shtepani, 2023). There is also a strong connection between street connectivity (both local and global) and accessibility within an urban environment. Street connectivity influences how easily people can reach different destinations, affecting overall accessibility in a city or neighbourhood.

Connectivity and axial maps were created using DepthMapX (depthmapX development team, 2020) that is a software tool designed for spatial network analysis, particularly in the context of space syntax. In order to obtain the graphical representations

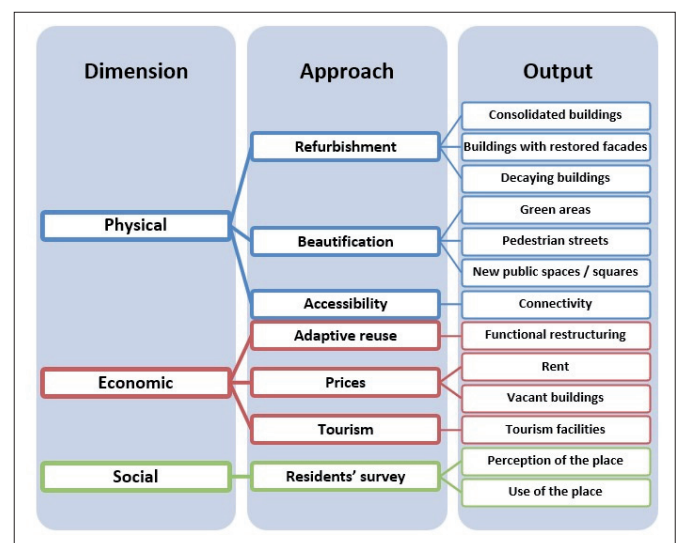


Fig. 2: Methods used for the current research
Source: authors' conceptualisation

several working steps were needed. The street network was extracted from OSM and then prepared in a suitable format, exporting information on street segments and nodes (intersections), assuring the data includes the necessary attributes such as segment length and orientation. After parameter configuration, we ran the depth and integration calculation to generate values for each segment. Connectivity measures how many streets connect to one street, showing how a space is connected with other spaces in its surroundings, while integration measures how integrated (or central) a street is to the network. The greater integration of the space, the more people will appear in it. For this reason, integration is sometimes called accessibility by SSA (SSA = space syntax analysis) researchers (Szczepańska, 2011). In contrast to global integration (Rn), Local integration value (R3) examines depths as far as three steps from the main line, which means it indicates a more localised structure. In the context of this research, the analysis of the historical city of Craiova was done within a 3 km radius, which represents the local area.

The results were correlated with the users' perceptions on accessibility to the historical centre of Craiova. The data related to people's perceptions of accessibility were gathered by processing the results of the survey. The connectivity of urban street networks increases accessibility in two ways: it provides direct and short routes from origins to destinations and, in case of longer length of streets it creates a greater number of frontages as destinations available within walking distance. Destinations are the main part of land use, and their number is strongly related to street length (Özbil et al., 2015). In order to assess economic revitalisation, continuous fieldwork beginning in 2018 allowed us to make a thorough inventory of vacancies, types of business in the area, as well as the evolution of rental prices.

Regarding the third component – social revitalisation (historical centre as an iconic area of the city), a survey of residents' perceptions and use of the space was taken, as well as participant observation. For this particular purpose, we used an open-source online survey application to develop a questionnaire. We prepared a draft, which was pretested (for length, item comprehensibility and relevance) with 10 respondents with different backgrounds. The final version of the survey comprised four main sections; the first one addressed aspects regarding the use of place (leisure preferences, accessibility, aesthetics, type of space used, activities, frequency, intensity, main issues related to the use of the space). The second part of the survey focused on the perceived changes in terms of aesthetics, accessibility, friendliness/ danger, facilities. The last section covered socio-demographic factors, such as age, gender, length of residence in the city, neighbourhood, income and education level. The third section included questions to assess the residents' attachment to the area and this particular section was used in a different study (Popescu et al., 2022). All but one questions were multiple choice questions, using a 5-point Likert scale. The survey was posted online, on the website of the Geography Department from the University of Craiova (it was described as research carried on by some of its members); it was advertised in the main newspaper of the city and also distributed and shared online using social media. Data were collected during the first two weeks of June 2021. There were 585 valid responses (Tab. 1).

The age structure suggests a relatively balanced representation across different age groups, as well as the place of residence, which is a positive factor for the study's external validity. Still, the sample includes a slightly higher share of female respondents (64%) compared to the resident population (55%).

To a population of approximately 300,000 people, the estimated population proportion that was used pp was 0.6. To calculate a representative sample size (minimum number of valid questionnaires) it was considered a common confidence level of 95%, which corresponds to a Z-score of approximately 1.96.

Age	(%)	Length of living in the city	(%)
≤ 23 years	12	≤ 5 years	7
24–33 years	17	5–10 years	6
34–43 years	33	11–20 years	8
44–55 years	28	≥ 20 years	78
> 55 years	10		
Gender	(%)	Place of residence	(%)
Women	64	City centre	16
Men	36	One of the neighbourhoods	74
		Metropolitan area	10

Tab. 1: Demographic characteristics of the respondents
Source: authors' survey

It was considered a margin of error of 5%, which corresponds to 0.05. According to this, we estimated that a sample size of approximately 369 respondents should be sufficient for the questionnaire to achieve a 95% confidence level with a 5% margin of error. For this study we received 588 responses, but only 585 were validated. A statistical data analysis was included to see if there is a positive correlation between the physical changes, perceived accessibility and social revitalisation. These variables were also considered having some influence in the economic revitalisation of the studied area.

The first step in our statistical data analysis was to perform a descriptive statistics and a correlation analysis that provided the means, standard deviations, and correlations between variables. The second step was to perform a regression analysis to test if the coefficients are statistically significant to a p-value < 0.05. As other studies have shown that the perception of people concerning the transformations of urban areas is affected by the length of residence (Kelly & Hosking, 2008; Lewicka, 2005; Popescu et al., 2022; Rollero & De Piccoli, 2010), we controlled this variable in all analyses.

4. Results

4.1 Physical changes

The physical dimension of the revitalisation includes streetscaping (23,000 sqm), retail modernisations, public space improvements, pedestrianisation, as well as improved accessibility. Side-buildings and various sheds were demolished, and the inner spaces were partially reconstructed, giving way to new attractive recreation areas and green spaces. A new and relatively large public area (Buzesti square) was created, where small scale sport, culinary and artistic events take place throughout the year.

Public spaces, streets and squares were subjected to modernisation and pedestrianisation, generating safe spaces for leisure, sport and cultural activities. Instead of congested narrow intricate streets, the area now offers promenades and meeting places for the locals and tourists alike, as well as a venue for various cultural events. While initially only part of the Lipscani street was for pedestrian use (some 250 m), currently all nine streets within the area are vehicle free, totalling 1,500 m. Lighting fixtures, urban furniture and large paintings on the side of the buildings were used to recreate the atmosphere of the Belle Epoque Era, seen as the Golden age of the city (Fig. 3).

Out of the 141 buildings in the study area, 20 did not suffer any changes (Fig. 4), not even face-lifts, being in various stages of decay. Less than a quarter of the buildings were actually consolidated, while for most buildings, the owners paid for only 'facelifts' of the facades because they were risking paying a much higher property tax if they failed to do so. Consequently, there are still 4 buildings where only the ground floor is in use, and 6 buildings the facades of which are already disintegrating in less than 10 years.



Fig. 3: Streets in Craiova's historical city centre before and after the revitalisation project
Source: authors (2012, 2022)



Fig. 4: Buildings inventory within the study area (2021)
Source: authors' elaboration

Apart from the physical renovation and the increase of pedestrian area, accessibility assessment was an important aspect of the physical changes that was analysed. Was the space more or less accessible from the point of view of its users? For the question related to accessibility the study uses space syntax analysis. Public space activation is crucial for enhancing the functions of an historical centre (Ge et al., 2023). Analysing connectivity helps identify potential activity hubs in these areas, contributing to community vitality and accessibility for certain social and cultural events like the Christmas fair, Shakespeare and Puppets Occupy Street festivals, summer music festivals (IntenCity), etc. is very important and planning the events and festivals in areas with high connectivity ensures easy access for attendees. The map shows an average value in terms of connectivity for the historical centre that is mainly a pedestrian area. In relation to connectivity, there is also the step depth in street network that determines the convenience for a pedestrian to travel. So, according to results in Figure 4, the street network system offers moderate alternatives by three to four path choices for a pedestrian in their travel from one place to another. Higher integration values (represented by warmer colors) indicate that the node is more integrated into the spatial network, which was related to the network's connectivity (Fig. 5).

Well-connected streets contribute to vibrant urban spaces, encouraging people to explore and spend time in different areas. This aspect of urban design positively influences the overall appeal and accessibility of a city. Connected street networks often support

mixed-use development, where residential, commercial, and recreational spaces coexist. This mixed-use approach contributes to increased accessibility by reducing the need for long trips to access different services.

The relationship between the global availability of space (global integration), and the local availability of space (local integration) lies in the clarity and readability of the space (intelligibility). The better the correlation between these measures, the better user moving along a given axis is oriented in space and knows where they are in the context of the entire city (Szczepańska, 2011). Understanding depth and integration becomes particularly significant for pedestrian movement. Integrated streets, characterised by their central and accessible nature, are likely to attract more foot traffic, contributing to improved pedestrian accessibility (van Nes, 2021). Integration (Fig. 6) is therefore about syntactic, not metric accessibility, and the word "depth" rather than "distance" is used to describe how far away a space lies.

Connectivity and integration are used to analyse streets in order to assess their depth and integration. Streets with low depth and high integration are considered more central and integral to the overall connectivity of the urban fabric, while streets with high depth and low integration are more peripheral (Mohamad & Said, 2014). By understanding depth and integration helps in predicting and explaining patterns of pedestrian movement. Integrated streets are likely to attract more foot traffic due to their central and accessible nature.

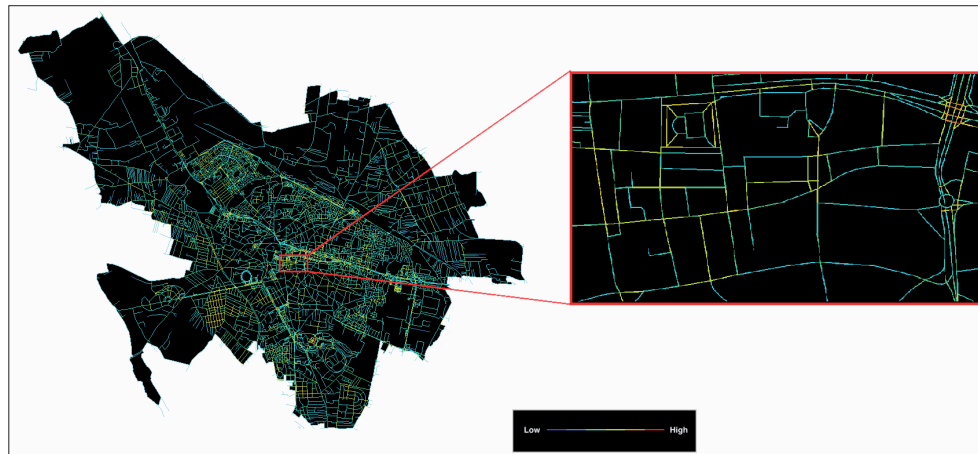


Fig. 5: Connectivity of Craiova and historical centre
Source: authors' elaboration

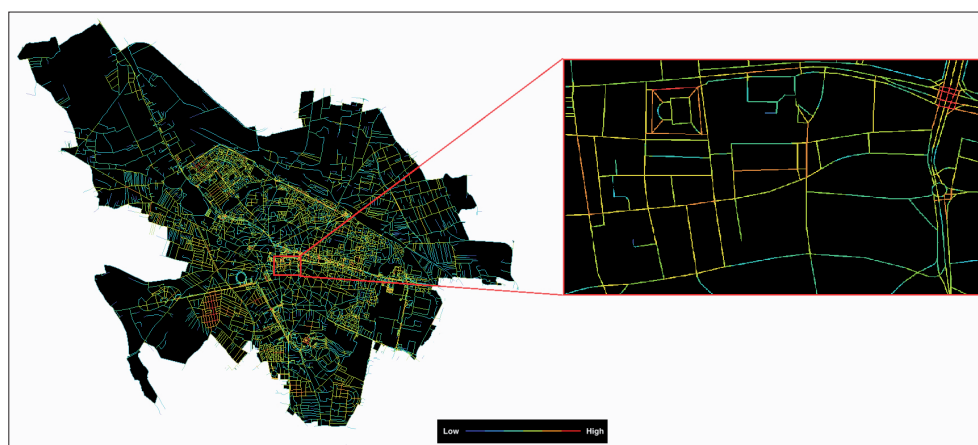


Fig. 6: Axial map of Craiova and the city centre: [Craiova] global integration (radius n); [city centre – medallion] local integration (radius 3)
Source: authors' elaboration

A highly connected street network, both locally and globally, generally leads to shorter travel distances. Reduced travel distances enhance overall accessibility, making it more convenient for individuals to access various destinations. Thus, by analysing depth and integration through space syntax, urban planners and designers can gain insights into the structure of spatial networks, helping them make informed decisions to enhance connectivity, accessibility, and the overall functionality of urban environments. This can be of great help to individuals with limited mobility which can also benefit from improved street connectivity, as it provides more options for reaching destinations. This inclusivity in transportation options enhances accessibility for people of all abilities.

In terms of peoples' perceptions, accessibility and connectivity are often subject to the same meaning. Thus, from the total of 585 people who took the survey, 49% declared that they see an improvement in the accessibility of the historical centre, while 36% said that they see no change after the renovation. Also 39% of the people described the city centre as accessible, while 68% pointed that the extension of the pedestrian area is one of the main positive outcomes. More than half of the respondents (55%) said that the historical centre is fit for walks which are among the main activities undertaken in this area, alongside with socialisation and recreation.

Accessibility can also be seen from the point of view of various transportation modes from personal car to common transport like bus and tram, as the closest bus station is less than 100 m, while other bus and tram stations range in the distance of 300–500 metres (Vilcea et al., 2018; Vilcea & Şoşea, 2020).

The feed-back from the residents is connected to physical changes performed in the historical area, effect on social activity and animation, perceived accessibility and economic benefits perceived by the locals due to physical transformations. These variables were considered to influence the most the economic regeneration and social revitalisation of the historical centre. As people who lived most of their lives in the same city may have a more general perspective over the physical, social and economic changes over time, the length of residence was included in the correlation. The statistical analysis indicated a strong correlation, especially between physical changes and social animation (0.763) and social activity (0.688). Accessibility is also correlated with physical improvement of the public space and increased social activities (Tab. 2). The connectivity of public spaces that makes walking favourable is an important demand for a functional pedestrian system that organises the pedestrian movement to follow the shortest distance between the different destinations within an area (Gehl, 2011). Length of residence had no correlation with any of the variables.

4.2 Economic revitalisation

The main purpose of the physical improvement of the city centre was to bring back business to the area following a mix-use concept, adapting historical buildings for new functions (a combination of commercial, catering and other services) (Figs. 7a and 7b).

The real estate market displays the effects of upgrading the buildings and the area in general. Before the revitalisation project, the residential and commercial activities were the most important functions for the study area, whereas at present, leisure, catering,

socialising and commercial activities account for the main functions of the area, while the residential stock in the area has been seriously depleted.

Along Mosoiu, Roman Rolland Streets and Buzesti square, several small restaurants, pubs, clubs and cafés cater to the needs of locals and tourists for cosy places. There were three large restaurants, which were usually used only for large private events

during the weekends, and some bars and cafes, while at present, there are over 25 HORECA units, quite popular among the foreign tourists, and many restaurants, pubs and cafés.

It is worth mentioning the fact that most of the buildings changed their functionality during or immediately after the revitalisation project and there followed 6 or 7 years when no intervention for any building took place. During the last years,

Variables	Length of residence	Physical changes	Accessibility	Discomfort (noise)	Discomfort (dirtier area)	Social animation	Social activities	Economic benefits
Length of residence	1.000							
Physical changes	0.113	1.000						
Accessibility	0.000	0.544*	1.000					
Discomfort (noise)	0.115	0.363	0.241	1.000				
Discomfort (dirtier area)	0.055	-0.109	-0.135	0.400	1.000			
Social animation	0.117	0.763*	0.530*	0.447**	-0.008	1.000		
Social activities	0.042	0.688*	0.553*	0.270	-0.076	0.629*	1.000	
Economic benefits	0.053	0.492**	0.436*	0.191	-0.154	0.487**	0.462**	1.000

Tab. 2: Correlations between variables that may influence economic regeneration (Note: Significant correlations are in bold (*p < 0.001; **p < 0.01) Source: authors' calculations

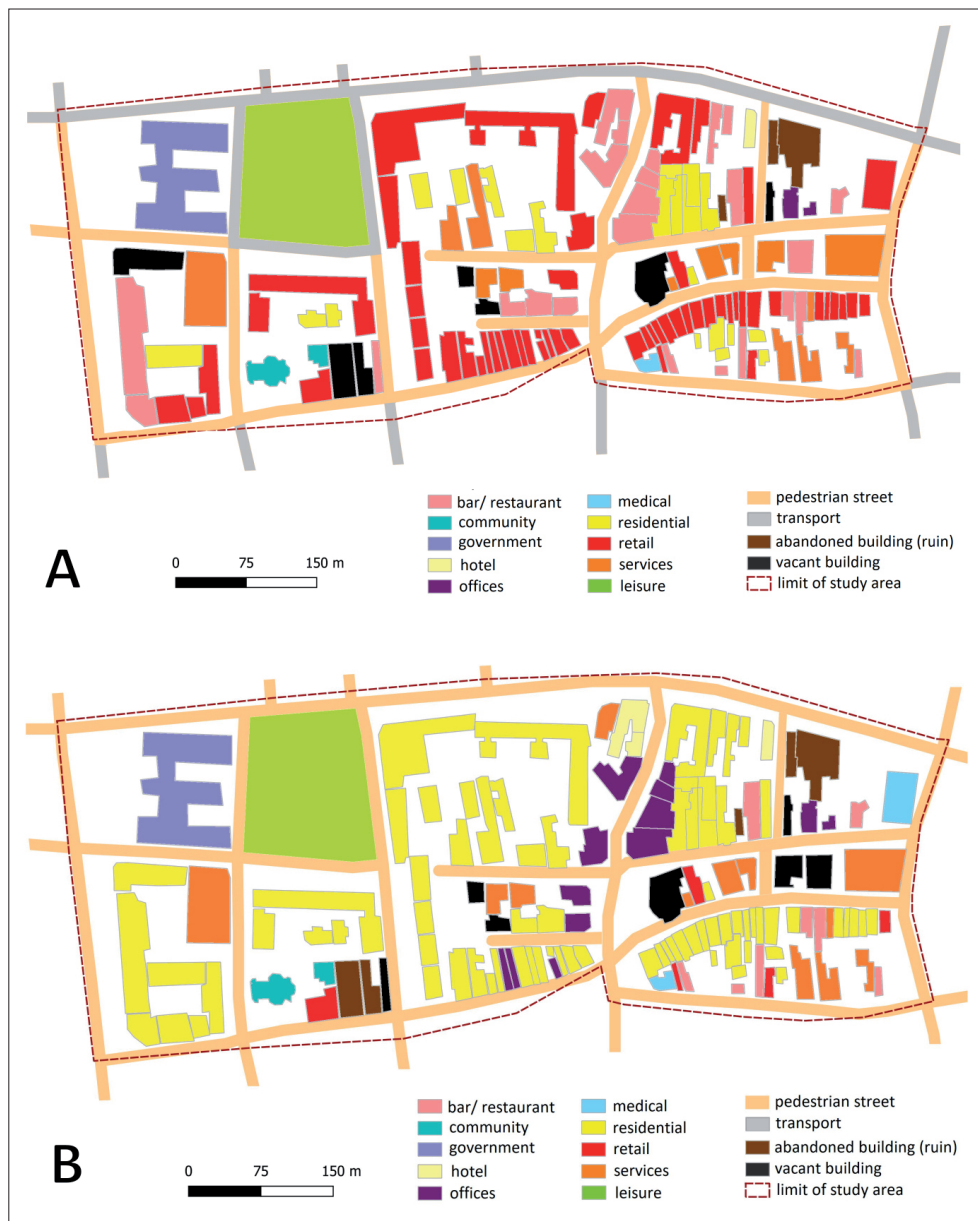


Fig. 7: Current land use on the ground floor (A) and on the upper floor (B) in 2021 Source: authors' elaboration

however, following the new zoning and the strategies for tourism development pushed by the local administration, investments were once again made in some of the buildings, which were converted into hotels (7 small hotels appeared during the last 5 years).

The rental and sales prices have increased steadily and considerably, the rent for smaller areas having more than doubled by the beginning of the pandemic. If before the revitalisation works (November 2010), the price varied between 5 and 10 €, beginning with 2015 until 2020, it reached 20 up to 25 €/sqm. The last two years witnessed a somewhat stagnant situation (lower price, around 10 €/sqm for larger places, double price for the smaller ones – up to 30 €/sqm). As evidenced in other studies, following the revitalisation works, both the price of the buildings and the rent increased (Vigdor, 2010).

The survey included some questions about peoples' perceptions regarding the economic revival of the study area, considering the fact that the historical centre is well known for its commercial streets. People were asked if they believe that the historical centre brings some economic value to the city and 82% of the respondents strongly considered that the economic value was increased once the area was renovated.

The correlation between variables that may influence economic regeneration indicates a positive moderate correlation between the improved physical aspect of the urban environment (0.492), increased accessibility (0.436) and social activities and animation (0.462 and 0.487) for a p-value < 0.05, demonstrating that the variables are statistically correlated. The analysis showed almost no correlation with the length of residence in this case (0.053), while the p-value was high over the value of 0.05 (Tab. 2).

Physical improvements convinced caterers to move into the area – mainly on Mosoiu Street, where pedestrianisation proved to be successful. This is not the case with all the streets, however, including the main commercial street – Lipsani, where the number of vacancies has remained quite high during the entire period, peaking at almost half during 2021. In fact, it is safe to say that the main commercial streets have had the highest number of vacancies after the revitalisation project (Fig. 8).

4.3 Social revitalisation

The research aimed to observe if the recent changes in street life patterns led to the social revitalisation of the urban city centre. According to the renovation plans the old city centre had been transformed into a pedestrian street system (Fig. 2) with

a moderate connectivity (Fig. 5) which increased the animation of the public spaces, well above the extended commercial activities, developing a comprehensive social and recreational city life (Ge et al., 2023; Gehl, 2013).

Previous studies on the same area (Popescu et al., 2020, 2022) showed that the city centre has become a new meeting place in a societal perspective. It is a great quality that people, regardless of age, income or status, can meet and socialise in the city space as they go about their daily errands.

According to the survey, pubs and restaurants in this area, as well as the newly-created Buzesti square, are a popular choice for meeting with family and friends at the end of the week (30% had as top choice a restaurant or bar in the historical centre and another 13% a cultural institution – be it theatre, philharmonic orchestra, cinema around the historic quarters). The top choices are the same, no matter the age group. A more detailed analysis of those preferring the historical centre, however, shows that those aged 34 to 54, with higher-than-average income are the most numerous. Within the historical centre, bars, restaurants and the pedestrian area are spaces that are the most frequently used by residents, no matter the age and gender, except for older people (who prefer the pedestrian and green areas). As for the visit frequency, there are two categories of residents: those that come frequently, at least once a week – mainly younger persons, and those that come seldom – mainly those aged 44 and over. The share of older people that visit the area daily, however, is much higher than the share of those in their early 20s or younger. In general, people spend one to four hours here, a time frame which is explained by the type of places that are used by most of the respondents.

The most important changes identified by respondents were the rehabilitation of old buildings (although there are numerous cases when only the façade of the building was restored), the larger pedestrian area, disappearance of thrift stores and establishment of new bars and restaurants. Less than a quarter of the respondents consider that the cultural and sports events that take place here are a significant improvement. The main advantages identified by the respondents relate to the particular atmosphere given by the old buildings and the fact that the area can be used for various activities, while the disadvantages stem from the busy area and noise pollution.

Due to improved street lights and extended pedestrian streets, some of the safety concerns (vehicles and darkness), the feeling of public safety greatly improved, allowing for activities to extend

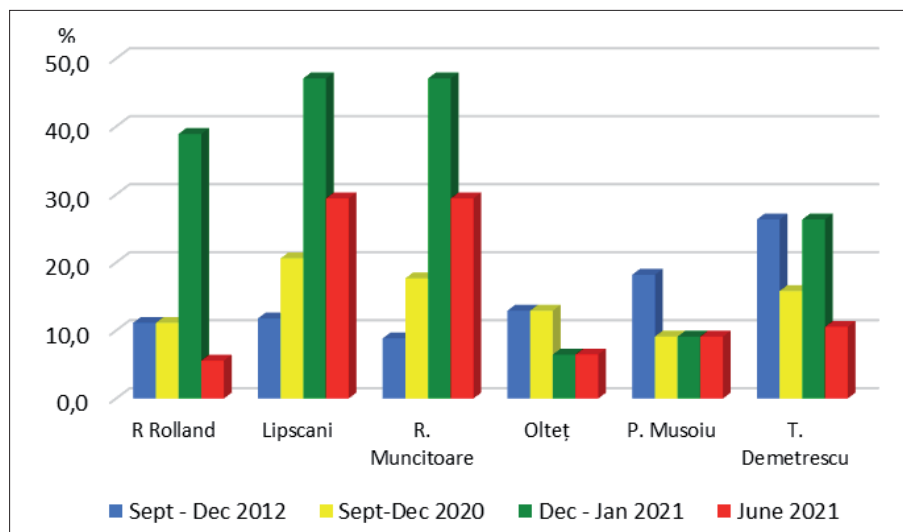


Fig. 8: Vacancies in the study area (2012–2022)
Source: authors' survey

well into the evening/night. The constant presence of local police officers in the area as well as the unobtrusive surveillance systems also contribute to this situation.

The statistical analysis following the correlation between selected variables (improved general aspect, accessibility, social interaction and possible discomfort (Tab. 2) showed that there is a strong positive correlation between the physical changes and social animation and activities (0.763 and 0.688), while the perceived discomfort (increased noise) is moderately correlated with the physical changes (0.363) and social animation (0.447). Almost 50% indicated a discomfort created by the increased noise. As previously, in the case of economic revitalisation, the analysis showed no correlation between the length of residence and the way people see the social revitalisation of the city centre. The respondents considered the area as safe (80%) and more suitable for recreational opportunities indicating a change from a passive use to an evident active one. Also, the outdoor social activities are strongly influenced by the quality of the outdoor urban space, especially by the variety of the recreational functions and social activities that develop once the physical aspect of the city is upgraded (Gehl, 2011). Beside the perceived improvement of the public space, 20% of the people indicated problems like little green spaces, dirty areas or overcrowding.

5. Discussion

The European financing for the revitalisation project was targeted only towards the public domain, i.e. streets, public squares, green areas, sewerage system, and not the decaying buildings, which were private property (99% of them). As all the buildings within the study area were nationalised during the communist period, the ownership of the buildings was a treacherous issue. The handling of nationalised housing in Romania had very peculiar traits compared with the other CEE countries, starting with the fact that the laws regarding nationalisation of buildings and terrains were not rescinded, tenants were able to buy at very low prices, property rights rarely returning to initial owners (Chelcea, 2003). Consequently, many of the buildings in the study area were divided between several owners, and most of them did not have the financial means to invest in the buildings. Few buildings were returned to the heirs of the initial owners, while others became 'no man's land' as they did not have a residential function during the communist period (so no tenants keen to buy their place of residence) and their rightful owners and their heirs did not raise any claims on these buildings.

In order for the project to be successful, the area needed to be kept in good repair, with good visual impact. Hence, city council forced the building owners to take care of the facades and roofs of the buildings, which was no easy or cheap endeavour, considering the age of the buildings and the need for conservation and preservation of their authentic features. There were significant differences regarding the buildings in the target area, as many small private owners only invested for facelifts of their buildings, while larger investors usually improved their properties by consolidating and adapting them to new functional needs (to turn them into hotels, restaurants or shops). Several years after the revitalisation works, local authorities recognised that there were still 13 buildings housing ramshackle dwellings and 9 plots that did not abide by the regulations and decided to raise the taxes on derelict buildings by up to 500% (Local Committee Craiova, 2017). Unfortunately, this decision did not change anything and ruined houses can still be found literally next to cosy and popular pubs, as it is the case of the so-called House with a tree, where the disputed ownership of the building is argued to be the main cause. Moreover, less than a decade after the facelift of the area, there are a few buildings storefronts that are beginning to show signs of decay, testifying for the poor work under limited financial means.

Despite the hopes and dreams of owners and authorities alike, the commercial properties in the area failed to attract the big names, constant and flourishing businesses, proving once again that turning neighbourhoods around is big business (Ford et al., 2008). There are two main reasons for it: i) very close to this area, within less than 5-minute walk distance, there is a large commercial centre, a symbol for the shopping in the city for almost five decades, where the big brands opened their shops; ii) most of the buildings in the area, particularly on Lipscani, România Muncitoare, Olteţ and Tr. Demestrescu streets are very narrow and long (only 5 to 10 meters wide, but sometimes just 2 or 3 m), thus hindering a proper display and use of the space. Even if the commercial activities are lagging behind, however, the pubs have proven to be a safe bet, as many within the study area have made the top ten list of pubs and restaurants in the city on the Tripadvisor list. Moreover, the overall appeal of the area for residents and tourists alike led private investors to convert some of these buildings to hotels (there are currently 7 small hotels in the area and several other rooms for renting).

There is no doubt that following the revitalisation works, the general aspect improved considerably, the area becoming much more lively and cleaner according to the residents' survey. Moreover, it ranks among the residents' top favourite places for spending time with family and friends and it managed to become an iconic place within the city. So, we can safely say that social changes, namely residents' use and appropriation of the space, as well as improved safety, were the most important ones that took place within the study area. The revitalisation project transformed this area from a congested and ill-perceived public area to a landmark for the city. Physical changes are also relevant, but despite improved accessibility, pedestrianisation and streetscaping, most of the heritage buildings were not properly consolidated, a practice which was also identified by various researchers in different cities (Balsas, 2007; Chelcea, 2006; Pascariu & Pascariu, 2002; Roşu, 2015). Similar to other people in former communist countries from CEE, those living in Craiova consider that the built heritage is important and must be preserved, but rarely take any tangible actions (Grazulevičute-Vileniske & Urbonas, 2014; Nedučín et al., 2019; Polanska, 2008). Regarding the economic dimension, the adaptive reuse of the heritage buildings and functional restructuring of the economic activities were only partially successful, as proven by the vacancy rates which have been rather high particularly along some streets and the lack of certain commercial activities that the local authorities targeted (high-end boutique shops, antiquity shops, bookshops, libraries, art galleries and cultural centres). Consequently, the results confirm that while the revitalisation project led to significant physical and social changes, the economic ones were not quite similar in scale. Considering that revitalising implies bringing back areas into active use and that 'revitalisation can only be defined qualitatively' (Heath et al., 2013), we can safely say that the social revitalisation of the historical centre in Craiova is the most successful element of the revitalisation project.

The study used the survey as a method to correlate people's perceptions regarding the revitalisation and transformation of the area. Even if perception about accessibility was also covered by the questionnaire, a more objective method was also chosen. Although the analytical procedure of the method is simple, objective, and replicable, the interpretation process of the numerical results remains complex, subjective, and therefore controversial. Also, scientists contesting the reliability of this method state that applying space syntax, while overlooking the social and psychological aspects of the people, lead researchers to speculate and generalise about the social rules that produce shared design features (Sun, 2013). For a more realistic result concerning accessibility and connectivity, the present study tries

to show a correlation between the mathematical results obtained using dedicated software to analyse space syntax and peoples' perceptions about connectivity using the survey. While space syntax is a valuable tool, researchers recognised its limitations, which should be considered when interpreting results and making decisions in urban planning and design (Pafka et al., 2020; Yamu et al., 2021). Combining space syntax with other methods and approaches can help mitigate some of these limitations and provide a more comprehensive understanding of urban spaces. The authors consider that experimenting the use of mixed methods explores the augmentation of traditional space syntax analysis through the inclusion of quantitative data collected by questionnaires, thereby shaping the understanding of social capital dynamics.

The transformations undergone by the city centre favour walking, considered the best way to get around, as is not polluting and contributes to keeping people healthy, while it provides a less complicated possibility for being present in the public environment (Gehl, 2011). The new legislation regarding the urban environment advocates for more walkable cities or neighbourhoods. In regards to the new recommendations about urban mobility that encourage the development of public spaces and more pedestrian areas, the city centre of Craiova provides such an environment that can be used for walking, sitting, relaxing, at the same time increasing the social and economic value of the area. But, depending on people's age and physical shape, walking may be also tiring, that is why people may be very careful in choosing their routes. Therefore, large deviations from the main direction or point of interest may not be easily accepted, as whenever people walk direct routes and shortcuts are preferred.

The second question of the study focused on the main beneficiaries of the revitalisation works. Theoretically, this was a people-based strategy, aimed at increasing life quality and comfort within the area, while ensuring the preservation of the built heritage; the main beneficiaries listed by the local authorities were the inhabitants living in the city centre (not only those in the study area), people working within the study area either for private companies or public institutions nearby, as well as all the persons that need the services they offer. For most of these people, the revitalisation works did have the benefits envisaged: new areas of recreation were created, new consumption places and green area appeared, the maintenance of the public domain improved. For the people actually living in the study area (less than 100 persons in 2013), life quality increased only to the extent they could cover the costs for the improvement. The technical infrastructure (water and sewage system, electric energy and gas distribution) was indeed updated, but only on the public domain. The findings of the current study point to the fact that not all the owners could afford or were interested in investing in the buildings for proper consolidation and improving the living standards.

Another question that guided this research addressed similarities between the revitalisation strategy adopted by the local authorities in Craiova and those elsewhere. Generally, many revitalisation projects are focused on the economic component, quite often targetting tourism development (Aigwi et al., 2018; Aykaç, 2019; Balsas, 2000; Ozus & Dokmeci, 2005; Tanrıku, 2023), sometimes to the detriment of the local community. This is the case especially for the already popular tourism destinations. Although Craiova has witnessed a steady growth of tourist flows during the last two decades (between 2010 and 2019, the number of tourists increased four times and in 2022 it reached almost the same number as pre-pandemic times), it still struggles to emerge as a competitive destination for city breaks in CEE. So, although from a wide perspective one of the goals of the project was to increase the area's appeal to tourists and increase the economic role of the city, the main focus was not on the economic component, but rather on the cultural and social one.

Whereas generally people-based strategies focus on 'human renewal' and improving the lives of residents through investment incentives, local hiring clauses and similar policy tools (Sutton, 2008), for Craiova this strategy was limited only to beautification projects and improvements of the public domain, so as to allow for new consumption spaces. Moreover, previous research has proven the importance of community participation for the revitalisation process, since without social engagement it is quite difficult to achieve the revitalisation of any area (Li et al., 2020; Murzyn, 2006; Rich & Tsitsos, 2016; Ripp & Rodwell, 2016; Šlebocka, 2021; Tanrıku, 2023). In Craiova, there were no social consultations regarding the revitalisation project, inhabitants were not encouraged to actively participate in the process. For a press interview, the mayor declared that she had talked to the people living in the area targetted by the project and that they all understood the need for investments and restructuring and were supportive of the project (Ungureanu, 2013). But that is the extent of the community participation.

Another issue is related to the process of gentrification. Whereas gentrification has been documented in numerous cities that underwent similar projects (Grodach & Loukaitou-Sideris, 2007; Larsen, 2005; Murzyn, 2006; Nedučin et al., 2019; Zielenbach, 2000), contributing to 'human renewal' (Sutton, 2008), this phenomenon does have some peculiarities in the study area. Whereas there are clear changes pointing to gentrification, mainly conversion of residential units into commercial space and an increasing number of rentals instead of owner occupancy, transforming lower class inner-city housing into middle and upper-class neighbourhoods (Chelcea, 2006), due to the new zoning approved by the city hall, all those who buy buildings in the area can no longer inhabit them permanently; they can only convert them to accommodation facilities for short term rental, commercial or other services.

There are several limitations of this study. The residents' survey was taken during the summer of 2021; therefore, some results may be influenced by the particular events caused by the restrictions during the pandemics. Also, the public use of spaces and economic use (vacancy of commercial spaces, rents) were also affected to some extent by the forementioned period. Moreover, given the peculiar Romanian context, the size of the city and its characteristics, the findings of the current research may limit the generalisation of results to other cities in different parts of the world.

6. Conclusions

This paper aimed to present an up-to-date discussion on the recent city-centre revitalisation intervention in Craiova, with a particular focus on the physical, economic and social aspects of the revitalisation process. The architectural wealth of the area together with the growing demand for entertainment places in the city centre were some of the major supporting factors of the revitalisation process. From this point of view, physical changes are undoubtedly the most striking ones in the city centre, as the degradation of the urban space was a major problem for both the residents and the authorities. Instead of the rundown and derelict environment, there appeared cozy restaurants, pubs and shops that capitalise on the historical buildings, as well as a large pedestrian area which favours numerous leisure and recreational activities. The mixed-use concept has proven to be only partially successful. The activity on some of the streets flourished after the revitalisation works – mainly those concentrating pubs and restaurants, while the commercial streets have had quite a high number of vacancies. If in the early 2000s, the area was not at all popular among residents, after the revitalisation project, the same area is the place where all ages, classes and lifestyles flock to either for meeting with family and friends or just to take a walk or for public interaction. This shift in the perception of the area is a great achievement on its own.

This study using space syntax analysis correlated with the locals' opinions on revitalisation projects of Craiova historical quarter can represent a starting point for local authorities in decision-making process concerning future urban planning projects, as connectivity is intricately linked to accessibility within urban environments. The study can be extended at the level of neighbourhoods or even the entire city, as a well-connected street network enhances mobility, reduces travel distances, and fosters an environment where people can easily access a variety of services and destinations. Connectivity maps can also be used to identify areas with lower connectivity where improved lighting, surveillance, or other safety measures may be necessary in order to prevent crimes or to enhance emergency response planning, ensuring that emergency services can efficiently navigate the urban network to reach different areas. This connection is a key consideration in urban planning and design efforts aimed at creating more accessible and liveable cities.

The study has wider implications for similar cities in developing countries that consider pursuing revitalisation projects, as well as for the local actors in Craiova that intend to invest in another revitalisation project for the remaining historical quarters of the city, providing empirical examination on the success and/or failure of urban interventions.

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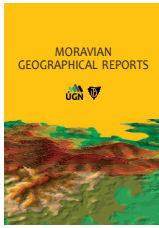
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Spatial mobility of the inhabitants of the countries of NATO's eastern flank in the event of a military conflict

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Abstract

In this article, we identify the spatial mobility of the populations of selected urban centres in Poland, Romania, Slovakia and Hungary. In total, 1,616 interviews were conducted. Additionally also interviews with the employees responsible for crisis management were conducted. Based on the analyses, five different clusters were identified, with different patterns of inhabitants in terms of their spatial mobility in the event of war. The most significant factors influencing their mobility in crisis situations are country of residence, age, number of people in the household and sex. This research can help develop evacuation strategies at different levels of governance.

Keywords: spatial mobility, planning evacuation, NATO, military conflict, Computer Assisted Telephone Interview (CATI), cluster analysis, Poland, Romania, Slovakia, Hungary

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1. Introduction

The geopolitical conditions and security issues in Europe dramatically changed as a result of Russia's annexation of Crimea (18th March 2014), the instigation of the 'dirty war' in Donbass (Fryc, 2015), and, finally, the invasion of Ukraine (24th February 2022). This situation has led to the forced migration of the population, which has significantly increased since the end of February 2022. According to UNHCR data (the UN Refugee Agency), nearly 5.89 million people have fled from Ukraine's territory since the beginning of the war. By far, the largest number of refugees have crossed the Polish-Ukrainian border, exceeding 3.3 million people (as of May 2022), while Romania has occupied the second place (ca. 757,000 of refugees from Ukraine). In addition to the widely understood problems of mass migration of people, it is worth noting that the issue of relations between the Russian Federation and Western countries, which have never been easy, now appear to be the worst since the collapse of the USSR.

Since ancient times, situations posing a threat to people have forced them to seek safe places and, consequently, to migrate. According to the definition provided by the European Commission's

Directorate-General for Migration and Home Affairs, this type of migration is characterised by an element of coercion, related to threats to life and lack of basic living conditions that result from natural or man-made causes (The European Commission, 2021: Glossary of terms). These migrations primarily involved chaotic escapes. Experiences gained from armed conflicts, however, including the present ones, have helped understand the role of early and planned evacuation in protecting their health and, above all, their lives. It is fundamental to point out the causes, nature, effects and scale of mass forced migration caused by armed conflicts (Szabaciuk, 2018).

The example of Ukraine demonstrates the importance of top-down and planned actions to ensure the safety of women, children, the sick, disabled individuals, and the elderly. Evacuation is a common strategy for dealing with emergency situations. It is one of the fundamental actions taken to protect the health and lives of people and animals, save property in all kinds of threats. Evacuation is a process in which people are moved from endangered areas to safe areas where they can stay until it is appropriate for them to return (Lumbroso et al., 2010;

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Saadatseresht et al., 2009). Evacuation can be conducted in a planned (preemptive) or immediate (urgent) manner. Planned (organised) evacuation refers to the prepared movement of the population from endangered areas. One of the key objectives of emergency evacuation planning is to ensure that evacuees leave the endangered area as quickly as possible and reach safe places. Therefore, when planning the evacuation process, the aim is to minimise the overall evacuation time to protect the health and lives of the population (Dulebenets, 2021). Hence, from this perspective and due to the highly dynamic situation in Ukraine, it is important to understand the spatial mobility characteristics of individuals in case the Russian Federation decides to escalate the war to NATO countries. Modelling the evacuation process is crucial, especially for authorities and those managing the process, to ensure efficient movement of evacuees to safe places and provide them with shelter. In the case of fleeing due to war, coordinated actions between the countries people are fleeing from and the countries they intend to reach are also important.

Incorporating human behaviour into modelling the risk associated with war is essential for developing effective management strategies. It should be emphasised however that the socio-demographic characteristics of individuals, such as age and health status, can significantly affect their evacuation capabilities (Dulebenets et al., 2019). In his research, Boyce (2017) noted that “disability” resulting from factors such as age has a significant impact on the time and manner of evacuation. Effective emergency evacuation is crucial, especially for particularly vulnerable populations disproportionately affected by threats, primarily due to age or gender (in the event of war, only children, women, and the elderly, i.e. the most vulnerable population, will be able to evacuate). The example of the conflict in Ukraine illustrates that in the event of the Russian Federation rapidly penetrating NATO territory and engaging in open armed conflict, the Alliance’s response may be delayed due to lengthy decision-making processes and a lack of rapid crisis management implementation mechanisms. Therefore, it is extremely important to take all actions to improve the process of civilian evacuation (Banasik, 2020).

To study the spatial mobility of the population resulting from the outbreak of war, four countries (and urban centres) were selected: Poland (Suwałki), Romania (Galați), Slovakia (Michalovce) and Hungary (Nyíregyháza): countries on the eastern flank of NATO, directly bordering Ukraine, and most threatened by Russian military invasion. Geographical literature on population mass-evacuation as a consequence of military conflict is very neglected. This article brings new knowledge in three relevant fields of research: geography of hazards, behavioural geography and geography of migration. This research aspires to contribute to the broader understanding of spatial mobility in the context of military conflict and to provide practical recommendations for improving evacuation planning and crisis management strategies in the selected cities and NATO countries. This study draws attention to the need for preventive measures that increase the population’s sense of security and prepare them for possible emergencies.

The paper is divided into six sections. Section two provides a review of the literature on the evacuation process, crisis management in NATO countries and factors determining human behaviour during disasters. Section three describes the material, methods and research area. Section four contains the results and the next section is discussion, while the final, sixth section provides conclusions and recommendations.

2. Theoretical background

2.1 Evacuation – types, planning, stages

Wars and military activities have triggered considerable flows of people in modern history. Human conflicts generate and

accelerate migration waves, some of them have major impact on demographic trends and ethnic patterns of the places of origin and destination areas. The importance of war-related forced migration – including refugee flows, asylum seekers, internal displacement – has increased significantly in its quantity and its political relevancy since the end of the Cold War (Castles, 2003).

The common strategy for managing emergency situations and essential activities taken to protect people and animals (their health and lives) and to save property in the event of any hazard (including war-related incidents) is called evacuation. It is the process in which people are moved from risk zones to safe areas where they can stay until their return (Lumbroso et al., 2010; Saadatseresht et al., 2009).

Evacuations can be associated with a broad range of man-made threats and natural events and are classified as one of three types: “voluntary”, “recommended”, and “mandatory” (Urbina & Wolshon, 2003). Evacuation can be conducted at different stages of the military-related event or incident – either before or after it triggers, it may be “planned” (pre-emptive, anticipatory) or “emergency” (immediate, urgent, *ad hoc*) (Borowska-Stefańska et al., 2022).

It is important whether evacuation is “conducted” (supervised and controlled) by an external entity (emergency services or military in particular) or by “self-evacuation” (Kolmann, 2020), and may be performed in an “organised manner” (co-ordinated) or “spontaneously” (*ad hoc*) (Gromek & Koziół, 2015). What differentiates these two latter forms is primarily that self-evacuation lacks management, supervision and control over its course by the authorities, leading to the spontaneous nature of the actions taken, where the lack of accurate information may lead to chaos (Kolmann, 2020). Evacuation may be conducted by “all means of transport”, even “on foot”.

An additional proposed division of evacuation includes four types: by invitation, choice, default or compromise (Drabek & Stephenson, 1971). Obviously, people should be properly informed about the evacuation process, and communication to the public and between individuals which improved intensively due to technological development and even cultural changes during the last decades. The process of evacuation includes five stages in this order (1) decision to evacuate, (2) warning, (3) withdrawal, (4) shelter, (5) return (Lim et al., 2013). The first three stages of evacuation are critical to carry out the planned evacuation sufficiently (Urbina & Wolshon, 2003). A key objective of planning evacuation in emergency situations is to ensure that evacuees leave the affected area as quickly as possible and reach safe places. Therefore, total evacuation time should be minimised, thereby protecting the health and lives of the population (Dulebenets, 2021). The objective of evacuation planning is to reduce the loss of human life and tangible damage caused by disasters (Jafari et al., 2005) (including war-related incidents). Two conflicting premises can be found in the scientific debates in relation to crisis management (including disasters) – on the one hand evacuation plans and their implementation are regarded as pointless (Clarke, 1999) and, on the other, better schemes and planning can improve crisis management (Cook & Melo Zurita, 2016). From our perspective, the latter one is regarded as better.

In research studies, many analyses are concerned with how to optimise the transport component of evacuation (Murray-Tuite & Wolshon, 2013). These are focused on evacuation in terms of the availability of people evacuated to temporary accommodation until the threat has disappeared (Borowska-Stefańska et al., 2017) or take into account the departure of evacuees from danger zones (Church & Cova, 2000). The aim of transport analyses, on the other is to optimise evacuation routes using various algorithms (Chen et al., 2012; Shahabi & Wilson, 2014; Borowska-Stefańska, et al., 2022).

Evacuation planning is especially necessary for authorities, planners and those managing actual evacuations where evacuees must be relocated efficiently to safety, and with the help of it, bottlenecks and other weaknesses can be discovered. Evacuation planning includes many behavioural and management aspects making this issue expressly complex. Emergency services use geographic information systems to support proper evacuation planning (Kevany, 2003). Emergency management should operate both on a macro scale (across administrative units) and a micro scale (across buildings) (Eckes, 2008; Li et al., 2016).

Mass evacuation tools applied for several hazards worldwide are as follows – simulation models based on human behaviour and based on traffic, time-line/critical path management diagrams. As part of the evacuation, behavioural analysis needs to cover these questions: (1) how many people will evacuate (evacuation participation rate); (2) when will evacuees leave in relation to an evacuation order; (3) what will be the rate of public shelter usage; (4) how many evacuees will leave the local area; (5) how many of the available vehicles will be used? Numerous decisions must be made at the individual level about whether to evacuate, when to evacuate, what to take, how to travel, route to travel, where to go and when to return (Alsnihi & Stopher, 2004). Evacuation-related traffic flows are predicted by traffic simulation models from a departure point, which is usually a residential area, to a destination (Lumbroso et al., 2010). A time-line diagram/critical path tool is the most basic form of mass evacuation ‘model’ available and it can then be applied to instruct those responsible for managing the evacuation what needs to be done, when it needs to begin, and approximately how long it might take for a given crisis scenario (Lumbroso et al., 2010).

The efforts of the authorities to ensure success during the evacuation from a risk zone, however, are highly impacted by the behaviour and attitudes of the residents which depend on numerous predictive factors (e.g. demographic features, expectations for evacuation, existence of their own plan, previous disaster (or war-related) experiences, type of government evacuation order, length of residence in the at-risk area, warning sources, psychological predictors and character of the risk) (Thompson et al., 2017).

2.2 Factors determining human behaviour during disasters

Disasters or catastrophes are phenomena that generate social and spatial disorganisation of the affected territories, inducing insecurity in the inhabitant communities (Provitolo et al., 2011). They can occur both from natural causes, over which people have no control, such as pandemics, tornadoes, landslides, etc., but also from artificial causes, the most destructive being armed conflicts (Grossi et al., 2020; Rinaldi, 2022; Sargiacomo et al., 2021). In addition to the loss of human lives and the displacement of a significant number of the population, disasters also cause significant material damage, which is reflected in economic losses (Botzen et al., 2019). Thus, in order to limit the impacts of disasters on human societies, it is necessary to take into account both the areas prone to such risks and the possibilities of mitigating them, but also the behaviour of people during and after their occurrence (Ejeta et al., 2015; El-Masri & Tipple, 2002; Gumasing & Sobrevilla, 2023).

For a deep understanding of people's behaviour in the face of a disaster, the psychological impacts that a certain danger can have on the individual must be taken into account. More often than not, the greater the devastation to the community, the greater the psychological impact on the survivors. In these cases, survivors become disoriented and may experience high levels of anxiety, depression, somatic symptoms, and generalised distress associated with widespread community destruction (Kohn & Levav, 1990; Labadee & Bennett, 2012). According to those indicated by New South Wales Health (2000), the common reactions of individuals

during the occurrence of a disaster may differ depending on their age category: the most affected are children and adolescents, who feel strong feelings of fear and want that their fears are both appropriate and shared by others; while adults and the elderly most often lose their lives balanced with the introduction of the enormous time, financial, physical, and emotional demands of recovery.

Individuals can react in the event of a disaster through under-estimation of danger, passivity, denial, over-estimation of capabilities. In the case of under-estimation of danger, individuals misinterpret the information they receive from the authorities or do not take it into account, without evaluating the danger they are in and the short reaction time they have at hand; while over-estimation capabilities happen when individuals are not aware of the gravity of the situation and consider that they are sufficiently prepared to face it (Adam & Gaudou, 2017).

At the same time, different individuals may have different perceptions about the disaster and the risk induced by it, resulting in different emotions, which weigh heavily in making a decision. In general, there is a difference between the behaviour of the two sexes in the face of an imminent disaster. Men prefer to defend their home, while women want to leave but usually end up staying with their partners because they are reluctant to leave them behind (Adam & Gaudou, 2017).

3. Material and methods

3.1 Study area

The research was carried out on residents in four selected cities. Adult women (18+) and men over 60 were included in the survey (CATI). We conducted surveys among adults who will have the right to evacuate. In Poland, these studies were carried out on the example of Suwałki – a city located in the north-eastern part of Poland, near the border with the Russian Federation (Fig. 1).

The Suwałki Gap is a strategic place that connects the Baltic states with the rest of the Alliance. This is a possible starting point for an armed conflict in the event of Russia's increasingly aggressive policy. In Romania, the city of Galați was selected for the study, it is one of the largest cities in eastern Romania, on the border with Moldova and Ukraine. Moldova's situation is also difficult at the moment – Transnistria is viewed as a flashpoint. On the other hand, in Slovakia, the research was covered the inhabitants of Michalovce. It is a city located in the south-eastern part of Slovakia, on the border with Hungary and Ukraine. The attitude of the Hungarian central authorities towards the armed aggression of the Russian Federation against Ukraine additionally complicates the situation of the inhabitants of this urban centre. In Hungary, the city Nyíregyháza, was selected for the study, it is one of the largest cities in eastern Hungary, on the border with Ukraine. Generally, in the group of four urban centres selected for the study, there are places of various sizes (Tab. 1).

The size diversity of the urban centres selected for the study is an opportunity to observe the declared communication behaviours of the population of local communities of various sizes. There is an additional (apart from the location in different countries and different geopolitical situations) factor that can potentially influence the characteristics of the inhabitants' transport behaviour.

In total, 1,616 surveys were conducted, minimum 400 in each urban centre. In Suwałki live total of 69,639 inhabitants, including women aged 18+ (20,535) and men aged over 60 (9,255). The minimum sample size is 379 with a confidence level of 95%. 298,584 people live in Galați, including women aged 18+ (136,007), and men aged over 60 (30,976). The minimum sample size is 383 with a confidence level of 95%. The town of Michalovce is inhabited by



Fig. 1: Location of the urban centres selected for the study against the background of the state borders of the countries of Central and Eastern Europe

Source: authors' elaboration based on database of topographic features and OpenStreetMap data

36,704 people, including women aged 18+ (6,031), and men aged over 60 (8,499). The minimum sample size is 378 with a confidence level of 95%. The city of Nyíregyháza is inhabited by 117,689 people, including women aged 18+ (47,848), and men aged over 60 (12,254). The minimum sample size is 382 with a confidence level of 95%.

The age and gender structure (also crosswise) of all four urban centres is similar. Some subtle distinguishing features can be identified (Tab. 2), however. For example, a Polish city is characterised by the most favourable demographic structure (the largest percentages in groups of young people). In turn, the city in Romania is in the most unfavourable position in this respect. These two basic demographic characteristics are of fundamental importance when making a possible decision regarding evacuation due to the threat of armed aggression. They are related, for example, with specific legal and administrative decisions (e.g. the obligation to defend the country), social roles (e.g. motherhood) or even emotional maturity. In the remainder of this article, the significance of these features was determined statistically.

It is worth taking a closer look at the spatial and functional structure of selected urban centres and the distribution of their buildings along with the spatial differentiation of the road network (Fig. 2). These are the features that also determine the spatial characteristics of mobility related to evacuation, considered in the short term. The mutual relationship between the location of buildings (especially housing and workplaces –

Urban centres	Country	Area [km ²]	Population	Population density [person / km ²]
Suwałki	Poland	65.52	69,639	1,062.86
Michalovce	Slovakia	52.88	36,704	694.04
Galați	Romania	243.63	298,584	1,225.59
Nyíregyháza	Hungary	611.01	117,689	192.61

Tab. 1: Basic statistical characteristics of the urban centres selected for the study

Source: authors' elaboration based on a database of topographic features, OpenStreetMap data and data from the statistical offices of the countries included in the study

Age category	Nyíregyháza	Suwałki	Michalovce	Galați
0–17	17.50%	19.05%	16.67%	14.68%
18–29	12.77%	13.57%	13.11%	11.20%
30–44	24.97%	24.24%	23.26%	26.05%
45–59	19.32%	19.62%	21.69%	24.10%
60 and more	25.44%	23.52%	25.28%	23.98%

Tab. 2: Age structure of the urban centres selected for the study

Source: authors' elaboration based on data from the statistical offices of the countries included in the study

large traffic generators) and the course of the main elements of the transport network (mainly roads) determines the efficiency of population movements.

In the case of evacuation (especially *ad hoc*), this relationship determines the number of places on the network where local bandwidth limitations will be activated. In the case of the analysed urban centres, the potentially most favourable situation in this regard concerns cities in Romania and Hungary. There are internal and external bypasses developed here, which have a chance to receive heavy traffic. The most dangerous situation is in Slovakia. There, traffic must be channelised in one artery. It must be borne in mind, however, that it is a small resort, so the streams of vehicles will not be large. In the case of Suwałki, the situation is mixed, as the outer ring road is not fully closed, while the traffic in the city centre must be managed by a relatively radial road system (however, with not very high technical parameters).

In the Polish town, as in the case of Michalovce, it is beneficial to extend the zones of residential development (it is not concentrated only in the centre of the town). Assuming that the evacuation process starts more or less at the same time, the journey will start at different sections of the network and the probability of induction of successive waves of vehicle flows is reduced. The most advantageous in this respect is the large mixing of land functions in the Hungarian city. Of course, this is a positive situation only in the case of self-evacuation. When it comes to organised evacuation, such a dispersion of residential areas is a major obstacle for the services responsible for this process. The very high concentration of residential areas in Galați is a significant challenge for the self-evacuation process. In a given unit of time, the transport system will be forced to handle very limited spatial resources, and huge demand for road infrastructure.

It is also worth mentioning natural transport barriers. Especially in the cases of Galați and Michalovce, there are banded transport barriers in the form of surface water. Bridges are very sensitive points of the transport system and should be carefully monitored during the evacuation process. In the case of the indicated cities, these are watercourses surrounding the areas of residential development from the east, which theoretically should not be the direction of first choice evacuation. This does not rule out a situation, however, in which the most advantageous evacuation path in the first stage will lead to the east, only to change its direction dramatically later. This is when bridge structures can become problematic.

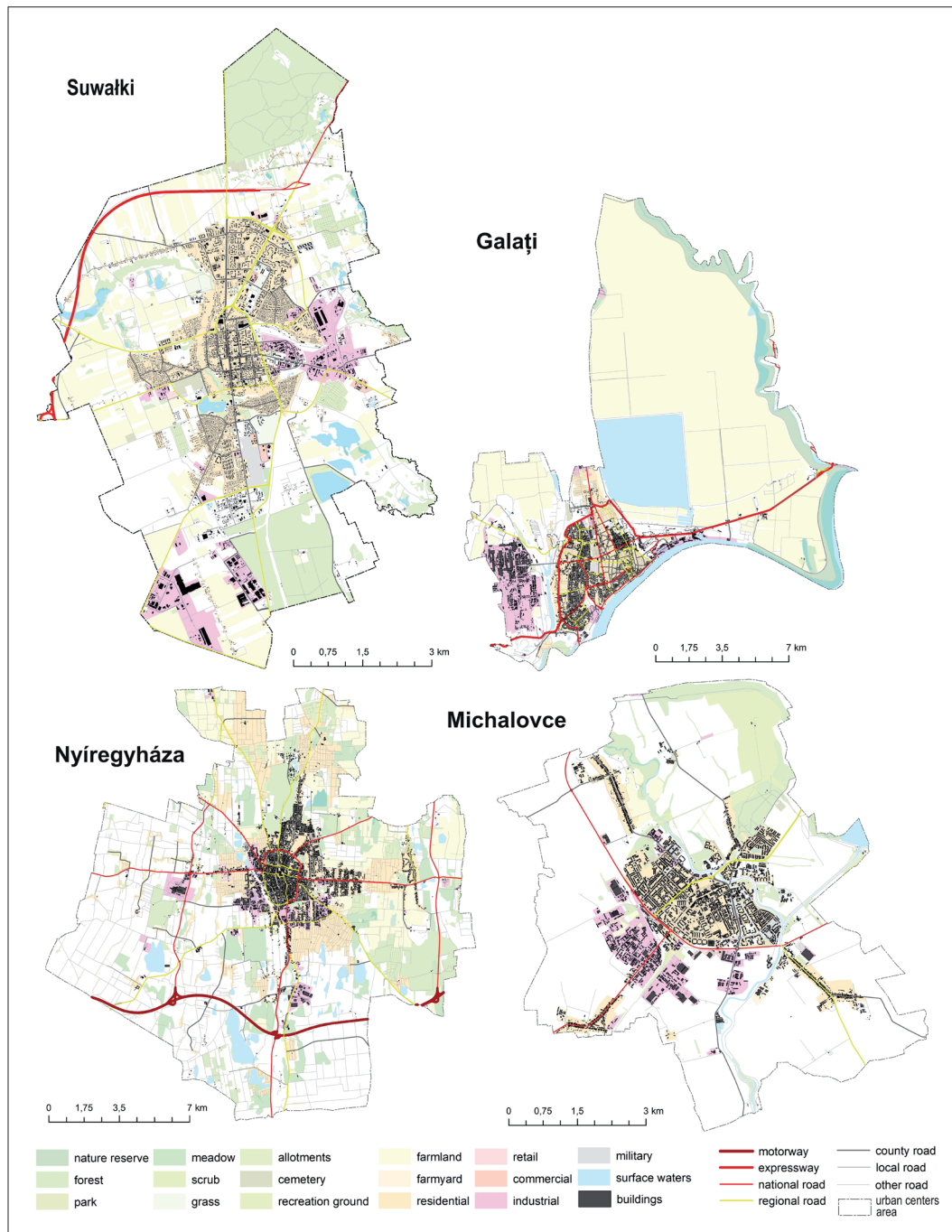


Fig. 2: Road network and spatial distribution of buildings against the background of selected forms of land use in the cities selected for the study
Source: authors' elaboration based on database of topographic features and OpenStreetMap data

3.2 Survey design

The whole research procedure consisted of ten stages: the first involved the development of the survey questionnaire for inhabitants of four urban centres from four countries (Eastern Flank of NATO). The second focused on the preparation of the guidelines for the interviewers who were to conduct the survey with inhabitants and enter data into the questionnaire. The next stage (third) was the pilot stage, combined with the resultant modifications to the questionnaire and the research procedure. During stage four, a meeting with the interviewers (from four countries) was held to discuss the implementation of the survey. Stage five saw the survey being conducted. Next, the acquired questionnaires were analysed, checked, and verified. Stage seven involved the development of the survey questionnaire for employees, who are responsible for crisis management in the surveyed urban centres. In the eighth stage, survey questionnaires

were e-mailed for completion. They were addressed to specific people involved in crisis management in the analysed urban centres, who had been determined in advance through interviews at the offices. At the next stage the questionnaires from the cities/towns halls were analysed, checked, and verified. The last stage (tenth) was devoted to analysing the data, based on which the final report was prepared.

In order to determine the characteristics of the evacuation process carried out by residents of Nyíregyháza (Hungary), Suwałki (Poland), Michalovce (Slovakia) and Galați (Romania), surveys were conducted. The study was carried out using the CATI technique on a sample of minimum 400 residents in each urban centre (from March 1st to April 12th 2023). It was to cover female adults (18+) and men 60 years of age or more. In total, 1,616 surveys were conducted, among the residents of Suwałki in Poland (ca. 70,000 residents), Galați in Romania (ca. 300,000 residents), Michalovce in Slovakia

(ca. 36,000 residents) and Nyíregyháza in Hungary (ca. 120,000 residents). Residency requirements, gender and age were the only criteria for entering the sample, therefore other characteristics were distributed randomly. The questionnaire consisted of three parts. The first relates to the characteristics of the respondent and household, the next to the awareness of risk, and the last tests knowledge of how to behave in the event of armed conflict (Tab. 3).

In order to assess the city's/town's preparation for war, surveys were conducted with employees responsible for crisis management at the local level. This survey took place in March and April 2023, via e-mail and telephone. Only no feedback was received on the part of the survey relating to the preparation of the city in Hungary for war. On the other hand, documentation at the national, regional and local level was obtained from all countries, relating to the evacuation of the population in the event of a military conflict.

The questionnaire consisted of two parts, including (i) documents related to crisis management (especially evacuation process during military conflict), and (ii) the assessment of the city's/town's preparation for military conflict (Tab. 4).

3.3 Cluster analysis

Cluster analysis is one of a myriad of techniques utilised in Exploratory Data Analysis applicable for pattern recognition in survey analysis. Acknowledging these patterns may yield

a better understanding of underlying social processes, cultural determinants, and general tendencies in the population. We have decided to use the K-means procedure for clustering the survey results.

As far as the software we have used is concerned:

- Pandas and numpy (Python libraries) were utilised for data preprocessing;
- Scikit-learn (also a Python library) was used for performing the clustering and evaluating the quality of resulting clusters;
- Matplotlib and seaborn (Python data visualisation libraries) were used for data visualisation; and
- Statistical software package R was used for statistical analysis of relationships.

3.3.1 Brief description of K-means method

Below we present an outline of a widespread representative-based cluster analysis, namely the K-means algorithm. The hyperparameters of this method (which have to be defined prior to execution of the algorithm itself) are the number of clusters *K* and the metric utilised to calculate dissimilarity of data. While the metric itself is usually connected to the problem statement and data we utilise, the choice of parameter *K* is up to the analyst. The algorithm begins by randomly selecting *K*-points v_1, \dots, v_K from

Respondent's particulars	Household	Total number of members Age of each members of household No. of cars Net income per capita
	Respondent	Gender Age Estate of residence Type of housing Education Driving licence Primary occupation Place of employment/school Experience in the evacuation process Duration of residence in the city/town
Questions about awareness of risk	Awareness of risk	The threat of war Periodic change of residence in case of war Who of the household would undertake the evacuation Who of the household would stay Reason for possible staying in the city/town
Knowledge about behaviour in the situation of war	Knowledge and human behaviour during evacuation	Educational activities in the field of conduct during war Behaviour after an alarm is announced The most important items to take with you during an evacuation Knowledge of evacuation instructions, evacuation paths, evacuation places Places of potential evacuation (places of refuge) Number of people used self-evacuation Number of people directed for evacuation by the service Evacuation directions Means of transport used for evacuation Assessment of the preparation of the country and the city/town for the war

Tab. 3: Schematic structure of the questionnaire
Source: authors' survey

Documentations of crisis management	National level	<ul style="list-style-type: none"> • List of documents at the national and regional level used by the city/town in the field of evacuation of the population in the event of war • List of documents and records relating to the evacuation process and the rules of conduct in the event of war. • Places of refuge or shelters in the city/town
	Regional level	
	Local (city/town) level	
Preparing the city/town for a military conflict	Knowledge and training in the field of evacuation	<ul style="list-style-type: none"> • Organisation of training on how to proceed during war for residents and employees responsible for crisis management. • Actions taken by the city/town to increase the safety of residents in connection with the military conflict. • Kind of support for town in improving the safety of the population

Tab. 4: Questionnaire for employees responsible for crisis management
Source: authors' survey

the space and assigning the observations contained in the dataset $D := \{x_1, \dots, x_n\}$ to one of the clusters, based on their proximity to the points v_1^1, \dots, v_K^1 . This forms us an initial set of clusters, denoted by A_1^1, \dots, A_K^1 . As we keep adding the subsequent points to the clusters, their geometrical centres are subjected to shift. Thus, we recalculate the new centroid for each cluster, obtaining v_1^2, \dots, v_K^2 .

Traditionally, the centroids are the multivariate means of the observations belonging to the given cluster and are used as a reference point, when calculating the distance between an observation and a cluster. And, as one may already suspect, this update of cluster centres causes the assignment to become outdated – therefore a new assignment must be calculated, resulting in the clusters A_1^2, \dots, A_K^2 . This new configuration is unlikely to be satisfactory and so the algorithm continues, aiming to improve it. Therefore, the process iterates between the following two actions: calculating the centroid for each cluster and updating the assignment of every observation. If any observation is taken out of its currently assigned cluster and put into another, then the centroids of each cluster are bound to change – therefore, the algorithm continues until no reassignment takes place.

3.3.2 Data preprocessing

Preparing the data for the clustering procedure resulted in the selection of 104 columns and trimming the number of observations to 1,615. Some variables, like occupation, had to be translated to binary values by one-hot Encoding. Others, like education, years spent at current place of residence or Likert scale questions, were simply mapped to respective integer values, allowing comparison between them.

In cases of questions regarding number of people in the household etc., the outliers were trimmed to the maximal value in the range of the majority of answers, although they were mostly isolated cases. Lastly, the standardisation of data was conducted on columns with non-binary values.

3.3.3 Selecting number of clusters

Selection of appropriate number of clusters cannot be done otherwise than performing K-means multiple times for different number of clusters and then selecting the best approximation. But how does one compare two distinct results of clustering.

To this end, one can use various validity indices, which are well described in chapter 17 of (ASA) (Gan et al., 2007). The selection of the final number of clusters K was based on three criteria:

- Within-cluster sum of squared distances (so-called inertia). The most common heuristic approach for determining the number of clusters in K-means algorithm is via elbow method. It consists of determining the position of the inflection point, i.e. the number of clusters, where the loss of inertia slows down significantly;
- Silhouette index and plots, which depict the similarity of observations to other points from their cluster and compare it with the similarity to the points of neighbouring clusters. The greater the score is, the better (more distinguishable) clusters are. This statistic can be computed collectively for each cluster, or shown as a mean value for all groups; and
- Finally, the Davies-Bouldin Index (DBI in short) (see Fig. 3), signifies the ratio of cluster dispersion (which can be thought of as self-similarity) to cluster distinctiveness from other clusters. The number of clusters can be chosen to maximise this worst-case-scenario index amongst all the clusters (Davies and Bouldin, 1979; Halkidi et al., 2002a, 2002b).

Based on the presented computations, we have decided to perform subsequent analysis for K equal to 5. Although the inertia plot does not clearly show, where the inflection point is, the peak of

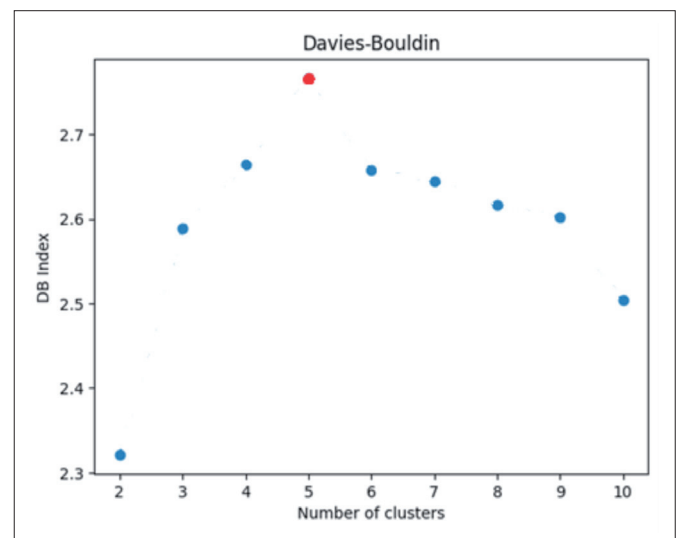


Fig. 3: Values of Davies-Bouldin Index for different numbers of clusters. Red colour marks the maximum of the obtained values, which is attained at the number of 5 clusters.

Source: authors' calculations

Davies-Bouldin Index is clearly visible and silhouette plots for this number of clusters are not outstandingly bad. The findings of this analysis are presented in the subsequent section.

4. Results

4.1 Analysis of survey with inhabitants

Based on this analysis, 5 different clusters were identified, which are characterised by different profiles of residents of the four urban centres in terms of their spatial mobility in the event of war. The most significant factors influencing their mobility in crisis situations are country of residence, age, number of people in the household and sex (Tab. 5).

Based on the conducted research, the following profiles were created.

Cluster 1

Respondents of the first cluster are primarily women (91.64%), mainly residents of two urban centres: Michalovce (Slovakia) – 34.49% and Galați (Romania) – 30.31%. These respondents are actively employed (working mainly outside the home). They primarily live in multi-family buildings (71.68%) and create two-person households. Their income per person in the household is within the minimum wage (35.54%) or within the average wage (31.71%). Over half of them have a driver's license (62.37%), and a significant portion of them declare that there is one car in their household (46.81%) (Tab. 5).

More than 50% of people in this cluster declare that they do not feel threatened by war in their place of residence, rather (26.4%) or definitely not (24.74%). At the same time, as many as 82.58% of them say that if war were to occur in their country, they would consider at least temporarily changing their place of residence (44.25% – responded definitely yes to this question; 38.33% – rather yes). Others do not know what they would do (16.38%) and only 1.05% of respondents said they would not change their place of residence even if war broke out in their country. At the same time, in the case of 88.67% of respondents' households (which have more than one person), other members would evacuate together with the respondent.

In terms of their knowledge and participation in evacuation training, the situation looks bad. Only 6.62% of people in this cluster stated that educational activities on how to behave in

Characteristics (N = 1,616)		Total sample [%]				
		Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
City/Town	Nyíregyháza (Hungary)	16.03	14.07	27.75	53.26	18.24
	Suwałki (Poland)	19.16	19.63	35.44	13.79	29.33
	Michalovce (Slovakia)	34.49	24.81	17.58	10.73	34.41
	Galați (Romania)	30.31	41.48	19.23	22.22	18.01
Gender	Female	91.64	77.41	75.0	76.25	89.38
	Male	8.36	22.59	25.0	23.75	10.62
Education	Primary or less	9.09	12.96	6.93	17.31	3.7
	Vocational	5.94	7.04	7.76	15.77	4.4
	Secondary	43.71	39.63	36.57	36.15	34.95
	Post-secondary	4.55	5.56	5.26	3.46	2.31
Age	Tertiary	36.71	34.81	43.49	27.31	54.63
	18–29	14.98	4.44	6.87	3.45	17.55
	30–44	27.18	12.22	17.31	12.26	30.02
	45–59	25.44	17.41	23.08	16.48	29.56
Type of residence	60 and more	32.4	65.93	52.75	67.82	22.86
	Single Family	28.32	29.63	35.38	34.62	29.4
Driving licence	Multifamily	71.68	70.37	64.62	65.38	70.6
	Yes	62.37	51.85	71.55	40.23	78.94
Number of cars in household	No	37.63	48.15	28.45	59.77	21.06
	0	24.82	47.85	16.06	55.64	14.79
	1	46.81	44.50	58.87	37.35	51.41
	2	22.7	6.22	20.0	6.61	26.76
Household size	3 or more	5.67	1.44	5.07	0.39	7.04
	1	16.38	30.74	19.23	40.23	11.09
	2	29.97	38.89	44.23	39.46	30.72
	3	25.78	15.93	16.76	10.34	26.56
	4	20.91	9.26	13.19	4.6	23.33
Work activity (in the last 7 days)	5 or more	6.97	5.19	6.59	5.36	8.31
	Student	0.7	0	0	0.38	0.23
	University Student	3.48	0.75	0.83	0.77	3.01
	Working away from home	45.99	24.63	34.99	19.92	48.15
	Working in hybrid mode	3.83	2.61	3.58	2.68	7.87
	Working from home	4.18	1.12	1.93	1.15	5.56
	Pensioner/retired	27.87	63.06	49.59	68.97	19.44
	Unemployed	4.88	1.49	2.2	1.15	4.17
Household's income	Not working for other reasons	9.06	6.34	6.89	4.98	11.57
	Subsistence minimum for 2022	4.18	1.85	2.2	4.21	2.77
	Minimum net salary in 2022	35.54	39.63	32.14	33.33	26.33
	Average net salary in 2022	31.71	32.59	24.45	32.57	27.94
	More than average salary	10.8	9.63	17.86	14.18	18.24
Professionally participate in the evacuation process	Refuse to answer	17.77	16.3	23.35	15.71	24.71
	Yes	8.71	7.78	10.74	3.45	8.08
Length of living in the current place of residence	No	91.29	92.22	89.26	96.55	91.92
	Since birth	33.8	25.19	27.9	29.5	37.96
	0–5 years	8.01	5.19	4.7	5.75	9.03
	6–10 years	6.27	5.93	3.31	4.98	7.87
	11–20 years	12.89	9.26	11.05	3.83	10.42
> 20 years	39.02	54.44	53.04	55.94	34.72	

Tab. 5: The respondents' characteristics in each cluster
Source: authors' survey and calculations

the event of war had been conducted in their place of residence in the last six months. In addition, as many as 81.18% of people in this cluster stated that they had never participated in such training. The positive fact is that 72.12% of the respondents would participate in such training if it was organised. Almost all of them (94.77%) stated that they had not been familiarised with the evacuation instructions in the event of war in their place of residence.

A majority of respondents in this cluster (60.98%) do not know where they should hide in case of war. They also do not know if there is a shelter or refuge in their place of residence (52.61%). Those who answered affirmatively to this question (they know there are shelters or safe places in their place of residence) point out that there is one or several such places, but only less than half of them (48.32%) know exactly where they are located. Over half of respondents (55.75%) declare that they do not know how to behave after the alarm is announced (due to the outbreak of war). If such an alarm was announced, 25.78% of them would call their families first, and as many as 21.25% would run away

from home. The positive fact is that the vast majority of people representing this group (69.69%) know what they should take with them when evacuating from the endangered area. The most commonly mentioned things to take were documents (23.47%), clothes (15.92%), food (12.5%), and money (11.56%).

All respondents in this cluster were asked where they would evacuate if war broke out in their place of residence, and one-third of them (31.77%) identified shelters or bunkers in their urban centre, while 19.49% identified public places in their place of residence. Only 10.47% of respondents from this group declared a departure to another country, and 9.75% to another urban centre in their country. The vast majority of people in this group answered affirmatively (80.49%) to the question of whether they would evacuate in the event of war, of which 82.68% would use a car for this purpose (44.16% of respondents declared self-evacuation by car as drivers, 38.53% by car as passengers). 79% of respondents would travel directly to a safe place during evacuation, and those who would stop along the way stated that they would like to take other family members with them (83.33%). At the same

time, 21.63% of households have people requiring evacuation by services due to their age or health status. Close to half of people in this cluster do not know if the place of residence is prepared for war (49.48%). The assessment of the country's preparedness for war is better – 39.37% of respondents believe that it is rather prepared, and 9.41% responded answered – definitely yes.

Cluster 2

Cluster 2 respondents are predominantly women (77.41%), but men also represent a significant group (22.59%). They are mostly residents of two urban centres: Galați, Romania (41.48%) and Michalovce, Slovakia (24.81%). The majority of these respondents are seniors (65 years and older – 65.93%), retired or on a pension (63.06% of cluster respondents). These respondents primarily reside in multi-family homes (70.37%) and have single or two-person households (38.89% and 30.74%, respectively). Their income per person in the household is either at the minimum wage level (39.63%) or falls within the national average (32.59%). More than half of them possess a driver's license (51.85%). A significant portion of them reported that there is no car in their household (47.85%), or there is only one car (44.5%) (Tab. 5).

Over 50% of respondents from this cluster stated that they do not feel threatened by war in their place of residence, either somewhat (22.22%) or strongly (25.56%). Nevertheless, a substantial 72.59% of respondents declared that they would not consider relocating if a war broke out in their country (51.11% responded with a strong “no” to this question, and 21.48% responded with “probably not”). Others are unsure (23.7%), and only 3.7% of respondents answered that they would probably or definitely relocate if a war broke out in their country. In 65.12% of the households of respondents who have more than one member, however, other members would also remain in place, together with the primary respondent. These respondents stated that their decision to stay in their current place of residence is connected to health (33.15%) and caring for other family members (22.83%).

Their knowledge about evacuation procedures is not sufficient. Only 3.7% of people from this cluster said that there were educational actions about dealing with war in their place of residence in the past six months. Additionally, 69.52% of these respondents reported never having participated in any similar training. The positive note is that 52.22% of respondents would participate in such training if organised. Almost all of them (97.04%) stated that they were not acquainted with instructions regarding evacuation in case of war in their place of residence. A vast majority of these respondents (58.15%) do not know where they should hide in case of war. They are also commonly uncertain if their place of residence has shelters or safe havens (49.63%). Those who responded positively to this question (knowing that there are shelters or safe havens in their place of residence) indicated that there is one or several such places, and more than half of them (66.28%) know exactly where they are. Over half of respondents (52.22%) stated that they do not know how to behave after an alarm is announced (resulting from the occurrence of war). If such an alarm were announced, 23.8% of them would barricade themselves in their apartment, and 21.48% would call their family. The substantial majority of people representing this group (72.22%) know what they should take with them when evacuating from the endangered area. The most commonly mentioned things to take were documents (19.16%), food (16.44%), clothes, and water (13.04% each), and medicine (10.87%).

All respondents from this cluster were asked where they would evacuate if war broke out in their place of residence, and 27.45% of them declared that they would stay at home, while 26.27% indicated that shelters or safe havens in their urban centre would be their choice. None from this group of respondents would

attempt a self-evacuation, and 40.74% responded that they would definitely not undertake it, 20.37% would probably not, and the remaining are still unsure. Almost half of the studied households would require evacuation by authorities (48.86%). 67.29% of respondents from this cluster have a negative opinion of the city's/ town preparedness in case of war. The preparedness of the country for war is even more disappointing – 75.75% indicated that it is not prepared (probably not – 26.49%, definitely not – 49.25%).

Cluster 3

Respondents from the third cluster are mainly women (75.0%), although the participation of men is also significant (25.0%). They are mainly residents of two urban centres: Suwałki (Poland) – 35.44% and Nyíregyháza (Hungary) – 27.75%. These respondents are middle-aged people, 45–59 years old (23.08%) or older (60 years and above – 52.27%), retired or on a pension (49.59% of respondents in this cluster) or working outside of home (34.99%). The respondents primarily inhabit multi-family buildings (64.62%) and form households of two people (44.23%). Their income per person in the household is within the minimum wage range (32.14%), or within the average wage range (24.45%). A significant majority of respondents in this cluster have a driver's license (71.55%). A significant proportion of them declare that there is one car in their household (58.87%) (Tab. 5).

Over 65% of people in this cluster declare that they do not feel threatened by war in their place of residence, rather (31.32%) or definitely (34.07%). At the same time, a very large 86.26% of respondents state that if a war were to occur in their country, they would not consider changing their place of residence (51.92% replied definitely not to this question, and 34.34% replied rather not). The rest do not know what they would do (13.74%). At the same time, 61.92% of household respondents (consisting of more than one person) stated that other members would also stay in place with the respondent. Respondents stated that their remaining in their current place of residence is primarily due to health reasons (20.0%) and care for other family members (28.1%). A fairly large percentage of these people (18.1%) also indicated patriotism as a reason for staying in their current place, even in the event of a war.

Their knowledge of evacuation procedures is also not at an adequate level (as with respondents from other clusters). Only 4.12% of people in this cluster stated that educational activities on how to act in the event of war have been conducted in their urban centre over the last six months. Additionally, 71.7% of people in this cluster stated that they have never participated in such training. A positive fact is that 53.3% of respondents would participate in such training if it were organised. Almost all of them (97.25%) stated that they have not been acquainted with evacuation instructions in the event of war in their place of residence. The significant majority of respondents in this cluster (66.21%) do not know where they should hide in the event of war. They are also often unaware whether there are any shelter or bunkers in their place of residence (48.08%). Those who answered affirmatively to this question (knowing that there are shelters or bunkers in their place of residence) indicate that there is one or several such places, and over half of them (61.82%) know exactly where they are located. Over half of respondents (51.65%) declared that they know how to behave after an alarm is announced (resulting from the occurrence of war) – which distinguishes this group. If such an alarm were to be announced, 19.51% would call their family and 19.23% would turn on the radio, television, or the Internet. A significant majority of people from this group (74.45%) know what they should take with them during an evacuation from an endangered area. The most frequently mentioned items to take include: documents (21.29%), food (16.32%), clothes (13.41%), money (10.23%), and water (10.13%).

All respondents in this cluster were asked where they would evacuate if a war were to occur in their place of residence, and 29.57% indicated shelters or bunkers in their urban centre. Over half of the respondents in this cluster (55.77%) definitely said they would undertake self-evacuation, 43.68% would rather do so, and only two people did not know if they would do it. Nobody indicated that they would not undertake self-evacuation. During self-evacuation, they would use a car – 84.81% of them, including 53.31% as drivers and 31.49% as passengers. These people would evacuate directly to a safe place without any stops along the way (78.85% replied). Those who declared any stops would have them in order to take other family members (87% response from those who would stop during evacuation). 24.02% of people in households in this group require evacuation by services. Nearly half of the respondents negatively evaluate the city's/town's preparation for war (rather negatively – 29.92%, definitely negatively – 20.5%), while the rest do not know whether the city/town is prepared (33.52%), or evaluate it positively – 11.36%, or definitely positively – 4.71%. The evaluation of the country's preparation for war is similar – 50.28% stated that it is not unprepared (rather not – 29.56%, definitely not – 20.72%).

Cluster 4

The respondents of cluster four are mainly women (76.25%), although the participation of men is also significant (23.75%). They are mainly residents of Nyíregyháza (Hungary) – 53.26%. These respondents are mainly elderly people (60 years and older – 67.82%), who are retired or receiving a pension (68.97% of respondents in this cluster). The discussed respondents mainly live in multi-family houses (65.38%) and form one or two-person households (40.23% and 39.46%, respectively). Their income per person in the household is within the minimum national wage per person (33.33%), or within the national average (32.57%). Over half of the respondents in this cluster do not have a driver's license (59.77%). A significant proportion of respondents declare that there is no car in their household (55.64%) (Tab. 5).

Over 83% of people in this cluster declare that they do not feel threatened by war in their place of residence, rather than somewhat (18.77%) or definitely (64.37%). At the same time, as many as 77.39% of respondents state that if war broke out in their country, they would not consider changing their place of residence (63.6% – answered definitely no to this question; 13.39% – rather not). In the case of 74.48% of households of respondents (which have more than one person), other members would also stay in place, together with the respondent. Respondents stated that their staying in the current place of residence is related to health (28.14%) and care for other family members (24.12%). A quite significant percentage of these people (19.6%) also pointed to patriotism as the reason for staying in the current location, even if war broke out.

Their knowledge of evacuation procedures is also not at an appropriate level (as with respondents from other clusters). Only 3.83% of people in this cluster said that in the last six months, educational activities on how to behave in the event of war were carried out in their place of residence. Additionally, 76.92% of people in this cluster stated that they have never participated in such training. Unfortunately, what distinguishes these respondents from other clusters is the fact that up to 43.68% of respondents would not participate in such training if it were organised. Almost all (96.55%) stated that they were not familiar with the evacuation instructions in the event of war in their place of residence. The vast majority of respondents in this cluster (71.26%) do not know where they should hide in the event of war. They also often do not know if there is a shelter in their place of residence (53.26%). Those who answered affirmatively to this question (know that there are shelters or places of shelter in their urban centre) indicate that there is one or several such places, but

more than half of them (53.85%) do not know exactly where they are. Over half (51.34%) of the respondents declare that they know how to behave after an alarm is announced (resulting from the outbreak of war). If such an alarm were announced, 20.69% would call their family, and 16.48% would turn on the radio, television, or the Internet, while 15.33% would lock themselves in their own home. It is favourable that the vast majority of people representing this group (63.98%) know what they should take with them during evacuation from an endangered area. The most often mentioned things to take were documents (18.07%), clothes (15.93%), food (15.22%), and money (10.38%).

All respondents in this cluster were asked where they would evacuate to if war broke out in their place of residence, and 36.93% pointed to shelters or bunkers in their urban centre. Only one respondent from this cluster would undertake self-evacuation in the event of war. 62.45% definitely would not undertake self-evacuation, and 19.16% rather would not, while 18.01% do not know what they would do. 35.22% of household members of respondents in this group need evacuation by services. Nearly half of the respondents do not have an opinion on the city's/town's preparedness in the event of war, and generally, positive ratings dominate in the other evaluations – rather positive (23.37%) or definitely positive (13.41%). Similarly, in terms of assessing the country's preparedness in the event of war, positive ratings dominate – 57.47%, including definitely positive (16.86%) and rather positive (40.61%).

Cluster 5

The respondents of the fifth cluster are predominantly women (89.38%). They mainly reside in two towns – Michalovce (Slovakia) (34.41%) and Suwałki (Poland) (29.33%). These respondents are the youngest among all analysed groups, with the majority being aged 30–44 (30.02%) and the second largest age group being 45–59 (29.56%), who mostly work outside of their homes (48.15%). These respondents mostly live in multi-family buildings (70.6%) and households of two people (30.72%), or larger households with children. Their income per person in the household is around the national average (27.94%), but there is also a significant percentage of respondents who declare earnings much higher than the national average (18.24%). The vast majority of respondents in this cluster have a driver's license (78.94%). A significant percentage of respondents report having one car or more in their household (85.21%, of which 51.41% have one car and the rest have more) (Tab. 5).

Over 65% of people in this cluster declare that they do not feel threatened by the presence of war in their town (37.64% somewhat disagree and 28.18% strongly disagree). As many as 91.22% of respondents say that if war were to break out in their country, however, they would consider changing their place of residence (61.66% strongly agree and 29.56% somewhat agree). In the case of 82.71% of households with more than one person who responded, other members would also evacuate with them.

Their knowledge of evacuation procedures is also not at an appropriate level (like respondents from other clusters). Only 2.31% of people in this cluster stated that there have been educational activities on how to behave in a war situation in their town in the last six months. Additionally, 83.1% of people in this cluster stated that they have never participated in such training. A positive aspect is that as many as 65.82% of respondents would participate in this kind of training if it were organised. Almost all respondents (99.08%) stated that they have not been acquainted with the evacuation instructions in case of war in their town. The vast majority of respondents in this cluster (66.74%) do not know where they should hide in case of war. They also mostly do not know if there is a shelter or refuge in their place of residence (50.58%). Those who answered positively to this question (knowing that

there are shelters or refuges in their place of residence) say that there is one or several such places and that more than half of them (63.87%) know exactly where they are located. More than half of respondents (64.9%) declare that they do not know how to behave after the warning alarm is sounded (as a result of war breaking out). If such an alarm were to be announced, 20.09% would flee their home, and 19.4% would turn on the radio, television or the Internet. The majority of people representing this group (70.21%) know what they should take with them during evacuation from a threatened area. The most common things mentioned to take were: documents (24.13%), money (14.51%), food (13.41%), and clothes (12.62%).

All respondents from this cluster were asked where they would evacuate if war were to break out in their town, and 23.81% indicated that they would go to another country (the only group with the highest percentage indicating evacuation to a distant place), while 22.38% indicated shelters or refuges in their town. 91.69% of respondents in this cluster would attempt self-evacuation in the event of war, with 64.2% definitely attempting self-evacuation and 27.48% rather attempting it. In the case of self-evacuation, they would primarily use a car for transportation (87.91%, of which 58.19% as a driver and 29.72% as a passenger). Their evacuation would mostly lead directly to a safe place (78.64%), and those who would stop along the way would do

so mainly to pick up their family (84.44%). 19.58% of people in households of respondents from this group would require evacuation by emergency services.

In the case of respondents from this cluster, they mostly negatively evaluate both their city/town and country's preparation for war (88.68% and 92.84% of respondents gave negative evaluations in these areas, respectively). No one evaluated actions by authorities at both levels as definitely positive, and only three people rather positively evaluated actions at the local level, while seven people positively evaluated actions at the national level. A small group of respondents did not have an opinion on these issues.

4.2 Analysis of survey with employees responsible for crisis management

The information obtained from the persons responsible for crisis management in each urban centre made it possible to identify a list of documents at local, regional and national level in the field of evacuation of the population in the event of war (Tab. 6).

A total of 8 documents, including as many as 6 from the national level, were identified as the basis for emergency management activities in the city of Nyíregyháza in Hungary. It can be noted that all the most important documents at the national level, as well as at the regional or local level, were adopted in 2021–2023.

HUNGARY

National level

- Law on the coordination of defense and security activities (Law 2021. XCIII.)
- Law on the disaster management and the amendment of certain laws related to it (Law 2011.CXXVIII.)
- 427/2022 (X.28.) Government Decree on the territorial and local rules of the defense and security administration
- 234/2011 (XI.10.) Government Decree about the implementation of the Law 2011.CXXVIII.
- 16/2013 (V.9.) decree of the Interior Ministry on sectoral national defense tasks affecting the responsibilities of the Minister of the Interior
- 62/2011 (XII.29.) decree of the Interior Ministry on certain rules of disaster prevention

Regional level

- Territorial emergency response plan of Szabolcs-Szatmár-Bereg county (reviewed in 2023)

Local level

- Emergency response plan of the city of Nyíregyháza (2021 – reviewed in 2022)

POLAND

National level

- Guidelines of the Chief of National Defence of 17.10.2008 on the evacuation of population, animals and property in case of a mass emergency
- Instruction on the principles of evacuation of population, animals and property in case of a mass emergency

Local level

- Municipal Crisis Management Plan (2022)
- Evacuation/Reception Plan for the Population in the town of Suwałki (2021)
- Civil protection plan 2012/2022
- Operational plan functioning of the town of Suwałki in conditions external threat security state and war (2021/2022)
- Organisational Regulations of the Town Hall in time of war (2022)
- Plan for the technical adaptation and relocation of the office to a command post at an alternate place of work in an external threat to security and in time of war, or in the event of specific threats making it impossible to continue operations at the current place of work

ROMANIA

National level

- Government Decision no. 1222 of 13.10.2005 regarding the establishment of evacuation principles in situations of armed conflict
- Order no. 1184 of 06.02.2006 of the Minister of Administration and Interior for the approval of the Norms regarding the organisation and assurance of evacuation activities in emergency situations
- Order no. 1352 of 23.06.2006 of the Minister of Administration and Interior for approval of the Organisational Methodology, ensuring evacuation activities of people, goods, documents and materials containing classified information, in situations of armed conflict
- The national response concept in the event of a nuclear – radiological accident

Local level

- Order-no.189-03.04.2023
- Order of the Inspector General No. 2 of 04.01.2019 approving the framework structure of the Emergency Preparedness Plan
- Decision No 862 of 16 November 2016 approving the categories of buildings for which the construction of civil protection shelters is mandatory, as well as those for which civil protection command points are installed

SLOVAKIA

National level

- Act No. 42/1994 on Civil Protection of Population
- Regulation of the Ministry of Interior No. 328/2012 on Evacuation
- Regulation of the Ministry of Interior No. 388/2006 on Details for Ensuring the Technical and Operational Conditions of the Civil Protection Information System

Local level

- Information for the public on civil protection in Michalovce district (based on Act No. 42/1994 on Civil Protection of Population)

Tab. 6: Documentation in the field of evacuation of the civil population
Source: authors' survey

Suwałki in Poland identified 6 documents at local level relating to emergency response, two of which related to the functioning and organisation of the office itself. The others are various types of plans: crisis management, evacuation and reception of population, civil defence and the functioning of the town of Suwałki in a situation of external threat to security and war. At regional level, no documents were identified. In Slovakia, the key documents at the national level date back to previous decades. The local authority in the Slovak town of Michalovce declares a lack of recent relevant documents that would assist them to control an evacuation process in case of emergency at the local level. Based on the valid national legislative documents, so-called district authorities (with selected administrative competences deconcentrated to LAU1 units) are responsible for regional civil protection information documents. These are, however, very general and do not include details on evacuation management. In Romania, the military conflicts emergency evacuations are organised from the legal perspective, at national level, the regulations generating effects for the local levels (local communities or counties). For example, the order No. 1184 of 06.02.2006 of the Romanian Minister of Administration and Interior, explains the regulations regarding the emergency evacuations procedures. Another order No. 1352 of 23.06.2006 of the Romanian Minister of Administration and Interior completes the previous order, by further explaining the activities for evacuation of people, goods, or documents with classified information, in case of a military conflict. At the county level, there are no specific relevant regulations, but strategical documents like the Galați Strategy for Development for the period 2016–2025, considers the military conflict evacuations, as risk situations for the local situation. The existing local regulations only explain how the county or local committees for emergency situations are organised. The local level only implements the measures designed in the national level regulations.

According to the survey conducted with employees responsible for crisis management at the local level in Poland and Slovakia since 2001, they have not organised any instructions for residents on how to respond in the event of war concerning civil defense and evacuation for inhabitants. This unfavorable situation also applies to the period directly from the outbreak of the war in

Ukraine (i.e. from 2022). The situation in Galați looks better in this respect, where such trainings for residents were organised, although it was long before the outbreak of the war – in the years 2001–2014. The next questions in the survey concerned employee training. Unfortunately, in this case, both in Michalovce and Galați, they were not conducted. Employees dealing directly with crisis management in Suwałki are definitely better prepared in this respect. They are constantly trained. After 2001, training courses on how to proceed in a war situation (in the context of civil defense and the evacuation process) were organised in Suwałki for the employees of the office involved in crisis management, this also applies to subsequent years, including the period immediately after the outbreak of war in Ukraine. Since 2022, the town has conducted two such trainings. According to the employees of Suwałki, the town is "rather yes" prepared for war. In the case of the urban centres of Michalovce and Galați, the respondents marked the answer – "difficult to say" (Tab. 7)

Respondents from all urban centres stated that additional measures should be taken in 2023 to increase the safety of residents in connection with a military threat, which relate to various aspects (Tab. 8).

5. Discussion

The analysis of spatial mobility of residents representing selected countries of the eastern flank of NATO indicated similarities in their transportation behaviour related to evacuation during wartime, between respondents from Slovakia and Romania, as well as Slovakia and Poland, and partially between Poland and Hungary (for middle-aged and younger seniors). The oldest Hungarian residents form a separate group of people with different declared behaviours. Residents in Hungary do not feel threatened by a potential war in their country and assess the actions of their authorities towards preparation for such situations both on a local and national level more positively. Hungarian residents declare greater knowledge of how to deal with the threat of war. In general, it should be emphasised that Hungary stands out among Central and Eastern European countries in terms of relations with Russia (Hennessy, 2023).

Aspect / response	Definitely yes	Rather yes	Difficult to say	Rather no	Definitely no
Managing a large-scale evacuation of the population – relevant guidelines are contained in documentation		S	M, G		
Managing a large-scale evacuation of the population – the relevant services have been adequately trained		S	M, G		
Capacity of safe places for civilians is adequate for the number of residents		S		M, G	
Residents are familiar with evacuation and protection measures in the event of war (e.g. evacuation routes and methods, means of transport)			S, M	G	
City/Town Hall employees (especially emergency management staff) are familiar with evacuation and protection measures in the event of war (e.g. evacuation routes and methods, means of transport)	S	M	G		
There is an inventory of relevant equipment (including personal protective equipment) for residents		M, G			S

Tab. 7: Preparedness of the urban centres to protect civilians and evacuate in case of war (Notes: S – Suwałki (Poland); M – Michalovce (Slovakia); G – Galați (Romania); Nyiregyháza (Hungary) – n/a)
Source: authors' survey

City/Town	Recommendations
Suwałki	<ul style="list-style-type: none"> • Provide air raid shelters for residents • Other (please, specify) acquire equipment and personal protective equipment for city residents
Michalovce	<ul style="list-style-type: none"> • Update crisis management documentation • Organise instructions for residents on the expected conduct in the event of war • Organise instructions for the personnel involved in crisis management on the expected conduct in the event of war
Galați	<ul style="list-style-type: none"> • Update crisis management documentation • More detailed provisions in the documentation on crisis management as regards the evacuation process following the occurrence of war • Organise instructions for residents on the expected conduct in the event of war • Organise instructions for the personnel involved in crisis management on the expected conduct in the event of war

Tab. 8: Recommendations for the urban centres to increase the residents' safety with regard to military threats
Source: authors' survey

Age also influences differences in mobility. Older people more frequently declare the intention to remain in their current place of residence, most often due to health reasons, the necessity to take care of other family members, and rarely patriotism. On the other hand, younger people (18–44) are significantly more likely to declare that they would change their place of residence if war occurred in their country (slightly over 60% of respondents from these age groups). Additionally, individuals from these age groups state that the remaining members of their households would also change their place of residence (around 75%). If war broke out in their place of residence, younger respondents (18–44) are significantly more likely to declare that they would undertake self-evacuation – about 75%. The older people would less often undertake self-evacuation (less than 50% of respondents from the two oldest age groups declare that they would undertake self-evacuation), and more often due to their age and health status, indicate the potential necessity for evacuation by services. Research conducted by Gershon et al. (2012) on the evacuation resulting from the terrorist attack on 9/11 on the World Trade Centre also confirms that age and health status influence people's mobility during the evacuation process. Individuals who declare the desire for self-evacuation most often indicate the car as the means of transportation used for movement, which is also confirmed by research conducted (Borowska-Stefańska et al., 2023; Efrat, 1992). In addition, all respondents most often indicated that in the event of a war (in their place of residence) and the need for evacuation, they would look for shelter within their place of residence, less frequently outside it. In this case, however, individuals from the youngest age groups, approximately 30% of respondents aged 18–44, would definitely go outside of their place of residence. In the case of individuals aged 45+, only about 17% declared their willingness to leave their place of residence if a war broke out in its territory.

The percentage of people declaring knowledge about the principles of behaviour in case of evacuation also increases with age. Such people declare that they have participated in previous training in this area. They also have greater knowledge of the location of shelter facilities (although they declare significantly more passive behaviour). Unfortunately, with age, there is a decrease in the willingness to participate in training aimed at increasing knowledge about the principles of behaviour in case of war. Younger people definitely more often declare the intention to evacuate, and the younger they are, the more likely they are to indicate another country as the escape destination (areas requiring evacuation at much greater distances). Younger people have often children under their care, hence their greater willingness to flee and protect themselves from military actions. Dash and Gladwin (2007) also confirm that the presence of children in the household influences parents' behaviours during evacuation. Unfortunately, younger people have less knowledge about how to behave in the event of a war. Additionally, they more often negatively evaluate the actions of the authorities in protecting the civilian population, both at the local and national levels.

It should also be noted that there are differences in spatial mobility of the population due to gender. Women are more likely to evacuate than men (who more often declare the intention to stay in place for reasons of state of health and patriotism), which is also confirmed by a study conducted by Strang (2013).

Unfortunately, these studies have also shown that the majority of respondents did not participate in training on evacuation in case of war. Additionally, they do not know the evacuation instructions, and have not been familiarised with them. On the other hand, as confirmed by research conducted by Gershon et al. (2007), experience and knowledge of readiness for emergency situations accelerate the evacuation process. It should be emphasised that knowledge of evacuation instructions – including locations to which one should evacuate in case of danger, as well as evacuation

paths – facilitates decision making (Simonovic & Ahmad, 2005). Unfortunately, the populations of the countries surveyed do not declare adequate preparation in this regard.

Additionally, it should be emphasised that the lack of knowledge about evacuation in case of war usually translates into a low assessment of the actions taken by the city/town or country in this regard. Only in Hungary does the situation look slightly different, as there are documents on the evacuation of the population in case of a war – primarily at the national level, which is also reflected in opinions about the country's (and city's/town's) readiness for a potential war.

6. Conclusions and policy implications

The research conducted in the four selected urban centres with their inhabitants revealed valuable insights into the complex behaviour of transportation during evacuation processes in the event of a military conflict. The study showed that demographic structure, country of residence, and knowledge of risk play significant roles in shaping the efficiency of population movements during evacuation.

The research showed that residents of the selected urban centres, representing countries on NATO's eastern flank, would mostly undertake evacuation in the event of a war. They are willing to do self-evacuation, using their personal vehicles, and would most often choose a facility located in their place of residence as a place of shelter (although younger residents are more likely to declare a willingness to leave the country in case of war). Only the oldest residents exhibit more passive behaviours, however – they frequently declare a desire to remain in their homes, which is related to both health concerns and patriotism. Unfortunately, residents of the studied countries do not possess knowledge of proper evacuation behaviour, particularly among younger people who declare a greater willingness to evacuate, including self-evacuation. This is an extremely unfavorable situation since this process affects the capacity of transportation systems and, therefore, the time required for evacuation. Hence, local authorities should organise educational activities – adjusted to residents' declared behaviours – while considering the specific challenges posed by each urban centre, such as demographic structure or limited road networks.

Moreover, civilians should be regularly informed about available evacuation routes, which should be adapted to the current traffic situation. Otherwise, they may use only familiar roads, which can delay the evacuation process. Unfortunately, according to the research, the authorities do not organise training in this area for residents.

The present research should be used, among other things, for the modelling of the evacuation process, preparing documents on this topic at a local level. This is particularly important since interviews with crisis management team members in these urban centres showed that such documents are missing, or residents are not aware of them. Authorities should consider these factors when developing comprehensive evacuation plans that cater to self-evacuation and organised evacuation scenarios, ensuring safety and well-being for affected populations. Such plans should address the specific challenges posed by the dispersion of residential areas, road network limitations, and demographic structures in each urban centre. By considering these factors and addressing the unique challenges faced by each urban centre, authorities can improve evacuation planning, ultimately promoting the safety and well-being of affected populations and local communities within NATO's eastern flank countries.

This research proves that the preparation of residents in the event of war is an important task for the city/town authorities, which should be carried out with due diligence and taking into account various factors.

Authorities should focus on:

- Information and education: the city/town government should regularly provide residents with important information regarding war threats, security procedures, and steps to be taken in the event of a conflict. They can organise meetings, seminars and workshops to raise public awareness of risks and rules of conduct;
- Evacuation planning: in the event of a war threat, city/town authorities should develop evacuation plans, identifying safe places of refuge and evacuation routes. These plans should be communicated to residents and updated regularly. Also organising drills and evacuation simulations can help residents familiarise themselves with the procedures and increase their preparedness in the event of a real emergency;
- Creating warning systems: the city/town authorities should invest in warning systems, such as emergency sirens or mass notification systems, which will be able to effectively inform residents about the threat of war. In the event of such an alarm, residents will know how to react and how to find a safe place of refuge; and
- Cities/towns should ensure proper spatial development planning – taking into account transport opportunities during mass evacuations, or providing shelters for residents (which have often been neglected for years).

The specific way to prepare residents for war may vary depending on local conditions, threats and available resources. Authorities should also work with the relevant security services, such as emergency services or the armed forces, to ensure consistency and effectiveness.

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Data availability statement

The data underlying this article will be shared on reasonable request to the corresponding author. There is no conflict of interests concerning all authors.

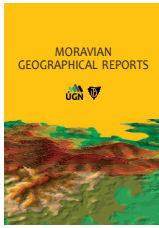
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Towards the deep learning recognition of cultivated terraces based on Lidar data: The case of Slovenia

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Abstract

Cultivated terraces are phenomena that have been protected in some areas for both their cultural heritage and food production purposes. Some terraced areas are disappearing but could be revitalised. To this end, recognition techniques need to be developed and terrace registers need to be established. The goal of this study was to recognise terraces using deep learning based on Lidar DEM. Lidar data is a valuable resource in countries with overgrown terraces. The U-net model training was conducted using data from the Slovenian terraces register for southwestern Slovenia and was subsequently applied to the entire country. We then analysed the agreement between the terraces register and the terraces recognised by deep learning. The overall accuracy of the model was 85%; however, the kappa index was only 0.22. The success rate was higher in some regions. Our results achieved lower accuracy compared to studies from China, where similar techniques were used but which incorporated satellite imagery, DEM, as well as land use data. This study was the first attempt at deep learning terrace recognition based solely on high-resolution DEM, highlighting examples of false terrace recognition that may be related to natural or other artificial terrace-like features.

Keywords: cultivated terraces, deep learning, landscapes, digital elevation model, feature detection, Slovenia

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1. Introduction

People build terraces into slopes to gain agricultural land, reduce soil erosion, reduce runoff, retain soil moisture, improve productivity, and provide gravity irrigation (Kladnik et al., 2005; Cicinelli et al., 2021; Slámová et al., 2015; Varotto et al., 2019; Zhao et al., 2021). A terrace comprises a flat or slightly sloping surface of varying width that is cultivated and a terrace slope (bank) of varying height (Ažman Momirski, 2008; Kladnik et al., 2016b). Lu et al. (2023, p. 2) defined terraces as “agricultural land with strip or wavy sections built on slopes greater than 2° along the contour direction”. These cultivated landscapes can be defined as a complex landscape system influenced by various natural and socio-geographical factors. Cultivated terraces (also cultural or anthropogenic terraces) were originally often intended for agriculture and can be described in most cases as agricultural terraces. They also have invaluable cultural, historical, ecological, aesthetic, touristic, and scientific value (Camera et al., 2018; Djuma et al., 2020; Ferro-Vázquez et al., 2017; Terkenli et al., 2019; Zoumides et al., 2017).

Cultivated terraces vary according to the period of origin, natural conditions, form, land use, ownership, etc. Many countries feature cultivated terraces (Berčič & Ažman-Momirski, 2020; Cicinelli et al., 2021; Jinwen & Yüanyan, 2012; Kladnik et al., 2017a; Slámová et al., 2017; Varotto et al., 2019). They are quite significant in some

areas, where entire stretches of land are designated as terraced landscapes, while they may be only visible upon closer inspection elsewhere (Kladnik et al., 2016b). Terraces can be active, inactive, or a combination of both (Berčič, 2016). Terraced landscapes are disappearing in places due to overgrowth (see also Gabrovec & Kumer, 2019; Moreno-de-las-Heras et al., 2019) or inappropriate management; however, they have been recognised as an important landscape element that needs to be protected and considered for revitalisation. Still, no clear criteria for identifying terraces have been developed and the management system is still fragmented in some areas, for example, in Slovenia (Kladnik et al., 2017b). Land abandonment and ageing of the owners are some of the reasons for the poor maintenance of terraces (Tarolli et al., 2019).

In order to efficiently combat the degradation of terraces in general, precise registers are needed that show the location and status of cultivated terraces. Maps are important for understanding the landscape (Gašperič, 2023); the overview of the locations of cultivated terraces is the basis for analyses of their ecological, social, and economic importance (Ferrarese et al., 2019) and can also indicate past agricultural land (Berčič, 2016).

Current data on terraced landscapes are not comprehensive. In the case of Slovenia, some cultivated terraces overgrown by vegetation were not recorded in the photo interpretation,

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topographic map analysis, and fieldwork in the earlier research by Kladnik et al. (2016b). Therefore, an important part of overgrown terraces might be missing and the most appropriate mapping methods using different datasets are still being developed. A review of past studies (see the following section for details) has revealed some gaps and opportunities for research:

- The deep learning recognition of cultivated terraces based solely on a digital elevation model has never been applied and tested for its robustness;
- Information on what kind of false recognition (false positives) and non-recognition (false negatives) can occur is still missing for different regions of the world, including the territory of Slovenia; and
- Recognition approaches based on digital elevation models (DEM) can be useful (and often the only possible method) in vegetated areas and countries where visual satellite or aerial imagery is less suitable for relief feature recognition.

To this end, our study focused on determining the optimal methodological approach for cultivated terraces recognition. The main objective of this study is to develop and test deep learning methods capable of automatically recognising cultivated terraces based solely on a high-resolution (1 m) digital elevation model. The study also examines the modelling results, points out potential problems, and provides suggestions on how to improve the training labels and modelling settings for further deep learning recognitions. Such approaches have not been used in Slovenia or anywhere else before, meaning the expected results are hard to predict.

It should be noted that since the current register of cultivated terraces in Slovenia is incomplete in some places where terraces are overgrown by dense vegetation, this also provides a real-life scenario to test the robustness of the deep learning to noisy training labels. This is an important computer-science research question for many recognition scenarios where accurate labels are hard to obtain. In addition, the results of the analysis can deliver important country-wide information on the location of unregistered terraces.

2. Theoretical background

In general, a number of international projects (Ferrarese et al., 2019; Scaramellini & Varotto, 2008) and studies on terraces have been done from different perspectives (Brown et al., 2020; Camera et al., 2018; D. Chen et al., 2021; Cicinelli et al., 2021; Deng et al., 2021; Varotto et al., 2019; Zoumides et al., 2017). To raise awareness about the importance of terraces, the Honghe Declaration was adopted worldwide in 2010 (Jinwen & Yuanyan, 2012). There have been many conservation efforts, analyses, and registration of terraces around the world, e.g. in Peru (Tillmann et al., 2020), China (Cao et al., 2020, 2021; Zhao et al., 2021), Japan (Kuroda, 2020), Italy (Pijl et al., 2021), and Slovenia (Kladnik et al., 2016b, 2017a). In 2010, the International Terraced Landscapes Alliance (ITLA) was established. Civil initiatives seek to recognise, protect, and conserve terraced landscapes, and some terraced landscapes have been inscribed on the World Heritage List (see Ažman Momirski & Berčič, 2016; Kladnik et al., 2017a).

Terrace recognition using satellite imagery was performed by Zhang et al. (2017). Their analysis used the Fourier transformation, edge characteristics, and a template matching algorithm. Sun et al. (2019) used satellite imagery to create a classification of terraced landscapes by using segmentation and k-nearest neighbour classification. Diaz-Varela et al. (2014) used a digital surface model and several spectral layers created from a UAV survey to perform an object-based image analysis and classification. As early as 2008, Ninfo (2008) used Lidar data to perform a terrace analysis using geoinformation methods to detect edges on a slope. The usefulness of Lidar data visualisations and analyses has been

addressed more frequently recently (e.g. Alberti, 2020; Ferrarese et al., 2019; Romero-Martín et al., 2020; Tillmann et al., 2020). In Italy, a curvature analysis of the Lidar digital elevation model (DEM) and other DEM-derived variables have been used to detect terrace edges (Ferrarese et al., 2019). A similar approach was used by Cosner and Tecilla (2020) and Stralla et al. (2018). Ferrarese et al. (2019) also used other approaches, for example, visualising DEM data with manual mapping of terraces. Godone et al. (2018) determined terraces from Lidar data using a method based on the height and slope analysis technique developed by Scott and Pinter (2003) when studying coastal terraces. Berčič (2016) used orthophoto imagery, land use layer, and relief slope (generated based on LIDAR) to visually interpret terraces. Satellite imagery and DEM were used to detect terraces with a random forest classifier (Cao et al., 2021). Visual interpretation is still a very common approach (Alberti, 2020; Ažman Momirski & Berčič, 2018; Romero-Martín et al., 2020; Tillmann et al., 2020). In Slovenia, terraces have been documented based on a systematic visual examination of orthophotos, topographic maps, and fieldwork (Kladnik et al., 2016a; Kladnik et al., 2016b; Šmid Hribar et al., 2017).

In the last two decades, more and more deep learning methods have been used to solve various scientific problems. They have proven to be applicable in cases where classical models have not been able to solve the problem (Alavi et al., 2016). Image analysis using computer vision methods (e.g. convolutional neural networks) is a relatively new interdisciplinary field that is growing in popularity, especially for the analysis of visual spectrum images (Buscombe & Ritchie, 2018; Redmon et al., 2016; Ren et al., 2015). These methods have also been used in medicine (Ronneberger et al., 2015) and remote sensing imagery (Chen et al., 2019; Wurm et al., 2019). In terms of the type of structures (cultivated terraces) we want to recognise in our study, they are mostly areas of different shapes and sizes with certain textural features. For this type of data, semantic segmentation models have been utilised with great success. Recently, studies on terraces recognition with deep learning based on satellite imagery have been conducted for loess plateaus in China (Lu et al., 2023; Zhao et al., 2021). Lu et al. (2023) and Zhao et al. (2021) introduced deep learning methods for recognising terraces using satellite imagery and optimising their results with the help of predefined masking (e.g. to eliminate flat areas with DEM or non-agricultural areas with a land use map). A preliminary study on the recognition of terraces with deep learning based on Lidar data was also conducted for southwestern Slovenia by Glušič et al. (2021).

3. Methods and data

The study modelled cultivated terraces based on a) an existing Slovenian register of cultivated terraces (Kladnik et al., 2016b); and b) a Lidar digital elevation model (provided by the Slovenian Environment Agency; Triglav Čekada & Bric, 2015). The modelling was conducted in four steps (see Fig. 1). First, we prepared the data of DEM and the current terraces register as described in section 3.2. Then, we tested a deep model on a subset of the data (this part was further divided into training, validation, and testing stages) as described in section 3.3. In the last step, described in 3.4, we applied the model to the entire country and evaluated the country-wide results in two phases. In the first phase, we quantitatively examined the input and result layers; in the second phase, we systematically examined the result layer qualitatively (visually) and analysed discrepancies.

3.1 Research area and basic characteristics of cultivated terraces

Slovenia (Fig. 2) is a diverse country, even at the European level, as different landscape regions intertwine here, namely the Alps, the Pannonian Basin, the Mediterranean, and the Dinaric Alps (Ciglič & Perko, 2013). Almost two-thirds of the country is

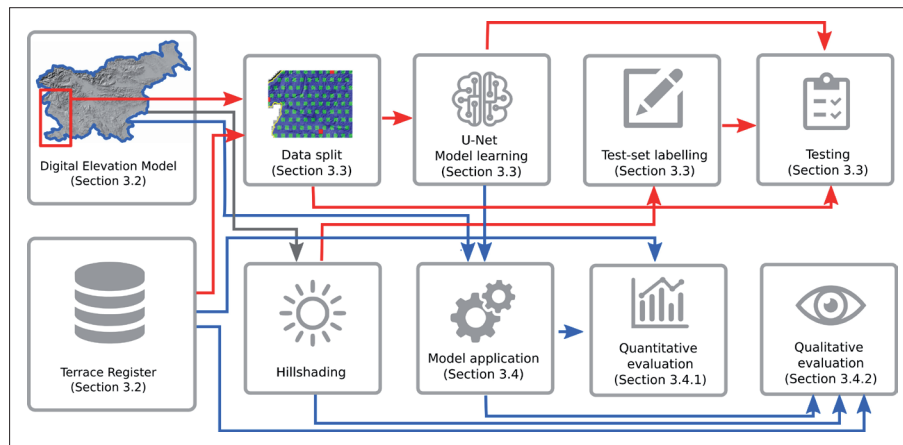


Fig. 1: Overview of the study workflow
Source: authors' conceptualisation

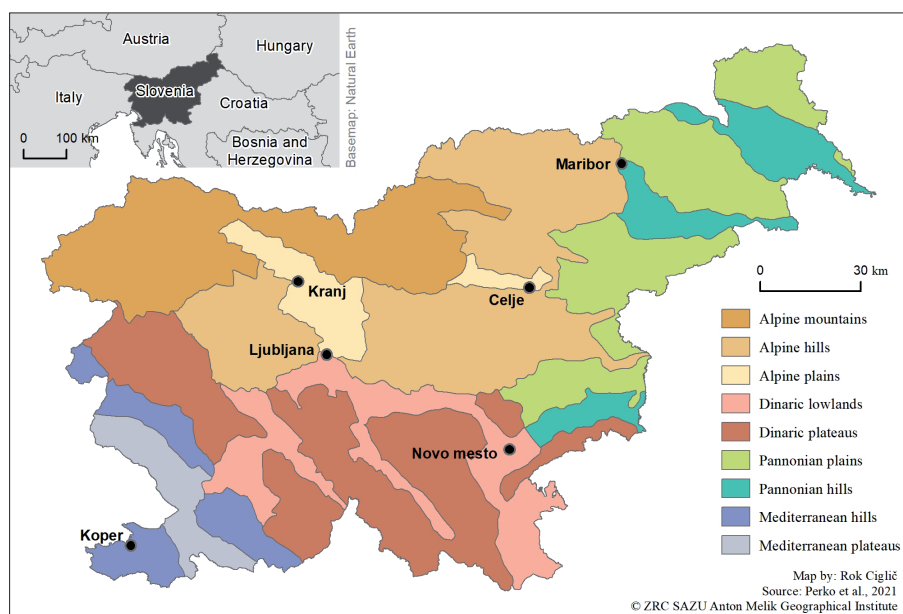


Fig. 2: Slovenian landscape types and location of Slovenia
Source: authors' elaboration based on Perko et al. (2021)

characterised by hills and mountains. More than 90% of the area is covered by loose sediments and sedimentary rocks; the greatest part of the country is composed of limestone. The country has a sub-Mediterranean climate in the southwest and a temperate continental climate in the central and eastern part and a montane climate in the northwest and north. The country has abundant water sources and forests cover approximately two thirds of the area; the widest spread form of natural vegetation are beech forests. Slovenia has just over 2 million inhabitants (Perko et al., 2020).

Terraced landscapes in Slovenia have been analysed in the past in the project 'Terraced Landscapes in Slovenia as Cultural Values' (Kladnik et al., 2016a; Kladnik et al., 2016b, 2017a; Šmid Hribar et al., 2017) as well as in other studies (Ažman Momirski, 2008, 2019; Ažman Momirski & Berčič, 2016; Berčič, 2016), constituting an important basis for further research with new methods.

The construction of terraces in Slovenia can be divided into two parts. Traditionally, terraces have been built in the Mediterranean parts of the country at least since the time of the Roman Empire for the cultivation of olive trees and vineyards. Until the 19th century, the terraced slopes were built with stones, but from then onwards, newer slopes were built without stones and were overgrown with grass. Land use also changed in different eras. Before the appearance of phylloxera, the terraces had a mixed

land use with combined vineyards and fields on the same terrace. Later, the fields were replaced by vineyards and orchards planted on the banks of the terraces. With the intensification of agriculture in Yugoslavia, terracing also became more common in other parts of the country. While some of the old terraces on unfavourable slopes were abandoned, mostly in the period from 1963–1990 due to the depopulation of the countryside, many new terraces were created with the help of machines and are used almost exclusively for viticulture (Titl, 1965; Kladnik et al., 2016b, 2017a).

According to Kladnik et al. (2016b), terraces in Slovenia occur from 0 m to almost 1,200 m above sea level, with the majority of them located in Mediterranean parts of the country. They are most commonly found at a height between 200 m and 300 m on flysch rocks on slopes between 15.1% and 30%. The width of the terraces can range from around 2 metres on steep slopes to 50 metres on flatter terrain, while their length can vary from around 10 metres to several hundred metres in newer terraces (Drobnjak, 1989).

3.2 Input data

The model for the recognition of terraces was created by using the DEM and vector layer of the terraces register. The DEM was available with a resolution of 1 m and provided by the Slovenian

Environment Agency. The DEM layer is based on the Lidar point cloud with a ground return point density of at least 0.5 points/m² and at least 15 cm of vertical precision (Triglav Čekada & Bric, 2015). The vector layer of terraces register was created by manually digitising orthophotos and topographic maps, and through fieldwork done by the Research Centre of the Slovenian Academy of Sciences and Arts (Kladnik et al., 2016b). The layers of orthophotos (0.25 m and 0.5 m resolution) and various topographic maps were provided by the Surveying and Mapping Authority. In the evaluation process, a generalised land-use information (provided by the Ministry of Agriculture, Forestry and Food) were used for analysis of relationships between terraces and land-use. The generalised categories for land use were defined on the basis of vegetation height and land use; the combining of land use categories was done according to Gabrovec and Kumer (2019). A forest mask (also provided by the Ministry of Agriculture, Forestry and Food) was used to conduct the analyses with and without forested area.

3.3 Modelling

We based our modelling on an advanced machine learning framework of deep learning. Deep learning models can solve many different tasks in processing visual and auditory data by adapting the architecture of the model and training it with a given collection of training data. The main advantage of deep learning methods is that they mostly operate directly on the raw input and are able to learn autonomously to extract relevant features from a large amount of data that can be used to achieve the set goals (Sarker, 2021). Considering the nature of the input data (rasterised Lidar DEM) and the terraced landscapes (diverse landforms with a repetitive structure), we based our study on semantic segmentation models. These models accept a region of spatially connected inputs (e.g. a rectangular image patch) and predict a class for each unit, i.e. pixel. Specifically, we based our model on the U-Net architecture, which was first used for medical image analysis (Ronneberger et al., 2015), but has subsequently been utilised extensively in other segmentation domains as well (Stringer et al., 2021). The U-Net architecture is widely used due to its relative simplicity. It is based on the idea of a fully-convolutional combination of an encoder and a decoder. The skip connections (connections that bypass one or more layers in a neural network; He et al., 2016) between corresponding layers of both units improve the accuracy of the resulting segmentation. Our model architecture is shown in Fig. 3.

Based on preliminary experiments on a smaller dataset, we reduced the number of filters in individual layers and reduced the number of free parameters by 25% in comparison to the original architecture (Ronneberger et al., 2015). The change was done to promote generalisation and prevent overfitting to the training data. The reason for this is that reduced models are forced to use their parameters more efficiently and tend to find solutions that generalise better to new data. Of course, there is a limit to this phenomenon, as a model that is too small may not learn to solve a complex problem at all. We also took great care to represent the terrain elevation data in such a way that small elevation changes would be noticeable. Instead of using the elevation directly, we provided the model with partial derivatives over X and Y of the elevation raster. These two derivatives were computed using the Sobel operator. Together, the derivatives can be viewed as a different representation of the local slope (magnitude of the combined derivatives) and aspect (angle of the combined derivatives). The reasoning for using derivatives instead of absolute elevation is to have the input values distributed over a similar interval regardless of the location in the raster. This is an important requirement for successful training of deep models.

The model was implemented using the PyTorch framework (Paszke et al., 2019) and learned from randomly initialised weights using the Adam optimiser (Kingma & Ba, 2014) with a learning rate of 0.001. The batch size was set to 20 samples of 572 × 572 pixels. During learning, the process was monitored by observing the model performance on a validation set to detect overfitting and determine whether further learning was still sensible. We experimented with different loss functions and found that (soft) Dice loss (Dice, 1945) was best suited for our use case. This type of loss is robust to unbalanced data (significantly fewer cultivated terraces than areas that do not contain them). The final model was trained on a single NVIDIA Nvidia Titan X (Pascal) GPU for about 3 hours (40,000 steps).

Due to the size of the raster, patch-based processing was required. In the training phase, we randomly sampled batches of 20 patches from the allocated training area. An additional condition was set for the sampling procedure: A selected patch had to contain at least 1% of the terraced area (from the terraces register). This constraint served two purposes: a) it ensured the numerical stability of the loss function in the presence of highly unbalanced data; and b) since manual interpretations and mapping for the register might have missed some cultivated terraces (e.g. in densely vegetated areas), we used this technique to implicitly

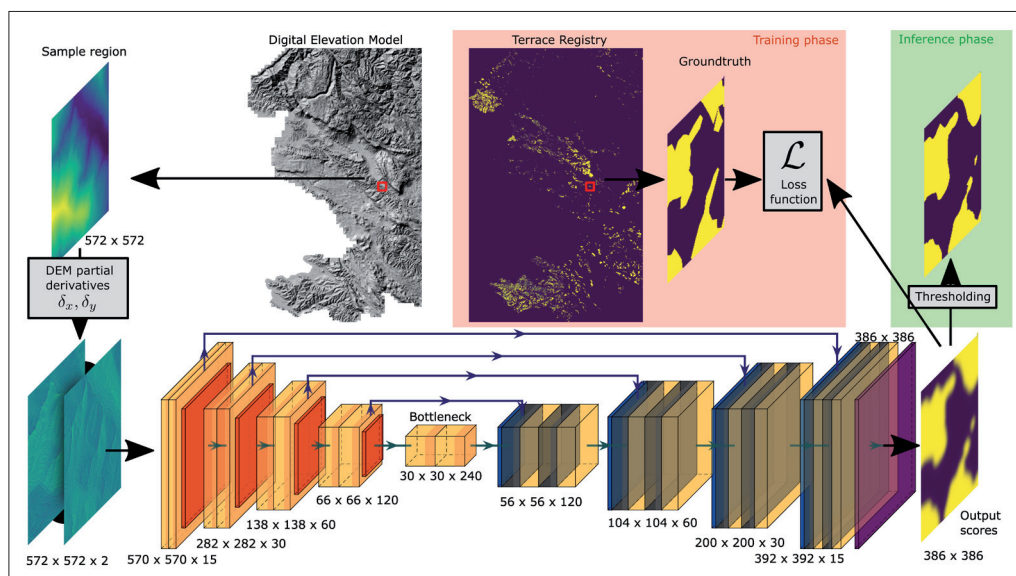


Fig. 3: Schematic representation of our segmentation model architecture
Source: authors' conceptualisation

avoid areas without terraces (e.g. mountains, flat areas) or areas where incomplete mapping might be present (e.g. forested areas). In the assessment phase, the raster was processed patch by patch in a scan-line algorithm. We also adjusted the padding to mitigate edge artefacts when joining individual patches back together.

The assessment of the model during and after the training phase was challenging due to inconsistencies in the labels used for training and the sensitivity of the classical overlap-based performance measures, frequently used when evaluating segmentation models. The assessment was therefore based on a mixture of validation on a larger subset reference data to determine overfitting and establish stopping criterion. The final test of the trained model was done on a smaller set of curated regions, not seen during the training. These regions were the only part of the data that was manually re-labelled (mapped) by the authors of this study using DEM and orthophoto references. The test data (test set) was used to establish an objective noise-free quantitative performance of the model and to observe how robust the model is to training noise. The selected quantitative measures for validation included accuracy, precision, recall, F1 score, and Jaccard index (Jaccard, 1912; Hicks et al., 2022). These measures have been frequently used in spatial analyses (e.g. Fisher et al., 2018; Abdi, 2020; Tang & Painho, 2023) and are all derived from the confusion matrix, but highlight different aspects of performance. The related equations are:

$$accuracy = \frac{TN+TP}{TN+FP+TP+FN},$$

$$precision = \frac{TP}{TP+FP},$$

$$recall = \frac{TP}{TP+FN},$$

$$F1\ score = 2 \times \frac{Precision \times Recall}{Precision + Recall} = \frac{2TP}{2TP+FP+FN},$$

$$Jaccard\ index = \frac{TP}{TP+FP+FN},$$

where TP denotes true positive pixels (correctly recognised as terraces), TN true negative (correctly recognised as not terraces), FP false positive (incorrectly recognised as terraces) and FN false negative (terraces, but not recognised).

Our model was trained in the region of southwestern Slovenia, shown in Fig. 4 (2,776.1 km²; 13.7% of the country). The region was divided into chessboard-like patterns as training (73.8%), validation (25.3%), and testing sets (0.9%). The size of each rectangle was 2048 × 2048 pixels. One pixel corresponded to 1 m². The main property of the small test set was that it was manually re-labelled (mapped) using Lidar hillshade data and visually validated.

3.4 Application to the wider area and its evaluation

3.4.1 Overlapping

After obtaining the final model, which was validated and tested, we applied the model to the entire country (20,271 km²). This allowed us to further assess its capabilities.

The evaluation consisted of two steps. By overlapping the terraces register and the computer-recognised terraces, we created a cross-tabulation and calculated the Jaccard Index, recall, precision (see 3.3 for the equations), as well as the kappa index. The kappa index is calculated by (Dettori & Norvell, 2020):

$$\kappa = \frac{p_o - p_e}{1 - p_e},$$

where p_o is an observed agreement and p_e is an agreement expected by chance.

These analyses were also carried out with a comparison of the location of the terraces with Slovenian landscape types (provided by Perko et al. in 2021) and land use data (provided by the Ministry of Agriculture, Forestry and Food).

3.4.2 Visual evaluation

An additional visual evaluation of the layer of recognised terraces was done by checking the shaded relief, which is commonly used for geomorphological features. It is based on a DEM that can be

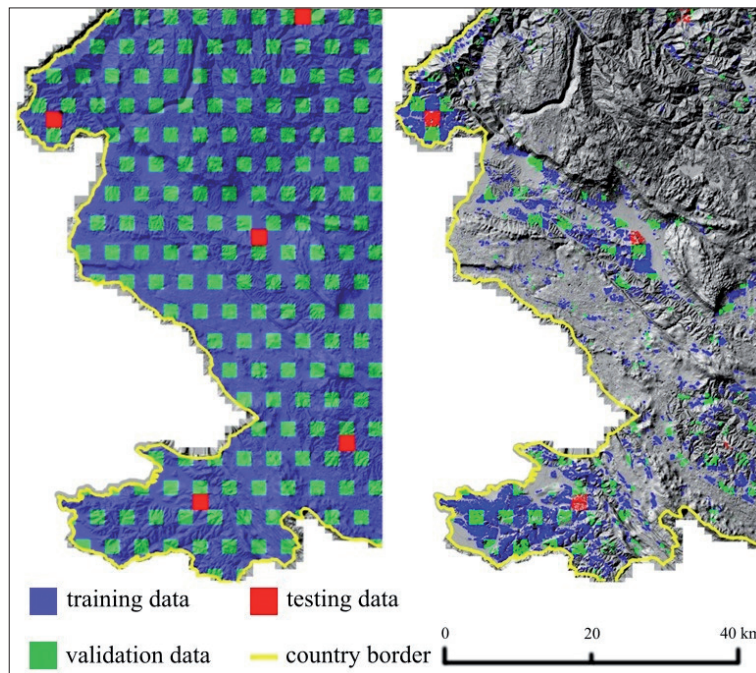


Fig. 4: Map of the area of the modelling phase (southwestern Slovenia) with a hillshade relief as the background
Notes: Left: the region was divided into training (blue), validation (green), and testing (red) sets. The yellow line denotes the country border.
Right: the same visualisation, but with a focus on the terraced regions.
Source: authors' elaboration

illuminated under different conditions so as not to miss shapes oriented at the same angle as the illumination (Chandler et al., 2018). In this way, we were able to estimate examples of terraces that were not recognised or were recognised falsely (see Fig. 9). This step is crucial for further approaches to cope with recognition processes, as the training set may not have been complete and this was the first example of the application of deep learning methods to the entire territory of Slovenia. In order to perform a country-wide evaluation of the resulting layer, two samplings were conducted. First, we divided the country into a grid of 1 km² squares. Then, we randomly selected 0.5% of all the squares (118 in total) to perform a visual evaluation. In addition, 0.5% of the squares (64 in total) with the lowest Jaccard index were selected for an additional visual evaluation, focusing on the areas with the least overlap between the terraces register and the computer recognised terraces. As some terraces covered with forest had not been fully mapped by Kladnik et al. (2016b), the analysis of the recognition success was done only for the areas outside the forests.

4. Results

The results are presented in two parts: first, in the scope of the classical machine learning process of model building, where the performance is assessed on test splits. Second, we evaluated the application of the model to the novel data outside the training area (application to the entire country) and summarised the results quantitatively as well as qualitatively.

4.1 Evaluation of the trained model

The model was first assessed on the test split of the southwestern Slovenia region (marked as five red squares in Fig. 4). The terraces in these five regions were newly digitised on the basis of hillshade relief. This binary mask layer of the testing terraces was then compared with the terraces recognised by the deep learning model and with the terraces register (Kladnik et al., 2016b). The results are summarised in Table 1. It is evident that the original terraces register (by Kladnik et al., 2016b) has some differences from the testing set of terraces obtained by observing the Lidar hillshade data. Our trained U-Net model outperforms this original terraces register. This indicates that the training procedure is robust to noisy inputs (due to missing or misplaced reference labels). This is especially true for weighted measures that are less sensitive to imbalanced datasets, i.e. the Jaccard index and the F1 score.

We also observed the discrepancy in the precision and recall scores indicating that the layer of the terraces register by Kladnik et al. (2016b) is more conservative, probably due to the fact that some densely forested areas were not taken into account, while the deep learning model does not have this bias, which leads to better recall.

	Accuracy	Precision	Recall	Jaccard	F1
Deep learning recognition (U-Net)	0.885	0.749	0.877	0.678	0.808
Terraces register by Kladnik et al., 2016b	0.850	0.784	0.633	0.539	0.701

Tab. 1: Quantitative results for the testing split. First row: comparison of the deep learning recognised terraces with the testing set of manually mapped terraces on a Lidar-based hillshade relief; second row: comparison of terraces register (by Kladnik et al., 2016b) with the testing set of manually mapped terraces on a Lidar-based hillshade relief
Source: authors' calculations

	Terraces register by Kladnik et al. (2016b)		Sum
	positive	negative	
Deep learning recognition positive	225.07 km ² (2.69%)	1,172.10 km ² (13.98%)	1397.17 km ²
Deep learning recognition negative	63.14 km ² (0.75%)	6,921.93 km ² (83.00%)	6985.97 km ²
Sum	288.21 km ²	8,094.03 km ²	100%

Tab. 2: Confusion matrices for non-forested areas in the entire country
Source: authors' calculations

4.2 Application to the entire country

The final model was applied to the entire country of Slovenia. Note that the only reference we had in this case was the terraces register by Kladnik et al. (2016b). Besides computing the overall comparison that provided some insights into the model's performance, we also conducted an in-depth analysis of the discrepancies according to landscape types and land use categories (section 4.2.1) as well as a detailed qualitative comparison of selected areas (3.2.2). As already mentioned, some of the analysis in this part was performed for areas outside forests.

4.2.1 Confusion matrix and measures of success

After applying the model to the entire country, we prepared a confusion matrix (Tab. 2) and calculated several indicators of success rate to assess the model's capability in general (including all areas) and for non-forested areas only (Tab. 3). We noticed that most of the indices were similar. The highest difference was observed between the accuracy rates. The higher value comes from the analysis of all the areas, which could be expected since the majority of the area is non-terraced.

The Jaccard index for terraces recognition outside forests with our deep learning model was 0.13, the Kappa index was 0.22, the overall accuracy was 0.85, the recall was 0.78, and the precision was 0.16. We see that the overall accuracy is high, but this is still the result of a large proportion of actual non-terraced areas. The proportion of true terraces detected is just over three quarters, and the predictive power is low.

Both terraces layers, i.e. the terraces register (by Kladnik et al., 2016b) and the deep learning recognition of our study, showed a higher percentage of terraces in the western and eastern part of Slovenia. We calculated the percentage of terraced areas outside forests in a 1 km² grid for terraces register and for the terraces recognised by deep learning, respectively (Figs. 5 and 6).

The differences in terraces distribution across Slovenia (Fig. 5 and Fig. 6) indicated that there might be differences in landscape settings (appropriateness and needs) for terracing across the country. After comparing different Slovenian natural landscape types (Perko et al., 2021; Tab. 4), it is clear that the highest success rate for areas outside forests is associated with the Mediterranean part of Slovenia (Mediterranean hills and Mediterranean plateaus), which is located in western Slovenia where the training labels were taken. These two types are followed by the Pannonian hills (on the eastern edge of the country) and two Dinaric landscape types (Dinaric plateaus and Dinaric lowlands). The Mediterranean landscapes and the Pannonian landscapes are also the most terraced regions in Slovenia, according to Kladnik et al. (2016b).

	All areas (including forests)	Non-forested areas only
accuracy	0.93	0.85
Jaccard index	0.13	0.13
Kappa	0.24	0.22
recall	0.75	0.78
precision	0.16	0.16

Tab. 3: Comparison of basic success rates
Source: authors' calculations

Landscape type	Jaccard index
Mediterranean hills	0.44
Mediterranean plateaus	0.22
Pannonian hills	0.12
Dinaric lowlands	0.11
Dinaric plateaus	0.11
Alpine hills	0.08
Alpine plains	0.05
Pannonian plains	0.03
Alpine high mountains	0.03

Tab. 4: The Jaccard index for terraces recognition according to the Slovenian landscape types (according to Perko et al., 2021)
Source: authors' calculations

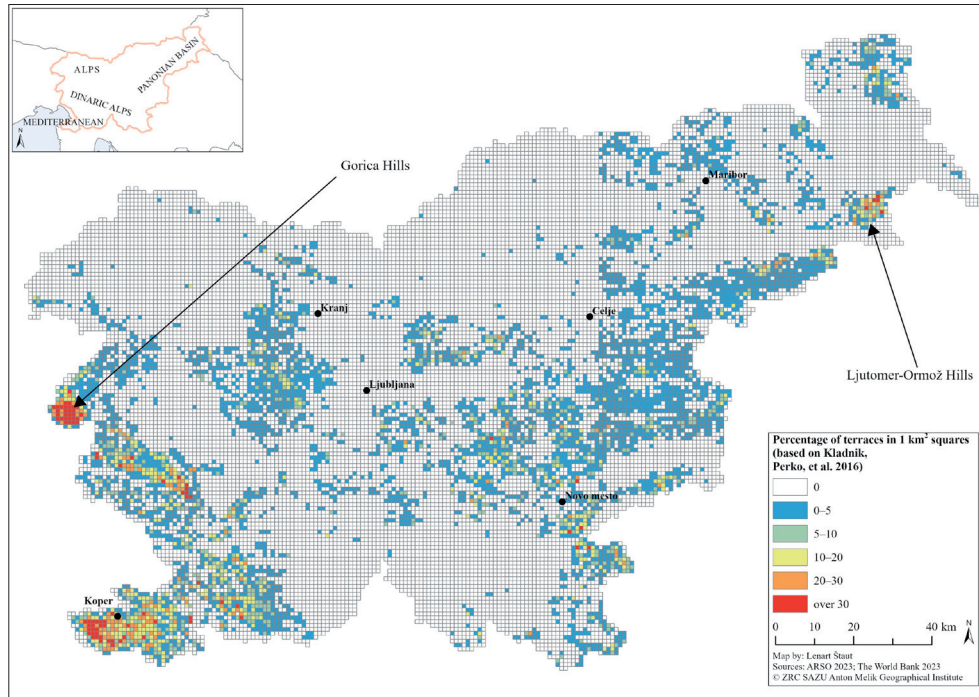


Fig. 5: Area of terraces defined in terraces register outside forests (shown as a percentage of 1 km²)
Source: authors' calculations

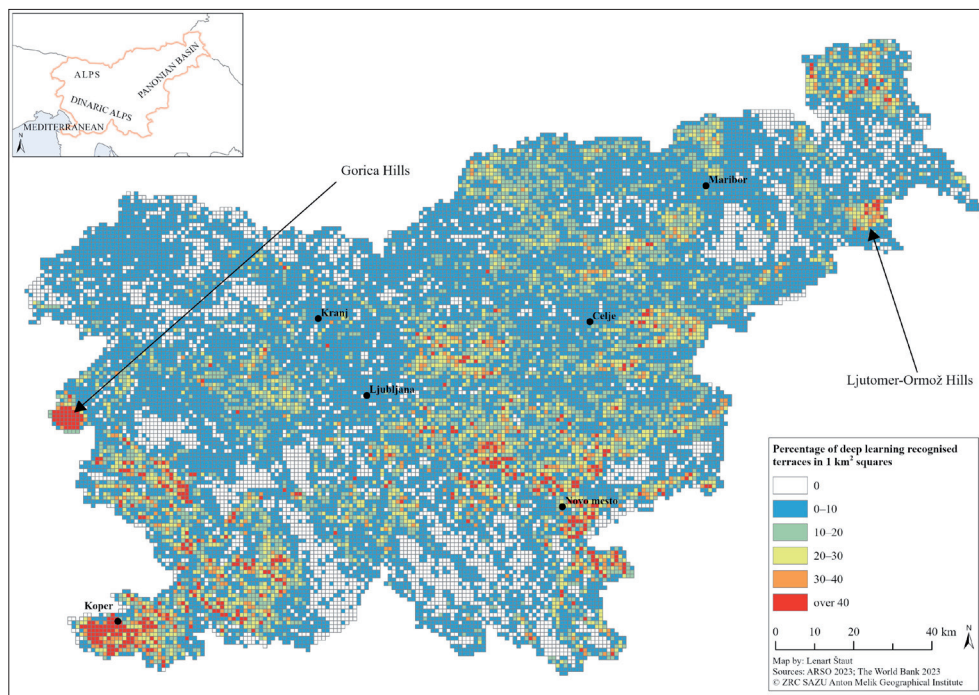


Fig. 6: Area of deep learning recognised terraces outside forests (shown as a percentage of 1 km²)
Source: authors' calculations

There are also differences in success rates outside the forests at a more detailed level between different regions of the country. We calculated the Jaccard index for 1 km² squares and found that most regions with well-preserved terraces, e.g. the Gorica Hills (Goriška brda) in the Mediterranean Hills in the west and Ljutomer-Ormož Hills (Ljutomersko-Ormoške gorice) in the Pannonian Hills in the east, had the highest success rate (Fig. 7). The terraces in the Gorica Hills are well maintained due to their importance in the regional economy. The area has intensive fruit and vine growing due to favourable warm Mediterranean climatic

conditions. With the introduction of agricultural machinery in the past, the terraces became wider and more uniform. The slopes (banks) became more stable and noticeable (Kladnik et al., 2016b). Similarly, some parts of the Pannonian Hills have an intensive fruit and vine growing production due to a continental climate and low altitude above sea level. In this area, terraces are located in a thermal belt at higher relative altitudes. Therefore, the terraces are clearly visible for human interpretation of the aerial imagery or the hillshade relief. Obviously, they are also easily recognisable to the deep learning method. On the other

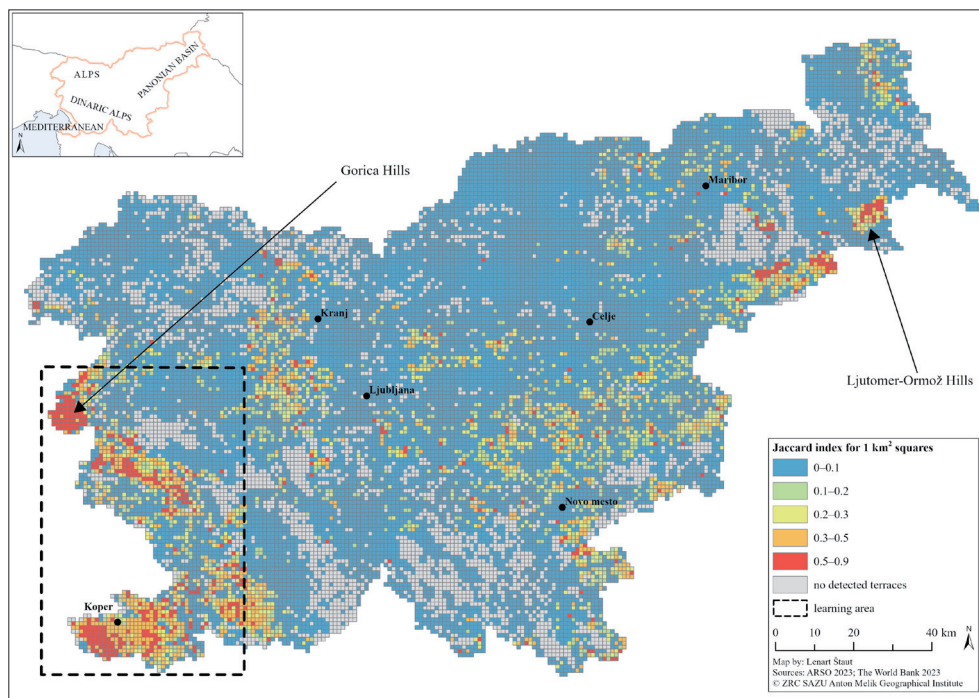


Fig. 7: Jaccard index for 1 km² (for non-forested areas). Regions in western and eastern parts of the country have the highest level of success rate
Source: authors' calculations



Fig. 8: Regularly maintained and well-visible terraces in Ljutomer-Ormož Hills (upper left; photo: Elena Odareeva, Adobe Stock) and Gorica Hills (upper right; photo: Marcin Juch, Adobe Stock). Less distinct terraces in Dinaric plateaus were used as fields in the past, but nowadays, they are covered with grass (bottom left; photo: Rok Ciglič) or sparse trees (bottom right; photo: Matevž Lenarčič). The photos have been used with authors' permission.

	Share of land use on terraces from the register [%]		Share of land use on deep learning recognized terraces [%]	
	forest included	without forest	forest included	without forest
Arable land	7.5	8.4	11.9	12.9
Vineyards	19.1	21.3	6.4	7.0
Other permanent crops	9.3	10.4	5.0	5.4
Grasslands	44.0	49.0	60.1	65.1
Other farm areas	7.5	8.4	4.4	4.7
Forest	10.4	–	7.8	–
Built-up area	2.1	2.3	4.3	4.6
Other	0.0	0.0	0.1	0.2
Total	100.0	100.0	100.0	100.0

Tab. 5: Relationship between terraces and different types of land use
Source: authors' calculations

hand, karst areas of Dinaric Alps are less favourable for farming in general due to high altitudes, lower temperatures, a thin soil layer, and the absence of surface water (Ciglič et al., 2013). Therefore, cultivated terraces and agricultural activity were generally quickly abandoned in the last decades and are therefore less visible in the landscape (Kladnik et al., 2016b). These areas have less distinct terraces now (e.g. gentle terraces in Dinaric regions covered with grass or sparse vegetation; Fig. 8).

We also examined the relationship between terraces and different types of land use (Tab. 5). We defined eight land use categories based on 2012 land use data. The results are presented for the terraces recognised by deep learning and the terraces register respectively. We repeated the analysis with forested areas excluded, as we assumed that terraces from the register are included in a lower percentage than those defined by the deep learning method.

Most of the terraces from the register are covered by grasslands, followed by those with vineyards. If we compare these results with the terraces recognised by deep learning, we see that these terraces are also most often covered by grassland, but there is a strong difference in second place with arable land instead of vineyards. In both cases, the third largest area is represented by forests.

4.2.2 Visual evaluation

Based on 118 randomly selected 1 km² squares and 64 randomly selected 1 km² squares with the lowest value of the Jaccard index, we gathered some observations on the success of deep learning recognition. Some areas were falsely recognised as terraces. This is because of various artificial shapes or features that look similar to agricultural terraces. For example, a road on a slope could be recognised as a terrace. Such a pattern with some smaller single terraces or single steeper slopes nearby can give an even stronger impression of a terraced area (Fig. 9A). Larger infrastructure elements, such as railway lines with embankments (Fig. 9B) or roads, especially those with repeated patterns of winding roads (Fig. 9C), can also be identified as terraces. In addition to these larger infrastructure elements, smaller paths on slopes, especially if they occur close together (e.g. due to grazing), can also be recognised as terraces. Small elevation differences due to different cropping structures (which influence the Lidar penetration to the ground) or different cultivation stages in the fields can be recognised as terraces (Fig. 9D). In some places, even barren agricultural land (fields) on the plain can be recognised as terraces (Fig. 9E), characterised by a repeating pattern of small 'ridges' and 'valleys'. The general landscape structure (mosaic) also influences the recognition algorithm, which recognises larger areas of terraces than they actually are. Some foothills of slopes with only one (large and distinct) edge were falsely recognised as larger terrace areas (Fig. 9F). On the other hand, some terraces are less pronounced and are crossed by non-terraced (but rough) relief, so that larger areas are identified as terraced.

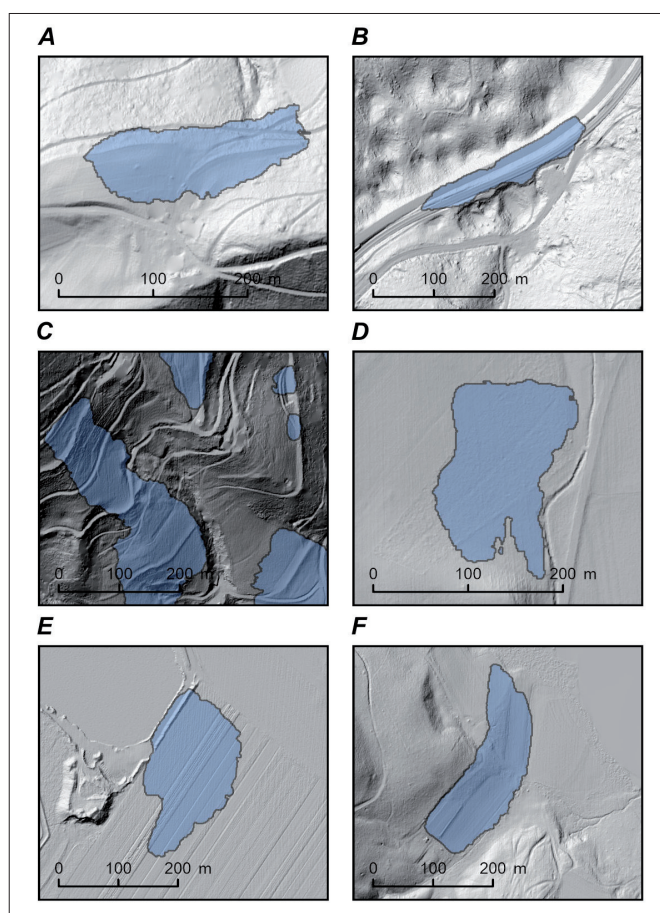


Fig. 9: Examples of falsely recognised terraces
Source: authors' calculations

After the visual examination of our results, it seems that deep learning recognition overestimated the number of terraced areas in the case of Slovenia. On the other hand, some terraces were not recognised by the deep learning method. There are cases where certain terraces or parts of them were not recognised by the model, which raises the need for further tuning the model or improving the training labels.

5. Discussion

In his study, Berčič (2016) predicted that recognition using machine learning could not be far off. Past studies (e.g. Cao et al., 2021; Glušič et al., 2021; Lu et al., 2023; Zhao et al., 2021) and our analysis support this prediction.

A comparison with some recent studies with machine learning approaches puts our work in a broader context. Cao et al. (2021) used several multispectral Landsat satellite images, GlobeLand30,

Google Earth imagery, and a SRTM digital elevation model to create a classification algorithm (random forest classifier) for terraces in China. The overall accuracies were 94.7% and 88.4% (after additional visual inspection) and the Kappa indices were about 0.71. The analysis was performed at 30 m resolution. Zhao et al. (2021) used a deep learning-based U-net approach and a spectral angle mapper approach for three study areas in China. Terraces were recognised based on Google Earth imagery and refined by DEM (produced by drone imagery with 1 m resolution). The first method provided an overall accuracy of 87 and 90%, the second 40 to 49%. Lu et al. (2023) used Google Maps satellite imagery and the U-net algorithm for terraces recognition; afterwards, digital elevation model, GlobeLand30, and vegetation correction data were used for corrections. Their overall accuracy was between 96.4 and 98.4% (depending on the processing stage). In contrast to these studies, our study was based solely on the Lidar DEM and existing terraces register (by Kladnik et al., 2016b), which was not entirely accurate. No satellite or aerial imagery was used in our process, as well as no post-processing using expert knowledge. We were interested in defining terraces even in heavily vegetated areas where terraces cannot be observed without Lidar technology as well as in studying the limits of using deep learning alone for the task. This means our method was a novel approach and these first results were consequently relatively poor. As in the case of the Chinese examples, Slovenian terraces recognition might still benefit from the inclusion of additional data, e.g. Landsat or Sentinel imagery or other commercial satellite imagery with a higher resolution, but the main goal was to test deep learning capabilities exclusively on DEM data due to the rather high forest cover in Slovenia (according to the Slovenia Forest Service, 58% of the country is covered with forests).

Some natural and artificial phenomena are similar to cultivated terraces and make the recognition more difficult. Since terraced landscapes are located in places where apparent patterns of two or more terraced surfaces appear (Berčič, 2016), it was not surprising that we encountered natural or other artificial terrace-like forms during the (mis)recognition. Natural terraces appear as step-like landforms resembling terraces, formed by natural processes (Kladnik et al., 2017a; see also Del Val et al., 2015; Ferk, 2016). In our case, some specific features were recognised as terraces (e.g. foothills). In contrast, there were many more examples of falsely recognised terraces associated with anthropogenic elements, such as roads and railway lines (see Fig. 9). We noticed that some slopes with road cuts can be recognised as terraces. According to a formal description, these can also be considered terraces, but they are not cultivated. The span of such a 'terrace' varies and there is no clear repeating pattern. Therefore, the solution could be to define the span of terraces more strictly and the minimum number of terraced surfaces in one terraced area. By including remote sensing imagery, roads can be excluded based on the spectral response for certain surface materials (asphalt, gravel).

Terraces generally share similar spatial texture characteristics (Zhao et al., 2021), whereas natural landscape types influence the shape and distribution of cultivated terraces to some extent (Berčič, 2016). Our analysis included different landscape types across Slovenia, where different geomorphic processes as well as anthropogenic influences are present (Zorn et al., 2020). These processes have left a characteristic imprint on the landscape, which means that cultivated terraces may differ from one area to another and therefore different recognition issues may arise regarding the success of modelling. In our case (Tab. 5, Fig. 7), the highest Jaccard index was observed in the Mediterranean hills (in the west) and the Pannonian hills (in the east), where terraces with vineyards are common (Ažman Momirski, 2019). The reasons for the higher success rate in these regions could be that the terraces in these areas have the most pronounced shape and are well maintained and less overgrown. Therefore, they are clearly

visible for human and deep learning recognition. In such areas, Lidar scanning of the ground is also more detailed with a higher density of ground points. Namely, data collection is easier due to plants (vines) growing in a row with some empty space all around, so the Lidar scanning can easily reach the ground. Based on the geometric characteristics of the terraces (which are usually more than 2 m wide; Drobnjak, 1989), we consider the 1m Lidar data to be sufficient and not the reason for the discrepancies. Terraces are most often covered with grasslands (as shown in Tab. 5). This is not surprising, because land abandonment and overgrowth of agricultural areas (fields) is very common in Slovenian peripheral areas (Gabrovec & Kumer, 2019), especially in the Dinaric Alps. The higher share of terraces recognised by deep learning is also related to arable land, which might also be the result of some misrecognised areas (see 4.2.2).

The advantage of deep learning is the modularity of the model architectures, which can be quickly adapted to new tasks. The convolutional neural networks we have used are very well suited for processing spatial data and remote sensing (Yuan et al., 2021), as they can efficiently model high-order dependencies in the local area. On the other hand, deep models require a large amount of data. In remote sensing applications, the sheer quantity is usually not a problem, but ensuring sufficient quality often is. Some features of interest may be missing in the training data. Moreover, labelled features rarely follow the exact boundary in the underlying raster, as human annotators are influenced by various factors and are seldom completely focused on their visual interpretation. Some objects are also complex to digitise (Van Coillie et al., 2014). Still, the main source of noise in our case is the absence of labels of overgrown terraces (Kladnik et al., 2016b; Glušič et al., 2021). As we observed in our case, the training procedure of deep models that considers several samples in a single step is surprisingly robust. This has been demonstrated by comparing our model's predictions to the testing labels (see 4.1).

There are more ways to further mitigate the problem of noise by considering additional data sources and domain knowledge. Since there are many features with terraces-like shape in the Lidar DEM data (e.g. winding roads, river terraces), the rate of falsely classified terraced areas could be reduced by including aerial orthophotos or other multispectral remote sensing images. Lu et al. (2023), refined the recognition results, obtained using deep learning on optical imagery using slope information and exclude areas with low levels of slope (e.g. less than 2°). The analysis of optical remote sensing images (e.g. aerial or satellite multispectral images) could help us in our case to exclude certain non-vegetated areas (such as roads covered with asphalt or stone quarries), but this approach solely cannot adequately improve capturing terraced areas with indistinct terrace banks and abandoned, overgrown cultivated terraces (Kladnik et al., 2016b). To provide solid morphological information, using Lidar data is therefore unavoidable in such cases and other data sources may only provide auxiliary information.

Looking at the specific failure cases of our model (see Fig. 9) we acknowledge the fact that the diversity of terraces and their similarity to other landscape features should be additionally investigated. A clear division between similar, terraces-like features could be promoted during training using similar landscape features. Such features might include a winding road, a railway line, or a road embankment, etc. and could be obtained from different sources (e.g. land use). The model may also lose sensitivity to some landscape properties due to our data encoding using DEM derivatives. This choice allows the model to focus on small changes in the landscape but makes it difficult to reconstruct coarser properties. The addition of a less detailed (generalized) DEM (e.g. averaged Lidar DEM) may help to provide more information about the general slope of the area and to exclude flat areas, where, for example, terraces-like pattern can be seen in the ploughed fields.

It is important to remember that our study only evaluates the capabilities of a deep learning model and does not consider manual pre- or post-processing, which can upgrade our approach. Despite the limitations of the presented model, we believe that computer analyses of digital elevation models are needed for successful construction and maintenance of terraces registers, especially in countries like Slovenia, where most of the land is covered by forests. In such scenarios, fieldwork is limited by potentially poor accessibility as well as time and financial constraints (Berčič, 2016). A more robust model, stemming from our work, could quickly and cost-effectively map abandoned and overgrown terraces to promote their potential revitalisation (Sakellariou et al., 2021).

Beyond terraces, other relief features could be tested for recognition possibilities with deep learning methods, for example dolines and collapsed dolines (e.g. Ciglič et al., 2022; Mihevc & Mihevc, 2021), denuded caves (Grlj & Grigillo, 2014), fluvial terraces (Wei et al., 2017), landslides (Verbovšek et al., 2019), alluvial fans (Norini et al., 2016), dunes (Mohamed & Verstraeten, 2012), and glacially reshaped landforms (Chandler et al., 2018). Despite the increasing availability of objective methods, manual mapping is still used to refine extracted features, e.g. fluvial terraces (Gardner et al., 2020). Deep learning is still underutilised in several geographical sub-fields, e.g. geomorphology and geomorphometry. Rare examples of the use of automated analysis include the analysis for categorising different rock types (Patel & Chatterjee, 2016), recognising dolines (Mihevc & Mihevc, 2021), and other geomorphic features (Maxwell et al., 2023).

6. Conclusions

Terraced landscapes are the result of human adaptation to nature, mainly for the purposes of improving the conditions for agriculture. Nowadays, many terraces are being abandoned, but if the need were to arise for their revitalisation (e.g. due to food shortages), it is important to know the locations of existing and abandoned terraces. In this work, we tested the possibilities for recognising terraces using a U-Net deep learning architecture and Lidar DEM. Unlike past studies, we did not use satellite or aerial multispectral imagery for the deep learning process. We found that the recognition of cultivated terraces solely with the Lidar DEM is possible. During the testing phase, the method showed robustness to the input training data, which is encouraging for further studies and improvement. Comparing the modelled layer and the layer of cultivated terraces, the register showed an overall accuracy of 85%, but the kappa index was only 0.22. A detailed inspection showed that the recognition was most successful in areas with pronounced terraces (e.g. the Mediterranean parts of Slovenia). Our results did not contain any post-processing and are generally not yet suitable for direct application, as there were quite a number of errors. However, our analysis was able to highlight a number of challenges (potential false recognition issues) that need to be considered when defining training datasets.

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