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EDITORIAL OFFICE

Faculty of Sciences
Department of Geography, Tourism and Hotel Management
Trg Dositeja Obradovića 3, 21000 Novi Sad, Serbia
tel. +381 21 450-105
fax +381 21 459-696
Official site: www.dgt.uns.ac.rs

CONTACTS

Lazar Lazić, PhD, full professor
Department of Geography, Tourism and Hotel Management, Serbia, lazar.lazic@dgt.uns.ac.rs

Dragan Milošević, teaching assistant
Department of Geography, Tourism and Hotel Management, Serbia, dragan.milosevic@dgt.uns.ac.rs

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Examining a Theoretical Concept – (Im)Mobility as a Factor of Perforation in a Rural Hungarian Context

Levente B. Alpek[A], Gábor Pirisi[A], Róbert Tésits[A], András Trócsányi[A], Éva Máté[A*], Ádám Németh[B]

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Abstract

Rural restructuring became a frame definition to describe the changing circumstances of rurality within modernization and post-modernization processes. When it comes to modernization, differentiation mostly denotes an increasing urban lifestyle, higher level of mobility and flexibility and dynamic society of the rural. However, a brief overview on rural spaces proved, that in many cases the new challenges of modernization or post-modern values indicate a fragmentation in societies. The approach to reach a higher level of mobility due to the centralized spatial structure of workplaces results in a distinction between social groups; what is more, demographic decline intensifies because of the relatively high mobility of certain rural groups. This paper focuses on those social groups, which have a relatively low level of mobility, therefore they get isolated in a rural locality. The settlements, where most of the local society lacks mobility, could cause the perforation of the settlement system, thus the isolation of some rural social groups leads to a dysfunctional settlement structure. In these terms, perforation means a process, in which a settlement loses connections with local centres or other communities due to the low mobility of residents. Therefore, perforation refers to the lack of local networks, an immobile society, and a set of problems, like unemployment, deprivation, or deviant behaviour. According to the author's presumptions, the mobility of residents could express the volume of perforation as the more isolated the residents are, the less network functions in a rural settlement system can be found. For this reason, this research measures the mobility level of residents in a Hungarian rural locality named Baranyai-Hegyhát, located in the Southern-Transdanubia Region. According to survey data, a mathematical model can describe mobility patterns in this area, which is used as a method to find isolating settlements in a disabled space. The theoretical concept of perforation is supposed to be an experimental approach to interpret complex isolation processes in rural spaces, as such, in this paper, we are to test our theory with the method of the Corrected Mobility Index.

Keywords: post-socialist rurality; rural restructuring; perforation of settlement structure; mobility; labour market; Hungary

[A] Department of Human Geography and Urban Studies, Institute of Geography and Earth Sciences, Faculty of Sciences, University of Pécs, Ifjúság útja 6. Pécs, H-7624; alpeklevente@gmail.com; pirisi.gabor@pte.hu; tesitsr@gamma.ttk.pte.hu; troand@gamma.ttk.pte.hu; mate.eva@gamma.ttk.pte.hu
[B] Institute for Urban and Regional Research, Austrian Academy of Sciences Bäckerstraße 13, 1010 Vienna, Austria; adam.nemeth@oeaw.ac.at
* Corresponding author: Éva Máté; e-mail: mate.eva@gamma.ttk.pte.hu

Introduction

The international geographic community—and many others—take different approaches when dealing with the issue of rural areas. Out of these approaches, perhaps the most significant trends in geography are those that deal with the transformation of rural societies (Cloke, 1993; 1995; Cloke & Little, 1987), the reorganization of the workforce (Massey, 1984; Massey, 1994; Milbourne & Kitchen, 2014) and issues such as the effect of the contraction of public utilities and local political interventions (Steinführer et al., 2014; Woods, 2005). The framework for research is rural restructuring, which largely covers the research dilemmas listed (Halfacree, 2006; Lowe et al., 1993; Marsden et al., 1990), although they may be quite different in their nature and approach to the topic. In the process of rural restructuring, the countryside reflects a reorganized socio-economic system as a result of modernization and post-modern transition, where the transformation of rural societies is governed by the need to adapt (Da Silva Machado, 2017; Halfacree, 2006; Woods, 2005; Woods, 2011). Adaptation manifests itself in achieving a higher level of mobility, which means social and spatial mobility at the same time, requiring a degree of flexibility for the success of economic restructuring and, finally, a kind of identity change by settlement communities through job centralization and specialization (Clout, 1972; Massey, 1984; Milbourne, 1997; Milbourne & Kitchen, 2014; Tigges et al.,1998).

One of the general characteristics of globalization is that the system of ideas and values of the global locations of the world has been able to reach almost every part of the space through the development of telecommunication tools, although their local interpretation is in accordance with local conditions may vary greatly (Castells, 1996; Massey, 2005; Soja, 1989). Out of all the ideas and values that span the world, perhaps the most spectacular is the spread of urban lifestyle in non-urban spatial segments (Cloke & Little, 1987; Dirksmeier, 2009; Halfacree, 1993; Hoggart, 1990; Woods, 2009). This can be explained by the increasing trends in the use of space by the societies of rural areas since perhaps the most significant benefit of modernization in these areas has been the centralization of jobs and the reduction of locally available employment (Massey, 1984). The working classes of the rural population thus typically find new jobs in cities, with many social consequences (Bourdieu, 1996). On the one hand, the disposition of the commuter layers is changing, which is manifested both in their way of life and their new way of raising capital (Burdack, 2013; Dirksmeier, 2007; Dirksmeier, 2009; Kühn, 2014; Milbourne & Kitchen, 2014; Vaishar & Zapletalová, 2009). If space is to be considered as a social formation, defining the countryside will prove to be an extremely difficult task, as the spatial practice and behaviour of an urbanized society in a rural space may refute its rural character (Dirksmeier, 2009; G. Fekete, 2005; Woods, 2011). In addition, there is another effect on the qualitative urbanization of rural areas, which is the fragmentation of local communities (Halfacree, 2006; Lennert, 2017; Marsden et al., 1990).

The society of a rural area, which is typically less differentiated than an urban society, may have distinct internal fractures. In Western European countries, counter-urbanization plays an important role in the development of internal fractures, which denotes the appearance of urban strata in rural areas and the emergence of a group with a different financial status (Cloke & Little, 1987; Cloke & Milbourne, 1992; Milbourne, 1997; Novotná el al., 2013). However, apart from the tendencies of counter-urbanization, there are other reasons for the internal fragmentation of the countryside. The issue of mobility thus becomes a central issue, as residents with commuter skills are already a separate segment of rural society (Andorka, 1979; Enyedi, 1980; Milbourne & Kitchen, 2014). As a more extreme example, young and educated populations migrating from rural areas can also be regarded as separate groups. Conversely, some rural societies may become characterized by immobility if their population lacks material assets, adequate education, or training, or if there are no accessible jobs. The number of jobs available locally is limited, so many people can become jobseekers, which further strengthens their marginal position (Enyedi, 1975; Markuszewska, 2015; Nagy et al., 2015). A particular consequence of the demographic and economic crisis is that elements of locally available infrastructure are becoming more and more scarce (Naumann & Reichert-Schick, 2012).

In the case of Hungary, general processes typical of post-socialist countries and some specific tendencies characterize rural areas. In this region, the process of rural restructuring differs from that of Western Europe, mainly due to earlier forced industrial development and the consequent depopulation of rural areas (Kiss, 2004; Kovács, 2001; Kovács, 2010, Šimon & Bernard, 2016; Spellerberg et al., 2007). Although the forced emergence of industrial societies may be regarded as a kind of modernization process, it pushed the transformation of the traditional peasant society at an extremely rapid pace, often not even lasting a generation, which has slowed rather than facilitated the transition (Kovách, 2012; Kovács, 2001). In the case of rural spaces, especially in Hungary, after the political transition, rural societies that were only superficially undergoing modernization are not able to cope with the challenges of the post-modern age (G. Fekete, 2005; G. Fekete & Lipták, 2011; G. Fekete 2016; Źonková, 2018).

In addition to the fragmentation of society, the Hungarian countryside faced a wider economic crisis during and after the political transition. On the one hand, the dissolution, transformation, and privatization of socialist cooperatives resulted in the loss of a significant part of agricultural jobs (Bandelj & Mahutga, 2010; Kovács, 2016; Nagy, 2007; Takács, 1999). Moreover, a substantial proportion of those employed entered the labour market, as low-skilled, unqualified jobseekers (Alpek et al., 2016; Pénzes, 2013). Another problem was the bankruptcy and closure of mainly light and food industries established in small towns because of centralized decisions, as part of a kind of decentralization industrial policy (Nagy, 2007). Although the crisis in the industrial sector had often meant the release of skilled, qualified masses, the escalated and protracted structural crisis and the lack of a new economic profile also led to the otherwise educated section of society losing their jobs (Barta, 2002; Molnár & Lengyel, 2015; Pirisi & Trócsányi, 2014b). In addition, in the case of small-town jobs, a significant proportion of workers came from the surrounding villages and suburbs, who commuted every day and who often lost their former (rural) social status as they had lost their previous jobs (Kovács et al., 2015; Pirisi et al., 2016).

In parallel, shrinking opportunities for marginalized groups also lead to the decline and often disappearance of elements of the service sector in villages. The deterioration of care systems pushes the less mobile and immobilized strata to a worse position, as they are typically poorer groups, marginalized people, who are already heavily burdened with having to spend on transport to meet their daily needs: shopping, medical care, arranging official matters, etc. (Kovách, 2012; Kovács, 2016; Kučerová et al., 2015; Nagy et al., 2015). Another issue is the sustainability of village small shops and pubs, which, in parallel with the shrinking rural population (Reichert-Schick, 2008), is no longer profitable to run. At the same time, small businesses are unable to compete with the price level of smaller or larger supermarkets and chain stores in the regional centres and so local retail outlets are forced to close their shops (Bajmócy & Balogh, 2002). Another element of the functional decline of rural settlements is the gradual withdrawal of public service providers, which is also justified by the principles of economies of scale (Kučerová et al., 2015, Sousa & Pinho, 2015).

When a significant part of the society of the settlements gets isolated, it could be interpreted as the perforation of the settlement network (Alpek & Máté, 2018; Máté, 2017). In the case of perforating villages and areas, a multilateral social space is emerged, which contains social groups characterized by higher mobility, while the communities that are immobilized or have extremely low mobility are higher in number and proportion than their more mobile counterparts. In this way, isolated members of settlements may lose contact with those living in other settlements, although we would emphasize that isolation in this sense is more about the degradation of informal relationships, since formal settlement connections, such as the need for an administrative office or access to educational institutions, may encourage (and force) the population to move. Rural perforation may rather be an advanced stage of a process where marginalized, isolated groups are drifting away from their wider municipal environment, both financially and mentally, and in the terms labour market.

According to the authors' assumption, the network of rural settlements could go under perforation if spatial interactions of communities are concentrated dominantly in their own locality. Of course, the scarcity of the 'space of personal practice' is extremely variable and unique, but it can be assumed that in many cases, without regard to official matters, it simply refers to the immediate environment.

The paper focuses on the issues of spatial mobility which is considered to be an important factor of perforation processes. As a part of the rural restructuring, perforation expresses the differentiation of rural societies according to their distinctive spatial practice, though the social background and the spatial disparities challenge rural inhabitants in everyday life. A further assumption is that the lack of mobility in rural areas could increase the negative effects of the erosion of rural settlement networks. According to the societal kind of our theoretical concept, the paper focuses on the subjective willingness and personal preferences of mobility in a rural area, the Baranyai-Hegyhát in Hungary. Thus, while most papers and theories presented above focused on the question, of what objective conditions obstruct inhabitants in their mobility according to statistics, hereby this study questions the subjective features and opportunities that rural inhabitants may hold, and furthermore, may create circumstances in which they become spatially mobile. According to these presumptions, the goals of this research are:

1. to interpret the weakness of spatial mobility—out of the perforation/isolation processes—mainly through the spatial dimension of the working age population in the labour market;
2. to use a multivariate mathematical measure, the Corrected Mobility Index (CMI) (Alpek et al.,

2016), to express the degree of mobility of the population of a given settlement;
3. to place particular emphasis on the role of subjective factors experienced by individuals upon examining mobility;
4. with the help of the numeric Corrected Mobility Index identify villages which are undergoing perforation.

The present study was evaluated by a model based on a questionnaire survey, which was named the average of continuous degrees of mobility (Alpek et al., 2016). The model provides a means of measuring job mobility opportunities for job seekers and workers, considering individuals' cost, travel distance, and travel time preferences in an employment centre/catchment area relation. The Corrected Mobility Index was deducted from the average of continuous degrees of mobility, using metrics that expressed personal abilities and availability of different transport options. With CMI values, the exact spatial layout of commuter networks could be detected, which describes the exact mobilities of rural inhabitants. In this study, mobility is interpreted as the opportunity and the willingness of commuting to work, which could underline the exclusion processes of certain social groups in rural areas.

Research methods

The main methodical challenge of this research was to measure the mobility of local residents. The basis for determining the degrees of mobility was a complex questionnaire survey conducted shortly before the pandemic in 49 settlements in the Baranyai-Hegyhát area. The target group of the questionnaire survey was the economically active population; 368 people gave valid answers. The selection of the survey pool was random sampling within the active age group, paying attention to involve at least 1% of the residents by settlements and gathering a gender-balanced sample. In total, 35.6% of the respondents were male, 64.4% female. During the evaluation, the gender imbalance was corrected by weighing the data. Regarding the age distribution, the average of the sample was 46 years, and the median value was 42 years, which we considered to be a representative sample according to the statistical mean age of the study area.

In the questionnaire, respondents gave their preferred time, distance, and cost preferences for commuting as well as the transport options available for them, along with several other mobilities modifying variables. In addition, questions related to the identification of employment centres and the financial situation also came up, which allowed the authors to define the subjective parameters of possible mobility. Thus, the survey and the index do not express the exact commuting networks (anyhow the statistics gather such data) but show the potential and limits of respondents to mobilise themselves.

The objective abilities of mobility were conducted by using secondary data as well by each settlement. The space/time/cost matrices of the mobility model are derived from different sources, depending on the means of transport and the connections studied. For car-based commuting, Google Maps' route planner (https://www.google.com/maps), and for public transportation alternatives (bus and train), the associated timetable databases (www.menetrendek.hu, www.volan.hu, www.mav.hu) provided information.

The framework for running the model was provided by simplified commutation graphs of the studied area. The peaks of these graphs were the 'attracted' places of the area, as well as the settlements that might function as employment centres. The latter was selected in several dimensions. First, relevant pieces of literature were used which focused on the commuting centres of Hungary (Pénzes et al., 2014). Secondly, the Hungarian Central Statistical Office (CSO) gathers commuting data at each census. The third dimension was the authors' own survey, in which respondents named the centres of Baranyai-Hegyhát they consider to be. Centres defined were divided into internal (with settlements which have small attractivity and are placed within the borders of the research area) and external (bigger towns and cities partly with regional importance, extended attraction zones). Commuting routes were calculated by the time, distance, and cost preferences the answerers gave.

The cost (Cx), distance (Dx) and time (Tx) thresholds used to quantify the degree of mobility were determined from the results of the questionnaire survey. In all cases, they are the first, third, sixth and ninth deciles of the answers to the questions about the maximum cost, travel distance and time that the respondents should spend. Costs are calculated in Hungarian Forint (HUF), distances in kilometres, and time values in minutes. For this paper, HUF values were converted into Euro (EUR) as a ratio of 1 EUR = 325 HUF, which was the annual average exchange in 2019. Related parameters for the most disadvantaged unemployed group under study were: $C1 = 0.003$ $C2 = 9.25$, $C3 = 30.75$, $C4 = 76.90$; $D1 = 10$, $D2 = 25$, $D3 = 30$, $D4 = 50$; $T1 = 10$, $T2 = 40$, $T3 = 60$, $T4 = 120$.

In this case, according to the calibration of the model, an excellent mobility opportunity is identified if the cost and time factors affecting commuting in the municipality are appropriate for 90% of the respondents. In contrast, the model shows highly unfavourable mobility within the limits of the analysis, provided that the transport conditions for commuting to work are appropriate for up to 10% of the study population. If full mobilization of the target group is a high priority, raising the thresholds is justified and vice versa.

Once the basic parameters were identified, the cost (CBV), distance (DBV), and time (TBV) baseline values were required to calculate the degree of mobility for each settlement. These baseline values in the three dimensions of mobility examined (cost, distance and time) show the extent of mobility that is provided by a given means of transport (the present study examined the possibilities of car, bus and train transport) in a particular commuter relationship applicable to the locality, considering the differing limit values given by the respondents. The minimum of default values is zero and their maximum is four. For a cost base value, the minimum is reached if, in each relation, the means of transport tested in one month is more expensive than the ninth decisimilarlyle of responses to the maximum acceptable cost, and the maximum is reached when commuting is free of charge for the commuter. The model calculated the baseline cost of settlements (CBV) for each examined transport vehicle and relation:

$$the\,CBV = \begin{cases} If\ x \le C_1; 4 - x \cdot \frac{1}{C_1} \\ If\ x \le C_2; 3 - (x - C_1) \cdot \frac{1}{C_2 - C_1} \\ If\ x \le C_3; 2 - (x - C_2) \cdot \frac{1}{C_3 - C_2} \\ If\ x \le C_4; 1 - (x - C_3) \cdot \frac{1}{C_4 - C_3} \end{cases} \quad [1]$$

The distance (*DBV*) and time (*TBV*) defaults were determined similarly:

$$DBV = \begin{cases} If\ x \le D_1; 4 - x \cdot \frac{1}{D_1} \\ If\ x \le D_2; 3 - (x - D_1) \cdot \frac{1}{D_2 - D_1} \\ If\ x \le D_3; 2 - (x - D_2) \cdot \frac{1}{D_3 - D_2} \\ If\ x \le D_4; 1 - (x - D_3) \cdot \frac{1}{D_4 - D_3} \end{cases} \quad [2],$$

$$TBV = \begin{cases} If\ x \le T_1; 4 - x \cdot \frac{1}{T_1} \\ If\ x \le T_2; 3 - (x - T_1) \cdot \frac{1}{T_2 - T_1} \\ If\ x \le T_3; 2 - (x - T_2) \cdot \frac{1}{T_3 - T_2} \\ If\ x \le T_4; 1 - (x - T_3) \cdot \frac{1}{T_4 - T_3} \end{cases} \quad [3]$$

where "*x*" always represents the travel cost, distance or tie calculated in each relation.

With the help of the *CBV*, *DBV* and *TBV* values thus obtained, we can calculate the Vehicle Mobility Factor (=*VMF*) values for each transport alternative as follows:

$$VMFij = \frac{TBV_{ij} + DBV_{ij}}{2} + CBV_{ij}$$

where

"*i*" represents the code of the device and "*j*" indicates the relationship between a specific employment centre and the settlement it is located in. But still, VMF is a result of abstract and theoretical calculations and does not exactly reflect the significance of subjective factors, personal availability, and preferences. Therefore, on the basis of the VMF values, a new, *Corrected Mobility Index* (CMI) was introduced.

The basis for the calculation of the CMI is that spatial mobility conditions, besides distance, time, and cost preferences, depend significantly on the subjective availability of devices, since there is no use in the availability of a transport alternative if it is not available to use effectively because of the discrepancies between public transport timetables and work schedule or other reasons. The degree of mobility can be improved if the commuter is more likely to have access to alternatives that make a significant contribution to mobility, otherwise, isolation may increase.

When calculating the CMI values, the alternative providing the best degree of mobility available to the individual under the conditions of the particular model—the highest VMF value—was considered, that is, we were looking for a maximum degree of mobility that also takes into account the subjective availability of devices. In view of the above, the *CMI* values were determined using the following formula:

$$CMI_j = \frac{\sum_{i=1}^{n} K_i \cdot VMF_{ij}}{\sum_{i=1}^{n} K_i}$$

where

- CMI_j – the value of the corrected mobility index for the studied commuting relationship and settlement;
- K_i – the proportion of those surveyed who, considering that they are striving for the highest degree of mobility, have the means of transport at their disposal;
- VMF_{ij} – VMF value of the given "*i*" device in relation to the examined "*j*";
- *n* - code of the tested devices (1 - passenger car, 2 - bus, 3 - train)

As to divide conditions, two variants were considered when determining CMI values. In the first case (CMI_1), in the case of commuting to work, the area-specific bus and train pass prices provided monthly costs, whereas, for cars, we used the average annual unleaded petrol ESZ-95 and diesel prices typical for the time of the survey, considering the consumption of six litres per 100 km. In the assisted version (CMI_2), we assumed that commuters would all use the highest possible reimbursement of travel costs[1], which is 14% (up to 111.35 EUR) of the monthly bus and train passes, and 0.027 EUR/km for cars. The former model shows the "minimum" mobility without support, while the latter quantifies the average of the "maximum" degree of mobility, considering the opportunities and commuting preferences of the subjects.

The two models of CMI were conducted in an internal and an external dimension as well, as earlier suggested. The internal CMI values show commuting opportunities to short distance travels to micro-centers (inside the case study area), the external defines the opportunities of longer distance everyday routes, making relative bigger towns and cities available outside the area. The importance of an extended model with big cities was justified simply by the fact that higher salaries and better working conditions are available in these centres, while in the internal model though the availability should be better, the job opportunities are narrower.

The individual questionnaires were processed after coding using MS Excel 2016 software. This software was also used for some data sorting, coding solutions, and for calculating descriptive statistical parameters and determining VMF and CMI values. The statistical operations were run using IBM SPSS Statistics 23.0. Libre Office 3.6 was used to populate the attribute tables of the digital maps, to arrange the data groups, and for QGIS 3.2.2 (Quantum GIS) and rendering.

Thus, the CMI can, overall, express the level of mobility opportunities and willingness to work for the active population of each municipality, thus providing an answer to the extent and level of participation of the settlement in regional labour market networks. Therefore, it also expresses the perforation processes of the examined settlement network, defining the range of immobilized settlements. It, therefore, examines a specific phenomenon of rural restructuring, which can examine opportunities and barriers to the financial security of the working-age population at a regional level.

Research area of the Baranyai-Hegyhát

The case study could be considered in many aspects as being typical for rural regions in East-Central-Europe. Located in South-West Hungary, the area has an extension of about 25 km from North to South, and 32 km from East to West. The name "Baranyai-Hegyhát" is not an exact name for the area, but this physical geographical unit fits the best to area, which overlaps administrative borders, including the counties Baranya (HU231 in EU nomenclature) and Tolna (HU233) counties. The case study was delimited by statistical methods, primarily focusing on commuting relations (Alpek & Máté, 2018; Pénzes et al., 2014). As it has been earlier described, the commuting centres of the area were first defined by literature, then by the census from 2011. Subsequently, proportions of commuters were calculated by settlement to one of these centres and a minimum of 20% was set. With this method 49 in a total of settlements were identified, which create a compact working entity.

Among the almost 50 settlements four own urban status and concentrates more or less complex central functions. Typical small towns in Hungary, not affected by suburbanisation or mass tourism, are usually shrinking (Pirisi & Trócsányi, 2014a). There are two towns being rich in central functions and urban character: Komló, a former socialist coal-mining town, completely deindustrialised after 1990, losing one-third of its population and now owning 22,000 inhabitants; and a more traditional small town of Dombóvár, originally a railroad junction with more diverse industry and services (population 18,000). The two other small towns, Sásd (pop. 3,000) and Mágocs (2,200) have limited functions and their urban character is less explicit as well, due to their size (Belusz-

[1] The Government Decree 39/2010 bids the employers to reimburse the costs of commuting to the workplaces up to a specific and annually revised value.

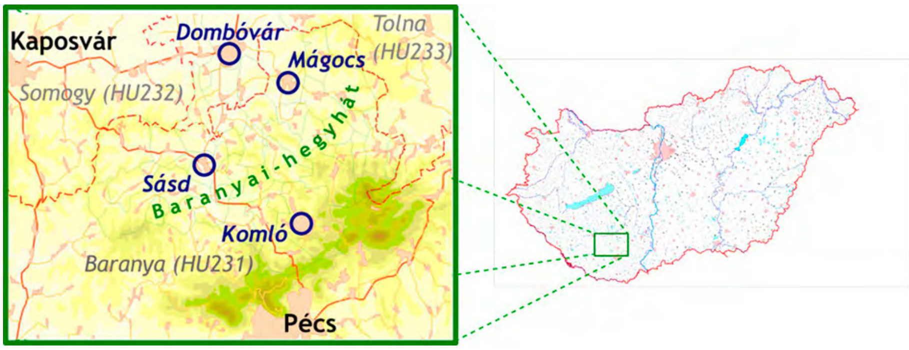

Figure 1. The location and landscape of the Baranyai-Hegyhát area
Source: edited by the authors

ky & Győri, 2011). Although their spatial role is important in such a region characterised by tiny and sometimes dead-end villages, they suffer themselves by lacking fundamental functions.

The fragmented settlement structure is combined with a small-village settlement system; the average size of the communities in the area is less than 300 people. The largest village in the region, Szászvár, with its 2,282 inhabitants, is comparable to more urbanized settlements at a regional level. Beside Szászvár, there are only just over a dozen of the villages with more than 500 inhabitants, while the number of settlements with a population of less than 200 is 14. The smallest village has a population of 30, according to statistics from 2017, but the survey revealed that the current population is less than 20 residents (Alpek & Máté, 2018).

As already has been noticed, the case study area could be considered as typical for the rural regions of East-Central-Europe, because of the followings:

1. The highly dispersed structure of population. Although the population density is not especially low (82.7 ppl/km²), the almost 70,000 inhabitants of the region are deconcentrated into 49 settlements, and almost half of them lives in 47 villages. The low number of inhabitants in these villages makes local markets unfunctional: the lack of consumers creates no opportunities for shops and makes public services locally unavailable, the lack of potential employees keeps potential investors away.
2. Despite the overall favourable situation of the country's labour market, unemployment cannot be abolished in the region. After 1990, the collapse of the highly intensive, industrialised, and concentrated agriculture and the socialist industry (in this area: coal mining in Komló and Szászvár) could never been fully replaced with new investments. Today, the local labour market is still based on micro-sized enterprises, basically in low-tech sectors. That leads to the outmigration of capable workforce, with the intensive mobility of better-educated women (Timár & Velkey, 2016)
3. The area is not directly connected with any bigger city. Although Pécs, a regional centre with 140,000 inhabitants is only 15 km's away to the south, that city is also a small island of urbanity in a dominantly rural region with a minor economic power (Molnár et al., 2018) practically unable to dynamize the research area.
4. Although the hilly landscape has high aesthetic value and some potential in tourism, the slopes and valleys of the Hegyhát mean the lack of major roads crossing the areas. Still today, there are lot of "dead-end-villages", having only a single and poor connection to network. The closest motorway ends in Pécs, while many secondary roads have serious quality issues. The only primary railway line serves rather the traffic to cross the area, not the local demands.

The role of mobility in perforation processes

Endogenous (internal, partially changeable by individual choice) and exogenous (external, only improved through broader community involvement and/or governmental measures) factors that are decisive for the mobility of society, including individual communities and individuals, affect the willingness of commuting and its parameters. These factors exhibit unique patterns across demographic groups as well as in space, and include, in addition to various objective factors (travel time, distance, cost), the subjective availability of individuals to each means of transport and commuter preferences. The importance of the latter is that even acceptable travel distances and costs can reduce the degree of individual mobility if, for some reason, the individual is unable or unwilling to do so. First, models of Corrected Mobility Index, both the internal and external are shown. Second, the internal and external models are being corrected with the possible financial reimbursement. Finally, authors made an attempt to define the positions of settlements according to the results if they were perforated or not.

Examining the spatial effects of endogenous and exogenous factors together, correcting for the degree of individual availability of each transport alternative, significant spatial differences can be observed in the examined area with the relations of the inner centres (internal model) of the area (Figure 2).

The most isolated area of the region runs in the southeast and includes predominantly low mobility areas (three or less). There is a clear difference between the two centres in the area with the highest number of agglomerations, Komló and Sásd (both with 12-12 settlements). Komló is the direct centre of about 60% of the settlements with low mobility (less than 2) in the region. The low degree of mobility in the urban environment is due to the transport geography and the peculiarities of the settlement structure and the high prevalence of dead-end villages. Although there are a larger number of dead-end villages in the vicinity of Sásd, but they have typically quick and in most cases direct access to the centre. This is reflected in commuting times as well as travel distances.

A low degree of mobility reduces the rate and extent of the spill over of socio-economic impacts, so in a centre surrounded by low mobility settlements, the risk of isolation can be significantly increased, which

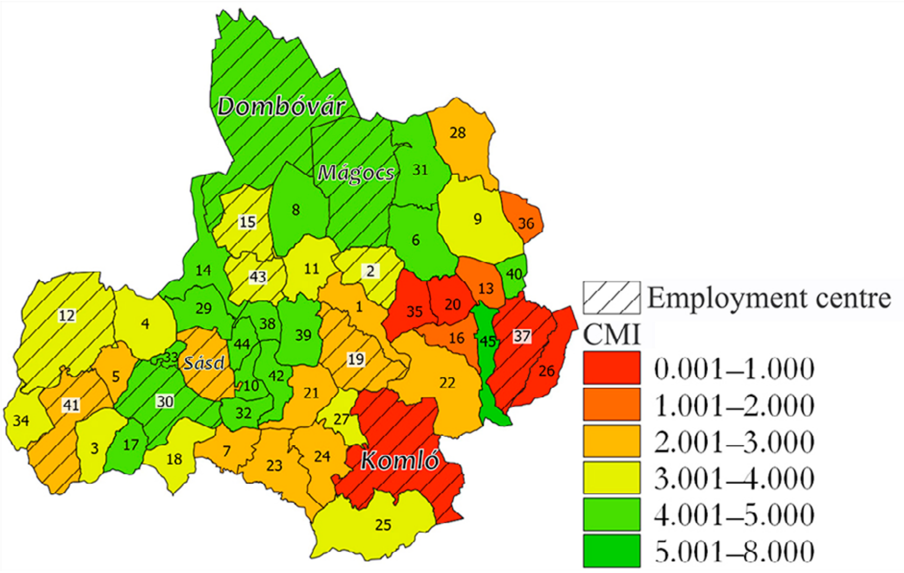

Figure 2. CMI-values of the settlements according to the internal model
Source: based on the authors' own calculation

Table 1. Codes used in the maps to label villages in the research area.

Name of village	Code in map	Name of village	Code in map	Name of village	Code in map
Ág	1	Kárász	16	Nagyhajmás	31
Alsómocsolád	2	Kisbeszterce	17	Oroszló	32
Bakóca	3	Kishajmás	18	Palé	33
Baranyajenő	4	Kisvaszar	19	Szágy	34
Baranyaszentgyörgy	5	Köblény	20	Szalatnak	35
Bikal	6	Liget	21	Szárász	36
Bodolyabér	7	Magyaregregy	22	Szászvár	37
Csikóstőttős	8	Magyarhertelend	23	Tarrós	38
Egyházaskozár	9	Magyarszék	24	Tékes	39
Felsőegerszeg	10	Mánfa	25	Tófű	40
Gerényes	11	Máza	26	Tormás	41
Gödre	12	Mecsekpölöske	27	Varga	42
Hegyhátmaróc	13	Mekényes	28	Vásárosdombó	43
Jágónak	14	Meződ	29	Vázsnok	44
Kaposszekcső	15	Mindszentgodisa	30	Vékény	45

Source: by the authors

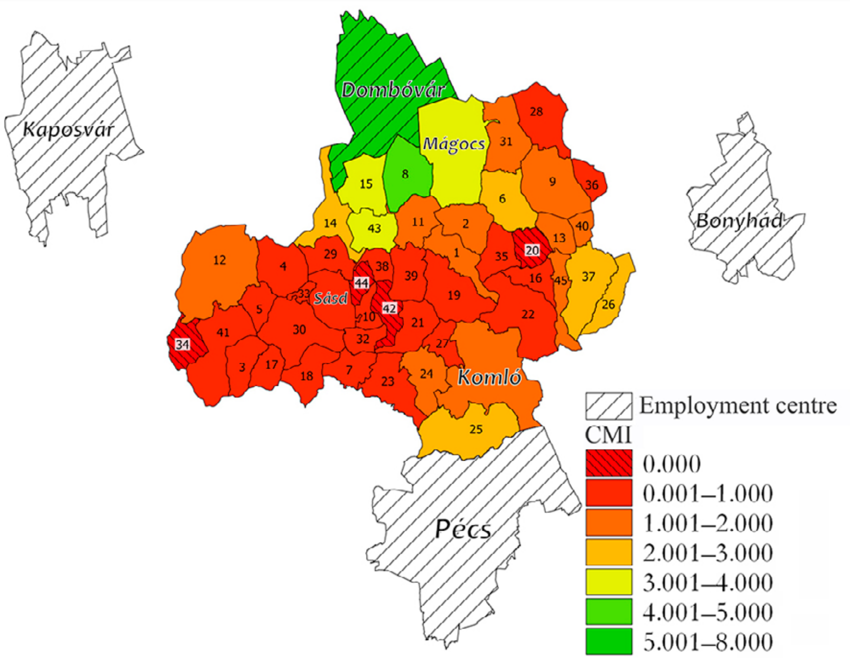

Figure 3. CMI-values of the settlements according to the external model
Source: based on the authors' own calculation

poses a major challenge to the studied area, especially to Komló and its caption area. At the same time, in the case of Sásd, the dead-end villages in the vicinity are more integrated, and their relevance is enhanced by the examination of the relations with big cities (external model) (Figure 3).

In particular, the significantly less favourable mobility opportunities in these relations make it more difficult to obtain better labour market opportunities offered by external centres. Contrary to the model of inner centres, the external transport links of the area and the lack of financial resources are the ones that reduce mobility the most. The spatial segment, characterized by an increased risk of isolation, expands considerably, and there are also large numbers of settlements that show zero or near zero mobility (Settlements nr. 20; 34; 42; 44; Figure 3).

A major zone in the West-East is emerging where commuting is a major challenge for the local population. This 'isolated' area comprises approximately 79.6% of the settlements examined and constitutes an inland area with a high degree of unfavourable mobility due to the remoteness of the centres, travel costs and times, i.e. (in a broader sense) the available means of transportation and the location of the settlements. Although these villages showed a higher degree of mobility in the internal model, the numerical results do not adequately reflect the fact that the labour supply of the internal labour markets in the region do not provide sufficient living conditions. The ability of reaching external centres could thus ensure the well-being of society.

The tensions revealed in the degree of mobility are alleviated by the range of transport subsidies, which, assuming the highest available reimbursement for all commuters in all relations, possibly could increase the average degree of mobility of the settlements in the region in the internal model (Figure 4).

The most important change resulting from the subsidies, examining the internal model, is that the zone with a moderate degree of mobility is significantly widening, and the proportion of associated settlements (with a CMI-value of four to six) increases 1.9 times (Figure 4). This is primarily due to the differentiated impact of transport subsidies on different means of transport. In 71.4% of the municipalities, cars are the "most efficient" commuting alternatives, 22.4% uses the train, and only 6.1% uses public buses. In contrast, if subsidies are considered, the ratio will be significantly reorganized, where 95.9% of settlements uses public transport, with more than 70% favouring bus service. Thus, in the case of transport subsidies, car is replaced by bus and, to a lesser extent, by train, the former remaining the best option in only 4.1% of the settlements. The effect is reinforced by the fact that the subjective accessibility of bus transport at the regional level is the highest among the respondents, which further weighs the extent of the improvement.

All in all, in the subsidized model, the low mobility zone is reduced to 16% of the settlements and to the south-east of the region. The position of dead-end villages (e.g., Hegyhátmaróc nr. 13, Köblény nr. 20) is particularly unfavourable in this area, where the higher travel distances are associated with connecting bus-

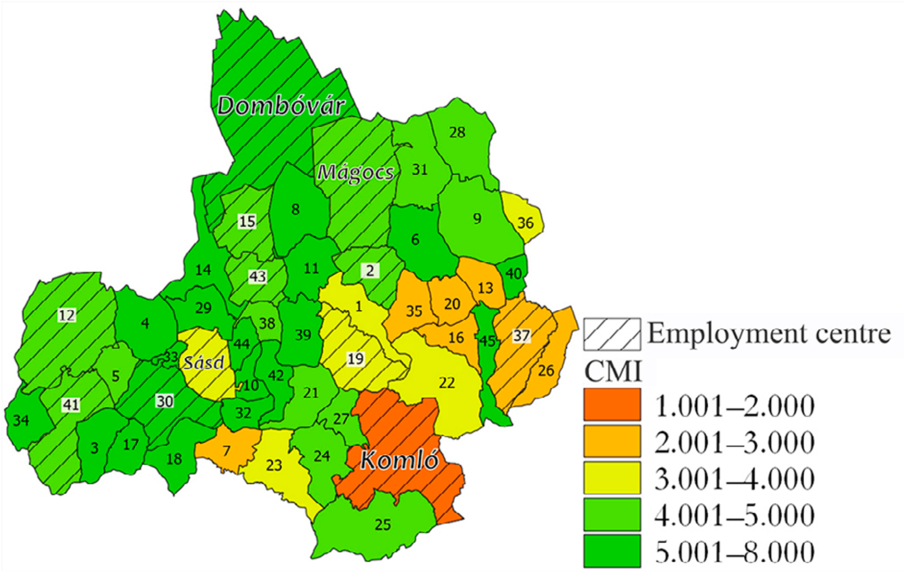

Figure 4. Modified CMI-values including transport subsidies (internal model)
Source: based on the authors' own calculation

es and the lack of rail transport. In general, less favourable commuting opportunities in this area are due not only to car costs, but also to the lower availability of cheaper buses with significantly longer travel times and rail transport, and, in the latter case, to the lack of connecting points.

In contrast, the external model features the subjective availability of devices in the full-price model to reduce mobility by 27.2%, which is a significant value, but the overall challenge for the entire region is that the Corrected Mobility Index in the region would not reach the two-limit value even if the "best" commuting alternative were available to the public (Figure 5). Costs play an important role here, which has primarily been a constraint in the preferences. At full cost in the external model, relations are 49% higher than the 77 EUR/month limit, identified as the maximum limit of extremely low mobility. It draws attention to the role of travel subsidies in improving mobility in the region.

In the model, which considers the cost-reducing effect of travel subsidies, the area of the inner isolation space segment is slightly reduced, the zero-mobility zone disappears, but the number of settlements with extremely low mobility rates remains high (Figure 5). Thus, in the case of a model with travel subsidies, the

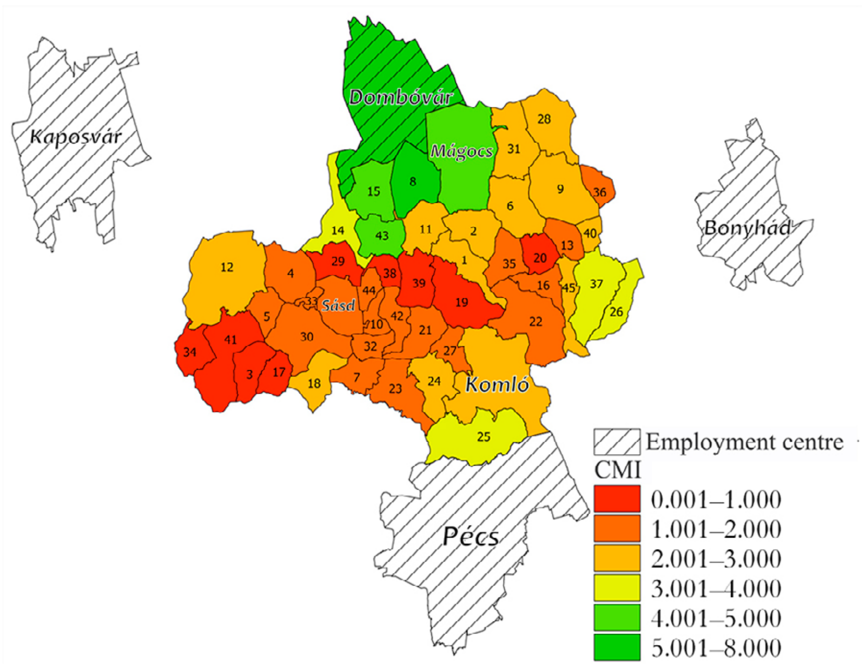

Figure 5. Modified CMI-values including transport subsidies (external model)
Source: based on the authors' own calculation

accessibility of the bigger centres is not improved to the same extent as was the case with the similar model of the inner centres, which further strengthens the closed nature of the area. Although there is some improvement in mobility due to the supposed reimbursements, it is not able to resolve the issue that certain groups of settlements are difficult to reach, and in these cases one's financial situation also severely hinders individual transport alternatives.

More than 55.1% of the settlements do not even reach the extremely low degree of mobility of two, and the availability of devices reduces the degree of mobility by about 14.3% compared to the available maximum. The rate of decline is lower than in the full-price model, which is due to the higher availability of public transport. Therefore, it is visible that the isolation of the settlements of Baranyai-Hegyhát is not really alleviated even when we include the travel allowance provided by the employer.

Based on the experience of the models, the settlements of the region could be separated by three main groups (Figure 6).

1. Only 10% of the settlements exhibited values above four in both relations (internal and external model), that is average or higher mobility. This is due to the interaction of several factors. Most of the transport alternatives in the studied relations can achieve a high level of mobility alone (except for one, in almost all commuting dimensions, each studied device had a direct connection to the centre). This way, the opportunities of the population are wider, which has a positive effect on mobility since high values can be achieved even if the availability of the primary alternative is lower. On the other hand, in these settlements the subjective availability of individual devices is higher than the regional average or not significantly below the average (cars had a 13.9% higher subjective availability than the regional average, while trains had a 10.5% higher subjective availability than the regional average.)
2. However, the risk of isolation is unquestionably present in the area, which is supported by the fact that 28.6% of the settlements had mobility values below four in both the internal and external model. These communal societies struggle to even reach the inner centres of the region, which, however, would not necessarily ensure them progress. The small towns in the area, which can be interpreted as potential employment centres, offer extremely limited opportunities with low income. If the opportunities were given, then the education attainment of the working age citizens would pose a problem. The average educational level of people living in rural areas in Hungary is extremely low, which was confirmed by the results of our questionnaire survey related to demography. The negative mobility characteristics of the region is thus related to the question whether the population can be integrated into the labour market or not, and if yes, to what extent.
3. Finally, for more than 60% of the settlements, their degree of mobility in the internal model was medium or higher value, while it remained below four in the external relations. Although they have shown signs of dynamism in internal relations, in fact their disconnectedness to external networks creates a high risk of long-term isolation.

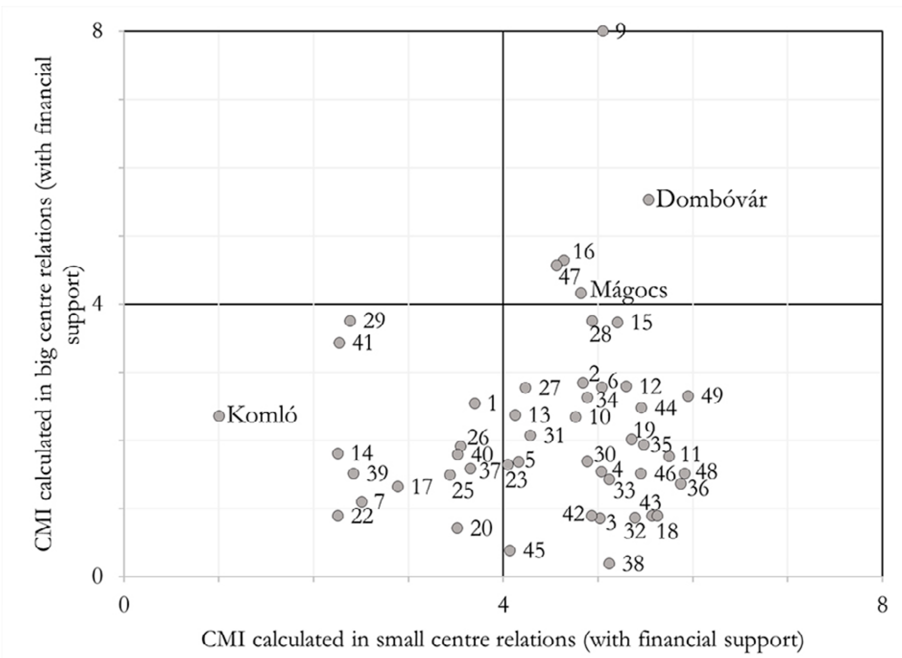

Figure 6. Comparing the CMI-values of settlements including subsidies according to the internal and external model
Source: based on the authors' own calculation

Conclusions

The study of subjective mobility gave answers to a specific, post-socialist process of rural restructuring, the perforation of the settlement network, in the sample area of a well-defined rurality, the Baranyai-Hegyhát. The application of the model in a rural area has highlighted a more general problem that is often overlooked in mobility-focused research, which is that individual mobility opportunities cannot be explored in detail by examining transport and communication infrastructure alone. On the other hand, subjective mobility also evaluates statistically less measurable parameters, such as financial status, available transport options or an individual's willingness to travel, which may give a more accurate picture of the internal dynamics of a settlement network in a region.

According to the results, the application of the model does not only reveal the internal characteristics of the given area of Hungary, but also provides more general experience of the transformation of the Eastern European countryside. The perforation process, which primarily refers to the weakening of local inter-settlement relations, can be well illustrated by the commuting constraints of the working age population of locals, considering the constraints of the financial resources involved and thus the constraints of other mobility. For small scale settlement systems, this is often less of a problem if the availability of local resources (material, intellectual, human, etc.), together with shorter mobility distances, ensures the internal functioning of the area. In the examined case (and possibly in other Eastern European relations as well) the internal resources of certain rural areas are extremely scarce, which is exacerbated by their gradual erosion because of shrinkage. In this way, not only the external, but also the internal communication systems of rural settlements become limited. In addition, the „rationalization" or „withdrawal" of state-run public services puts further pressure on more marginalized communities. The seriousness of the latter can be measured primarily by the fact that the conditions of electronic administration are provided from an institutional point of view, but in many cases the level of development of the local infrastructure does not reflect the needs involved. On the other hand, the user side is not adequately equipped either.

Although the concept of rural restructuring is of general application, local particularities distinguish it from the Western European type of differentiation processes in which the phenomenon is described. In our research, we have concluded that the following criteria can be seen at our test site, compared to Western samples.

1. The mobility opportunities of the stationary rural population are limited by both transport and financial means. The former does not only concern the regularity of public transport but is primarily concerned with access to any transport system, either if it is a bus, a train or even a car. Financial shackles are not only represented in the lack of money for transport, but they also pose a problem in workplace integration, for example. Most of the respondents do not have proper clothes, shoes and coats, and in some cases, they do not even own a bathroom at their place of residence.
2. The receiving side of the labor market discriminates in many ways against (potential) rural workers. Among the results, there was a model presented, that supported commuting and one that did not, based on the assumption that the employers would provide some sort of financial support. Unfortunately, however, the reality is, according to the respondents in the research, that when the employer would have to provide travel allowance, they would rather not employ these candidates. This is a spatial discrimination in Hungary, which makes it impossible for the rural population to find employment on the labor market, thus weakening the internal relations of rural areas.
3. One of the characteristics of the processes of rural restructuring in Western Europe is the emergence of post-modern social values in rural areas. One of the more pronounced manifestations of this is the intensified disorganization tendencies, which are primarily due to recreation, appreciation of natural values, calm environment, and self-realization. The background of this migration process is the individual decision and subjective motivation of individuals, which is often coupled with the values and mentality of middle-class groups involved in counter-urbanization. In contrast, in post-socialist rural areas, moving to the countryside is often caused by the rise in the cost of urban life. This way, the rural lifestyle is not a path chosen by individuals, but a constraint created by living conditions. All of this is reinforced by the fact that, in post-socialist areas, mobility opportunities in the traditional population tend to be based on constraints rather than on free choice. All in all, the counter-urbanization processes only have a marginal, yet specific (indicative of international migration) presence in these areas.

These differences are confirmed by the results of the research, which, while focusing on the issue of mobility, have highlighted other features of the field, such as the particular problem of counter-urbanization, the economies of scale of market services or the withdrawal of local public services. The examination of the Baranyai-Hegyhát pilot area, applying the subjective mobility model, draws attention to the deficiencies of the area's permeability, its external and internal communication systems, and the weakening of the connection intensity of its networks. At the same time, the model may also respond to the post-socialist features of rural restructuring, which may be expressed, for example, in the processes of isolation of an active society in rural communities.

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Light Pollution Mapping in Pécs City with the Help of SQM-L and VIIRS DNB. The Effect of Public Luminaire Replacements on the Sky Background of the Urban Sky

Péter Gyenizse[A*], Emese Soltész[A], Dénes Lóczy[A], János Kovács[A], László Nagyváradi[A], Tibor Elekes[B], Sára Bodza Gyenizse-Nagy[C], Gergő Németh[A], Ákos Halmai[A]

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Abstract

Recently light pollution has been one of the most dynamically increasing form of environmental pollution. Light, if it arrives at the wrong place, time, quantity and quality, is harmful to human health and the physical environment – not to mention that it is a mere waste of energy. The brightness of the sky above Pécs was measured by SQM-L instruments in 2011 and 2019. Maps of the different neighbourhoods with different levels of light pollution have been prepared. In addition, special VIIRS day/night band satellite images were also analysed using QGIS software. Our investigations coincided with the modernization of street lighting in the city. The impact of LED illuminators installed along main roads in Pécs was observed locally.

Keywords: light pollution mapping; SQM-L; VIIRS day/night band; QGIS; TIN; Thiessen polygon; Pécs

Introduction and objectives

Humanity is constantly shaping its natural environment and this transformed environment affects the living creatures inhabiting it. This influence is more pronounced in areas with high population density, such as in the vicinity of large cities. The transformation of nature often leads to natural disasters involving major damage. For instance, in mountainous and hilly areas flash floods and landslides can occur due to deforestation, which inflict damage to elements of the built environment and even claim human lives (Mezősi, 2022).

A less tangible but increasingly studied form of environmental pollution is nighttime light pollution. Inadequate lighting of our environment (Artificial Light At Night - ALAN) can damage both the wildlife of the area and human health. Artificial night-time lighting is increasing worldwide by 2-6% per year. Engineers and lighting technicians are designing and producing more and more efficient luminaires, but this does not reduce the amount of electricity used for lighting, which results in unnecessary over-lighting in most places (Árgay, 2020).

[A] Institute of Geography and Earth Sciences, Faculty of Science, University of Pécs, Ifjúság útja 6., Pécs 7624, Hungary, gyenizse@gamma.ttk.pte.hu, zsetlose@gmail.com, loczyd@gamma.ttk.pte.hu, jones@gamma.ttk.pte.hu, nagyvarl@gamma.ttk.pte.hu, gergotab@gmail.com, halmaia@gamma.ttk.pte.hu
[B] Institute of Geography and GIS, Faculty of Earth Science and Engineering, University of Miskolc, Building A4, Miskolc-Egyetemváros 3515, ecoeti@uni-miskolc.hu
[C] Institute of Game Management and Nature Conservation, Kaposvár Campus of Hungarian University of Agricultural and Life Sciences, Guba Sándor u. 40. Kaposvár 7400, Hungary, gyenizse.n.sara@gmail.com
[*] Corresponding author: Péter Gyenizse, e-mail: gyenizse@gamma.ttk.pte.hu

Light pollution is defined by the social organization International Dark Sky Association (IDA) in the following way: „The inappropriate or excessive use of artificial light – known as light pollution – can have serious environmental consequences for humans, wildlife, and our climate. Components of light pollution include (Internet 1):

- Glare – excessive brightness that causes visual discomfort
- Skyglow – brightening of the night sky over inhabited areas
- Light trespass – light falling where it is not intended or needed
- Clutter – bright, confusing and excessive groupings of light sources."

The most important sources of light pollution are inadequate public lighting, street lamps, reflectors of industrial estates, decorative illumination of buildings and venues of sports and other events, and the light used for advertising at night.

The present paper is mainly concerned with light emanating from luminaires to the wrong place (skyward) and with inappropriate, excessive amounts of light. This form of light pollution is called astronomical light pollution. However, light pollution has a significant impact on the biosphere as a whole, including human health, which is called ecological light pollution (Longcore & Rich, 2004). In the majority of cases, both forms of light pollution occur simultaneously.

In addition to their impact on their immediate environment, ALAN sources contribute significantly to the brightening of the night sky and astronomical light pollution. The shining of the sky is primarily caused by the light reaching above the horizon plane from the lamps. This is expressed by the Upward Light Output Ratio (ULOR), ranging between 0-1. In the astronomical sense, we speak of a light pollution-free solution if the ULOR = 0. In the last decade, a number of mainly LED luminaires have been developed with a ULOR value of zero.

In 2014, the local government of Pécs launched a public lighting modernization program, in the frame of which, starting from 2015, the lamps along important public roads will be replaced with LED light sources. In the year 2019, marking the end of the time interval of our investigation, there were 20,238 public luminaires in the city. Of these, 7,195 were replaced with LED lights between 2015 and 2019, which is 35% of the total number (data source: Pécs City Council).

Astronomical light pollution is measured using different methods around the world, including measurements made from the surface of the earth in the direction of the sky, as well as top-down observations from outer space, possibly using aerial devices.

The light measuring devices traditionally used in lighting technology are not sensitive enough to measure the brightness of the night sky. For this purpose, the Unihedron company developed the Sky Quality Meter (SQM) instruments (Internet 2), which are widely used due to their low price. These measure the average sky brightness of a specific observation location with great accuracy (Internet 3). The temperature compensation of the SQM is therefore found to be adequate for use in the field over the range of -15°C to 35°C (Schnitt et al., 2013). The instrument was also involved into the investigation, because it is fast and efficient, i.e. it enables measurements to be taken at many measuring points within a short period.

While measurements from the surface typically provide light pollution data for a single location, measurements from satellite maps refer to large within a short time. Operational Linescan System (OLS) instruments have been installed on Defense Meteorological Satellite Program (DMSP) platforms since the 1970s. The Suomi National Polar-Orbiting Partnership (SNPP) satellite Visible Infrared Imaging Radiometer Suite (VIIRS) instrument used in this study, launched in 2011, can be considered their improved version. One of the channels of VIIRS is the day/night band (DNB), which can take low-light images at night at a wavelength of 0.5-0.9 µm. DNB is a calibrated radiometer with a spatial resolution of 742 meters and a dynamic range of 14 bits. Since 1996, the Earth Observation Group at NOAA/NGDC has been generating global annual nocturnal light composites from DMSP-OLS and VIIRS DNB data (Baugh et al., 2013; Elvidge et al., 2017).

The SQM and the VIIRS DNB have different spectral sensitivities. While the SQM is sensitive in the whole province of visible light (Internet 3), the VIIRS DNB is not sensitive in the visible blue province (Chen et al., 2021). This latter fact also influences the perception of LED lamps (Sanchez de Miguel et al., 2020).

The objective of the present research was to create as detailed an astronomical light pollution map of the city of Pécs as possible. To this end, surface and space measurements and data taken both from the surface and from outer space were used to reveal in light pollution for the city of Pécs between 2011 and 2019. What effect the LED lamps installed as part of the public lighting modernization program since 2015 had on the astronomical light pollution conditions of the city?

In the literature the measurement of urban light pollution using the SQM method is amply treated but measurements are restricted to few points and, thus, unsuitable for mapping. In most of the cases, permanent measurement stations at fixed locations are used to monitor light pollution in the centre of an individual city possibly with one or two permanent stations in the outskirts (Faid et al., 2016; Pavlić & Željko, 2020; Pun et al., 2014; Puschnig et al., 2022). In contrast, in the present study during the two measurement campaign light pollution in Pécs was surveyed in detail, employing numerous measurement points and mapped. The purpose was to compare the maps made at different dates.

There are light pollution studies where the SQM (or similar) measurements survey to calibrate the VIIRS DNB (or similar) data for light pollution mapping (Duriscoe et al., 2018; Katz & Levin, 2016; Nisar et al., 2022). In this paper, however, the two data series are treated separately and two independent methods are applied to detect the changes in the spatial pattern of light pollution in Pécs. The results are not affected by the spectral sensitivity of the instruments, they supplement each other.

Study Area

Pécs is a city in southwestern Hungary, with an area of 163 km² and a population of 140,000 (Figure 1.A). It lies on the southern slopes of the Mecsek Mountains and in the Pécs Basin. As a result of its basin character, the light pollution from the neighbouring settlements is eliminated by the ranges of the Mecsek Mountains and the Baranya Hills. The closest major town, Komló (population: 22,000) is located on the opposite side of the Mecsek, at 13 km distance, in valley. The two small villages in the Pécs Basin, in the immediate vicinity of Pécs (Pellérd & Keszü) are insignificant in this respect and did not disturb the measurements.

The neighborhoods of Pécs are listed in Figure 1.B shown with numbers. Inhabited since Roman times, the inner city (16) is located on the border of the two landscapes. The most important public and railway transport routes run here in east-west direction, along which the city has been expanding with mixed construction for centuries. Typically, the largest industrial and commercial establishments are also located along this axis (2, 13, 22, 23). Only in the second half of the 20th century did the city expand to the southern side of the once swampy basin, where the cityscape is mostly dominated by housing estates with blocks of flats (30). The hillslopes used to be vineyards (1, 4, 5, 7, 8, 9, 10, 17, 18), but in the 20th century it is increasingly occupied by residential areas and family homes and some villages were also added to the city (11, 27, 32, 33, 36).

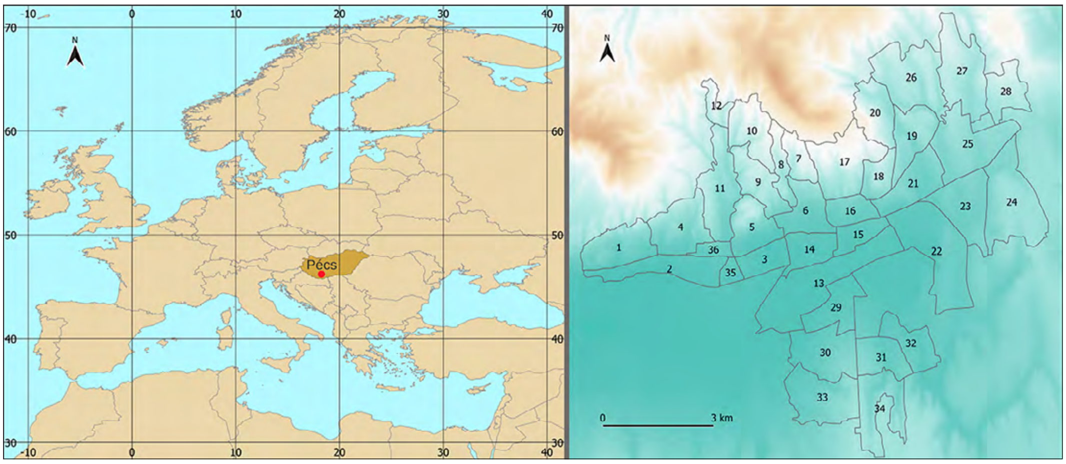

Figure 1. Location of Pécs in Europe (A) and its neighbourhoods (B)

Data and methods

For the research, we also used both data collected by authors during field work and satellite remote sensing data. To collect field data, car drives around the city were used to measure the background brightness of the sky in places without direct lighting with Sky Quality Meter L equipment (SQM-L), and also recorded the GPS coordinates of the measurement points (Figures 2.A. and 2.B). On 2-7 May 2011 for four nights at 236 places, and in 21-25 October and on 23-24 November 2019 the background brightness of the night sky at 261 locations over five nights was measured. In both cases, this meant driving around 300 km in and around Pécs. In all cases, the measurement sites were free from direct lighting. If there was a street lamp nearby, we covered its direct light with some object. Measurements were made observing IDA instructions (Internet 4).

The measurements were carried out under excellent bright skies after a cold front. We started the measurements after the end of astronomical twilight, making sure that the Moon was not above the horizon. We calibrated the results measured on different days since the atmospheric parameters (e.g. humidity, see Table 1) changed slightly from night to night. For this purpose, we designated three control measurement points along the road north of the city, 250-350 high above the city centre, at 4-5 km distance from there, on the slopes beyond the crest of the Mecsek Mountains, where urban light pollution is limited to a narrow section of the sky around the zenith, where the SQM-L data are collected. We started the measurements there every evening.

Table 1. Meteorological data for the days of measurement at midnight (meteorological station of the University of Pécs, 46°04'40.4"N, 18°12'22.3"E, elevation: 174 m)

Date and Time (CET)	Temperature (°C)	Relative Humidity (%)
02. 05. 2011 24:00	14.5	72.2
04. 05. 2011 24:00	5.7	70.0
05. 05. 2011 24:00	7.2	54.4
06. 05. 2011 24:00	8.4	57.7
21. 10. 2019 24:00	17.6	79.0
22. 10. 2019 24:00	17.8	66.0
23. 10. 2019 24:00	14.9	72.0
24. 10. 2019 24:00	13.3	85.0
23. 11. 2019 24:00	6.6	77.0

We used a SQM-L device for the measurement (Internet 5). It measures the average brightness of the sky above the observer in units of magnitude/square second (m/arcsec^2), so they provide a single numerical data for each observation. SQM-L only works in the range of visible light, its measurement accuracy is ±0.10 m/arcsec^2.

The L type SQM instrument has a much smaller field of view than previous SQM instruments. Approximately 90% of the light is collected from a 38° wide field of view (Internet 6), which is extremely beneficial in urban conditions because it is not disturbed by lights close to the horizon.

Recently, the issue of aging of the SQM devices has been raised (Bará et al., 2021; Puschnig et al., 2021). This only affects permanent stations exposed to weather in open spaces. The device used in the present study, however, is stored in climatized rooms, in drawer, packed in plastic bag with silica gel between two campaigns.

It is worth noting that the magnitude used in astronomy is a roughly logarithmic scale in reverse direction, therefore the higher values in the figures and tables represent the darker sky, the lower values the brighter.

Three measurements were taken at each location, and the data were averaged. The measurements of several consecutive nights were calibrated with the data of the three control points. The sky brightness values measured at the control points were averaged. The control values of each measurement day differed slightly from the average. All the measurement data from that day were modified accordingly.

The 2011 and 2019 locations overlapped to a significant extent, but not completely. Although we visited all 2011 measurement points in 2019, there were sites which were no longer suitable for repeated measurements because their environment had changed. In 2019, we also added new locations for future investigations. Between the measurement periods of 2011 and 2019, we had 155 shared, overlapping locations. Two measurement points were considered identical if there was a maximum distance of 150 meters between the two data collection locations. The 155 common measurement points were used to analyze changes over time (Figure 2.C).

In addition to surface measurements, we also downloaded and analyzed the raster files created by the VIIRS DNB instrument as well as the latest WGS 84 pro-

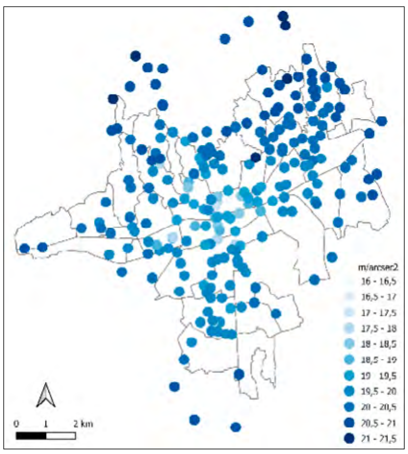

Figure 2.A. Sites and values of measurements in 2011

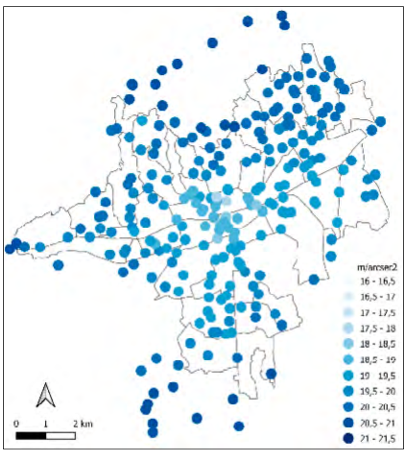

Figure 2.B. Sites and values of measurements in 2019

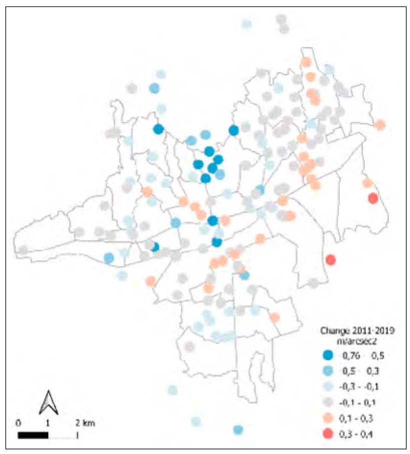

Figure 2.C. Common locations and changes in their background brightness between 2011-2019

jection GeoTIF layers released on 07/08/2022 from eogdata.mines.edu (Internet 7). Unfortunately, the SNPP probe only carried out measurements for the first time in 2012, there are no data for 2011. The downloaded GIS layers contain average values of the lights observed on the night side of the Earth for the years 2012 and 2019. They are masked and free from disturbing effects (e.g. moonlight). The area around Pécs was cut out from the global GIS layer. The pixel size of the already pre-processed stands in the examined area is 463×324 m (0.00416666° × 0.00416666°). Calibrated VIIRS DNB data are expressed in W cm^{-2} sr^{-1}.

The analyses and maps were prepared using QGIS software versions 3.16 and 3.22.

Results and discussion

Individual light pollution sources were assessed separately and represented on a map (Figure 3). Light pollution in Pécs is basically caused by public lighting in built-up areas. Despite the improvements, the majority of luminaires currently do not meet the ULOR = 0 condition. Especially high-power lights were placed along the main traffic arteries with heavy traffic and the more important first and second order roads.

The brightest area is the inner city (downtown) and its surroundings, where many buildings are illuminated, car parks are amply lit, and street lighting is also denser. Due to their design and brightness, the decorative lighting of the downtown church on the main square (Figure 4.A), the City Hall (Figure 4.B), the Pécs National Theatre, the Pécs Basilica and the Pécs Calvary Chapel are extremely light polluting. The nocturnal lights of the Árkád shopping center south of the city center and the surrounding parking lots, the long-distance bus station, the railway station and the nearby sports fields appear as bright spots on the map. In the western part of the city, the lights of the Clinic's building and parking lots, and further away the lights of shopping centers and industrial estates form light pollution hotspots. In the south, next to Pécs Plaza and other shopping centers, the reflectors of the local bus station can be highlighted. In the eastern part, the main pollution sources are the thermal power plant and other industrial facilities, as well as the parking lots of shopping centers. The PMFC football stadium holds training sessions on a daily basis, but also matches on a monthly basis, which then makes the football field the biggest source of light pollution in the city (Figure 4.C). The Expo Center in Pécs is also brightly lit on a few occasions in a year. The color-changing decorative lighting of the TV tower above the city, on the top of the Misina mountain, disturbs the nocturnal rhythm of the living world as a powerful source of light.

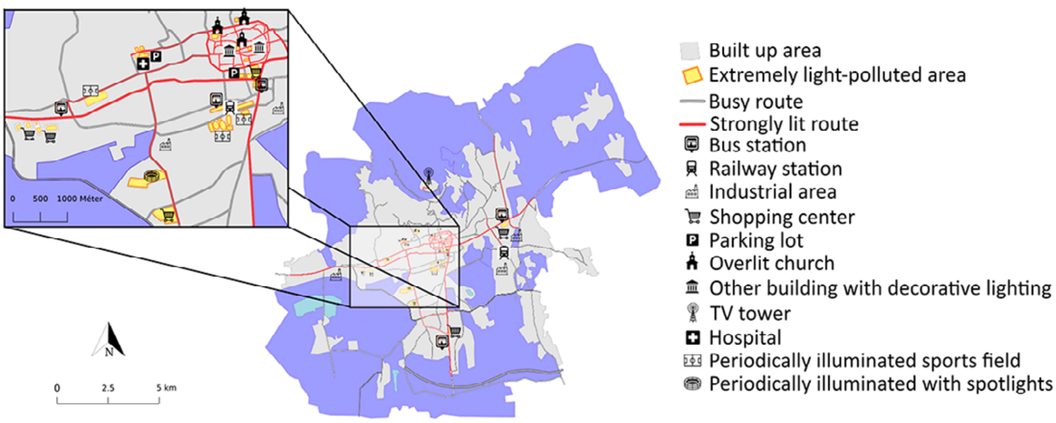

Figure 3. Major sources of light pollution in Pécs and environs

The astronomical light pollution of the new LED lamps is visibly much lower than that of previous lamps. Most of their light emission is directed downwards (Figure 4.D).

In the SQM-L measurements, the darkest average sky brightness value (21.05 m/$arcsec^2$) was measured NE of the city, on the crest of the Mecsek Mountains. The clearest average sky brightness value (17.85 m/$arcsec^2$) was recorded in the inner city. The maximum value of VIIRS DNB was 50.46 W cm^{-2} sr^{-1}/pixel in the inner city of Pécs (the minimum is 0 in areas further away from the city).

The difference between the 2011/12 and 2019 data was calculated for both vector and raster layers. For the 155 common points, the largest background brightness increase was found in a newly built part of the Újhegy (24) neighbourhood (+0.40 m/$arcsec^2$). The highest degree of darkening of the sky back-

Figure 4. Negative and positive examples of lighting in Pécs (2019). The photos were taken in fog. Ornamental lighting and the reflectors of the stadium are largely directed above the horizon (A, B, C), while the new LED lamps fully below the horizon (D)

ground was observed south of the railway station (-0.76 $m/arcsec^2$) (Figure 2.C).

In the VIIRS DNB images taken between 2012 and 2019, brightness increased most in the eastern part of the city, in an industrial area (+8 W cm^{-2} sr^{-1}/pixel), while brightness dropped most (-12 W cm^{-2} sr^{-1}/pixel)in the central part of Megyeri kertváros (30) (Figure 5.C.3).

The satellite image as a tessellation model can be interpreted as point measurements in a regular grid network extended into a surface. Similarly, a raster GIS layer can be created from surface measurements through conservative methods, Thiessen polygon (THI) and Triangulated Irregular Network (TIN) calculations (with a pixel size of 20×20 meters) to present light pollution and its fluctuations as a continuous surface. However, resolution is spatially variable, since the spatial distribution of the SQM-L measurement locations does not form a unidistance network either. Unfortunately, the number of common ground measurement points is only 155, compared to the number of pixels in the satellite image, of which 407 are located in the interior of Pécs. The interpolation results are shown in Figures 5.A.1-2. and 5.B.1-2. Along with the satellite images, a raster file was also prepared for the raster file showing the difference between the 2011/12 and 2019 data (Figures 5.A.3, 5.B.3).

Average change for the 155 common points between 2011-2019: -0.05 $mg/arcsec^2$.

Average change for Thiessen polygon surfaces: -0.02 $m/arcsec^2$; for TIN surfaces: -0.03 $m/arcsec^2$; for VIIRS DNB layers: -1.77 W cm^{-2} sr^{-1}/pixel.

For the entire area of the city, a very weak light pollution reduction trend can be observed in all cases (although within the measurement error limits).

Data reading at the neighbourhood level allowed the comparison of the raster surface data obtained by different methods and their verification. Using the Zonal Statistics module of the QGIS software, average light pollution values were extracted from the polygons of each city neighburhoods, which were ranked. In Table 2, in the case of the rankings obtained from all three raster surfaces, the 5 darkest neighbourhoods with the clearest sky are marked in blue and the 5 neighbourhoods with the brightest skies are marked in yellow. These show a fairly good match for the raster surfaces generated from two types of data collection, but actually created utilizing three approaches. In Figures 6.A. and 6.B., for both 2011/12 and 2019 it is visible which neighbourhoods were in the first or last 5 places on the list obtained by at least one method. The most light-polluted parts of the city are typically around the inner city, and the parts with the darkest skies are located on the edge (hillslopes with family homes). Between the two dates, it can be observed that Megyeri kertváros (30), which is characterized by blocks of flats and heavy-traffic roads, was excluded from among the most light-polluted neighbourhoods, but Északmegyer and Vágóhíd (13), which have industrial estates and sports fields modernized during the investigation, were included in this group. Szabolcs (27) and Nagyárpád (32) on the outskirts were the least light-polluted neighborhoods.

The above picture is differentiated through the assessment of the neighbourhoods which showed the largest average change in light pollution during the study period. In this case, too, the 5-5 neighbourhoods with the largest average increase or decrease from all three raster layers were identified. In the centre only the light pollution of the inner city (16) increased, while it decreased in the adjacent areas otherwise highly light-polluted compared to 2011. In the east, presumably due to the industrial park, average light pollution in the Balokány and Basamalom neighbourhoods (22) increased. Light pollution increased in the neighborhoods on the edge of the city, with otherwise lower pollution. These are mostly single-family residential areas, where the light pollution may have been caused by large-scale housing construction and the subsequent infrastructure developments that were significantly supported by the government in the last decade. The situation of the city neighbourhoods with the largest average reduction in light pollution is well suited to the alignment of the routes with heavy traffic. In our opinion, the decrease can be largely explained by the fact that the most powerful luminaires were replaced with LED ones as part of the lighting modernization program which started in 2015.

Neighbourhood-level data were also used to check the information from the three raster layers. Since they were obtained from data collection with two different instruments and the dimensions of the measured data are also different (m/arcsec^2 and W cm^{-2} sr^{-1}). Therefore, Spearmann's rank correlation was used based on the average light pollution order of the neighbourhoods from the three data sets (Table 1 THI_R, TIN_R, VIIRS_R The correlation between the THI_R and TIN_R rankings from the same data source is obviously extremely strong (2011: 0.966; 2019: 0.978), but also very strong between rankings of different origins. Between THI_R and VIIRS_R it is 0.893 for 2011 and 0.929 for 2019, while between TIN_R and VIIRS_R 0.905 for 2011 and 0.937 for 2019. The correctness of the research results is confirmed by the rank correlation indicators, that the data from different data collection methods show very similar results.

The raster surfaces derived from our the SQM-L measurements by authors and the VIIRS DNB satellite images are in principle also suitable for mapping light pollution changes below neighbourhood level. Since data collection and data processing methods can be loaded with uncertainty and errors, it is better to highlight only the clear trends through the visual interpretation of these layers. Most of the details are provided by the VIIRS DNB surveys and their difference map (Figure 5.C.1-3). Our previous findings are confirmed by the fact that in both the 2012 and 2019 records, the area around the city center is the most light-polluted, and pollution decreases towards the edges. Compared to the neighbourhood-level studies, the decrease in light pollution along the east-west and north-south axes of the city are better detectable from the VIIRS DNB pixel-level difference map. This reduction, in our opinion, was mainly due to the replacement of lamps along main roads and at bus stations. On the VIIRS DNB difference map, the average light pollution of Megyeri Kertváros (30) has decreased extremely, and an extreme brightening can be observed in the eastern industrial park. However, by our own SQM-L measurements these changes are judged to be of lesser extent. The contradictions partly result from the different spectral sensitivities of devices.

Conclusions

Light pollution changes in Pécs from 2011 to 2019 was mapped based on field measurements and satellite image analyses. The need for the investigation was also justified by the modernization of public lighting in the city since 2015. It was found that average astronomical light pollution, projected over the entire built-up area, probably decreased to a minimal extent, but this reduction is within measurement (uncertainty) limits. The findings are in accordance with other studies (Kolláth et al., 2016). The neighbourhood level study showed that the most light-polluted area of Pécs is the inner city and its vicinity, while the least light-polluted are the regions with family homes on the slopes of the Mecsek Mountains.

Both neighbourhood-level investigations and interpretations of the raster layer with a better spatial resolution showed that along the east-west and north-south axes of the city, astronomical light pollution within the city decreased slightly. In our opinion, this is most likely due to the replacement of luminaires along the main roads. It is sensible installing LED lamps that meet the ULOR = 0 condition, not only to save electricity, but also to reduce astronomical light pollution.

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Appendix

2011/12	2019	Change 2011-2019
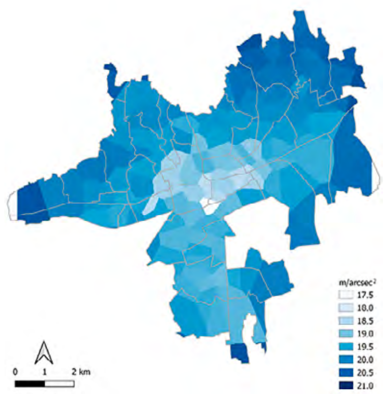	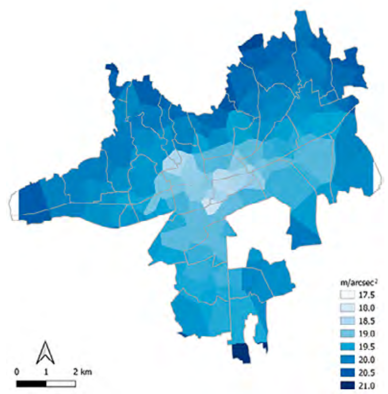	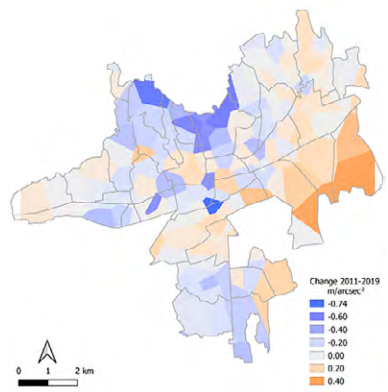
Figure 5.A.1. Thiessen polygon surface created from the SQM-L measurements in 2011	**Figure 5.A.2.** Thiessen polygon surface created from the SQM-L measurements in 2019	**Figure 5.A.3.** Difference of Thiessen polygon surfaces created from the SQM-L measurements in 2011 and 2019
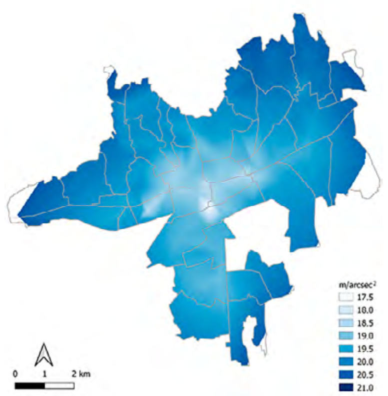	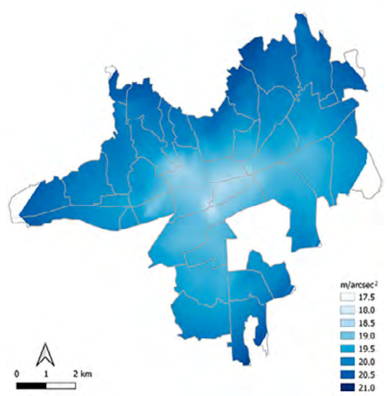	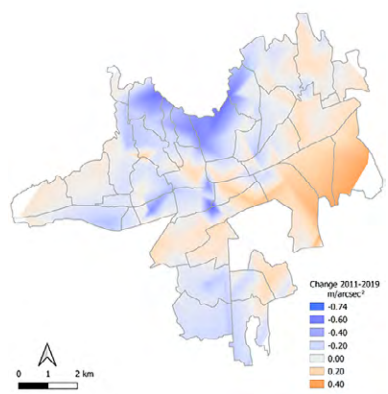
Figure 5.B.1. TIN surface created from the SQM-L measurements in 2011	**Figure 5.B.2.** TIN surface created from the SQM-L measurements in 2019	**Figure 5.B.3.** Difference of the TIN surfaces created in 2011 and 2019
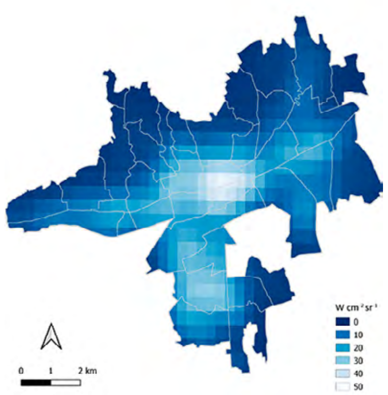	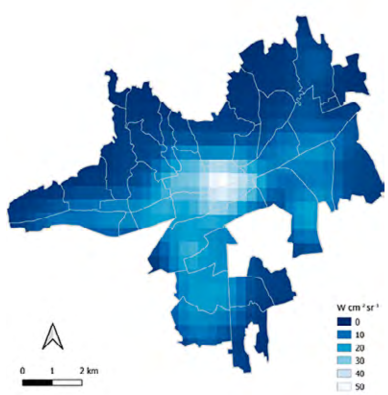	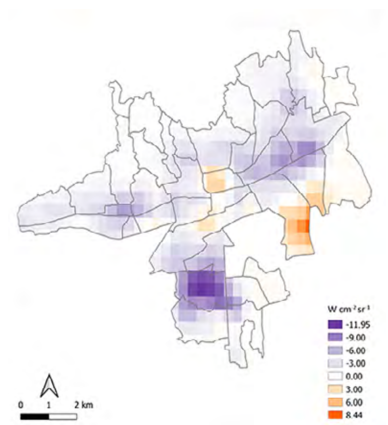
Figure 5.C.1. Annual average intensity from VIIRS DNB data (2012)	**Figure 5.C.2.** Annual average intensity from VIIRS DNB data (2019)	**Figure 5.C.3.** Difference between annual average intensities from VIIRS DNB data between 2012 and 2019

Table 2. Average values and rankings for the neighbourhoods interpreted from raster layers

CQ_ID	2011/2012						2019					
	THI	THI_R	TIN	TIN_R	VIIRS	VIIRS_R	THI	THI_R	TIN	TIN_R	VIIRS	VIIRS_R
1	20,30	3	20,35	3	4,98	8	20,26	4	20,31	4	3,09	6
2	19,88	10	19,86	13	13,29	21	19,98	9	20,00	12	11,25	21
3	19,20	32	19,16	32	21,09	30	19,33	29	19,32	30	20,23	32
4	19,98	8	20,03	10	7,34	13	19,97	11	20,02	9	5,46	12
5	19,50	24	19,45	26	14,54	24	19,56	24	19,54	24	12,10	23
6	18,98	33	18,98	33	26,82	33	19,02	33	19,04	33	24,70	34
7	19,66	17	19,65	19	8,98	15	20,04	8	20,01	10	6,87	14
8	19,54	22	19,60	23	9,21	16	19,75	17	19,82	16	7,97	16
9	19,57	20	19,57	24	7,42	14	19,68	21	19,69	23	7,10	15
10	19,80	14	19,90	12	2,29	4	20,17	6	20,22	6	2,10	5
11	19,85	12	19,91	11	4,40	7	19,98	10	20,00	11	3,53	8
12	20,32	2	20,41	1	1,06	1	20,35	2	20,44	1	0,92	1
13	19,26	31	19,26	31	18,73	27	19,22	32	19,21	32	17,27	29
14	18,84	35	18,84	35	26,66	32	18,99	34	18,98	34	24,48	33
15	18,58	36	18,76	36	36,48	35	18,59	36	18,71	36	35,71	35
16	18,89	34	18,91	34	39,26	36	18,93	35	18,91	35	40,49	36
17	19,52	23	19,53	25	9,96	17	19,86	14	19,86	15	8,28	18
18	19,34	28	19,36	27	14,33	23	19,40	27	19,42	27	10,33	20
19	19,85	11	19,85	15	6,45	12	19,89	12	19,88	14	4,00	9
20	20,10	7	20,07	7	2,06	3	20,23	5	20,28	5	1,62	3
21	19,37	27	19,36	28	19,18	28	19,35	28	19,36	29	13,95	26
22	19,68	15	19,69	17	11,11	19	19,52	25	19,53	25	12,37	24
23	19,48	26	19,62	20	16,16	26	19,28	30	19,38	28	14,29	28
24	20,21	6	20,07	6	5,40	9	19,87	13	19,78	19	5,76	13
25	19,80	13	19,86	14	12,08	20	19,74	18	19,78	18	8,09	17
26	20,29	4	20,29	4	3,48	6	20,31	3	20,32	3	2,08	4
27	20,23	5	20,24	5	6,11	11	20,17	7	20,19	7	4,98	11
28	20,39	1	20,40	2	1,38	2	20,36	1	20,35	2	1,55	2
29	19,34	29	19,33	29	21,99	31	19,25	31	19,26	31	17,60	30
30	19,28	30	19,32	30	28,07	34	19,42	26	19,44	26	18,57	31
31	19,68	16	19,71	16	11,08	18	19,69	19	19,73	20	8,50	19
32	19,96	9	20,04	9	3,04	5	19,81	16	19,96	13	3,48	7
33	19,49	25	19,66	18	13,54	22	19,60	23	19,80	17	11,28	22
34	19,65	18	20,05	8	5,74	10	19,81	15	20,16	8	4,50	10
35	19,55	21	19,61	21	15,41	25	19,67	22	19,72	21	12,70	25
36	19,61	19	19,60	22	20,44	29	19,69	20	19,69	22	14,16	27

CQ_ID = number of neighbourhood (see Fig.1); VIIRS = average pixel values (W cm^{-2} sr^{-1}) from VIIRS DNB surveys of neighbourhoods; VIIRS_R = rankings of pixel values for neighbourhoods from VIIRS DNB surveys; THI = background sky brightness interpreted from the Thiessen polygon surface; THI_R = ranking of average sky brightness of the neighbourhoods interpreted from the Thiessen polygon surface; TIN = value of average background sky brightness interpreted from the TIN surface; TIN_R = average background sky brightness interpreted from the TIN surface

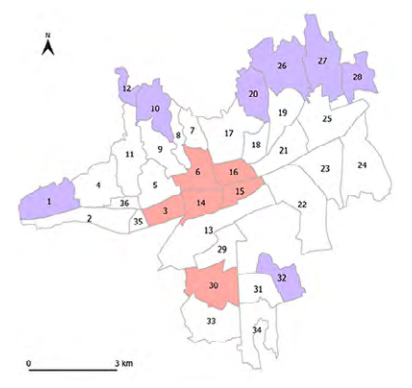

Figure 6.A. Neighbourhoods with the lowest (blue) and highest level of astronomical light pollution based on THI_R, TIN_R, and VIIRS_R in 2011/12

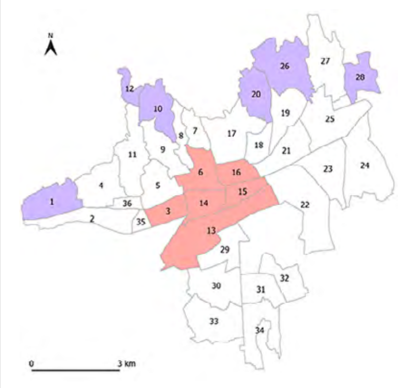

Figure 6.B. Neighbourhoods with the lowest (blue) and highest level of astronomical light pollution based on THI_R, TIN_R, and VIIRS_R in 2019

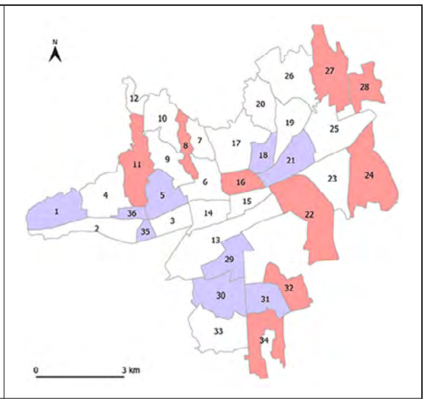

Figure 6.C. Neighbourhoods with the lowest (blue) and highest change in astronomical light pollution between 2011/12 and 2019

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Coastal Regions in the Geography of Innovation Activity: A Comparative Assessment of Marine Basins

Andrey Mikhaylov[ABC*], Anna Mikhaylova[B], Daniil Maksimenko[D], Mikhail Maksimenko[D], Dmitry Hvaley[B]

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Abstract

Across the globe marine coasts are experiencing an outstripping growth of the population and economic activity, a phenomenon known as coastalization. Most global cities and industry clusters are located in coastal regions acting as economic growth nodes for their respective countries. This divergence is equally true for national innovation systems, gravitating towards highly urbanized coastal areas. The study is designed to evaluate the spatial stratification of the knowledge production between the coastal regions located in different marine basins – Azov-Black, Caspian, Baltic, Arctic, and Pacific. In order to level-out the national differences of the innovation policy and institutional architecture, the research is held in a single country – the Russian Federation. Our research hypothesis suggests that the knowledge production domain of the innovation activity is influenced by urbanization and coastalization, i.e. the proximity to the core city and the coast. We also expect that the coastalization factor would be reflected in intensified involvement of coastal municipalities in knowledge production networks. The study is based on processing the ROSRID database of 66,647 research projects implemented in 2017-2019 and geocoded using the Yandex.Maps API. The research has shown that the urbanization factor has the strongest influence in configuration of R&D networks – the core centers of knowledge production are the largest cities in marine basins that give further impetus to the involvement of neighboring municipalities. Nearly 70% of municipalities across marine basins have limited or no involvement in the knowledge production, except the Baltic and Azov-Black Sea basins that feature the strongest performance. Overall, the proximity to the coast of non-freezing seas has a positive correlation with the number of R&Ds executed and funded. Considering the research topics, the share of marine-related research is typically funded by coastal regions, whereas the executed R&Ds cover a broad variety of topics. Research results enrich the notion of geography of innovation and advance our understanding of the spatial factors in knowledge distribution within the national innovation system.

Keywords: geography of innovation; knowledge distribution; knowledge production; national innovation system; coastal regions

[A] Institute of Geography of the Russian Academy of Sciences, Moscow, Russia; mikhailov.andrey@yahoo.com; tikhonova.1989@mail.ru; hvaley_gusev@mail.ru
[B] Immanuel Kant Baltic Federal University, Kaliningrad, Russia
[C] Southern Federal University, Rostov-on-Don, Russia
[D] Higher School of Economics, Moscow, Russia. dmaksimenko@hse.ru; mmaksimenko@hse.ru
[*] Corresponding author: Andrey Mikhaylov; e-mail: mikhailov.andrey@yahoo.com

Introduction

The uneven distribution of wealth in the context of the north-south divide, between macro-regions (e.g., Western and Eastern Europe), as well as at the inter- and intra-regional levels within countries is a well-established pattern. Starting with the early foundational research on the spatial configuration of the economy by Walter Christaller, August Lösch, and other prominent scholars, scientists around the world record the existence of central places and their center-peripheral relationships with adjacent territories. As the economy developed and evolved, different elements have been perceived as the nuclei of growth – agriculture (as noted in the Thünen's model), industry (e.g. Weber's theory on spatial economics), and today, the multiple factors behind the knowledge-based economy have come to the fore (Christopherson & Clark, 2007; Švarc & Dabić, 2017). Building on the recent findings of innovation studies (Philipson, 2020), and the geography of innovation in particular (Malecki, 2021), the knowledge production function is the primary element of innovation activity and entrepreneurship, and research and development (R&D) is an important driver of regional growth (Capello & Lenzi, 2013). It must be said that R&D cannot be equated with knowledge, and knowledge with innovation (Capello, 2017), since the generation of knowledge, nor innovation does not necessarily coalesce in space and time (Capello & Lenzi, 2013). However, R&D indicators are being widely used in Science, Technology and Innovation (STI) studies (Schot & Steinmueller, 2018), and the interrelation between entrepreneurs' innovative performance and regional innovation system 'thickness' is proven (Rypestøl & Aarstad, 2018).

In our approach, which relies on the notion of knowledge flows (Sorenson et al., 2006), and their relevance to innovative development and regional growth (Rodríguez-Pose & Crescenzi, 2008), we explore the movement of new knowledge resulting from R&D projects as a basis for innovation activity. In accordance with Asheim & Gertler (2005), we recognize the importance for the generation of new knowledge of a variety of interactions between different actors – firms, organizations in the scientific sector, government agencies. In this regard, the analysis of R&D projects as the basis of a knowledge production system, in our opinion, is of greater interest than, for example, the analysis of patents (Bilbao-Osorio & Rodríguez-Pose, 2004) or publications (Mikhaylov et al., 2020), because funding and execution of R&D involves a wide range of organizations in a triple helix mode. The possibility of geocoding the location of all organizations involved in the knowledge production process and quantifying their contribution to R&D makes it possible to assess the configuration and strength of internal and external links for knowledge production. As noted by Karlsson and Gråsjö (2021) with a reference to Johansson and Lööf (2014), the ability to combine external and internal knowledge positively affects the efficiency of economic agents and their ability to generate new knowledge.

Previous studies held internationally show that the localization of innovation activity is influenced by a number of factors, the main one being proximity to economic agents engaged in the same industry (Karlsson & Gråsjö, 2021). The combination of clustering and agglomeration of territorial innovation models support localized knowledge spillovers. On the one hand, the localization of the knowledge-intensive economy has increased the competitiveness of cities in the accumulation of labor resources and economic activity, on the other hand, it forms new growth nodes that meet the modern requirements of highly qualified personnel and high-tech business – new learning regions. Examples are San Jose, a satellite of Los Angeles, with Silicon Valley as a driver of its development, Innopolis in Russia, a satellite of Kazan, or the Pangio Techno Valley in Korea, a satellite of Seoul. At the same time, according to Pontikakis et al. (2009), more general R&D is effective in core regions, while more specific R&D finds more application in peripheral regions.

The focus of our study is on coastal regions traditionally featuring distinctive patterns in the distribution of economic, settlement and other activities associated with the influence of the coastalisation factor, which has been previously confirmed by Small and Nicholls (2003). It is noteworthy that a significant part of the largest cities and highly developed regions of the world is located in the coastal zone (Cracknell, 1999). In Europe the coastal regions concentrate 42% of the population, generating 43% of the total GRP (Mikhaylov et al., 2018). By studying the increased concentration of people, urban density, industrial clusters, and accumulation of other economic activity in the coastal areas of marine basins, scholars have elaborated on the concept of coastalisation (Mikhaylov et al., 2018). High institutional thickness, a rich variety of interrelated and complementary businesses, as well as the availability of financial, intellectual, and human resources, are argued to be the cause and effect for the development of coastal territories (Anderson, 2005; Merk et al., 2013). Based on the factors of the territorial capital of coastal territories, various territorial innovation systems are being formed here, which are often mentioned as best practices in the implementation of the transition strategy to a knowledge-based economy (e.g. Witte et al., 2018).

The purpose of the study is to assess the spatial stratification of innovation activity between coastal regions located in different sea basins – the Baltic, Caspian, Azov-Black, Arctic, and Pacific. The following hypotheses were tested in this study: 1) at the regional level, the innovative activity gravitates towards the nodes of the national space – the core cities; 2) at the municipal level in coastal regions, along with the urbanization factor, the knowledge flows are expected to be influenced by the coastalisation factor, localizing near the coast.

Data and methods

Research area

The study covers all coastal regions of Russia – a country often perceived as 'a sea of land' (i.e. a huge land mass) but actually having a total coastline of 46,000 km, facing 3 oceans and 13 seas. Regions are attributed to the coastal type by having some coastline (a direct access to the sea or ocean). Of the 85 regions in total, 23 are coastal, dominated by the Arctic basin – 30.4% and the Pacific basin – 26.1%. On the Atlantic side, two basins are distinguished – the Baltic basin and the Azov-Black basin, comparable to the Arctic basin by the number of regions.

The study was implemented on two levels – regional and municipal, including the inner districts of large cities. Out of 2,398 municipalities, 547 (22.8%) are part of the coastal regions. The detailed breakdown of the coastal regions shows that 33.3% of municipalities have direct access to the sea (Table 1).

Research data

Data on the knowledge production is sourced from the ROSRID database of the Center of Information Technologies and Systems for Executive Power Authorities (CITIS), which provides an overview of all R&D projects and the results of intellectual activity in Russia. The data covers reports on 66,647 projects of 2017-19. The dataset includes project name, keywords, OECD fields of science and technology classifications (FOS), funding volume by source, and the list of contractors.

Data on the location of R&D contractors and customers was sourced from the SPARK-Interfax database by linking the organization name to the tax number in the State Register of Legal Entities. The addresses of legal entities were geocoded using the Yandex.Maps geocoder API in the geopy 2.2.0 Python package and aggregated at the municipality level. Population data was obtained from the statistical database of Rosstat as of the most recent year available (January 2021-2022).

Data on the proximity of the municipality to the coast and the core city of the basin were obtained by geoinformation calculations using the built-in modules of the QGIS 3.14 program. The proximity to the core city is the distance from the geometric center of the municipality to the nearest city that acts as the core in the basin (this might not coincide with the administrative center of the region that the municipality belongs to). St. Petersburg and Kaliningrad were singled out as core cities for the Baltic basin; for the Caspian basin – Astrakhan and Makhachkala; Azov-Black basin – Rostov, Krasnodar, Simferopol, and Sevastopol; for the Arctic – Krasnoyarsk, Arkhangelsk, Yakutsk, Murmansk, Petrozavodsk, Novy Urengoy, and Noril-

Table 1. Geography of the study by marine basins

Marine basin	Coastal regions		Municipalities	
	No.	Name	No.	Coastal, %
Azov-Black Sea	4	Krasnodar Krai, Rostov Oblast, Republic of Crimea, Sevastopol	136	31.6
Caspian Sea	3	Astrakhan Oblast, Republic of Dagestan, Republic of Kalmykia	78	21.8
Baltic Sea	3	Kaliningrad Oblast, Leningrad Oblast, St. Petersburg	59	52.5
Arctic	7	Arkhangelsk Oblast, Nenets Autonomous Okrug, Murmansk Oblast, Republic of Karelia, Republic of Sakha (Yakutia), Krasnoyarsk Krai, Yamalo-Nenets Autonomous Okrug	173	18.5
Pacific	6	Kamchatka Krai, Magadan Oblast, Primorsky Krai, Sakhalin Oblast, Khabarovsk Krai, Chukotka Autonomous Okrug	101	58.4
Total	23	–	547	33.3

sk; for the Pacific – Anadyr, Vladivostok, Magadan, Petropavlovsk-Kamchatsky, Khabarovsk, and Yuzhno-Sakhalinsk.

Research procedure

There are two levels of study: regional and municipal. At the regional level, the indicator weights and territorial connectivity of marine basins and individual coastal regions was assessed in relation to knowledge production. Two blocks of indicators were analyzed: 1) R&D execution: the number of contractors in total and per region, the number of completed projects and their funding, the number of R&D customer organizations (internal and external); 2) R&D funding: the number and volume of projects funded, average project size.

Special attention is paid to assessing the influence of the factor of proximity to the sea on executed and funded R&D, highlighting the share of marine-related research. To do this, an analysis was made of the titles, keywords, and FOS of R&D projects with the emphasis on marine and maritime topics. Also, among the over 160,000 unique keywords and phrases attributed to distinctive projects, 1,063 were related to the sea (containing "marine-", "fish-", etc.). Overall, 20 coastal regions and 48 municipalities were involved in marine-related research.

At the municipal level, the divide of outgoing and incoming knowledge flows was assessed as a result of the cross-effects of proximity to the core city, the degree of urbanization, and proximity to the coast.

Research results

Regional projection of knowledge flows

Moscow is the hub of national knowledge production. The capital city accounted for 89.8% of funded and 66.7% of executed R&D, featuring the highest average funding volume per project among other regions – 0.24 million USD (14.9 mln rubles). In coastal regions, R&D funding amounted to 1.02 billion USD (63 billion rubles) – almost half that of inland regions (or 5.9 times including Moscow). By the number of R&D projects, the coastal regions are also half that of inland regions (excluding Moscow), and by the number of contractors – more than 2.2 times lower, with the average number of contractors – 22 vs. 34. However, the average project size is somewhat larger: 72.7 thousand USD (4.5 mln rubles) in coastal, and 69.5 thousand USD (4.3 mln rubles) in inland regions. There is a strong differentiation of coastal regions in knowledge production by marine basins (Table 2).

The second largest knowledge production center is St. Petersburg, part of the Baltic Sea basin. This explains its high share by the concentration of contractors (55%), the number (51.5%) and volume (56.7%) of R&D registered. Second is the Azov-Black Sea basin, where the city of Rostov-on-Don is the core. In third place is the Arctic basin with Krasnoyarsk being the core city. The Caspian basin regions have the smallest contribution – about 6% of contractors and 3% of R&D, and the polarization of the innovation space is around Makhachkala.

By the average R&D contractors' density per coastal region (excluding St. Petersburg, as due to its weight, it greatly distorts the distribution), the highest values are in the regions of the Azov-Black Sea basin – 40 institutions per region, which also surpass the inland regions (34 per region). In the other four basins, the values are below the inland regions. Most modest values are of the Pacific basin – 15 contractors per re-

Table 2. R&D performed in coastal regions of Russia by marine basins, 2017-19

Marine basin	Contractor		R&D projects		
	Total	Regional average	No.	Volume, mln USD	Average R&D cost, thousand USD
Azov-Black Sea	161	40	3,008	161.0	53.3
Caspian Sea	59	20	456	35.6	77.5
Baltic Sea	522	29*	7,201	575.2	61.4*
Including Saint Petersburg	464	464	6,855	553.9	80.8
Arctic	117	17	1,899	136.5	72.7
Pacific	90	15	1,407	106.5	75.9
Supplementary					
Inland regions	3,514	34*	52,677	7,891.6	69.5*
Including Moscow	1,457	1,457	24,588	5,937.3	240.7

*Note: * excluding Moscow, St. Petersburg*

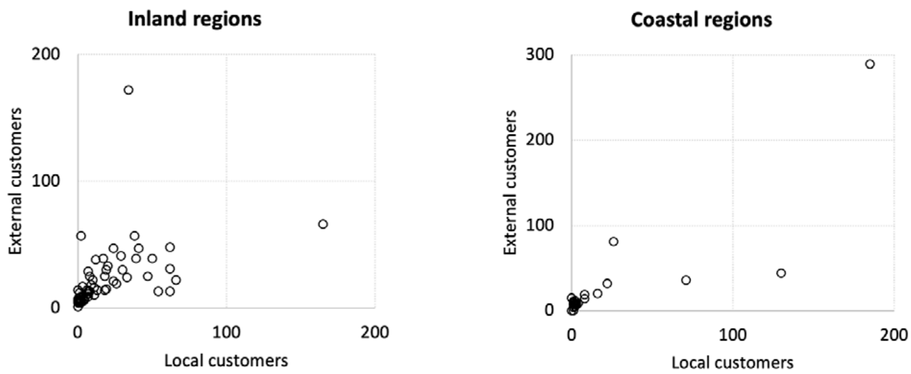

Figure 1. Distribution of regions by location of organizations that finance R&D

gion. Most regions facing the Pacific Ocean (Magadan Oblast, Sakhalin Oblast, Chukotka Autonomous Okrug, Kamchatka Krai) are poorly involved in the knowledge production system having a much smaller number of R&D contractors than the two leading regions – Primorsky Krai and Khabarovsk Krai. By the level of funding, on average, the largest projects are implemented (besides St. Petersburg) in the regions of the Caspian and Pacific basins, and the smallest – in the regions of the Azov-Black basin. Organizations that finance R&D in the coastal regions are located both within coastal areas and outside – in the inland regions, primarily in Moscow (Figure 1).

The correlation coefficient between the number of external and internal R&D customers for the coastal regions (excluding St. Petersburg) showed a noticeable positive relationship (equal to 0.588) – a probability of 95%; variability index is 34.6%. For the inland regions (excluding Moscow), a similar calculation showed a much smaller mutual dependence, the relationship of 0.457.

In the Azov-Black basin, a significant part of R&D customers is domestic, concentrated in its coastal regions. Thus, for R&D performed in the Rostov Oblast, customers were 3 times more likely to be located within the region: 130 vs. 44. Similarly for the Krasnodar Krai, the gap is twofold – 71 vs. 36. Localization of customers and contractors within the same region aligns research topics to the interests of regional development, covering the demand of local organizations. R&D in Sevastopol and the Republic of Crimea is still largely funded from other Russian regions. However, the number of domestic customers in Crimea (22 organizations) is higher than in most other coastal regions.

The regions of other marine basins (except St. Petersburg) are significantly inferior to the Azov-Black basin both in terms of the total number of R&D customers and by the internal/external ratio, with the latter prevailing. St. Petersburg has the dominance of external customers by 1.6 times; however, their total number (474 organizations) outlines the city as one of the largest cores of the national knowledge production system, satisfying not only external, but also their own demand. Table 3 reflects the relationship between the coastal regions of marine basins and inland territories by knowledge production.

Regions of the marine basins primarily act as contractors rather than funders. This is seen from the multiple excess of R&D performed over funded, both

Table 3. R&D funded by the coastal regions by marine basins, 2017-19

Marine basin	R&D funded from outside the region			Completed/funded R&D ratio	
	No.	Volume, mln USD	Average volume, thousand USD	By number	By volume
Azov-Black Sea	176	4.0	22.6	17.1	40.7
Caspian Sea	19	0.7	37.2	24.0	50.1
Baltic Sea	317	13.5	42.0	22.7	42.6
Including Saint Petersburg	263	12.6	48.5	26.1	43.9
Arctic	152	3.5	22.6	12.5	39.2
Pacific	66	3.6	54.9	21.3	29.3
Supplementary					
Inland regions	35,744	3,079.3	85.6	1.5	2.6
Including Moscow	31,348	2,787.2	88.9	0.8	2.1

in quantity and volume. For inland regions, this gap remains modest. The dominance of R&D funded over completed is typical only for Moscow, since the capital hosts the majority of organizations that finance R&D. There is also difference between the average funding per project – expensive projects are, generally, held in coastal regions.

Excluding the absolute leader St. Petersburg, the largest volume (by amount) of external R&D was funded by the regions of the Azov-Black, Pacific, and Arctic basins. With that, while in the case of the Azov-Black and Arctic basins, the average project size fluctuated at the level of 22.6 thousand USD (1.4 mln rubles), the regions of the Pacific basin had larger projects – on average, 54.9 thousand USD (3.4 mln rubles) each. The impact of coastalization on the knowledge production was assessed by evaluating the share of marine-focused R&D (Table 4).

There are also differences between marine basins. For the Baltic Sea basin, the proximity to the core cities (St. Petersburg and Kaliningrad) and the coast turned out to be a significant factor influencing the volume and amount of R&D performed. In second place is the Azov-Black basin, which has a tripolar system for knowledge production, including the core cities – Rostov-on-Don, Krasnodar, Simferopol-Sevastopol. For the Arctic basin, high executed R&D is typical for municipalities that are remote from the coast and is strongly associated with the settlement system. Also, a very strong positive relationship between the executed/funded R&D and the population size is typical for the Caspian basin.

Table 4. Coastalization factor on the R&D focus in the regions of marine basins, 2017-19

Marine basin	Marine-related R&D, mln USD		Share of marine-related R&D in total volume, %	
	contractor	customer	contractor	customer
Azov-Black Sea	15.15	1.94	9.4	49.0
Caspian Sea	1.46	0.03	4.1	4.0
Baltic Sea	22.64	3.58	3.9	26.4
Including Saint Petersburg	21.75	3.43	3.9	27.2
Arctic	11.63	0.10	8.5	2.9
Pacific	17.81	0.43	16.7	11.7

R&D held in coastal regions, generally, had a broader agenda. The share of marine-related R&D in the Azov-Black and Arctic basins did not exceed 10%, and for the Baltic and Caspian basins – 5%. The exception is the regions of the Pacific Basin, where 16.7% of marine R&D was registered. In relation to R&D commissioned outside, the share of marine topics is significant for the Azov-Black and Baltic basins. The lowest demand is from the regions of the Caspian Basin and the Arctic (less than 5%).

Municipal projection of knowledge flows

This section is devoted to the analysis of center-peripheral and coastal patterns of knowledge flows at the municipal level in the context of marine basins. Table 5 presents the coefficients of paired correlation for the entire array of municipalities in coastal regions for R&D funded/executed and such parameters as population, distance from the core city and the coast.

The strongest relationship is between the number of R&D executed and the population size (0.601). Organizations performing R&D tend to be located in populous municipalities. The factor of spatial proximity to a large core city or the coast is less significant.

Figures 2-4 present a typology of municipalities in coastal regions by the ratio of executed/funded R&D. In the Azov-Black basin, as well as the Baltic one, over half of the municipalities are involved in the knowledge production – a high result compared to other marine basins (Fig. 2). About 32% Azov-Black basin municipalities are predominantly consumers – R&D is held in 23% of municipalities, primarily, in Rostov-on-Don, Krasnodar, Sevastopol, Yalta, Novocherkassk, and the Simferopol area.

The neighboring Caspian basin, in contrast, is significantly inferior not only to the Azov-Black, but also to other basins by its involvement in knowledge production (Fig. 2). Over 88% of the Caspian municipalities did not execute/fund R&D. Only 9 municipalities executed R&D, led by Astrakhan in the Astrakhan Oblast, Makhachkala in the Republic of Dagestan and, to a lesser extent, Elista in the Republic of Kalmykia.

The Baltic Sea basin has a high rate of involvement in the knowledge production – over 59% municipalities, with the core role of St. Petersburg. All three groups are diversely represented: Predominantly producers (35.6%), Miscellaneous (3.4%), Predominantly consumers (20.3%). The regions of the Arctic basin are stretched from west to east and north to south of Russia, making this basin diverse in R&D conditions. Over 75% of the municipalities of this basin are classified as not involved in knowledge production, another 16%

Table 5. Correlation coefficients between for municipalities of coastal regions

Indicators	R&D executed		R&D funded	
	Value	Number	Value	Number
All municipalities				
Proximity to core city	-0.164	-0.179	-0.106	-0.171
Proximity to the coast	-0.074	-0.068	-0.050	-0.073
Population size	0.457	0.601	0.245	0.566
Azov-Black Sea basin				
Proximity to core city	-0.237	-0.245	-0.218	-0.135
Proximity to the coast	-0.138	-0.121	-0.146	-0.135
Population size	0.613	0.804	0.682	0.723
Caspian Sea basin				
Proximity to core city	-0.130	-0.185	-0.196	-0.223
Proximity to the coast	-0.067	-0.078	-0.049	-0.085
Population size	0.885	0.945	0.834	0.908
Baltic Sea basin				
Proximity to core city	-0.313	-0.354	-0.231	-0.311
Proximity to the coast	-0.212	-0.238	-0.159	-0.209
Population size	0.273	0.304	0.107	0.258
Arctic basin				
Proximity to core city	-0.190	-0.162	-0.127	-0.159
Proximity to the coast	-0.015	0.032	0.076	0.014
Population size	0.882	0.954	0.663	0.909
Pacific basin				
Proximity to core city	-0.239	-0.234	-0.215	-0.218
Proximity to the coast	-0.065	-0.052	-0.015	-0.026
Population size	0.776	0.800	0.774	0.742

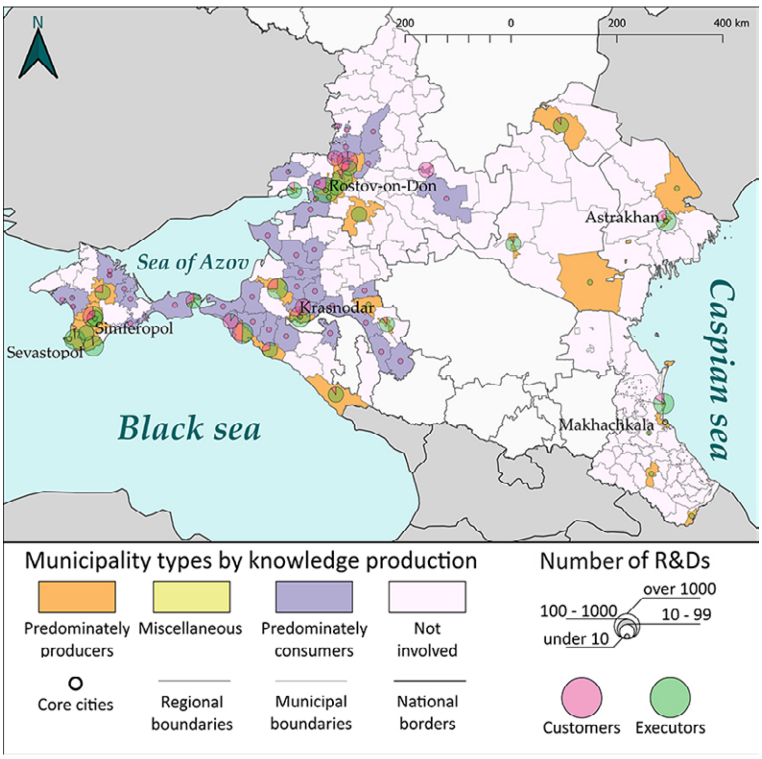

Figure 2. Typology of municipalities in the Azov-Black Sea and Caspian Sea basins for knowledge production

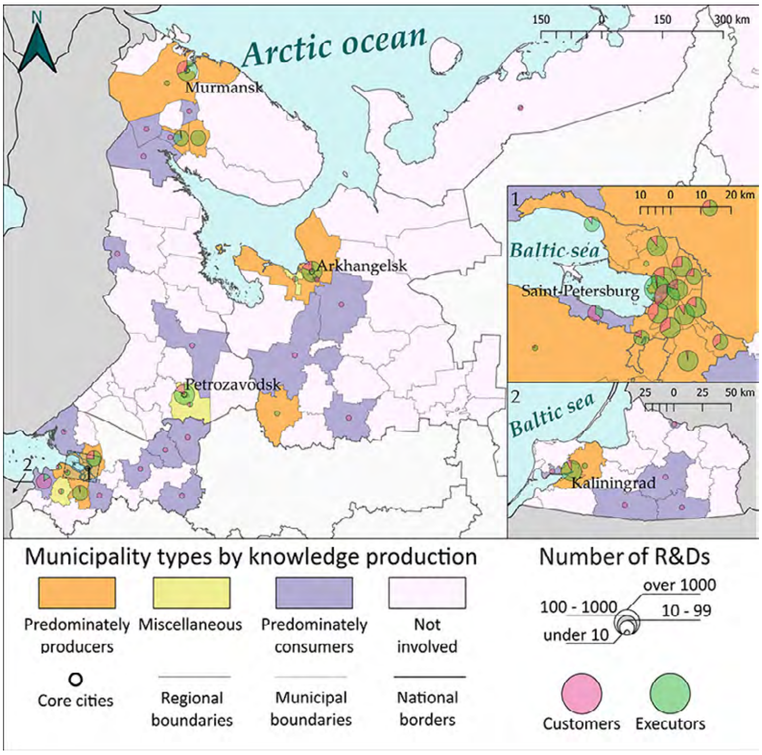

Figure 3. Typology of municipalities in the Baltic and Western Arctic basins for knowledge production

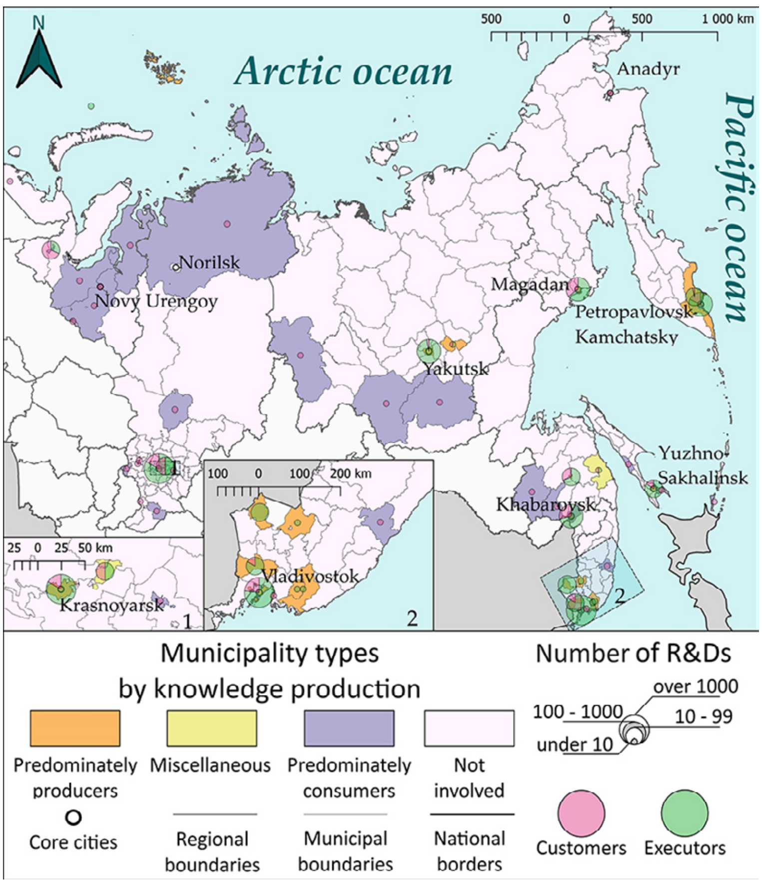

Figure 4. Typology of municipalities in the Pacific and Eastern Arctic basins for knowledge production

are predominantly consumers. Only 6% are assigned to the group of Predominantly producers: in the western part of the basin these are Arkhangelsk, Petrozavodsk, Apatity and Murmansk, and in the eastern part remote from the coast – Krasnoyarsk and Yakutsk. The Pacific basin also has a significant share of municipalities not involved in R&D – 79.2%. Among the other municipalities, the largest number are Predominantly producers – 11.9%, the group Predominantly consumers included 7.9%. Vladivostok, Khabarovsk, Petropavlovsk-Kamchatsky, and Magadan are most actively involved in the process of knowledge production.

Discussion and conclusions

The geography of innovation systems is configured based on the location and networking of the institutions involved in knowledge production and commercialization. Studies have proven that innovation activity requires a favorable milieu that enables entrepreneurship and fosters the generation of scientific and technological knowledge (Schot & Steinmueller, 2018). It is often stated that the institutional thickness of regional innovation systems is the key to generate, transfer, and absorb new knowledge – the cornerstone of the modern knowledge-driven economy (Rypestøl & Aarstad, 2018). Firms located in areas with rich and diverse territorial capital have higher chances for knowledge spillovers and cross-fertilization. In this context, coastal regions are of significant interest, as they have continuously been regarded as densely populated and well developed, enjoying the coastalization effects (Mikhaylov et al., 2018).

The widely described supremacy of coastal areas has been extensively studied with respect to demographics and industrial development but has received less attention in innovation studies (Witte et al., 2018). This is equally relevant for the research of Russian scholars: the maritime issues were a traditional research topic of Soviet human geographers, and in the recent years, it regained its prominence with a bias towards the assessment of the socio-economic development of territories (Druzhinin, 2022).

This article covers the gap by evaluating the spatial configuration of the knowledge production domain of the national innovation system, focusing on the role and embeddedness of the coastal regions located in different marine basins – the Baltic, Caspian, Azov-Black, Arctic, and Pacific. Being all located in a single country – Russia, there will be no difference in STI policy, providing a more insights on regional and municipal differentiations. It is noteworthy that the coastal municipalities of Russia cover 27.5% of the entire territory of the country and accumulate 14.2% of its demographic potential with an upward trend (as of 2019), while retaining pronounced parametric inter-municipal differences depending on the socio-economic development and length of the coastline (Druzhinin & Lialina, 2020).

In this research we have analysed the binary customer-contractor ties of 66,647 R&D projects across all regions and municipalities of the country with the aim of testing two hypotheses. *Firstly*, the urbanization factor was expected to cause asymmetry in the national innovation space, featuring active knowledge production activity in major cities and adjacent municipalities. It is found that the urbanization factor has the strongest influence – the largest centers of knowledge production are the largest cities of marine basins, giving impetus to the development of neighboring municipalities. Vivid examples are the Baltic Sea basin with the leadership of St. Petersburg as the largest national innovation center and the core city, and the Azov-Black Sea basin with a spatial triangle of core cities – Rostov-on-Don, Krasnodar, Simferopol-Sevastopol. Moreover, the stronger the core, the greater the effect of proximity to it on the knowledge production function. Although a significant part of the municipalities of coastal regions is still not involved in the knowledge production (above 70%), in marine basins with strong core cities the share of uninvolved municipalities is significantly lower.

Secondly, in line with the coastalization phenomenon, it is expected that innovation activity will be clustered in coastal areas and decline with the distance from the shoreline. Being tested at the municipal level, we did not observe a strong influence on the localization near the coast on the knowledge production (even negative correlation for the Arctic basin). However, the nature of funded R&D by coastal regions is specific, focusing on marine-related topics, this extends the findings by Pontikakis et al. (2009).

Our observations correspond with some recent studies held in the Baltic Sea region countries. For instance, Simensen and Abbasiharofteh (2022) have analyzed the R&D networks in Norway, showing the paramount role of large cities in the national knowledge production system (Oslo, Bergen, Trondheim, and Stavanger), although being less pronounced in the maritime-related sector. The municipal level research on public funding of research, development and innovation (RDI) across Finland held by Makkonen and Mitze (2022) suggests that major cities and the surrounding areas are represented by the most active firms, located in the coastal agglomerations of Helsinki, Turku, and Oulu. Notable that during the pandemic year of 2020 the innovative activity of coastal and peri-urban municipalities increased.

Another phenomenon of spatial stratification of innovation activity in the coastal zone, which remained outside the scope of this study, is associated with its high international communication potential. Neighboring with the regions of foreign countries across the sea (Baklanov, 2022) supports the flow of knowledge and innovation, the 'stickiness' of which, among other things, is supported by a common maritime theme. Active trans-aquatic interaction is particularly typical for the countries of the Baltic Sea region, including the formation of specialized forms of maritime innovation activity (Meyer et al., 2021a,b). It can be assumed, as a future hypothesis, that coastal municipalities, which are also frontiers, are more actively involved in the generation of knowledge and innovation.

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Analysis of Urban Development on Land Cover Changes of Three Cities of Gujarat State, India

Alpesh M. Patel[A*], Anil Suthar[B]

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Abstract

Urbanization generally serves as a key navigator of the economic growth and development of the country. There is a need for fast and accurate urban planning to accommodate more and more people in the city area. Remote sensing technology has been used for planning the expansion and design of city areas. A novel machine learning (ML) classifier formed by combining AdaBoost and extra trees algorithm have been investigated for change detection in the urban area of three cities in the Gujarat region of India. Using Indian Remote Sensing (IRS) Resourcesat-2 LISS IV satellite images, the performance of the object-based AdaBoosted extra trees classifier (ABETC) in terms of overall accuracy (OA) and kappa coefficient (KC) for urban area change detection was compared to benchmarked object-based algorithms. As the first step in object-based classification (OBC), the Shepherd segmentation algorithm was used to segment satellite images. For all three cities, the object-based ABETC demonstrated the highest efficiency when compared to conventional classifiers. The rise in the built-up area of Ahmedabad city has been noted by 87.39 sq km from the year 2011 to 2020 showing the urban development of the city. This increase in the built-up area of Ahmedabad was compensated by the depletion of 30.26 sq. km. vegetation area, and 57.13 sq. km. of open land class. The built-up area of Vadodara and Rajkot city has been enlarged by 17.24 sq km and 6.79 sq km respectively. The highest OA of 96.04% and KC of 0.94 has been noted for a satellite image of Vadodara city with a novel object based ABETC algorithm.

Keywords: urbanization; change detection; object based classification; multispectral image

Introduction

Change detection (CD) is the cause of action for finding variation in a particular land area at different time intervals (Singh, 1989). Remote sensing technology is very useful for various applications of CD like agricultural and forest monitoring, evaluation of natural disasters, environmental and landscape tracking, and study of urban surroundings (Lu et al., 2004; Singh et al., 2011). Urbanization and its development planning play a key role in the economic growth of a developing country like India. The migration of people towards city areas has generated complex problems related to traffic management, water quality, availability of fresh air, and drop in vegetation areas (Pacifici et al., 2007). Change detection in the urban landscape is a challenging task and needs persistent monitoring due to the constant interaction of humans, deficient spectral discrimination ability, complexity of actual structures, and geometric deformation (Pacifici et al., 2009; Gamba 2012; Jia et al., 2015). The analysis of very high resolution (VHR) satellite images pro-

[A] Department of Electronics and Communication, Vishwakarma Government Engineering College, Chandkheda, Affiliated to Gujarat Technological University, Ahmedabad, Gujarat 382424, India; am_patel@gtu.edu.in.
ORCID iD: https://orcid.org/0000-0001-8846-4771
[B] New L. J. Institute of Engineering and Technology, Ahmedabad, Gujarat, India; sutharac@gmail.com.
ORCID iD: https://orcid.org/0000-0003-3267-8636
[*] Corresponding author: Alpesh M. Patel; e-mail: am_patel@gtu.edu.in

vides a cost-effective solution for change detection in complex urban areas. The change detection techniques are mainly bifurcated into supervised or unsupervised techniques (Coppin et al., 2002; Lu, 2004). The alteration in the atmospheric situation and radiance variation, which takes place at distinct acquisition times, are some of the exterior factors that may reduce the performance of the unsupervised method (Wang et al., 2018). The supervised CD technique is highly effective and workable compared to the unsupervised one for multitemporal satellite data (Bruzzone et al., 2000). The CD algorithms are also categorized into various categories like thresholding, image differencing, vegetation index differencing, image ratioing, transformation, and post-classification change detection. Post-classification change detection is a widely used technique for urban growth estimation (Reba et al., 2020). From the literature of the last few decades, the various post-classification change detection methods can be mainly divided into pixel based change detection (PBCD) and object based change detection (OBCD) techniques based on the basic processing unit (Zhang et al., 2018).

PBCD is a traditional approach that works on the spectral property of a single-pixel value and OBCD functions on a group of pixels having common characteristics called polygons or objects as basic processing blocks for image operations (Weih et al., 2010). PBCD techniques are largely used for medium and low-resolution satellite data, composed of finding pixel-by-pixel difference images and exploring them to acquire a change map (Zhang et al., 2018). Principal component analysis (PCA) (Deng et al., 2008) and change vector analysis (CVA) (Bruzzone et al., 2000) are some of the methods of PBCD that have been applied for the change detection task. For VHR satellite data, most PBCD techniques suffered from "salt and pepper" noise as the spatial-contextual details have not been considered (Wu et al., 2020).

OBCD methods overcome the above drawbacks by including spatial and contextual information in form of objects generated by segmenting the image into spectrally similar and meaningful polygons (Blaschke et al., 2010; Duro et al., 2012). For change detection applications in complex urban territories, object based technique has shown higher performance in form of classification accuracy (Blaschke et al., 2001). The availability of VHR satellite data and high-speed computational machines in the last few decades have assisted object based methods for change detection applications (Chen et al., 2012). For multispectral satellite data, stacking of different image bands, segmentation of the stacked image, sampling of segmented objects, extraction of various features, and classification are key operations for object based methods of classification in the post-classification change detection process. The main elements responsible for creating uncertainty during OBC operations are parameter tuning for the segmentation algorithm, strategies for selecting training data, extracting features from segments, and selection of appropriate supervised classifier and its parameters (Ma et al., 2017). The performance in terms of the accuracy of the OBCD process highly depends on the use of a proper classifier algorithm and its parameter tuning.

In recent years, different supervised classifier algorithms have been applied for object based methods of classification. Walter et al. (2004) have implemented an object based method with a supervised maximum likelihood classifier (MLC) for multispectral images. Desclée et al. (2006) introduced a statistical object based method and achieved higher overall accuracy compared to pixel based method for two different data sets. Hegazy et al. (2015) performed the change detection study of Mansoura and Talkha cities of Egypt for monitoring urban growth using a geographic information system (GIS) and found an expansion of built-up area by more than 30% and a reduction in vegetation area by 33%.

X. Wang et al. have applied the ensemble method to combine the output of multiple classifiers for object based change detection in an urban area using VHR QuickBird satellite images (Wang et al., 2018). The ensemble learning technique has shown better results in terms of classification accuracy compare to single classifiers like k-nearest neighbor (KNN), support vector machine (SVM), and random forest (RF) for the OBCD process (Wang et al., 2018). The performance of the adaptive ensemble method using extreme learning machines (ELMs) was investigated with Landsat-5 and Landsat-7 data sets and showed better results in terms of accuracy compared to single ELM for change detection (Khurana et al., 2020).

The increase in urban land area of 52.47% for Kathmandu city of Nepal was detected using Landsat-5 and Landsat-8 images for 20 years duration using remote sensing and GIS by Wang et al. (2020). This urban expansion took place with a cost of 9.28% of forest and 9.8% of agricultural land. Idowu et al. (2020) studied change detection for Lagos city of Nigeria using object based nearest neighbor classifier algorithm by integrating Landsat-7 and Sentinel 2A images. They have found 55.5% raise in the built-up area from the year 2001 to 2016 and a fall off of wetlands and forest areas.

Random forest (RF) (Stefanski et al., 2013; Wang et al., 2019; Belgiu et al., 2016) and support vector machine (SVM) (Mountrakis et al., 2011; Thanh et al., 2018; Laso et al., 2020; Pham et al., 2019) are benchmark classifiers used in object based method of classification of satellite data. Rizvi et al. (2011) have demonstrated the use of a modified cloud basis function as a kernel for artificial neural network (ANN) for QuickBird satellite images of suburban areas and found higher classification accuracy compare to radial basis function neural network (RBNN). Feng et al. (2018) have illustrated rotation forest with majority voting (RoF-MV) based OBCD method using Gaofen-2 (GF-2) satellite images of the urban area. RoF-MV method has shown a higher kappa co-efficient for accuracy measurement compared to RF-MV and ELM-MV (Feng et al., 2018). The performance in terms of the kappa co-efficient of the RF and RoF algorithm was found higher compared to SVM and Wishart classifier for Radarsat-2 satellite images and the execution time of the RF algorithm was noted very less compared to the RoF algorithm by Du et al. (2015). Colkesen et al. (2017) have compared the classification accuracy of the canonical correlation forest (CCF) algorithm with benchmarked RF and RoF algorithms and found that the CCF algorithm has higher overall accuracy for Landsat-8 (L-8) images compared to the RF algorithm but the computational time requirement for classification using CCF algorithm was also very high.

In a developing country like India, lots of people are migrating from rural to urban areas for getting better infrastructure, health, and other facilities. There is a strong need for better urban planning to accommodate migration and maintain the ecosystem. Remote sensing technology is used widely for this task. A very large amount of satellite data are available and there is a need for faster and more accurate machine learning (ML) algorithms for the analysis and investigation of urban areas for urban development planning.

The concept of the ensemble learning technique is to use several single classifiers' predictions to predict the final output for increasing the classification accuracy. For VHR satellite data, the ensemble learning methods have shown better performance in terms of classification accuracy compared to individual classifiers (Samat et al., 2018). Among the supervised classifiers, the extra trees classifier (ETC) is a highly efficient and faster ensemble classifier. It is a tree-based ensemble ML technique having different node splitting concepts by arbitrarily picking samples and cut-points (Geurts et al., 2006).

In this paper, urban area change detection of three cities of Gujarat state of India was investigated using a novel object based AdaBoosted Extra Trees Classifier for VHR satellite data. The proposed OBCD method was constructed by integrating a multi-class AdaBoost and Extra-Trees splitting algorithm with a stratified random sampling of training samples.

- The first part of the paper consists of an investigation of comparative analysis for object based DT, RF, ETC, AdaBoosted RF, and ABETC algorithms for the classification of satellite images of Ahmedabad, Vadodara, and Rajkot cities of the Gujarat region. The results have shown superior performance for ABETC in terms of classification accuracy.
- In the second part, the urban change detection investigation of the three cities has been introduced with a highly efficient object based ABETC algorithm and change detection maps for the built-up area were generated.
- A detailed change detection comparative analysis for Built-up, Vegetation, and Open land classes using object based DT, RF, ETC, ABRFC, and ABETC algorithms have been demonstrated for data sets of Ahmedabad, Vadodara, and Rajkot cities.

Study Area and Data

Gujarat has been among the highest leading industrialized states in India. Ahmedabad, Vadodara, and Rajkot are some of the major cities of the state. Ahmedabad is the largest city in terms of area as well as a major economic and industrial hub of the state. Because of urbanization, the population of the city area of Gujarat state has grown significantly in the last decades.

The satellite images from Indian Remote Sensing Satellite IRS-R2 with 5m spatial resolution have been used for the change detection study of these cities. LISS-IV (Linear Imaging Self-Scanner) sensors have been used for obtaining this very high resolution (VHR) satellite data with three (Red, Green, NIR) spectral bands. These three bands are stacked to generate the false color composites (FCC) images. The subset images of Ahmedabad with a size of 5104 × 4862 pixels for the years 2011 and 2020 are used for built-up change detection of the city. The subset images of Vadodara and Rajkot have the dimension of 3029 ×3174 pixels and 2124× 2481 pixels respectively. These subset images are covered with varying land types like vegetation, open land, and built-up. The subset of FCC images of the cities has been shown in Figure 1.

A contemporary multispectral sensor with a considerably large resolution, the resourcesat-2's LISS-IV sensor has enormous potential for creating high-quality images of land use and land cover. The brief details of the LISS-IV multispectral satellite images used in the study of change detection of the urban area are mentioned in Table 1.

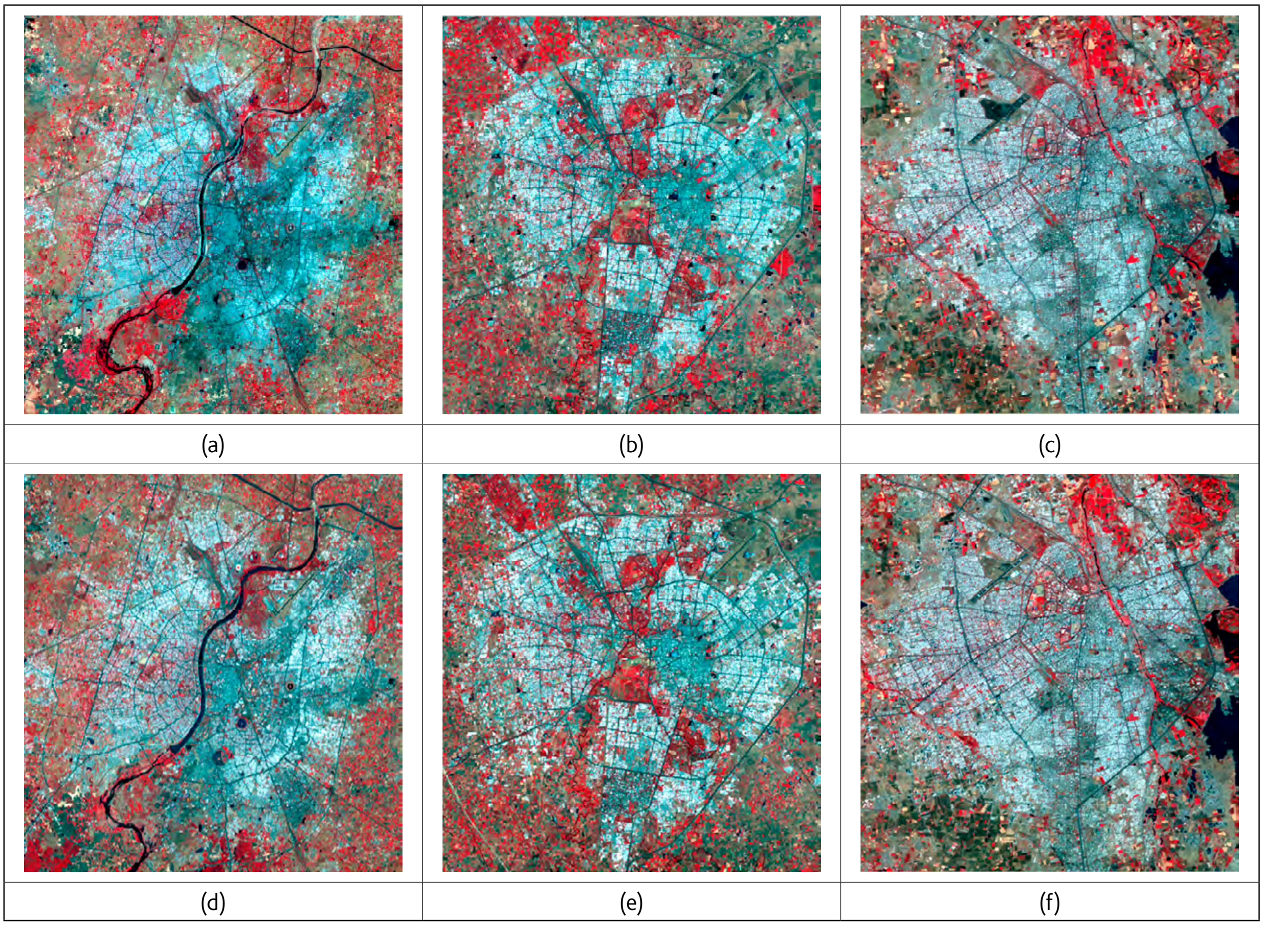

Figure 1. Images of the study area (a) Ahmedabad of year 2011, (b) Vadodara of year 2013, (c) Rajkot of year 2014, (d) Ahmedabad of year 2020, (e) Vadodara of year 2020, (f) Rajkot of year 2021

Table 1. Details of the LISS-IV multispectral images

Parameter \ Sensor Instrument	LISS-IV
Spectral bands (µm)	B2: 0.52-0.59 (green), B3: 0.62-0.68 (red), B4: 0.77-0.86 (NIR)
Data quantization	10 bits
Spatial resolution (m)	5.8
Swath width	70 km in mono mode, 23 km in Multispectral mode
Detector line arrays x No of elements	1 x 12,288 Mono mode; 3 x 12,288 Multispectral mode
Revisit Period	5 days

Methodology

Change detection investigation of three cities of Gujarat using a post-classification comparison method was carried out with object based image classification having image segmentation as the most important step. The various implementation steps of the proposed method for OBCD are shown in Figure 2.

LISS-IV multispectral images of IRS-R2 satellites for three cities are obtained. The FCC images are generated by stacking spectral bands. Image segmentation, feature extraction, object based classification and investigation of change area are the major processing steps of this OBCD method. The shepherd

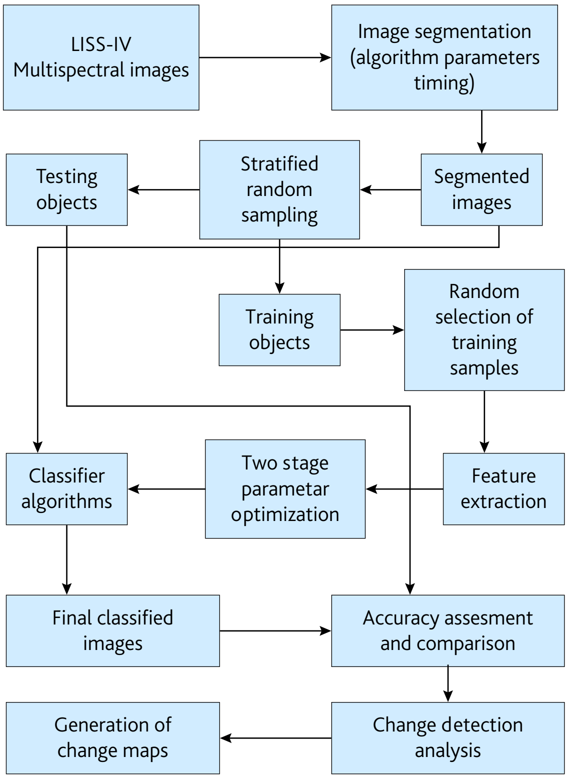

Figure 2. Flow chart of proposed OBCD method

segmentation algorithm was used to obtain segments of these FCC images. The stratified random sampling technique was adopted for distinguishing training and testing segments. The randomly selected training samples were directed for feature extraction steps. The segments and their extracted features were utilized in the classification step with two-stage parameter optimization using the grid search cross validation (CV) module of scikit-learn (Pedregosa et al., 2011). The performance assessment of different classifier algorithms and their comparison results were summarized before picking the final classified images for change detection analysis. These classified images were used for generating change detection maps for the built-up area of three cities.

Multispectral Image Segmentation

The initial processing steps of the OBCD method consist of dividing the multispectral stacked image into spatially unbroken groups of analogous pixels with indistinguishable spectral properties known as segmentation (Blaschke et al., 2014; Singh et al., 2014). The segmentation algorithm can be of different classes like point-based, edge-based, and region-based (Schiewe et al., 2002). The aim of the segmentation process is to create segments or objects with different aspects of similarity considering various dimensions (Blaschk et al., 2010). These objects also consist of auxiliary spectral details like mean and median numbers of each band in contrast to individual pixels.

Segmentation operation was carried out using the shepherd segmentation algorithm (Shepherd et al., 2019) implemented with open source library RSGISLib (Clewley et al., 2014). The concept of segmentation is to split the image into the same kind of land cover, the complete feature, like a vegetation block, will be caught as a single object so it can be later classified into a suitable class. In the case of under segmentation, more than one feature, like vegetation and open land, may combine into a single object, and classification of such features is not feasible (Shepherd et al., 2019). As per (Shepherd et al., 2019) and (Carleer et al., 2005), a little over-segmentation can merge segments of matched class into a single object, so it was applied to maintain the performance of a later stage.

The parameters that need to be tuned for this algorithm are straightforward and less in number. Further, this algorithm is greatly scalable to large landscape areas with an iterative elimination process and is suitable for a broad range of sensors (Shepherd et al., 2019).

The shepherd algorithm operates in four different steps. In the first step, an unsupervised k-means clustering technique is applied for seeding the image. Better results were obtained with an efficient computational requirement for k-means compare to other clustering mechanisms like mean-shit, Iterative Self-Organising Data (ISOData), and fuzzy k-means (Shepherd et al., 2019). Clumping is performed as a second step in which pixels are bunched to the appropriate cluster center for making physically labeled regions. In the third step of the algorithm, the bunch below minimum dimensions are combined with spectrally nearest and bigger than itself neighbor. This iterative elimination starts with regions having the smallest size and it reduces the number of clumps drastically. Relabeling of the clump is the last step for ensuring sequential numbering of the clumps which makes the next step of classification more systematic (Shepherd et al., 2019). The two important parameters for this algorithm are the number of initial clusters k for k-means, and the minimum clump size for the elimination process (Clewley et al., 2014). The number of initial seeds k is the key parameter for making spectral differentiation among the classes. The less value of k generates few clusters which results in under-segmentation and a higher value of k creates smaller segments resulting in over segmentation. As per (Mathieu et al., 2007) and (Aguilar et al., 2013), key parameters of the shepherd segmentation algorithm were finalized using a systematic trial and error technique with a visual inspection of segmented results. The number of seed k was fixed at 60 and the maximum iteration was finalized at 100.

Shepherd et al. (2019) have investigated the performance of this segmentation algorithm in detail for three different sensors with benchmark segmentation algorithms like the multiresolution segmentation algorithm used in eCognition, the mean-shift algorithm used in Orfeo toolbox, the algorithm of Felzenszwalb and Huttenlocher, and the quick-shift algorithm and found that this algorithm compares advantageously in most resulted comparative metrics.

Labeling of Samples

Open source QGIS software (QGIS Development Team, 2019) was used to label the segments or objects generated by the segmentation process by visual exposition for all three city images. Built-up, vegetation, and open land are the three classes in which all the segments were labeled. These labeled segments were separated into training and testing segments with a stratified random sampling method. The classification performance of the classifier may be affected by the number of training segments used to train the classifier algorithm (Du et al., 2015). From each class 800 samples have been selected randomly through QGIS form which 640 samples per class were utilized for training the classifiers and 160 samples per class were used for investigating the accuracy of the classifiers.

Benchmark Classifiers

DT, RF, and SVM are the standard classifiers for object based classification of remote sensing images found in the literature. SVM technique focuses on acquiring a hyperplane for differentiating segments into fixed classes as per training data (Mountrakis et al., 2011). It is a non-parametric statistical method and advantageous where kinds of attributes are more in comparison to samples (Mountrakis et al., 2011; Pedregosa et al., 2011).

A decision tree is a type of classifier that may be described as a recursive division of the instance space and its nodes are arranged to form a rooted tree. Every internal node of the decision tree divides the instance space into a number of sub-spaces based on a specific discrete function associated with the input feature values. In the easiest and most typical scenario, each test takes into account a single attribute, dividing the instance space depending on the value of an attribute. Classification and regression trees (CART) is a non-parametric decision tree algorithm implemented for object based classification of segmented images using (Pedregosa et al., 2011). It uses Gini's impurity indicator as a splitting norm to spilt the node to form a binary tree structure. In this algorithm, the value of the target variable was estimated by using simple decision rules concluded from training data features. For a given labeled training data, this algorithm iteratively divides the feature space in such a way that the training segments with similar labels are grouped. The key parameters used for optimizing this algorithm were the number of features that need to be considered for node split and the maximum depth of the decision tree.

RF classifier is an assembly of weak learners for obtaining the best classification results and shown higher classification performance with quick operation time (Du et al., 2015). Constructing a huge number of de-correlated trees, and subsequently averaging them, is how random forests significantly modify bagging. RF algorithm has shown higher performance than tree-based ensemble techniques and bagging tree algorithms. A relatively large amount of input variables may be handled by the RF algorithm without overfitting, and they produce very good accurate predictions. RF classifier is regarded as one of the most reliable and versatile learning methods accessible. In this algorithm, trees are assembled using the re-sampling method with replacement, and the features are also randomly sampled for deciding the best node split (Du et al., 2015; Breiman et al., 2001). Finally, the majority voting method is applied for allocating class labels to unknown segments. The number of estimators, splitting criteria, amount of features, and the number specifying the depth of the tree were observed as parameters of concern for RF optimization using (Pedregosa et al., 2011).

AdaBoosted Extra Trees Classifier

In this method, extra trees classifier (ETC) and AdaBoost SAMME (Stagewise Additive Modeling using a Multi-class Exponential loss function) classifiers (Hastie et al., 2009) were combined with dual-level of its parameter optimization.

In the ETC method, the picking of cut-points for numerical attributes takes place completely randomly without considering the target variable (Geurts et al., 2006). The algorithm arbitrarily selects individual features and cut-point for each node such that completely randomized trees are generated whose formation is not dependent on the target variables of training segments (Geurts et al., 2006). Further, for developing a tree, ETC utilizes all training samples instead of bootstrap replicas used by other ensemble methods which makes it divergent from other tree-based ensemble algorithms (Samat et al., 2018). Geurts et al. (2006) have experimentally demonstrated smaller computation time for extra trees compared to other ensemble algorithms like tree bagging and RF. This computational efficiency of ETC becomes higher as the number of features increases and is found more than ten times quicker compared to RF. This algorithm was executed using (Pedregosa et al., 2011) for object based classification of all three city images. The parameters observed as dominant parameters for optimizing the extra trees algorithm are the maximum depth of the tree, the number of trees in the forest, and the number of attributes required for node split.

The adaptive boosting algorithm presented by Freund et al. (1997) adaptively fine-tunes the errors of a weak hypothesis that is given by a weak learning algorithm for boosting the prediction of weak learners which is also called AdaBoost. For stated distribution *D* over training segments, this algorithm aims to discover the ultimate hypothesis with relatively less error. This algorithm sustains a set of weights w^t for a group of training samples *N*. These weights are normalized for evaluating distribution pt for iteration t (Freund et al. 1997).

$$p^t = \frac{w^t}{\sum_{i=1}^{N} w_i^t} \tag{1}$$

This distribution applied to a weak learner that creates a hypothesis h_t with a minor error.

$$e_t = \sum_{i=1}^{N} p_i^t \left| h_t(x_i) - y_i \right| \tag{2}$$

The weight vector updating parameter β_t is set as

$$\beta_t = \frac{e_t}{(1 - e_t)} \tag{3}$$

This boosting method creates a new weight vector w^{t+1} using the new hypothesis h_t,

$$w_i^{t+1} = w_i^t \beta_t^{1-|h_t(x_i)-y_i|} \tag{4}$$

Succeeding *T* such iterations, the resulted hypothesis h_f integrates the results of the *T* weak hypothesis with a weighted majority vote.

The above AdaBoost algorithm was observed as an extremely successful algorithm for two-class classification issues. The AdaBoost SAMME (Stagewise Additive Modeling using a Multi-class Exponential loss function) algorithm is immensely competitive regarding misclassification error rate and is used for multi-class problems (Hastie et al., 2009). This multi-class algorithm merges the weak learners and reduces the exponential loss. This algorithm adaptively integrates a chain of weak classifiers with the weight enhancement of training segments. The weights of wrong classified samples are raised and the steps are repeated.

Parameter Optimization

The values of the parameters of ABETC were finalized in two steps. In the first step, the grid search cross validation (CV) module of (Pedregosa et al., 2011) was used for the optimization of the parameters of the ETC algorithm. The number of forest trees, maximum tree depth for expanding the nodes of trees, and a number of attributes utilized for node splitting are parameters used for optimization. The five-fold CV was used for obtaining the best values for these parameters. The optimized ETC classifier with its final parameter values was used as the base classifier in the implementation of the AdaBoost SAMME algorithm. In the second part of the parameter optimization, parameters of this combined algorithm like the learning rate, and the maximum number of weak classifiers are optimized using a five-fold CV through the grid search module. After parameter optimization, multiple ETCs were generated and trained sequentially. The weight of the training samples used for training of the above optimized base classifiers was also updated adaptively. After completing a specified number of iterations, the final prediction was produced using a majority vote. The same method was followed for implementing the AdaBoosted random forest classifier (ABRFC) and results have been compared in terms of classification accuracy.

Change detection analysis was carried out from the final classified images of object based ABETC classifier. The LISS-IV images used here have a 5m pixel resolution. So, the area represented by one pixel of the VHR image was calculated as 25 square meters. Then the number of pixels of each class and their area in square kilometers were calculated for images of three cities on different dates. In the last step change map for the built-up area of three cities was generated using (Clewley et al., 2014).

Experimental Results and Discussion

The LISS-IV images of Ahmedabad for the years 2011 and 2020 have been classified using an object based method with the shepherd segmentation algorithm. Tables 2 and 3 show the performance comparison of DT, RF, ETC, ABRFC, and ABETC classifiers for these images. The overall accuracy (OA) and kappa coefficient (KC) are measured and considered as evaluation criteria for the above classification algorithms. All the segments of the images have been labeled in three different classes called vegetation, built-up and open land. 160 samples from each class have been used for testing the performance of the classifiers and 640 samples from each class were used to train the classifiers. The selection process of training and testing segments was done with a stratified random sampling technique through QGIS software.

Table 2. Accuracy Statistics comparison for DT, RF, ETC, ABRFC, and ABETC Classifiers for Ahmedabad 2020 dataset

Classes	DT		RF		ETC		ABRFC		ABETC	
	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA
Vegetation	0.93	0.93	0.93	0.94	0.93	0.94	0.94	0.94	0.93	0.95
Open land	0.94	0.94	0.96	0.95	0.98	0.95	0.98	0.95	0.98	0.97
Built-up	0.78	0.77	0.82	0.83	0.80	0.85	0.80	0.85	0.84	0.85
OA	89.56		91.48		92.08		92.03		93.46	
KC	0.86		0.89		0.89		0.89		0.91	

Table 3. Accuracy Statistics comparison for DT, RF, ETC, ABRFC, and ABETC Classifiers for Ahmedabad 2011 dataset

Classes	DT		RF		ETC		ABRFC		ABETC	
	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA
Vegetation	0.87	0.95	0.87	0.96	0.87	0.96	0.88	0.96	0.86	0.96
Open land	0.95	0.92	0.98	0.95	0.98	0.95	0.98	0.96	0.98	0.95
Built-up	0.82	0.84	0.84	0.85	0.85	0.87	0.85	0.86	0.87	0.88
OA	89.55		92.08		92.61		92.58		93.05	
KC	0.87		0.90		0.90		0.90		0.91	

Table 4. Accuracy Statistics comparison for DT, RF, ETC, ABRFC, and ABETC Classifiers for Vadodara 2020 dataset

Classes	DT		RF		ETC		ABRFC		ABETC	
	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA
Vegetation	0.97	0.95	0.95	0.97	0.96	0.96	0.96	0.96	0.96	0.97
Open land	0.93	0.90	0.93	0.94	0.94	0.95	0.94	0.95	0.96	0.95
Built-up	0.85	0.92	0.94	0.92	0.94	0.93	0.95	0.92	0.95	0.96
OA	91.90		94.04		94.80		94.51		96.04	
KC	0.88		0.91		0.92		0.92		0.94	

Table 5. Accuracy Statistics comparison for DT, RF, ETC, ABRFC, and ABETC Classifiers for Rajkot 2021 dataset

Classes	DT		RF		ETC		ABRFC		ABETC	
	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA
Vegetation	0.96	0.91	0.98	0.94	0.98	0.95	0.98	0.96	0.97	0.95
Open land	0.93	0.90	0.90	0.96	0.92	0.95	0.97	0.92	0.96	0.95
Built-up	0.83	0.92	0.94	0.88	0.91	0.90	0.89	0.98	0.93	0.97
OA	90.93		93.22		93.55		94.93		95.53	
KC	0.86		0.90		0.90		0.92		0.93	

The class-wise performance evaluation in terms of user's accuracy (UA), and producer's accuracy (PA) is also mentioned in the accuracy statistic tables. The built-up area change is the key parameter for demonstrating the urban development of any city. Another concern class is the vegetation area for maintaining a good ecosystem in growing cities. Among the DT, RF, and ETC classifiers, OA and KC of the ETC algorithm were found higher as shown in Tables 2 and 3 for Ahmedabad data sets. The consolidated Ada-Boosted Extra Trees Classifier (ABETC) has shown the highest performance with OA of 93.46% and KC of 0.91 for the Ahmedabad data set for the year 2020. For Ahmedabad 2011 dataset also, the object based ABETC algorithm has excelled with an OA of 93.05 % among these five algorithms. The classification accuracy in terms of overall accuracy was found better for the ABRFC algorithm compare to the RF algorithm.

The performance comparison of these object based classification algorithms for the Vadodara dataset of the year 2020 and the Rajkot dataset of the year 2021 is mentioned in Tables 4 and 5. For these datasets also,

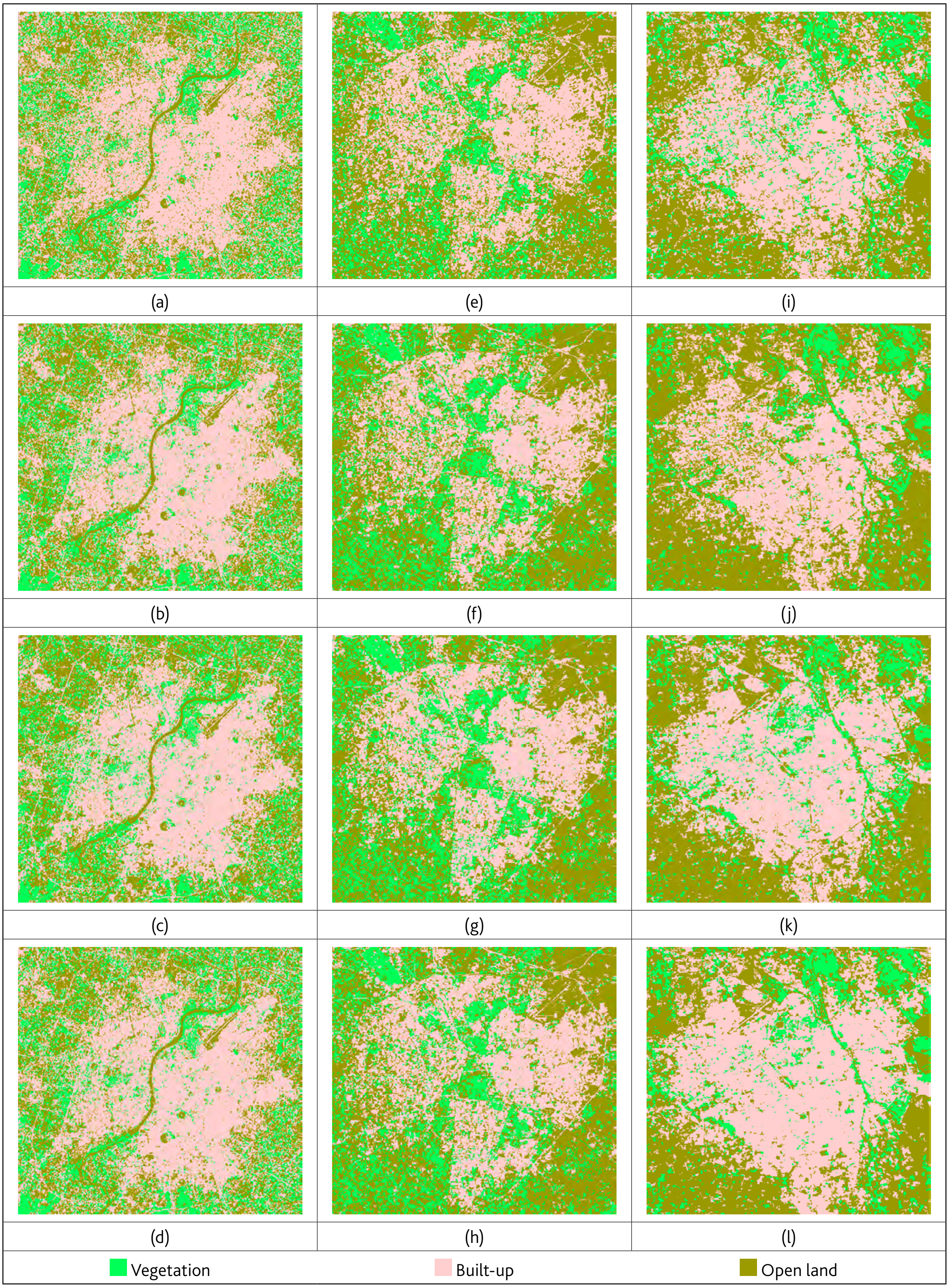

Figure 3. classified images of (a) DT, (b) RF, (c) ETC and (d) ABRFC classifiers for Ahmedabad 2020 data set; (e) DT, (f) RF, (g) ETC and (h) ABRFC classifiers for Vadodara 2020 data set and (i) DT, (j) RF, (k) ETC and (l) ABRFC classifiers for Rajkot 2021 data set

the ETC algorithm has shown higher OA compared to DT and RF. The ETC has indicated overall accuracy of 94.8% and 93.55% for Vadodara 2020 and Rajkot 2021 images respectively.

Compare to ABRFC, the ABETC has shown superior results in terms of OA and KC for both these images. The highest value of the kappa coefficient was 0.94 with an object based ABETC classifier for Vadodara 2020 data set. As shown in Tables 4 and 5, the integrated ABETC algorithm has demonstrated superior performance among these five object based algorithms with an OA of 96.04% for the Vadodara 2021 image and 95.53% for the Rajkot 2021image.

Chen et al. (2017) used a multiple classifier system (MCS) to assess a time series of cloud-free Landsat-5 TM, Landsat-7 enhanced thematic mapper plus (ETM+), and Landsat-8 operational land imager (OLI) sensors to map LUC changes in Guangzhou, the capital city of Guangdong province in China, from 1987 to 2015. SVM, C4.5 decision trees, and artificial neural networks (ANN) were employed as the training algorithms of the base classifiers for the novel MCS classification approach, which resulted in a higher Kappa coefficient (0.87) than any base classifier. The best overall accuracy was attained by MCS based on Weight Vector enhanced by AdaBoost, which scored 88.12%. SVM, ANN, and C4.5 came in second, third, and fourth, respectively, with 82.85%, 81.77%, and 80.20% overall accuracy.

To obtain results with a better degree of accuracy, Avashia et al. (2020) used numerous categorization techniques. Using Landsat images, they investigated the evaluation of various classification algorithms, including hybrid, unsupervised, decision tree categorization, and object-based image analysis (OBIA), for mapping out the changes in land usage in Indian cities. The findings imply that employing multi-level classification for various Indian cities at various stages of the classification process will increase accuracy levels. They employed DTC and OBIA classification methods for difficult classes. For Ahmedabad, Vadodara, and Rajkot cities, the highest overall accuracy obtained by them are 90.06%, 91.93%, and 89.94% respectively. The best kappa co-efficient value recorded by them for Ahmedabad, Vadodara, and Rajkot city is 0.88, 90.04, and 87.87 respectively.

The final classified images of the Ahmedabad 2020 data set, Vadodara 2020 data set, and Rajkot 2021 dataset using object based DT, RF, ETC, and ABRFC classifiers are shown in Figure 3. All the images have been classified into vegetation, open land, and built-up class. The vegetation class was shown in green color and the built-up class in dark off-white color. As mentioned in Tables 2 - 5, the object based ABETC classifier has indicated the best performance with regard to OA and KC, the object based change detection (OBCD) analysis was carried out using classified images of this classifier.

Figure 4 shows the result of the OBCD map of a built-up class of Ahmedabad data set from the year 2011 to 2020. The classified images of the year 2011 and 2020 using the ABETC classifier are displayed in Figure 4(a) and Figure 4(b) respectively. A remarkable increase in built-up area from the year 2011 to 2020 can be visualized from these images. Using these classified images, a change detection map was generated as shown in Figure 4(c). In this map, the green color indicates that this area was part of the built-up class in the years 2011 and 2020. Because of urban development, some of the open land and vegetation area has been converted into built-up areas. This conversion was shown as a gain in a built-up area with a dark off white color. Similarly, change from built-up to vegetation or open land class was indicated with red color in the change detection map. The classified results of the ABETC classifier of Vadodara 2020 and Rajkot 2021 datasets are shown in Figure 5 and Figure

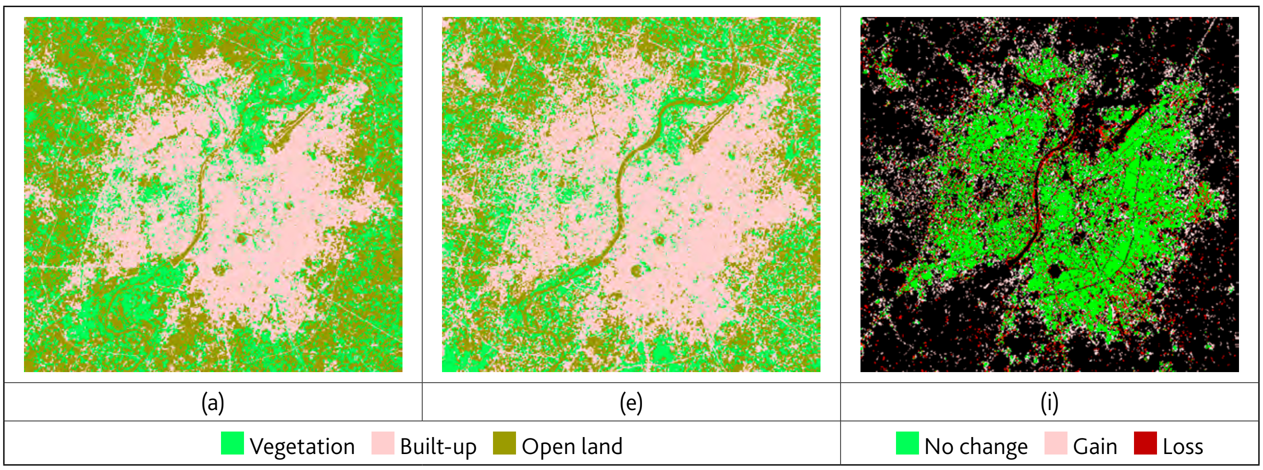

Figure 4. OBCD results using ABETC for Ahmedabad Data set. (a) Classified Image of the year 2011 (b) Classified Image of the year 2020 (c) Built-up area change map of Ahmedabad

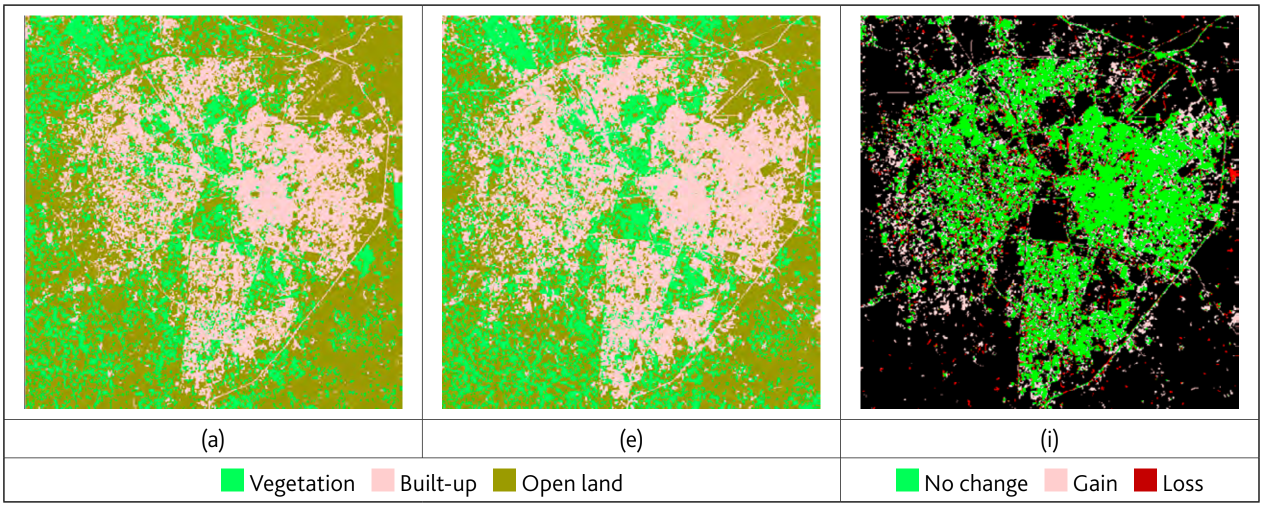

Figure 5. OBCD results using ABETC for Vadodara Data set. (a) Classified Image of the year 2013 (b) Classified Image of the year 2020 (c) Built-up area change map of Vadodara

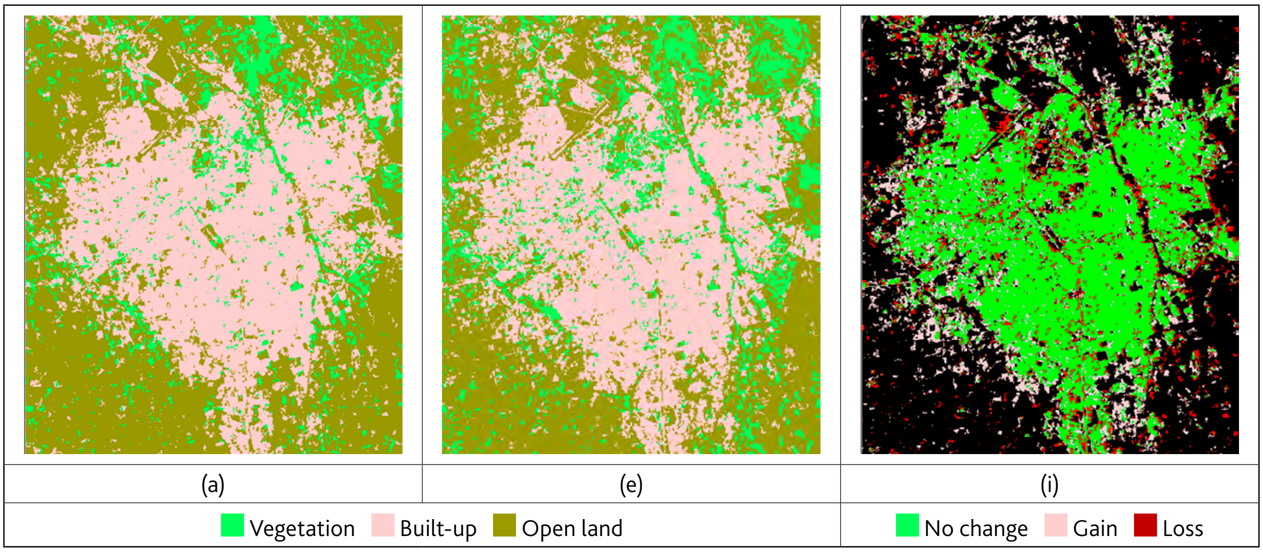

Figure 6. OBCD results using ABETC for Rajkot Data set. (a) Classified Image of the year 2014 (b) Classified Image of the year 2021 (c) Built-up area change map of Rajkot

6. The significant rise in built-up class can be noticed from the year 2013 (Figure 5(a)) to 2020 (Figure 5(b)) classified images of Vadodara. Figure 5(c) shows the OBCD map of the Vadodara data set, produced using classified images of the ABETC classifier. From Figure 5(c), the gain in the built-up class can be found in the outer part of the city area. The change detection map of the Rajkot data set, fabricated using object based ABETC classified results (Figure 6(a) and Figure 6(b)) is shown in Figure 6(c). The major increase in built-up class can be visualized, as illustrated in Figure 6(c), along three sides of the city area.

The change detection statistics of the Ahmedabad, Vadodara, and Rajkot data set are shown in Table 6, 7, and 8 respectively. The built-up area of Ahmedabad was changed from 214.4 sq. km. in the year 2011 to 301.79 sq. km. in the year 2020. This increase in built-up class was compensated by the depletion of 30.26 sq. km. vegetation area and 57.13 sq. km. of open land class. From the year 2011 to 2020, the built-up area of Ahmedabad has increased by 40.76% which shows the very high rate of urban development and migration of people in the city area. The 18.97% loss in vegetation class is also a matter of concern for maintaining the ecosystem of the city. As shown in Table 7, the built-up area increased by 17.24 sq. km from the year 2013 to the year 2020 for Vadodara city. The vegetation class was also expanded by 8.44 sq. km. and the open land area shrunk by 25.68 sq. km. The built-up class of Rajkot for the year 2014 was 50.42 sq. km. and it has increased to 57.21 sq. km. in the year 2021. The growth in the built-up and vegetation class of Rajkot was adjusted to 12.31 sq. km. of open land area. The area statistic graph of this analysis is shown in Figure 7. The expansion of the built-up area and decline in the vegetation and open area can be visualized from this graph.

Table 6. Change detection Statistics for Ahmedabad data set

Classes	Year 2011		Year 2020		Overall Change	
	Area sq. km.	% Area	Area sq. km.	% Area	Area sq. km.	% Change
Built-up	214.40	34.67	301.79	48.80	87.39	40.76
Vegetation	159.52	25.79	129.26	20.90	-30.26	-18.97
Open land	244.52	39.54	187.39	30.30	-57.13	-23.36
Total	618.44	100.00	618.44	100.00		

Table 7. Change detection Statistics for Vadodara data set

Classes	Year 2013		Year 2020		Overall Change	
	Area sq. km.	% Area	Area sq. km.	% Area	Area sq. km.	% Change
Built-up	63.26	26.32	80.50	33.49	17.24	27.25
Vegetation	52.72	21.93	61.16	25.45	8.44	16.01
Open land	124.37	51.75	98.69	41.06	-25.68	-20.65
Total	240.35	100.00	240.35	100.00		

Table 8. Change detection Statistics for Rajkot data set

Classes	Year 2014		Year 2021		Overall Change	
	Area sq. km.	% Area	Area sq. km.	% Area	Area sq. km.	% Change
Built-up	50.42	38.27	57.21	43.43	6.79	13.47
Vegetation	13.53	10.27	19.05	14.46	5.52	40.80
Open land	67.79	51.46	55.48	42.11	-12.31	-18.16
Total	131.74	100.00	131.74	100.00		

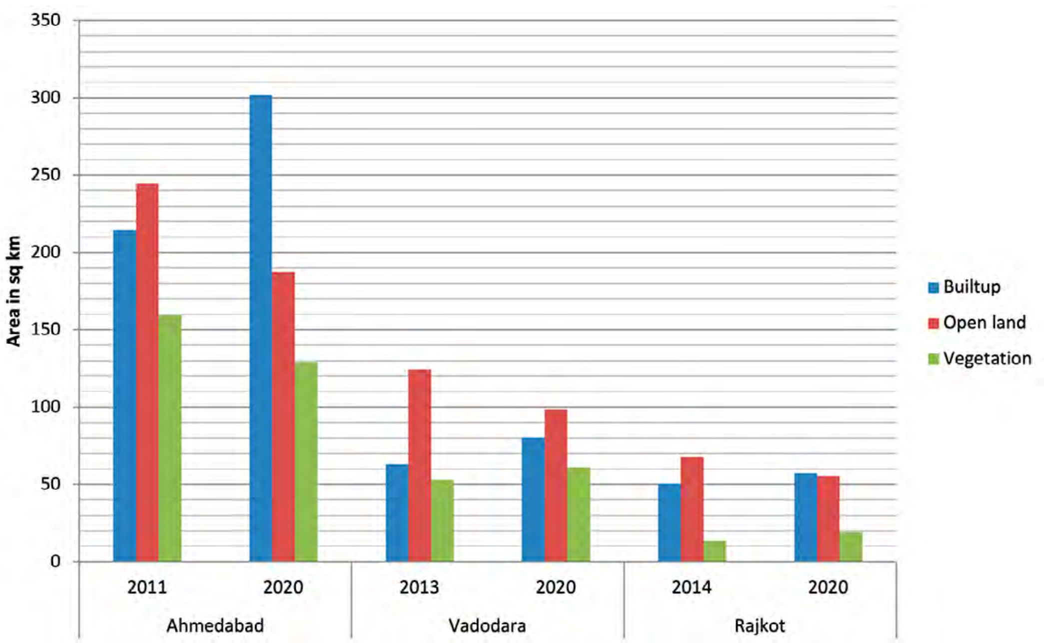

Figure 7. Area statistic graph of three data sets

The change detection comparisons of the Ahmedabad, Vadodara, and Rajkot data sets are shown in Tables 9, 10, and 11 respectively. These tables show the area obtained for Built-up, Vegetation, and Open land classes using object based DT, RF, ETC, ABRFC, and ABETC algorithms. The change detection comparison graphs of the Ahmedabad, Vadodara, and Rajkot cities using these algorithms are revealed in Figure 8, Figure 9, and Figure 10 respectively. The enlargement of the built-up class and decrease in the open land class can be visualized for all these algorithms from these graphs.

Tables 2 to 5 have mentioned the various accuracy statistics and comparison of five object based classifi-

Table 9. Change detection comparison for Ahmedabad data set (Area in sq. km.)

Classes	DT		RF		ETC		ABRFC		ABETC	
	2011	2020	2011	2020	2011	2020	2011	2020	2011	2020
Built-up	205.91	308.64	225.4	295.47	214.96	294.09	223.68	313.81	214.4	301.79
Vegetation	144.21	124.3	155.35	132.67	161.64	137.16	154.6	126.42	159.52	129.26
Open land	268.32	185.5	237.69	190.3	241.84	187.19	240.16	178.21	244.52	187.39
Total	618.44	618.44	618.44	618.44	618.44	618.44	618.44	618.44	618.44	618.44

Table 10. Change detection comparison for Vadodara data set (Area in sq. km.)

Classes	DT		RF		ETC		ABRFC		ABETC	
	2011	2020	2011	2020	2011	2020	2011	2020	2011	2020
Built-up	68.67	82.9	65.23	81.95	63.85	81.37	62.58	80.96	63.26	80.5
Vegetation	45.1	56.94	53.41	57.15	53.99	60.7	51.14	57.13	52.72	61.16
Open land	126.58	100.51	121.71	101.25	122.5	98.29	126.63	102.26	124.37	98.69
Total	240.35	240.35	240.35	240.35	240.34	240.36	240.35	240.35	240.35	240.35

Table 11. Change detection comparison for Rajkot data set (Area in sq. km.)

Classes	DT		RF		ETC		ABRFC		ABETC	
	2011	2020	2011	2020	2011	2020	2011	2020	2011	2020
Built-up	50.79	54.13	51.17	53.97	51.38	56.94	50.71	56.47	50.42	57.21
Vegetation	12.37	18.93	13.22	18.85	13.28	19.67	13.02	19.65	13.53	19.05
Open land	68.58	58.68	67.35	58.91	67.08	55.13	68.01	55.62	67.79	55.48
Total	131.74	131.74	131.74	131.73	131.74	131.74	131.74	131.74	131.74	131.74

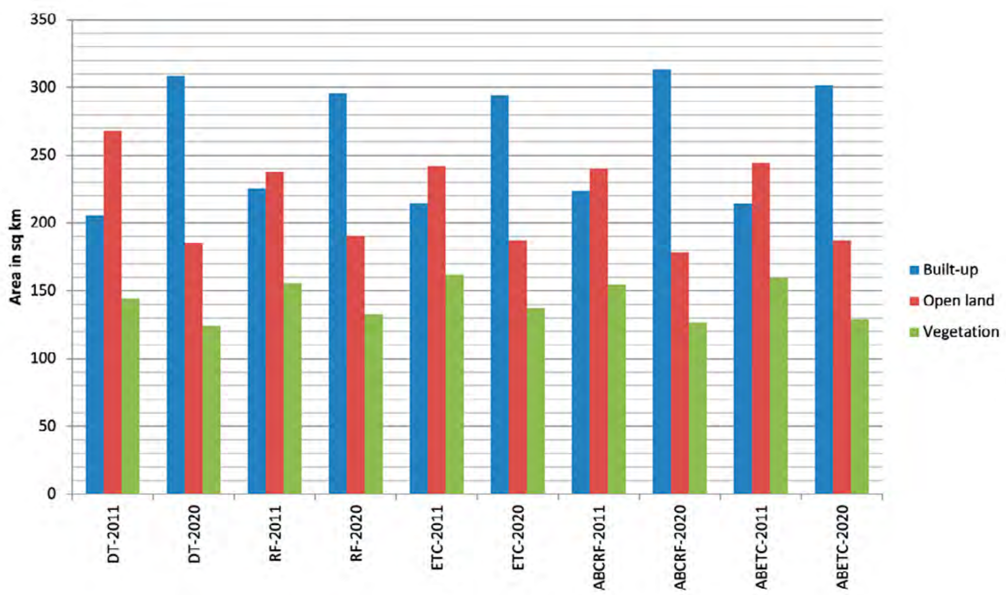

Figure 8. Area comparison graph of Ahmedabad data sets

er algorithms for the Ahmedabad, Vadodara, and Rajkot data sets. The object based integrated AdaBoosted extra trees classifier (ABETC) has demonstrated the highest performance in terms of OA and KC for all the data sets. The results of this highly efficient classifier were used for change detection analysis (Table 6-8) and change map generation. The rise in a built-up area for Ahmedabad was found higher compared to the Vadodara and Rajkot data set with a significant fall off of vegetation class.

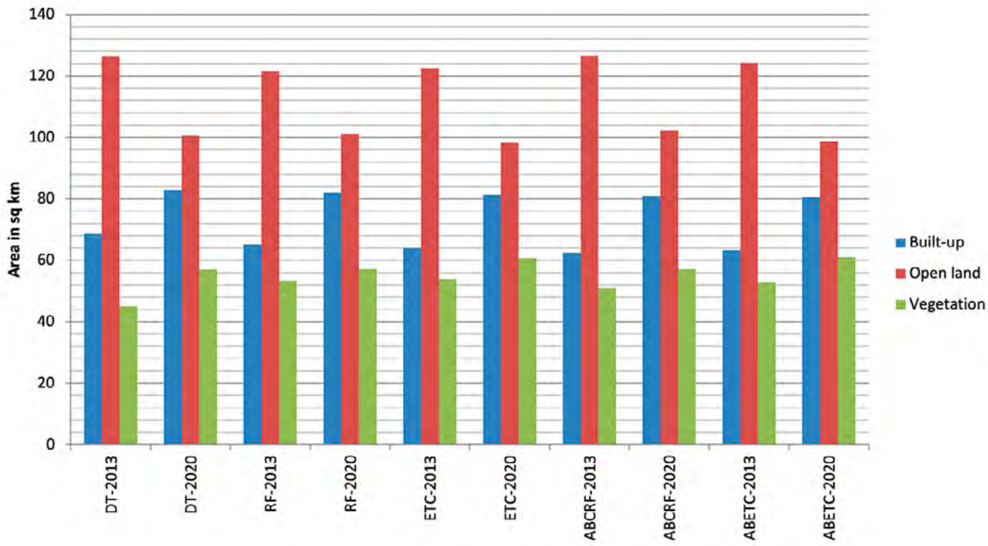

Figure 9. Area comparison graph of Vadodara data sets

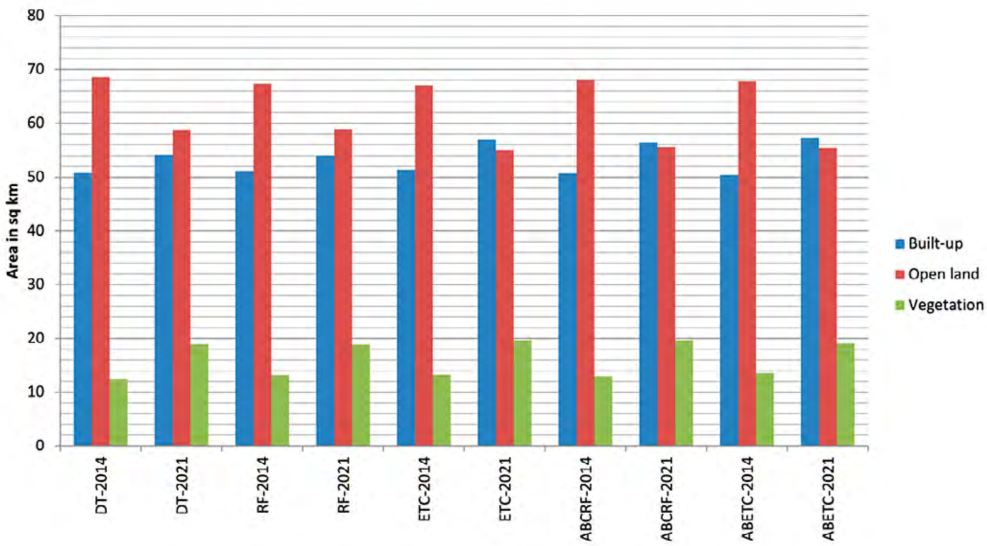

Figure 10. Area comparison graph of Rajkot data sets

Conclusion

In the past few years, the migration of people from rural to urban areas has increased in the fast-developing state of Gujarat. So, speedy and perfect planning of infrastructure development and its implementation considering the upcoming future environmental issues is very necessary. In this paper, a novel OBCD technique is presented by consolidating the multi-class AdaBoost SAMME algorithm and the extra trees ensemble method with the Shepherd algorithm as a segmentation step. The accuracy statistics of object based ABETC classifiers were compared with object based DT, RF, ETC, and ABRFC by measuring OA and KC. This comparative analysis was carried out with Ahmedabad, Vadodara, and Rajkot data sets. The object based ABETC has illustrated the most accurate results concerning classification accuracy with a kappa coefficient of 0.94 for the Vadodara data set. The change detection statistics and built-up change map were generated from classified images of object based ABETC classifiers. A rise of 40.76% in the built-up area has been noted from the year 2011 to 2020 for Ahmedabad with a remarkable decline in vegetation area. In the last seven years, a 27.25% increase in the built-up area of Vadodara and 13.47% growth in the built-up class of Rajkot have been measured. The expansion of the built-up class shows the growth of urbanization in the city area. For future investigation of micro details of the urban area, ultra high resolution images with more bands and focused on some specific part of the city may be used.

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Declaration

Conflict of interest: The authors declare that they have no conflict of interest.

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The Competition Between Discount Stores and COOP in Northern Hungary: A Case Study

Tamás Sikos T.[A], Csaba József Kovács[B*]

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Abstract

In the past decades, the expansion policy of hard discounters is receiving increasing scientific attention. One of the main reasons of their success is location choices, which needs geographical thinking and knowledge of socio-economic environment. Although it has key importance to gain high purchase power territories in this competition, each company have to implement their own geo-strategy. While discount stores are operating in the town, national franchise small stores have an extensive network in the rural area. This paper is a case study which deals with competition of hard discounters and Coop in Northern Hungary.

Keywords: discount chains; retail; Aldi; Lidl; small store; Coop; territorial competition

Introduction

The fast expansion of discounters all over the world significantly shifted market power structures, and in the span of a few years, changed the entire structure of the small retailer business sector. This is the most notable reason for how discounters became more of a focus of professional interest in recent years (e.g. Skordili, 2013; Jürgens, 2014; Hajdú, 2017; Chenarides et al., 2021). In Visegrád countries, notable market share acquisition was achieved by the discounters in recent decades. Market shares within small retailer business markets owned by discounters was 37% in Poland, 30% in Hungary, 26% in the Czech Republic, and 19% in Slovakia in 2020. The increase of 9 percentage points in Hungary, and 7 percentage points in Poland between 2017 and 2020 achieved by discounters also counts as a regional record (Zsubori, 2021).

The number of studies conducted on the analysis of retail networks at regional or local level is relatively few in East-Central Europe, but there has been a revival of interest in this research field in recent times (e.g. Sikos, 2018; Križan et al., 2022; Trembošová et al., 2022). The territorial analysis of retail store networks is particularly important in the current crisis period, as food security has become one of the most important sustainability challenges of our time. Grocery retail chains are play an essential role in this topic area (Sikos, 2019). Our research aims to fill this gap and to study supply chain issues at regional level. This study analyses the retail store network and market power structure related to foreign discounter expansion in the Northern Hungary region. The data used in the study came from internet data collection, official statistical databases, literature sources, and scientific works. Further data was collected from widely acclaimed internet business news portals. Among the hard discounters, Aldi, Lidl and Penny Market operate in the region. These chains were compared with the Coop chain in this study. The reason our choice fell on the Coop retailers' cooperative chain is that this is the cooperative system that has the most ex-

[A] Faculty of Economics, University of Miskolc, H-3515 Miskolc-Egyetemváros, Miskolc, Hungary; sikos.t.tamas@uni-miskolc.hu, ORCID: https://orcid.org/0000-0002-1650-5084
[B] Food Chain Research Department, Institute of Agricultural Economics, H-1093 Zsil u. 3-5., Budapest, Hungary; kovacs.csaba@aki.gov.hu, ORCID: https://orcid.org/0000-0002-8061-5835
[*] Corresponding author: Csaba József Kovács; e-mail: kovacs.csaba@aki.gov.hu

pansive chain of retail stores, ran by the biggest employee fleet both in Hungary, and the Northern Hungary region (Sikos, 2022). Northern Hungary offered a sufficient sampling area because the hierarchy of settlements includes almost all the existing variations of settlements, in a rather large sample size within this region. Another important perspective during the choice of sampling area was that the size of settlements in most of the region don't reach the limit of economising regarding size which make the operations of modern discounting forms sustainable. Discounters always aim to maximise cost efficiency in any elements of enterprise operation, therefore, they can offer the lowest prices on the market to their consumers. In practice, the backbone of their competitive strategy is made up of low prices (Azeem & Sharma, 2012). Hungarian business chains that mostly have small retailers, and smaller-scale supermarkets only have a chance of staying in competition, and keeping their consumer base on niche markets, in a price-sensitive consumer market like Hungary. The research study of Publicis Groupe shows the current economic crisis has made consumers even more price-sensitive, which has affected Hungarian retailers the most in the Visegrád Group (Piac & Profit, 2022).

However, when looking at the entirety of Europe, another general tendency is that discounters are focusing on elements which weren't a part of the discounting model before more and more recently. There are a multitude of good examples for this, like open-view bakeries in stores (Foottit, 2014), expanding the product palette (Paul, 2016) or the expanding towards online foodstuffs purchase (Borland, 2019). The COVID-19 pandemic also made discounters feel the necessity to move, which made discounters increase their pace in developing online delivery services (Toua, 2020). Aldi and Lidl discounters can be considered even more flexible, as if needed, they are even willing to deviate from the discounter form as well. The Aldi Local in London, while the Lidl Express in Arlington (USA) offered localised aid for the problems of urban expansion. These discounters are only half the size of their normal discount store sizes, however, the choice of products is almost double that of a hard discounter. Though official communication deems this a one-time solution, and not the tendency of moving towards the comfort stores, they can be considered a precedent regardless (Tisza, 2019).

The other factor of their successes is the great marketing strategy, which includes the efficient market and competition strategy positioned for the discounter's own characteristics following Porter's typology (1985), where division strategies used by enterprises can be sorted into three distinct categories. An enterprise may be doing a cost leadership (no frills) strategy, a differentiation (unique products and services-based) strategy, or a focus (specialised products and services) strategy. While the two former strategies can be followed for separate segments at the same time, the point of the focus strategy is to select a specific target area of the market (usually a niche) to compete in. However, segmentation doesn't necessarily happen based on the types of consumers, it may also be for example a specific geographic location. In their title "Marketing war", Ries and Trout (1986) discuss the enterprises' competitive strategies based on their specific positions on the market. They differentiate between those that dominate the market, that increase market share, that aim for profitable survival, and that aim for survival. These can conduct defensive strategy, offensive strategy, flanking, or guerrilla warfare. In their book "Blue Ocean Strategy", Kim and Mauborgne (2005) argue that there are two types of markets in general, which are saturated markets, where only extreme competition may bring success to an enterprise (red oceans), and new, untouched areas of market competition (blue oceans), where due to the lack of rivals, quick and easy growth is possible for enterprises.

The literature sources specifically dealing with market strategy of small retailer business is extremely rich in material (Walters & Knee, 1989; Kent & Omar, 2003; Seth & Randall, 2005; Morschett et al., 2006; Klemz et al., 2008; Watson, 2011; Yang et al., 2017 etc.). This is understandable, as enterprise strategy's importance is something that's ever-present, especially in small retailer business, since the business chains have to conduct extreme market competition for the customers on the developed countries' saturated markets. We may want to highlight some of the works at hand on the topic, relating to our specific area of research. The study of Colla (2003), which deals with the expansion of discounters and the market competition strategies used. Schmid et al. (2018) introduce the expansion strategies of the discounters Aldi and Lidl. Hökelekli et al. (2017) and Knudson and Vu (2017) research the market defence possibilities successfully applicable to traditional small retailer business actors in their studies. Another notable source is Cleeren et al. (2009)'s research results, who concluded that competition within groups made up of the specific forms of stores is more intense than the competition between stores operating in different forms. Gonzáles-Benito (2003) researched the competition between different forms of stores. The results of empirical research showed that in an urban environment, the presence of discounters had a greater effect on hypermarkets than other small retailer business forms. However, most of the stores in retailers' cooperative can be found in rural areas, where these modern store forms can't operate in financial efficiency. As such, this size level of settlement may offer a niche market for Coop stores (Sikos, 2019).

Following the Regime Change, the East-Central Europe region was easily conquerable for foreign discounters, and was considered a desirable market for them. Though consumer purchase power in the countries of the region was weaker than in countries that have better income levels, discounters used their advantage in strength to quickly obtain an advantageous market position, thereby obtaining a larger market share. These markets lacked modern chain stores that have a national network, which were mostly present in Western Europe at the time. This is one of the reasons why the market concentration in the countries of East-Central Europe was much lower post-Regime Change, than in most Western Europe countries. Even today, market concentration doesn't reach the levels considered normal for Western Europe's countries (Pénzes & Pólya, 2018). The economic performance of chain stores operating in the discounter form is supported by efficient enterprise headquarters, organised management, logistics and sales even in these countries.

The disadvantage of Hungarian chains comes from their lack of geographic cohesion, the differing value systems of owner circles, and that the oversized organisation determining the strategy of chains comes from differing interests. In the case of domestic cooperative chains, though we can consider them extensive based on number of stores, the notable majority of members only have individual small retailers even today. The development of the store chain wasn't done based on a strategy of specified choice of establishment location, but it was fundamentally a spontaneous result. Furthermore, significant hardships and competition disadvantages come from how cooperation doesn't expand to the entirety of the cooperative, but only for certain partial areas. This results in an extremely de-centralised enterprise management different for each store, which makes building a coherent cooperative strategy very hard. Hungarian store chains working in franchise systems (Coop, CBA, Reál) can't compete with larger international chains either in prices or in product palette (Mayer & Bakshandey, 2015). This is one of the reasons the market concentration shows a gradually increasing trend in Hungary. However, despite all hardships, the fact that Hungarian chains could survive and remained an important part in the Hungarian foodstuffs sector as opposed to several other countries of the region should be considered a tale of success (Kopcsay, 2014).

State of discounters on the Hungarian market

We continued our research by going over the most notable stops of multi-national discounters and the analysis of their current market positions. Penny Market was the first hard discounter in the Hungarian market during its entry in 1997, which also offered a significant market position. Competitors Lidl and Aldi opened their first Hungarian stores in 2004 and 2008 respectively. Soft discounters (Plus, Profi and Jééé) counted as competitors within the segment until the early 2010s. Nowadays, however, none of the latter are present in the domestic foodstuffs retail trade, their stores were bought out by rivals.

In Hungary, food and foodstuffs mixed store forms produced 55% of the small retail business trade in 2021. Total annual balance was 18,2 billion Euros[1] (HCSO, 2021).

Below is a comprehensive figure showing changes in processes based on distribution channel (Figure 1).

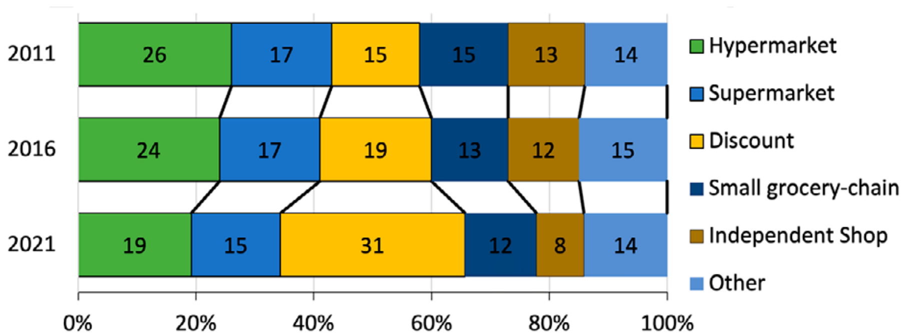

Figure 1. Distribution of sales channels in Hungary, 2011-2021
Source: self-made, based on GfK Hungária (household panel) data

[1] The average of the minimum and maximum values of the 2021 median price value of the National Bank of Hungary (1 Euro = 358,5 HUF) was used as a basis. According to the HCSO's data report, the food and foodstuffs mixed category produced 6532 billion HUF in 2021.

Table 1. The most important features of food supply chains in FMCG sector, 2020

CHAIN	FORM	No. of stores	Gross income (million EUR)	Average gross income per store (million EUR)	FMCG rank
Tesco	Hypermarket	201	2043	10,2	2.
Spar	Supermarket	588	2024	3,4	3.
Lidl	Discounter	186	2282	12,3	1.
Aldi		147	978	6,7	9.
Penny Market		226	1021	4,5	8.
Reál	Small retailer business	1189	1172	1	6.
CBA		1987	1484	0,7	5.
Coop		4063	1791	0,4	4.

Source: Self-made, based on Trade Magazin FMCG Toplists

In the main timeframe of hard discounter expansion, the last ten years brought significant structural changes in the foodstuffs small retailer business sector (Figure 2). The share of the hypermarket channel, leading in 2011 showed a decrease, and lost its leading position by today. Small chains also lost out in this timeframe, decreasing their market share from 15% to 12% by 2021. At the same time, the discounter channel achieved significant growth, partly by opening new stores, and in many cases, by buying out rivalling store chains. The state of independent small retailer stores is the least advantageous out of all the competitors, as they're threatened by being totally crippled within the sector. They don't have enough competitive edge compared to chain stores. A part of the small retailer store owners joined a cooperative during the timeframe in question, while another part of them had to terminate business completely. These processes are shown in the drastic, 13% drop in independent small retailers' market share.

Though recent decades showed a tendency of distribution channels increasingly blending together in the case of chain stores, we can still identify some larger actors behind the various forms of retailer business, who were capable of controlling the changes in the market structure. Therefore, enterprises' competitive positions which have a chain in the Northern Hungary region are also worthy of a short overview. During the analysis, we compared Tesco hypermarket-chain, Spar supermarket-chain, three German-owned discounters (Lidl, Aldi, Penny Market) and Hungarian retailers' cooperative chains (Coop, CBA, Reál) (Table 1).

The domestic FMCG sector is highly concentrated, the three biggest chains produced almost half (44,4%) of the ten biggest FMCG chains' total income in 2020. Based on the total gross income, the biggest actor in the Hungarian market is Lidl (2282 million EUR), which is followed by Tesco (2043 million EUR) and Spar (2024 million EUR). None of the small retailer businesses even come close to these values. The efficiency of the discounter model is supported by the differing values of income on average for one store by retailed form as well. Using the 2020 data of the Trade Magazine, we can conclude the following: average gross income annually was 12,3 million EUR for Lidl, 6,7 million EUR for Aldi, and 4,5 million EUR for Penny Market. On the contrary, the efficiency of domestic chains is significantly lower. Reál, CBA and COOP only had between 0,4 and 1 million EUR income on average per store. Data clearly shows that from the perspective of efficiency, Lidl is the best in the FMCG sector, which can produce up to 30 times the income of the Hungarian chains in a year.

Discount chains achieved their extreme business values with merely 559 store units, while Hungarian small retailer chains produced their much more modest gross annual income average with 4447 store units. We could say that while discount chains collect the Pounds, domestic chains are vying for the Pennies. One reason for this is the centralised enterprise management and more efficient operations already mentioned, while other is the larger store form, which has an overall better income production capacity. It is similarly important to note that this is exactly the reason discounter chains and supermarkets generally aim for the higher ranks of settlement hierarchy, in towns. Foreign store chains draw in customers from neighbouring settlements that have a larger population and better purchasing strength. Small settlements with low consumer purchasing strength are generally not notable enough to have a larger store present. These have been gradually left behind, due to the domestic store chains having their store networks all over the place, and their stores operating much less efficiently. In spite of this, even their profitability by unit could increase in the last five years (ie. the Trade Magazine's FMCG Toplists). Partially due to the advantageous economic position, and partly due to the rationalisation of the number of stores.

Despite their alleged profitable operations, Hungarian small retailer chains had to face a significant loss in market share compared to discounters. Nowadays, they only have a chance at competing on niche markets where discounters can't establish a presence, mainly due to their size and operational model. Hungarian chains should expect further reduction in their market shares still, but they still have decent chances of winning their battle for survival with their coherent business policy.

Discounter chains in Northern Hungary

Location and catchment area of foodstuffs retailers

The number of stores belonging to hard discounter chains (Aldi, Lidl, Penny Market) have been increasing steadily in recent years. During the year 2020, Northern Hungary already had 46 foodstuffs discounters in operation, which were all established in towns (Table 2). Discounter presence by county is highly differentiated, which is related to the economic development of the various counties, and their income generation capability. Penny Market owns 52.2% of the region's discounter stores, followed by 37% owned by Lidl, and 10.9% owned by Aldi, which is the smallest segment of the market. The shares by county also show significant differences. For example, in Borsod-Abaúj-Zemplén County, 54,2% of the discounters are Penny Markets, followed by Lidl and Aldi. The increase in strength and rapid expansion of foodstuffs discounters within the foodstuffs small retailer business sector in Northern Hungary are inhibited by two factors. One is the location of logistics centres outside the region (the closest one for Aldi is in Biatorbágy, Szigetszentmiklós for Lidl, and Karcag for Penny Market), whereas the problem of optimal operations of a store, which we could describe by saying the region's purchasing power index is extremely low.

Table 2. Distribution of discounter stores by county, 2022

County	Aldi	Lidl	Penny Market	Total
Borsod-Abaúj-Zemplén	4	9	13	26
Heves	1	5	6	12
Nógrád	0	3	5	8
Total	5	17	24	46

Source: webpages of the discounters

Though we can assess the return of a store annually for each actor on the market based on market information we possess, which, in turn, can be used to assess the actors' efficiency, we can't use these to estimate returns for each individual store. However, we consider it important to estimate the returns of various stores, or at least, their generation of consumer interest. However, there are no public business data available to support this. Therefore, we decided that we would try and approach the interest in various stores indirectly. To achieve this, we used the number of Google evaluations for stores in various settlements. We understand that this estimation will not give a precise understanding, but we may be able to better establish our estimation of the stores' efficiency, likeability and consumer interest (Figure 2). We obtained the evaluation score of the stores by collecting the last quarter's evaluations from Google's system for the specific store units, and aimed to categorise the discounter stores using this. Based on our results obtained, we conclude that in towns, where the Lidl chain is present, it is the most liked one as well. It's much more liked than the second placer Penny Market. Aldi's likeability in the Northern Hungary region is hard to measure, as there are only four stores in the specific region (Hatvan, Miskolc, Kazincbarcika and Sátoraljaújhely). Note that the strategy of choosing locations for stores that Aldi uses is uncommon, as they focus on Budapest, and follow their competitors, meaning they have a habit of placing new stores near other chains' hypermarkets or supermarkets, or discounters, in order to drain some of their customers.

Discounters can be found in either county seats or towns. However, we can also observe significant differences between settlements on the same level of the settlement hierarchy. While Hatvan, Eger, Kazincbarcika and Sátoraljaújhely all house three discounters, Miskolc has eight, while the rest of the locations are in mid- and small towns. Among the counties of the Northern Hungary region, and within their specific partial locations' areal borders, there are very notable inequalities in the structure of the chain store systems. About two-thirds of Borsod-Abaúj-Zemplén county has a lack of discounters, and the situation isn't much better in Nógrád county either, as they also need to deal with both the small number of stores, and similarly to Borsod-Abaúj-Zemplén county, areas with a complete lack of stores. Of the 610 settlements of the region, only 22 has discounters, and Penny Market's share is the largest in the area. The majority of the discounters are located near main travel routes, and most of the consumer purchasing strength is concentrated here as well. Therefore, it's no surprise that the discounter stores are found in more populated towns and near main roads (M3 motorway: Hatvan, Gyöngyös, Miskolc; near the main road 37: Miskolc, Szerencs, Sárospatak; near the main

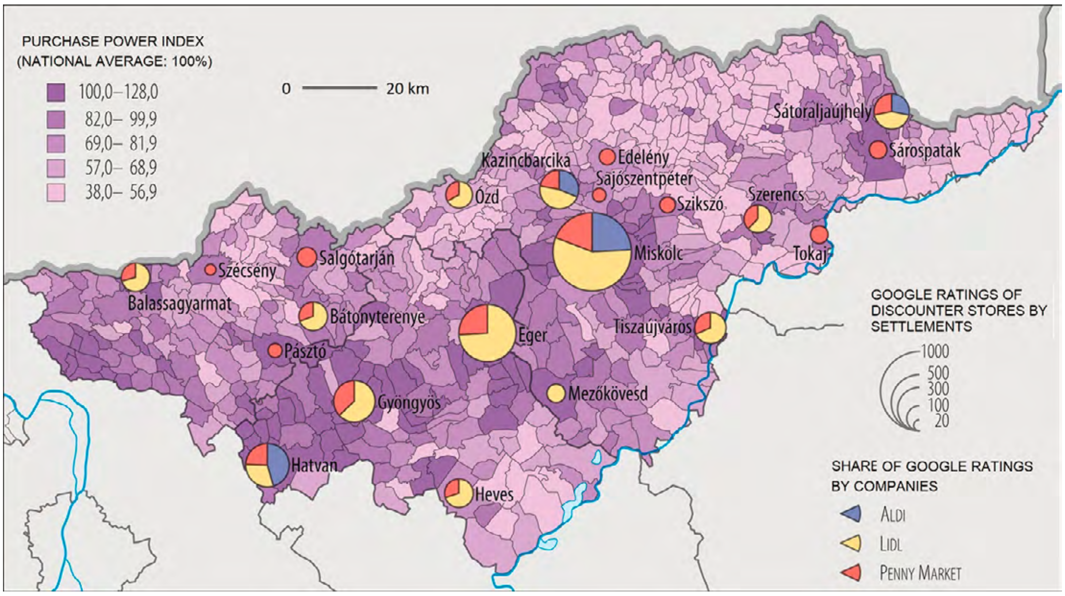

Figure 2. Discounter stores by number of Google ratings (Q3 2019*) and Purchase Power Index (2019)
Source: own research, drawn by Fanni Koczó

** Penny Market in Füzesabony and Lidl in Salgótarján were not included in the survey, because they opened their stores in these cities after 2019. The size of the pie chart increases with the total number of Google reviews among discounter retail companies. Pie charts represent the proportion of ratings given by the customers in each city in the third quarter of 2019 as well*

road 21: Hatvan, Pásztó, Bátonyterenye, Salgótarján; near the main road 25: Eger; near the main road 26: Miskolc, Sajószentpéter, Kazincbarcika, Ózd). In order to operate discounter stores optimally, a population of about fifteen- to twenty-thousand is necessary, or a settlement of lower population that reaches this criterion with the addition of agglomeration population. The optimal size of business can be reached by discounters at their units established near the main roads. During the choice of location to establish new stores, areas with lower consumer purchase strength are automatically ignored.

Approachability of discounters

The choice of locations to establish new stores is a highly complex issue, which only considers consumer purchase strength index and its analysis by location one of the necessary factors, whereas there are several similarly important factors, like the location of competitors, the reachability of settlements, local legal environment, and other such factors increasing the consumer interest in said stores. Most of the consumers will choose the shortest route to reach a discounter, if there are no stores in the near proximity. According to our research, the average approachability of discounter stores is somewhere between twenty-five and thirty minutes. Naturally, even from areas further away, these stores are frequented, however, beyond the thirty-minute threshold, the frequency of visits decreases significantly, unless the travel to the town is paired with going to work (Figure 3). Discounters mainly focus on towns, and their ten-kilometre agglomerations cover their catchment areas fundamentally, which is why a significant share of the rural areas rarely ever obtain their products. The Central Cserhát Area of the Northern Hungary region, and the small villages that make up the Borsod-Abaúj-Zemplén county's so-called "waning moon"[2] area have the most notable lack of stores. A significant share of settlements remained without support, which made the connection of these areas to the labour market weaken, further reducing the income production capability of these areas sink into uncertainty. This all resulted in the tightening of the bottleneck of basic supply and transport options in the area. These areas were heavily impacted during earlier decades – "active" age people moved away, while elderly didn't have sufficient reserves. We can also observe an increase in population in these areas, mainly due to the decrepit and devalued real estate, which caused the poor – most notably gypsies

[2] In the northern belt of the Borsod-Abaúj-Zemplén county, near the national border, from the southern border of the Ózd district, from Borsodnádasd to Hegyköz, until Sátoraljaújhely's townscape border, a coherent area of hamlets 20-35km wide, disadvantaged and bad natural attributes, disadvantageous traffic situation, quickly degrading and impacted by frantic migration issues bordering on hysterical escape (Beluszky, 2019).

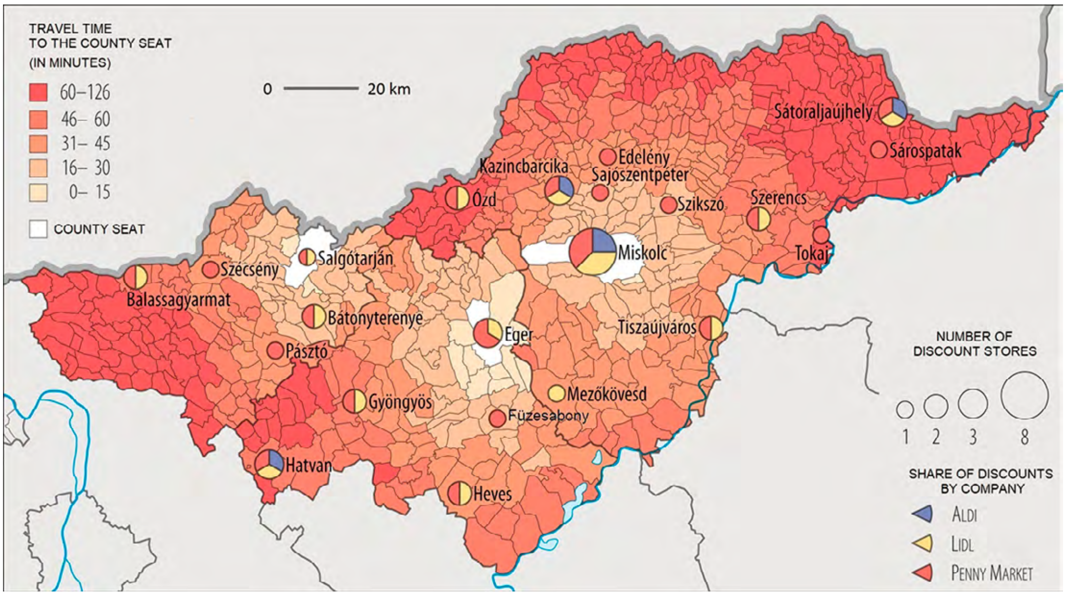

Figure 3. Accessibility and distribution of discounter stores, 2022
Source: own research, drawn by Fanni Koczó

– moving into the area. Based on the above, we can understand why discounters avoid these areas, as there's insufficient purchasing strength for their safe operations. However, from areas like this, even accessing discounts near is questionable (Figure 3).

Discounters can only be accessed within one to two hours of travel from 32,7% of the region's hamlets (193 settlements), and from forty-five minutes to up to one hour of travel from 23,9% (141 settlements). This time is significantly increased due to the frequency of mass transport lines. Nowadays, during the times of the COVID-19 pandemic, leaving these settlements becomes even more of an issue, since a notable number of people living in these areas who used to have work in towns or other settlements in the near region became unemployed. This also means that the bottleneck of employment and mobility for these areas become even tighter, at the same time as the availability of a higher level of trade supply becomes less prevalent. In these villages carrying the burden of "poorness", people are often less afraid of the pandemic, and more afraid of starvation. Only the Miskolc Campus joined the programme dubbed "Universities Fighting World Hunger"[3]) among Hungarian campuses. This is an initiative formed by the Auburn University in the United States in 2004, working together with the UN's World Food Programme. Data also shows that in highly disadvantaged areas, discounters are no longer present, as neither their operations can be sustained with sufficient economic security, nor reaching them from hamlets became any easier. This may open a niche for Coop ABC and Coop Mini stores.

Niches next to discounters

The legislation dubbed "stopping malls" fundamentally exists to improve the competitiveness of domestic store chains, as the "law on stopping malls" is basically equivalent to a "discounter stop", seeing how large investment projects to build trading centres basically froze during the 2009 financial and economic depression (f.e. Origo City, Neo Center, Mundo, Wedding Plaza etc.). Only projects which were impossible to freeze were completed (f.e. Corvin Plaza, KÖKI Terminál, Árkád2 etc.). These projects mainly concentrated in Budapest. At the same time, the "stopping malls" legislation stabilised the state of hypermarkets compared to discounters. German hard discounters on the foodstuffs small retailer business sector were hampered shortly in their dynamic growth due to the "stopping malls" legislation, this timeframe opened an opportunity for the development of domestic chains. This is how the opportunity of rethinking business opened up for Coop, and by changing their business strategy, they could find a niche, thereby impacting small stores (Table 3).

[3] The fundamental goal of UFWH is to work out and initiate an action plan for students and professors, which offer incentive for the community of the University to actively fight against starvation. The UFWH group of the Miskolc University works together with the Red Cross of Borsod-Abaúj-Zemplén county by collecting long-expiring foodstuffs for locals who starve, and need help from others. The enterprises in the foodstuffs small retailer business sector are also partners.

Table 3. Distribution of Coop stores by county, 2022

County	Coop Mini	Coop ABC	Coop Szuper	Total
Borsod-Abaúj-Zemplén	136	86	48	270
Heves	33	63	28	124
Nógrád	42	25	9	76
Total	211	174	85	470

Source: self-made, based on Coop webpage

In this new situation, Coop stores were the most successful in holding on in the categories for small villages and hamlets, via their Coop ABC and Coop Mini stores. These store forms make up 82% of Coop stores in the Northern Hungary region. The aim of the Coop ABC and Coop Mini stores operating in the ten-kilometre catchment area of discounts is to drain their customers, and increase their return (Figure 4). In some areas of the Northern Hungary region, Coop stores became market leaders: these are the Karacs Valley, the lower Bükk, the Bódva Valley, and the Bodrogköz. As these areas don't have a high consumer purchase power, discounter chains can't penetrate these markets while assuring sustainable economic activities. Nearly a quarter of the region's settlements were left completely unattended, and even independent small stores have trouble with surviving here. Supply in these areas has a scarce product palette, via the roaming store network, the village administrator system, and the movement of these areas' population via automobile traffic.

In the current study, we calculated the so-called penetration index (PEX) indicator for discounters (Aldi, Lidl, Penny Market) and Coop (Coop ABC, Coop Mini) in order to prove which level of the settlement hierarchy they can establish a presence in. Small retailer business research experiences until now showed that PEX analyses may offer assistance in identification of similarities and differences between store chains. The usage of the method helps with the identification of how many percentages of the sample consisting of different size category settlements have the presence of at least one small retailer business unit (Tiner, 2010). The analysis for penetration level was based on the similar analysis of Tibor Tiner (2019), conducted for seven settlement categories. Data summarized can be seen in Table 4.

We can see the following facts from the PEX value table:

- For settlements that have a population of over 10.000, all stores' PEX values are above 0.500 except Aldi. Penny Market has an especially pronounced presence even among these, which has a store in every one of them. Coop ABC and Lidl are not far behind. In this settlement category, Aldi is present with a relatively low value of 0.286. The reason for this is the scarce amount of shops. The population of the category's fourteen settlements, which makes up 2,3% of the total settlement amount, is 430.746.
- In settlements with a population of between five and ten thousand, Penny Market's dominance is still un-

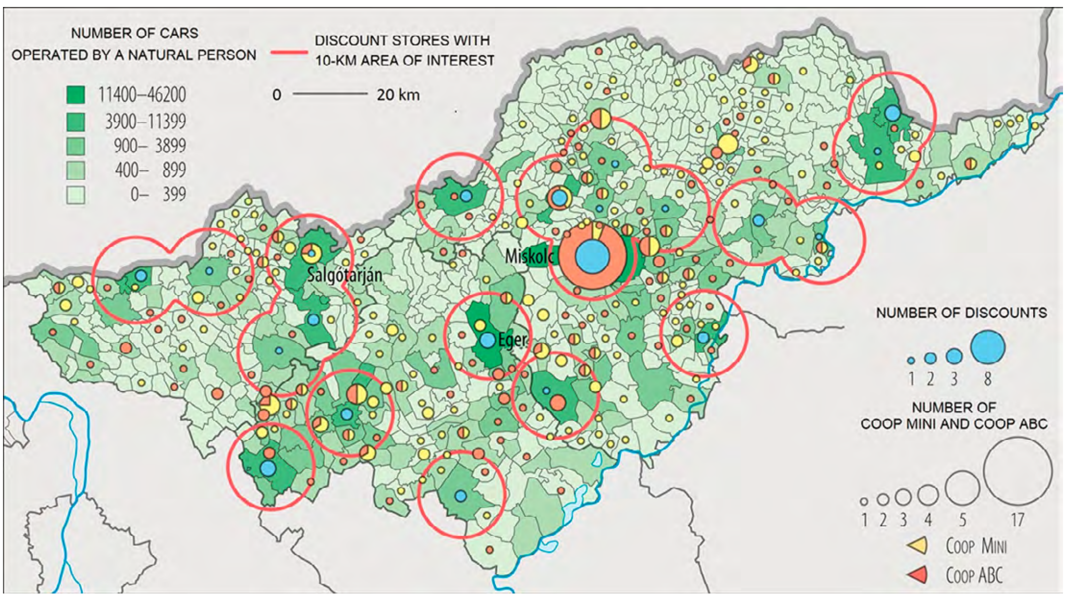

Figure 4. Distribution of discounters, Coop stores and car supply, 2020
Source: own research, drawn by Fanni Koczó

Table 4. Penetration Index of discounters and Coop stores by settlement size category, 2021

Population	Number of settlements	Aldi	Lidl	Penny Market	Coop ABC	Coop Mini
>10000	14	0,286	0,786	1,000	0,857	0,643
5000-10000	13	0,000	0,154	0,538	0,462	0,231
2000-5000	78	0,000	0,000	0,013	0,564	0,346
1000-2000	141	0,000	0,000	0,000	0,404	0,355
500-1000	153	0,000	0,000	0,000	0,111	0,366
200-500	140	0,000	0,000	0,000	0,007	0,264
200>	71	0,000	0,000	0,000	0,000	0,056

Source: self-made, based on the chains' webpages

questionable, with its 0.538 PEX value. They are followed by Coop ABC, with a PEX value of 0.462, further followed by Coop Mini with a PEX value of 0.154. Coop Mini, however, is significantly behind Coop ABC, as we can see. This category of settlements makes up 2,1% of the total in the region with 13 settlements, that have a population of 90.370.

- Settlements with two to five thousand population are ruled by Coop ABC with 0.564 PEX value, and Coop Mini with 0.346 value. Penny Market is also present with 0.013 PEX value, but their presence is negligible. The category is made up of 78 settlements, which amounts to 12.8% of the total, and has a population of 221.409.
- Discounters couldn't establish a presence in settlements with a one to two thousand population, only Coop ABC with a PEX value of 0.404, and Coop Mini with a PEX of 0.355 are on the market here. Note that in our study, we don't include the CBA stores[4] as their role on the market is negligible. The category consists of 141 settlements, making up 23.1% of the total. Coop ABC is present in 57 settlements, while Coop Mini is present in 50 settlements. A total of 117 small retailer business units operate in these settlements, which have a combined population of 204.189.
- In hamlets with 500 to 1000 population, Coop Mini is the dominant with a PEX value of 0.366. In this category, not even Coop ABC has a significant presence anymore. Note that Coop is the only chain which has a store in almost every second village. The category has 153 settlements, making up 25,1% of the total. The Coop stores supply a combined population of 112.411.
- In the category of settlements with a population of 200 to 500, Coop Mini's 0.276 PEX value once again offers it market leadership, while Coop ABC and its 0.007 PEX value is more symbolic. The latter only has a single store in the category consisting of 140 settlements, which amounts to 23% of the total. The combined population is 45.779.
- In settlements below 200 population, only Coop Mini can establish a meagre presence. Coop Mini stores have a PEX value of 0.056 here, which suggests that one out of every seventeen to eighteen settlements are capable of sustaining a store. The significant majority of the category doesn't have any foodstuffs small retailer business. The population of the category is 7.359, shared across 71 settlements, which makes up 11.6% of the total.

We can derive notable conclusions from the summary of PEX index values conducted for the various store chains (Figure 5).

Based on Figure 5, we can conclude that Coop ABC and Coop Mini stores have a significant role in the entirety of the foodstuff's small retailer business network, and a similarly significant presence in all categories of the Northern Hungary region's settlement hierarchy. They also have a dominant role in the category of population below 5000. The Coop store chain has an important role in supplying hamlets, but in the settlements that have less than 200 population, their presence and importance basically shrinks to the level of the locals, as the profits of the store are scarce compared to their stores established in mid-sized or larger settlements.

[4] Based on CBA's webpage, the total number of stores in 2022: four in Nógrád, two in Heves, and none in Borsod-Abaúj-Zemplén counties respectively.

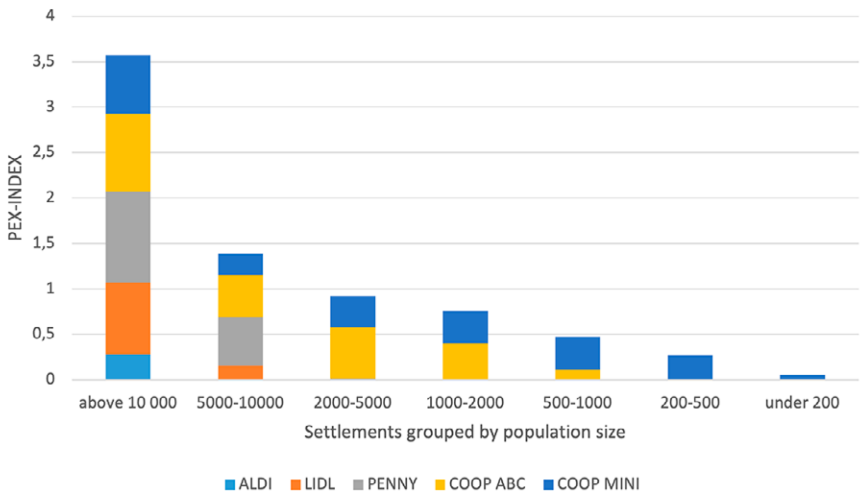

Figure 5. Penetration Index of FMCG Companies by settlement size category, 2019
Source: own research

Conclusion

Discounters have become a key element of the regional food supply chains with their low product prices and relatively wide product range. Despite their extensive network of discounters, they don't have a catchment area the all levels of municipalities. The size of the settlement and the purchasing power constraints were evident in the model region under study. Obstacles to entry caused by the size of the settlement and the purchasing power is also well documented in our study region. These market access barriers increase the importance of co-operative retail stores at lower territorial levels in a sustainable shop network. It is not economically feasible to operate a shop in the smallest settlements, therefore public assistance is needed in these areas.

Features of the retail store network and territorial obstacles were identified in the model region that hinder the development of a sustainable retail network at local level. The short summary of our research is as follows:

- Discounters dominate in the settlements of 10.000 population or above in the Northern Hungary region, their expansion wasn't significantly hampered by the "stopping malls" legislation. Retailers' cooperatives cannot compete with discounters in terms of prices and product selection. Although, increasing the proportion of local foods in the product mix could be an effective competitive strategy for them.
- Out of all discounter chains, Penny Market has the most significant network of stores, their role is most definitive in Borsod-Abaúj-Zemplén county.
- The most dynamic enterprise among the targets of the analysis, and the most profitable one as well was Lidl, their return on average for a store is over 12.3 million EUR.
- Coop stores are present in almost all segments of the settlement structure, but in the category with a population below 200, they are more about helping sustain the local society than realising profits. Coop's profits are produced in larger settlements.
- Most of the member of retailers' cooperatives are located in rural areas where discounters cannot operate economically, and so this level of settlement is a potential niche market for them.
- Cooperation of Coop members does not cover the whole organisation, but only parts of it. It results in highly decentralised corporate management systems, which varies from business to business. These features make difficult for retailers' cooperatives to develop a coherent cooperative geo-strategy.
- Law on "stopping malls" helped reposition the Coop network, and changing their business structure, which necessitated a paradigm shift in the thought process of the management.
- The supply of settlements belonging to the "waning moon" of Borsod-Abaúj-Zemplén is scarce. In this category, even Coop stores have hardships with survival. The fundamental supply of small villages is almost entirely inexistent, village stores can somewhat help here, but due to low purchasing power, even sustaining these is questionable.
- Mobile stores help sustain these small villages, but their presence may impact still operational stores even more.

However, this research has only covered a small slice of the role of retail networks in food safety. Further research is needed to understand the recent issue in more detail. Future research directions could focus on how retail networks contribute to social innovation, security of supply or environmental sustainability at local level. An other important research question is the role of discounts in the UN AGENDA 2030 sustainability goals.

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Introducing Greenswales: a Nature-based Approach to Preserve Seasonal Channels – Learnings from Chandigarh, India

Ankita Sood[A*], Arindam Biswas[A]

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Abstract

For long, the cities depended on grey infrastructure for draining stormwater. However, incidences of pluvial flooding are increasing, and existing grey infrastructure is unable to take up the additional stormwater load. Consequently, planners are forced to think of new and sustainable alternatives for stormwater management. Natural channels can supplement the stormwater drainage systems, but these channels in cities are reclaimed to provide land for housing and other functions despite their crucial role. This study presents the case of a natural channel in Chandigarh (India) that is redeveloped as a greenspace without compromising its function of stormwater conveyance. We analytically discussed the non-intentional preservation of this seasonal natural channel and introduced a new term, greenswales, for similar arrangements. A greenswale is defined as the stretch of greenspaces laid over a natural channel, ephemeral or intermittent, having stormwater detention and conveyance as primary functions during precipitation. This study's significant finding is that the seasonal natural channels in a city can be safeguarded through the judicious superimposition of green spaces over them. Crucial lessons from this case can guide new developments in utilising natural seasonal channels as a nature-based solution for stormwater management, reducing the load on grey infrastructure and providing the city with a greenspace.

Keywords: greenswales; pluvial flooding; natural channels; nature-based solutions; stormwater management; urban streams

Introduction

Today cities are more vulnerable to pluvial flooding than ever (Miller & Hutchins, 2017), which is an urban water logging issue arising from the limited drainage after precipitation (Hammond, Chen, Djordjević, Butler, & Mark, 2015). Cities inherently generate about five times more runoff than a forest of the same size due to their high impermeability (EPA, 2010b; Khaladkar, Mahajan, & Kulkarni, 2009). Additionally, rainfall intensity is increasing worldwide, governed by climate change scenarios that cause more runoff in even short rainfall spells (IPCC, 2014). These two factors of high impermeability and climate change, are causing increased runoff volume in urban areas. Most cities are struggling to manage this additional load of surface runoff and hence face pluvial floods (Prokić et al., 2019; Savić et al., 2020).

The last century witnessed a complete dependence on grey infrastructure for stormwater management, which comprises pipes, culverts and pumps. Most of which are now proving undersized to take up the entire runoff volume (Huong & Pathirana, 2013; Miller & Hutchins, 2017; Zhou, 2014). It is an eye-open-

[A] Department of Architecture and Planning, Indian Institute of Technology Roorkee, India, 247667
[*] Corresponding author: Ankita Sood; e-mail: asood@ar.iitr.ac.in

er for new developments to design infrastructure with higher capacity than their current requirement, keeping in mind the future climate change scenarios. However, laying monofunctional grey infrastructure is unsustainable and cost-intensive (Pitman, Daniels, & Ely, 2015; U.S. Environmental Protection Agency, 2014; Zhou, 2014). Moreover, it is now proven that the fundamental approach of grey infrastructure to take stormwater immediately away from the city as waste causes problems like downstream flooding and groundwater depletion. So, this conundrum of the 21st century is forcing planners to find alternatives for managing stormwater in cities. Nature-based soultions (NbS), that weave natural features or processes into the built environment, have emerged as a sustainable solution to various urban issues stormwater management and pluvial flood mitigation (Anderson et al., 2022; Langergraber, Castellar, Andersen, et al., 2021; Langergraber, Castellar, Pucher, et al., 2021; Pearlmutter et al., 2021).

Undeveloped areas have a well-established system of draining stormwater. The vast network of seasonal channels drains the runoff from the land surface to the rivers and ultimately to the seas and oceans after any precipitation event (Hadley, 1968). These natural channels play a crucial role in flood abatement (Ray, Pandey, Pandey, Dimri, & Kishore, 2019; Tingsanchali, 2012). So how can the planners use this pre-established drainage network, as an NbS, to a city's advantage? It is the guiding question of this research. The broader research aim is to find a sustainable supplement to grey infrastructure for carrying additional stormwater in urban areas.

Direct utilisation of seasonal channels for stormwater drainage is challenging. Urban areas have negative connotations with seasonal channels. Ephemeral and intermittent natural channels with seasonal streams are highly vulnerable to encroachment and neglect in their non-functioning months. They get filled during the land reclamation process and become non-existent to provide land for infrastructure (Sood & Biswas, 2021). Those that survive are marred with encroachment, garbage and debris dumping, and consequently reduced stormwater carrying capacity (Satterthwaite, Huq, Pelling, Reid, & Lankao, 2007). Thus, there are two issues one is to safeguard seasonal channels during the city development phase, and the other is to preserve urban channels from the ill practices of garbage dumping and encroachment.

A seasonal channel in Chandigarh city (India), namely N-choe[1], survived the city development phase and has retained its function over the years without succumbing to the pressure of urbanisation. This paper is a detailed case study of N-choe and results in identifying the factors that influenced its preservation during the city's development and afterwards. Results from this study will add to the inventory of sustainable stormwater management methods.

This paper is structured in five sections to elaborate on the study process. This introduction section further describes N-choe in Chandigarh and its new role as a public greenspace. Section 2 outlines the method employed in this study. Section 3 has results and discussion on the genesis and evolution of the Leisure valley to investigate the N-choe preservation. Section 4 has conclusions drawn from the analysis and presents the scope for future research.

About Chandigarh and N-choe

The city of Chandigarh (30.74°N, 76.79°E) lies in the foothills of the Shivalik mountain range of the Himalayas in the north of India (Figure 1). It is a union territory and a shared capital of the two adjacent states: Punjab and Haryana. The city has an area of approximately 114 km^2, a population of more than 1 million, and an elevation of around 321m from the mean sea level. It was built in the 1950s and was planned by the French architect Le Corbusier with 55 sectors in a grid-iron pattern. Chandigarh is globally known for its visionary planning and the contribution of Le Corbusier (Jonathan Glancey, 2015).

The city topography is majorly plane, with the backdrop of Shivalik hills in the north. Apart from N-choe, the city has three other seasonal channels: Sukhna choe, Patiala Ki Rao, and Choe Nala (Figure 1). N-choe originates in sector three of Chandigarh, meanders through various city sectors, and exits from the city at sector fifty-one. From there, it enters the adjacent Mohali city in Haryana state and finally descends into the Ghaggar river. Patiala Ki Rao and Sukhna choe originate in the Shivalik hills and flow through the western and eastern sides of the city, respectively. Choe Nala originates in sector 29 in Chandigarh city.

Symbiosis of N-choe and Leisure valley

A green belt named Leisure valley is strategically placed over the N-choe. This 8 km long green belt dominates the green landscaped areas in Chandigarh due to its size and influence. Leisure valley stretches from one end of the city to the other and covers eight sectors (Chandigarh Administration, n.d.). It comprises majorly ten public gardens (Figure 1). People from neighbouring sectors frequently use these themed gardens for walks, picnics, exercises, relaxation, and other leisure activities. The organic sprawl of Leisure valley is in stark contrast with the rigid grid-

[1] Choe means stream in the local (Punjabi) language.

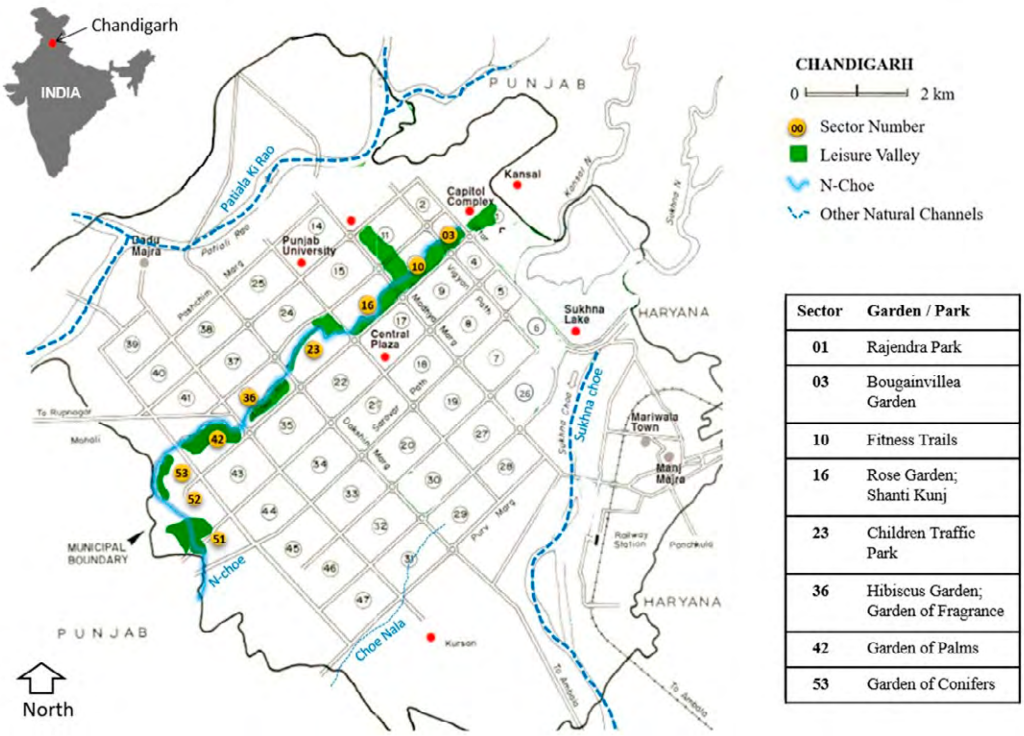

Figure 1. Location of Chandigarh city on the map of India (top-left); Location of N-choe and Leisure valley in Chandigarh
Source: Developed from the tourism map of Chandigarh

iron plan of Chandigarh. The N-choe underneath provides Leisure valley with its linearity and continuity. The Leisure valley's width and shape vary from 55m to 300m for accommodating functions like playgrounds, sports courts, parks and lakes (Figure 2). Leisure valley provides benefits associated with all greenspaces like shading, evaporative cooling, rainwater interception, storage and infiltration while reducing pollution and sequestering carbon (Bartens et al., 2008; Rosenzweig et al., 2015; Xiao, Mcpherson, Ustin, Grismer, & Simpson, 2000). Some artificial storm drains have outfall at N-choe in sector 51 (MC Chandigarh, 2017).

In many Indian cities, areas next to natural channels have a poor quality of life due to the excessive garbage dumping in channels that reduces them to foul-smelling drains. In contrast, Leisure valley's presence has contributed significantly to enhancing the quality of life of its residents (Chaudhry & Tewari, 2010). Owing to the enormous size of Leisure valley, Chandigarh's per capita green cover is the highest among major Indian cities at 38m^2 (Ramaiah & Avtar, 2019). A study in 2013 found that air quality is better in areas near the Leisure valley, and the noise levels are lower in the gardens than in roads and habitat areas (Chaudhry, Sharma, Singh, & Bansal, 2013). Leisure valley is a part of the city's identity. It contributes to the city's aesthetic enhancement and is a popular tourist attraction in Chandigarh (Chaudhry & Tewari, 2010).

Figure 2. (a) In sector 10, the Leisure valley accommodates various sports courts within 188m width, (b) In sector 23, 55m wide section accommodates only the N-choe lined with fully grown trees, (c) Sector 36 has the N-choe with playgrounds within 184m width, (d) In sector 42, thick urban trees accompany the channel within 123m width, (e) To have a lake (water retention structure), the width at sector 42 is 185m, (f) The Leisure valley sees its maximum width of 300m in sector 53, accommodating a humongous park.
Source: Developed by authors using Google Earth

Data and method

The study is based on the case study research method exploring reasons for N-choe preservation. A mixed-method approach is adopted that includes literature review and survey. The two techniques supplement each other by overcoming the weakness of the other. From the literature review, this study critiques and synthesises the relevant literature on Chandigarh city, natural channels, and public spaces in an integrated way. The facts and data are obtained from journals, governmental web pages, and conference papers. A survey of locals has strengthened the argument.

The analysis finds two answers: Which urban planning decisions safeguarded the N-choe's existence during the city development phase; and which social factors made it a well-accepted public place afterwards?

Survey process

A survey research technique helps to gather information by asking questions to a predefined group of people. In this study, the survey group comprises people living in Chandigarh and its vicinity. A total of 134 people responded to the survey. The online questionnaire was limited to only three questions for a better response rate (Table 1). The first survey question filters respondents to people who have physically visited the N-choe site. The second and third questions are to investigate people's perception of N-choe. During the data cleaning process, the people who responded positively to question 3 but failed to mention it in question 2 were rejected because of their ambiguous responses.

Table 1. Survey questionnaire

Question	Choices
How did you get to know about Leisure Valley?	• I have visited the place • I have read/ heard about it
Which of the following are parts of Leisure Valley? (You may pick many options)	• Gardens • Golf course • A stream • Forest • A river • Parks • Lakes and ponds • Playgrounds • Other
Have you seen any stream running through Leisure Valley?	• Yes • No

Source: Authors

Results and discussion

The preservation of N-choe is purely non-intentional, confirmed by Chandigarh's documented history. There is no mention of the need to preserve N-choe or to use it as a stormwater management system, which is because i) the city was designed with well-laid grey infrastructure for handling stormwater, ii) pluvial flooding was not a recognised issue in the last century when Chandigarh was built, and iii) dependence upon nature-based solutions for stormwater management is a recent strategy. Many planning and design decisions made for Chandigarh city have contributed to the preservation of N-choe. Careful observations have led to the identification of those contributory factors, which are discussed below:

Planning strategy influence on the N-choe preservation

1. **Edict of Chandigarh:** Chandigarh planning edict required providing an uninterrupted view of Shivalik hills even from the farther end of the city (Chandigarh Development Authority, n.d.). It needed a long corridor running from North to South in the city, and the eroded N-choe in the site, with its north-south alignment, provided the opportunity to realise this vision. Therefore, though unintentionally, the Chandigarh planning edict served as a by-law and paved the way for N-choe's preservation. Otherwise, neo-developments often destroy the seasonal channels to reclaim construction land.
2. **Greenspace landuse assignment:** Establishing a visual connection with Shivalik hills required a judicious landuse assignment to the N-choe for curbing any future construction and encroachment possibilities. The desired corridor could be a plaza, an arcade or a broad shopping street. However, the decision to develop this corridor as greenspaces is a significant factor that preserved N-choe.
   Greenspaces do not necessarily require surface levelling, allowing N-choe to retain its concave cross-section and streamflow function. Moreover, greenspace landuse saved N-choe from concretisation and safeguarded its soft bed and edges. Concretisation of channels increases streamflow velocity and poses a threat of downhill flooding (Ramachandra, Shivamurthy, & Aithal, 2017). Contrary to paved surroundings, green surroundings give room for channel flooding by allowing it to swell during heavy rains. Greenspaces also accommodate and propagate riparian vegetation, which is essential for improving stream water quality (Dosskey et al., 2010) and checking soil erosion. Thus with the superimposition of greenspaces, N-choe could retain its function of streamflow, floodability, and water quality enhancement with minimal alterations.
3. **Bridges and culverts:** Leisure valley, seemingly a long green belt, is not a continuous stretch of greens but a series of greenspaces having roads as distinctive boundaries. Road construction in neo-developments is a leading cause of seasonal channels' destruction and extinction. Fortunately, in Leisure valley, bridges and culverted roads maintain traffic without hindering the streamflow continuity of N-choe underneath (Figure 3 and 4).

Social influence on the N-choe preservation

In many cities, public greenspaces are also threatened by encroachment and landuse change (Li et al., 2019). However, the Leisure valley is a well-accepted public place. Social surveillance and a sense of place attachment are two intangible aspects that have reduced the

Figure 3. Bridges (encircled yellow) allowing the vehicular and pedestrian traffic flow without disturbing the streamflow in N-choe
Source: Developed by authors from the Google Earth imagery

Figure 4. Pedestrian bridges over N-choe in Leisure valley;
Source: Chandigarh web portal, n.d.

chances of N-choe's encroachment by changing its perceived value from a wasteland to a utilitarian public place.

Social surveillance: Public places with high and uniform footfall benefit from social surveillance (Shehayeb, 2008). The underused areas face negligence, get subjected to rampant encroachment, and fall prey to malpractices like drug abuse and garbage dumping. Thus to keep negative elements at bay and keep a check on ill practices, a public place must strive for social surveillance by ensuring high and uniform footfall through design. Social surveillance instils a sense of security among women, children and other marginalised groups and increases their presence in the public realm. Diversification of footfall fosters social cohesiveness and makes social surveillance robust.

Sense of place attachment: Users develop a feeling of attachment with the place if a place is a part of their day-to-day lifestyle (Hashemnezhad, Heidari, & Hoseini, 2013). Place attachment is a psychological approach in bringing about positive behavioural change in people. Najafi and Kamal (2012) suggest that people who feel emotionally attached to a place are more involved in preserving the area and do not take undue advantage (Najafi & Kamal, 2012). There is active reporting of issues related to ill-maintenance or negligence and diligent pressure on the authorities for immediate redressal of complaints. Thus, the sense of place attachment plays a significant role in safeguarding a public space.

Leisure valley enjoys social surveillance and instils a sense of place attachment among users because of the intrinsic qualities of equity, variety, accessibility, activity and adaptability:

1. **Equity:** Equity and inclusion are imperative for a happy environment and to build successful public places (Ouf & El-Zafarany, 2018). Good governance has made the entire stretch of Leisure val-

ley open to the public. Therefore, it is frequented by people of all ages, genders, races, and socioeconomic statuses, including the urban poor and minorities. Leisure valley's location keeps it distinct from neighbourhood parks where people have a sense of ownership and restrict the entry of vulnerable and marginalised user groups. The places with controlled or limited access are more vulnerable to damage, encroachment, and vandalism by non-users. Equity generates high footfall by being receptive to all and strengthens social surveillance.

2. **Variety:**
   a) ***Variety in design:*** By planting varying fauna, different Leisure Valley gardens have achieved distinctive visual characteristics. The variety reflects in the names of gardens which adds to the legibility of this public place. Rose garden, Bougainvillea garden, the garden of Palms, the garden of conifers, the Hibiscus garden, and the garden of fragrances have unique qualities and ambience. Design variety prevents monotony, encourages exploration of the green belt's entire length, and distributes footfall over the whole stretch.
   b) ***Variety in usage:*** Themed parks and gardens in the valley are also associated with diverse usages. For example, Rajendra park and fitness trails are majorly associated with fitness activities, jogging, horse riding, and yoga. Rose garden, Bougainvillea garden, and Hibiscus garden are also used for fitness activities by the neighbouring people but are known for their aesthetics and association with recreational and leisure activities. Smriti upvan in sector one has a more sentimental value attached to it as people plant trees here in the memory of the departed souls. This variety in usage attracts people with diverse interests and adds to footfall.
3. **Accessibility:** Visual and physical connections with surroundings determine the accessibility of a public place (Madden & Schwartz, 2000). The Leisure valley has multiple access points in every sector. The choice of entering and exiting at any point promotes walkability and gives comfort. Its proximity to bus stops and parking gives the transportation mode choice and enhances the accessibility. Tree foliages help to establish visual connect from a distance and orients the visitors. This ease of access contributes to the high and spread-out footfall.
4. **Activity:** Leisure valley is part of people's day-today activities like exercise, play, and relaxation owing to its proximity to the residential area. People also visit these gardens for social interactions, picnics, and leisure. Leisure valley carnival is held every year in February and the annual Rose Festival in February/ March when the roses bloom to their full glory. These festivals celebrate the uniqueness and grandeur of Leisure valley, attract a full range of diverse people and create inclusiveness (Ouf & El-Zafarany, 2018). Daily, seasonal, and annual activities make Leisure valley a significant part of citizens' lives and instill a deep sense of place attachment.
5. **Adaptability:** The valley is evolving and thriving over the years as per people and time demands. The flexibility in its concept and planning has allowed Leisure valley to grow, modify, change, and adapt. Landuse assignment as greenspaces during the conceptualisation period of the 1950s fixed the function of Leisure valley. However, the design and growth of the Leisure valley is a continuous process. For example, Bougainvillaea garden in sector three was established in 1976, and Smriti upvan in sector one was developed in 1998. Moreover, by 2031, the cycle tracks will make their way into the Leisure valley to have sustainable transportation means in the city (Chandigarh Development Authority, n.d.). Thus adaptability has let the Leisure valley stay relevant in changing times and build an emotional connection with all generations.

The flowchart in figure 5 summarises the factors discussed in subsections 3.1 and 3.2. It shows the linkages between various contributory factors and their associated benefits which led to N-choe preservation.

Validation

Out of 134 respondents, 67 (50%) had not visited the leisure valley and, therefore, were not considered in the analysis. From the remaining 67, 10 were rejected on the grounds of ambiguity in their responses. Hence, the analysis is based on 57 responses from people who have visited the Leisure valley. 98% (56) of respondents claimed that Leisure valley is a garden or park, whereas only 67% (38) know of a stream or river in Leisure valley. Moreover, only 53% (30) of respondents have seen a stream in the leisure valley.

Survey results show that people definitely perceive leisure valley as a greenspace, but only a few know of it as a seasonal stream. Therefore, we can confidently conclude that greenspace landuse assignment to N-choe has changed its perception of a seasonal waterbody (or wasteland in dry months) to user desired public greenspace.

Concept of greenswales

The primary outcome from the N-choe case study is the knowledge that landuse change can safeguard the existence of seasonal channels, and judiciously overlapped greenspaces can preserve their function over the years. Conclusively, we introduce a new term,

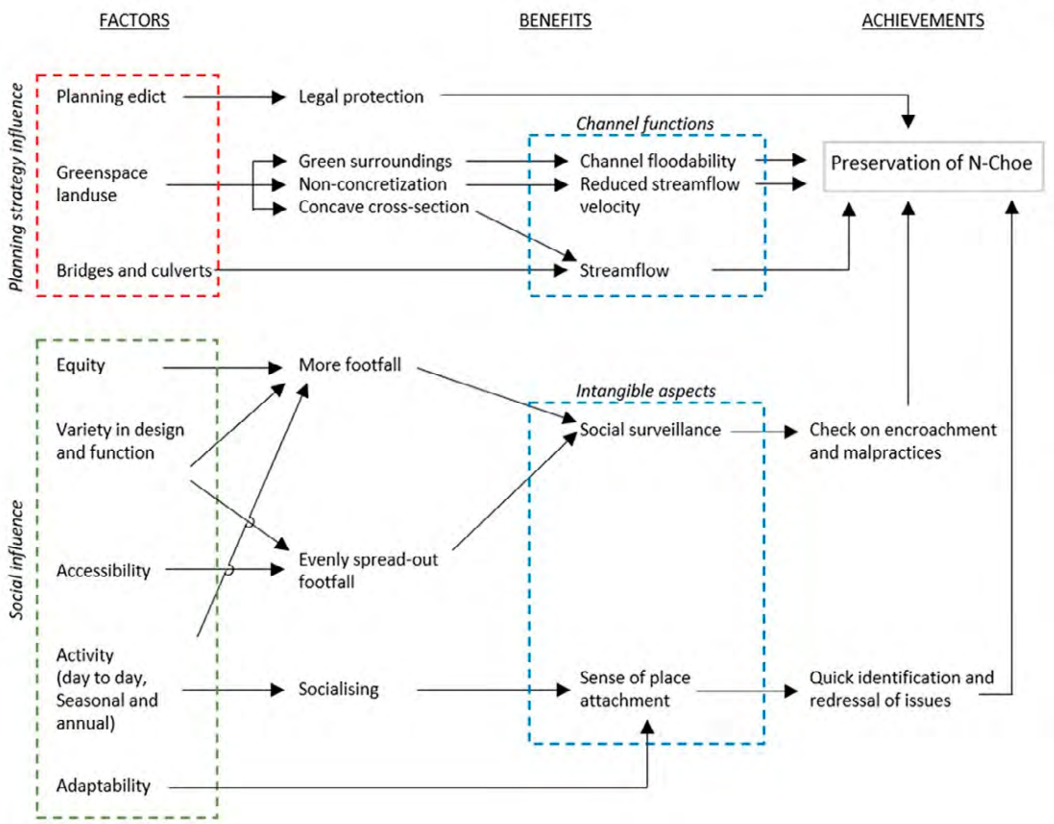

Figure 5. Summary of the contributory factors and their benefits that contribute to the N-choe preservation

greenswale, to convey the symbiosis of seasonal channels and overlapping greenspaces.

A greenswale is defined as the stretch of greenspaces laid over a natural channel, ephemeral or intermittent, having stormwater detention and conveyance as primary functions during precipitation.

The term greenspaces emphasise the type of landuse without any limitation to vegetation choice. The greens may vary from lawns to urban forests and be inclusive of bluespaces depending upon social, environmental and hydrological needs at the local level (L. Taylor & Hochuli, 2017). Greenswales qualify as a nature-based solution with ecological and social benefits of greenspaces, and hydrological advantages of natural channels.

The terminology greenswale finds its origin in the term bioswale. Bioswale or vegetated swale is a linear form of bioretention used to partially treat water quality, attenuate flooding potential and convey stormwater away from critical infrastructure (Mcpherson, 2017). Bioswales are designed as gently sloping depressions planted with dense vegetation or grass, and they treat stormwater runoff from rooftops, streets, and parking lots (Purvis et al., 2018). The need for introducing the new term greenswale lies in the differences between the two. Bioswales are plantations over artificial drains, whereas greenswales are plantations over seasonal natural channels. Planners have the choice to place bioswales anywhere depending upon need, whereas greenswales can only be at the natural channels. In principle, bioswales mimic natural hydrology; on the other hand, greenswales attempt to preserve the pre-development hydrology of the area. Additionally, greenswales can retent more water for flood mitigation than bioswales by virtue of the green spread on either side.

Conclusion

Planners in 21st century are finding sustainable solutions for managing stormwater and mitigating pluvial floods. Many studies on sustainable stormwater management suggest that nature-based solutions (NBS) can supplement the grey infrastructure in taking up the additional runoff and prevent pluvial flooding (Chan et al., 2018; Suppakittpaisarn, Larsen, & Sullivan, 2019; The World Bank, 2019). NBS are solutions inspired and supported by nature, provide environmental, social, and economic benefits and help build resilience (European Commission, 2016).

This case study of non-intentional preservation of N-choe in Chandigarh city offers learnings to preserve crucial seasonal channels and yields the concept of greenswales. A greenswale is a natural channel overlapped by greenspaces. The provision of greenswales at the planning stage of neo-developments can provide upcoming cities with a sustainable and floodable public place. In addition, greenswales can accommodate shaded and scenic cycleways and walkways because of their linearity and city-long stretch. Greenswales' function of stormwater management and pluvial flood mitigation, along with other ecological and social benefits, situates it in the realm of nature-based solutions.

We identified that the N-choe survived land reclamation and is still functioning because of the greenspace landuse assignment. Greenspaces have replaced N-choe's seasonality with year-long utility. More importantly, the assigned function and design has not interfered with the channel's function. Following the detailed documentation of N-choe and Leisure valley in this paper, city planners can develop greenswales in neo-development projects. The city of Chandigarh has focused on the aesthetic and recreational aspects of Leisure valley and has not fully utilised its potential as a stormwater management tool and floodable greenspace. However, the greenswales need not limit their function and should actively contribute to stormwater drainage and pluvial flood mitigation.

Scope for future research

This study has followed the qualitative approach and paves the way for quantitative research in the future. The catchment size of N-choe and its runoff carrying capacity can be investigated in future research to expand the concept of greenswales. This study is limited to understanding the preservation of N-choe, but there is a scope for advancing this research by investigating Leisure valley's role in biodiversity preservation and GHG reduction. The multi-faceted research on N-choe and Leisure valley may result in a holistic urban solution to climate change adaptation and mitigation. This study's results further open the way for pilot projects to implement and test the greenswale effectiveness.

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SHORT COMMUNICATION

Urbanization Trends in the 21st Century - a Driver for Negative Climate, Noise and Air Quality Impacts on Urban Population

Stevan Savić[A*], Miloš Bjelić[B], Dragana Šumarac Pavlović[B], Dragan Milošević[A], Jelena Dunjić[A], Lazar Lazić[A], Mileta Žarković[B], Tatjana Miljković[B]

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According to climate change, an increase in various extreme climate and weather events, such as heavy precipitation, storm weather, longer drought period, tropical cyclones, snow blizzard, and among them more frequent and severe heat waves, can be expected in coming decades (IPCC, 2021). In parallel with climate change, cities experience very intensive urbanization in the last few decades (UN, 2018), and as a result, the urban area will increase by 141 % in low-income countries, 44 % in lower-middle-income,

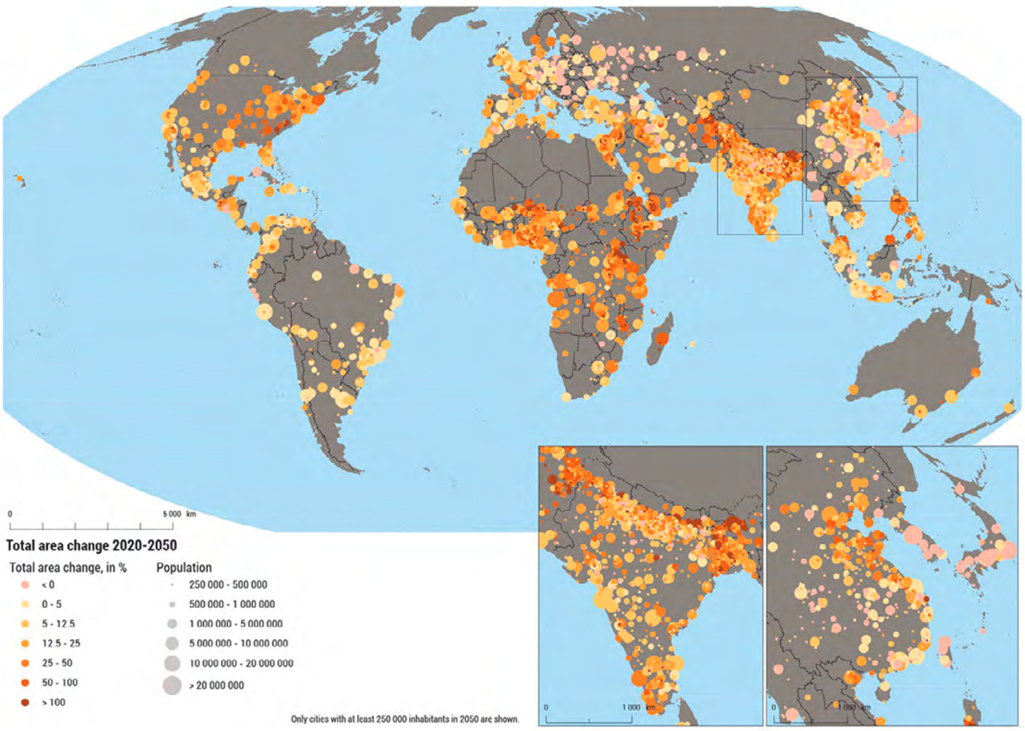

Figure 1. Projections of the urban area change (in %) and population in cities across the Globe for the period 2020-2050
Source: UN, 2022

[A] Chair of Geoecology, Faculty of Sciences, University of Novi Sad, Trg Dositeja Obradovića 3, 21000 Novi Sad, Serbia
[B] School of Electrical Engineering, University of Belgrade, Bulevar kralja Aleksandra 73, 11000 Belgrade, Serbia
[*] Corresponding author: Stevan Savić, e-mail: stevan.savic@dgt.uns.ac.rs

34 % in high-income, and by 13 % in upper-middle-income countries until 2070, compared to city land area in 2020 (UN, 2022). Consequently, more land areas and more world population (Figure 1) are under modified climate (urban climate), changed air quality conditions (such as Ozone, NOx, nanoparticles, but particularly in PM1, PM2.5 and PM10) and additional noise stress.

The combined climate and urbanization pressures on public health and the environment in cities will continue in coming decades and will increase the necessity to provide more optimal solutions to monitor and assess urban environmental risks, and to find effective ways to implement these in practice. The defined interaction process "climate change-urbanization-urban climate" where the climate conditions are recognized as an important risk factor in cities (Savić et al., 2022), in the further steps of the environmental risk adaptation, wider risk factors within cities should be considered. Therefore, the interaction process "climate change-urbanization-urban environment" should include, in addition to climate condition risks, air quality and noise risks as elements that are directly driven by current weather conditions, traffic intensity, industrial and construction activity, heating supply in winter, and urban design application, and all of that should be included in future urban environmental risk assessments.

Significant processes contributing to urban environmental risks - an overview

The latest IPCC report (IPCC, 2021) presented that global surface temperature[1] has increased by 0.99 °C from 1850–1900 to the first decades of the 21st century (2001-2020) and by 1.09 °C from 1850–1900 to the last decade period (2011–2020). It means, that the increasing temperature trend is constantly enlarging decade by decade, and in a parallel concentration of the CO_2 is constantly increasing and reached annual averages of 410 ppm. Also, datasets reveal that hot extremes (hot days, heatwaves) have become more frequent and

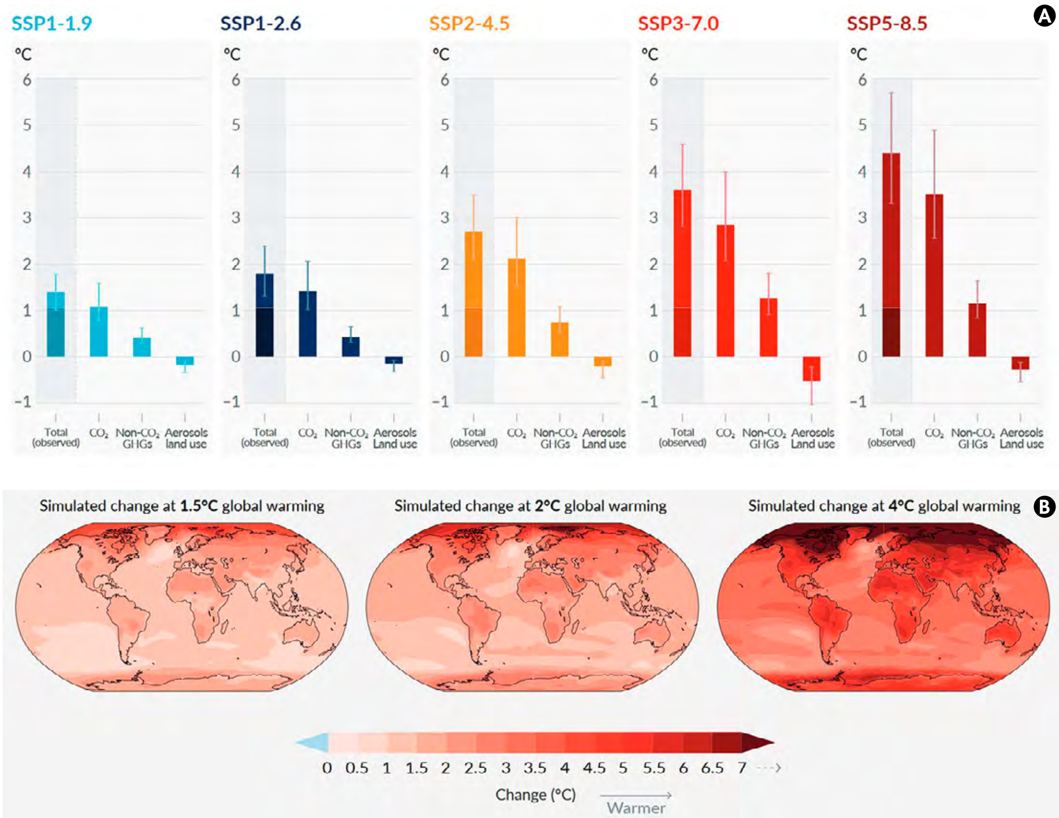

Figure 2. A) Contribution to global surface temperature increase from different GHG emissions. It is presented the change in global surface temperature in 2081-2100 relative to 1850-1900 (in °C). For this projection were used five SSP scenarios based on different CO2 and GHG emission levels (SSP1-1.9, SSP1-2.6 – very low and low, SSP2-4.5 – intermediate, SSP3-7.0, SSP5-8.5 – high and very high emissions); B) Spatial distribution of the global annual mean temperature change (°C) relative to 1850-1900, in situation if temperature rise by 1.5 °C, 2 °C or 4 °C (simulated)
Source: IPCC, 2021

[1] The term „global surface temperature" is used in reference to both global mean surface temperature and global surface air temperature throughout the IPCC report.

more intense across most land regions since the 1950s, while cold extremes (frost/ice days, cold waves) have become less frequent and less severe. Based on projections (Shared Socio-economic Pathways - SSP3-7.0 and SSP5-8.5) of high and very high CO_2 and GHG (greenhouse gas) emissions, in comparison to the average temperature from 1850-1900, the global surface temperature will be higher by 2.8 – 4.6 °C (SSP3-7.0) or by 3.3 – 5.7 °C (SSP5-8.5) until the 2100 (Figure 2A). In the same Figure (2B) are presented simulated temperature levels and spatial distribution of thermal conditions that are mostly dominant in the northern hemisphere (IPCC, 2021).

In the next five decades, in case that the global surface temperature increases by 2 °C relative to 1850-1900, the frequency of hot extreme events will increase about 15 times, and intensity will rise by about 2.5 °C. Even more, the projection shows that if the temperature changes by 4 °C, the frequency of hot extreme events will increase about 35 times, and intensity will rise by about 5.5 °C (Arias et al., 2021). Therefore, today, but also in the future, cities will experience extreme thermal conditions more often and more intense compared to non-urbanized areas (rural areas) due to the amplification of air/surface temperatures, and as result this will trigger the urban heat island (UHI) effect (Lauwaet et al., 2016). These temperature-caused effects (UHIs) are contributing to more thermal stress and increasing morbidity/mortality cases across European cities, as well as impact-

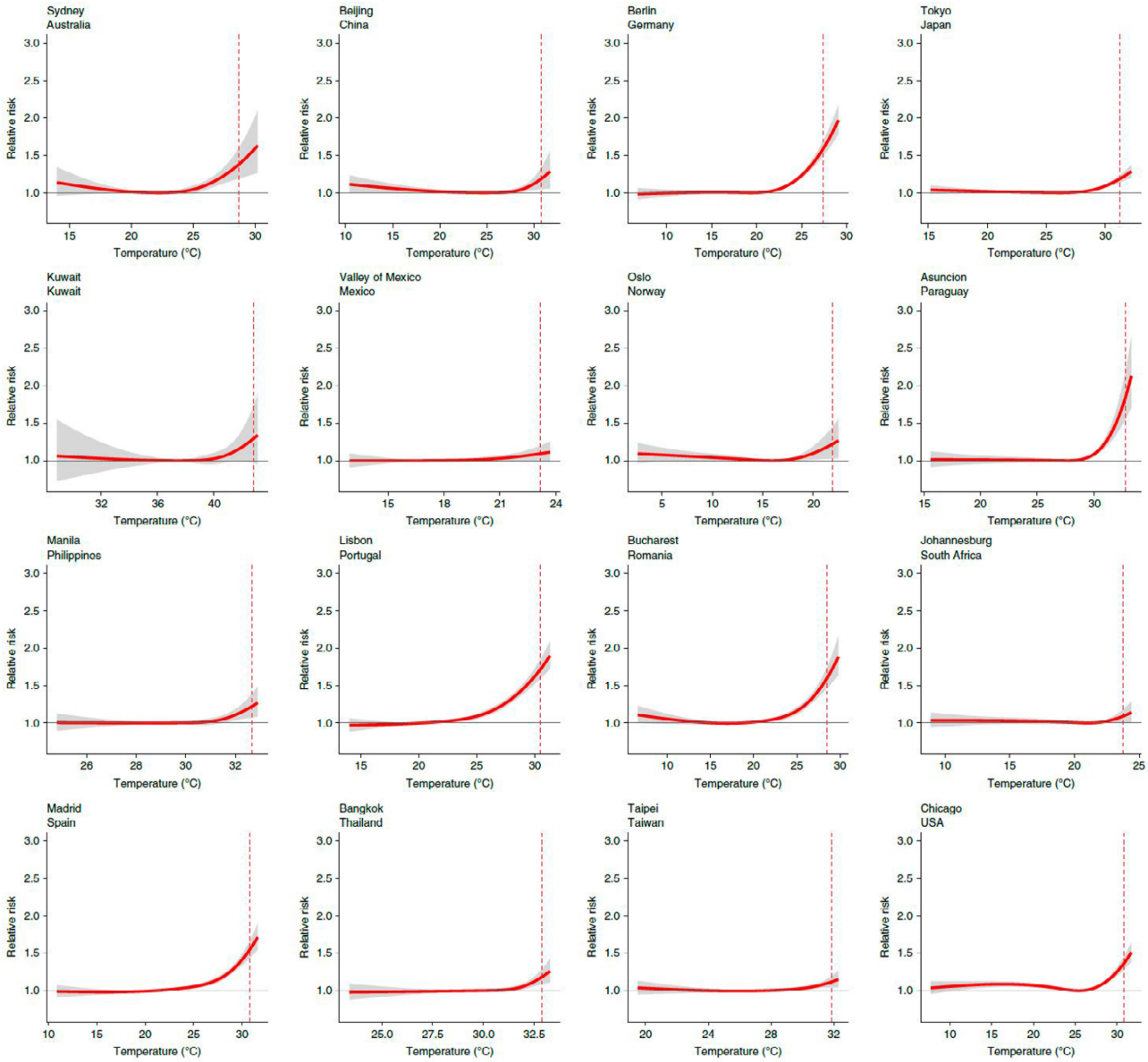

Figure 3. A) Heat-mortality relations for 16 representative cities where the functions represent the cumulative relative risk of death over a 10-days lag period for each temperature value. Exposure-response associations are estimated as best linear unbiased predictions and reported as relative risk (with 95 % CI, shaded grey) for a cumulative 10-days lag of warm-season temperature, versus the optimum temperature (temperature of minimum mortality)
Source: Vicedo-Cabrera et al., 2021

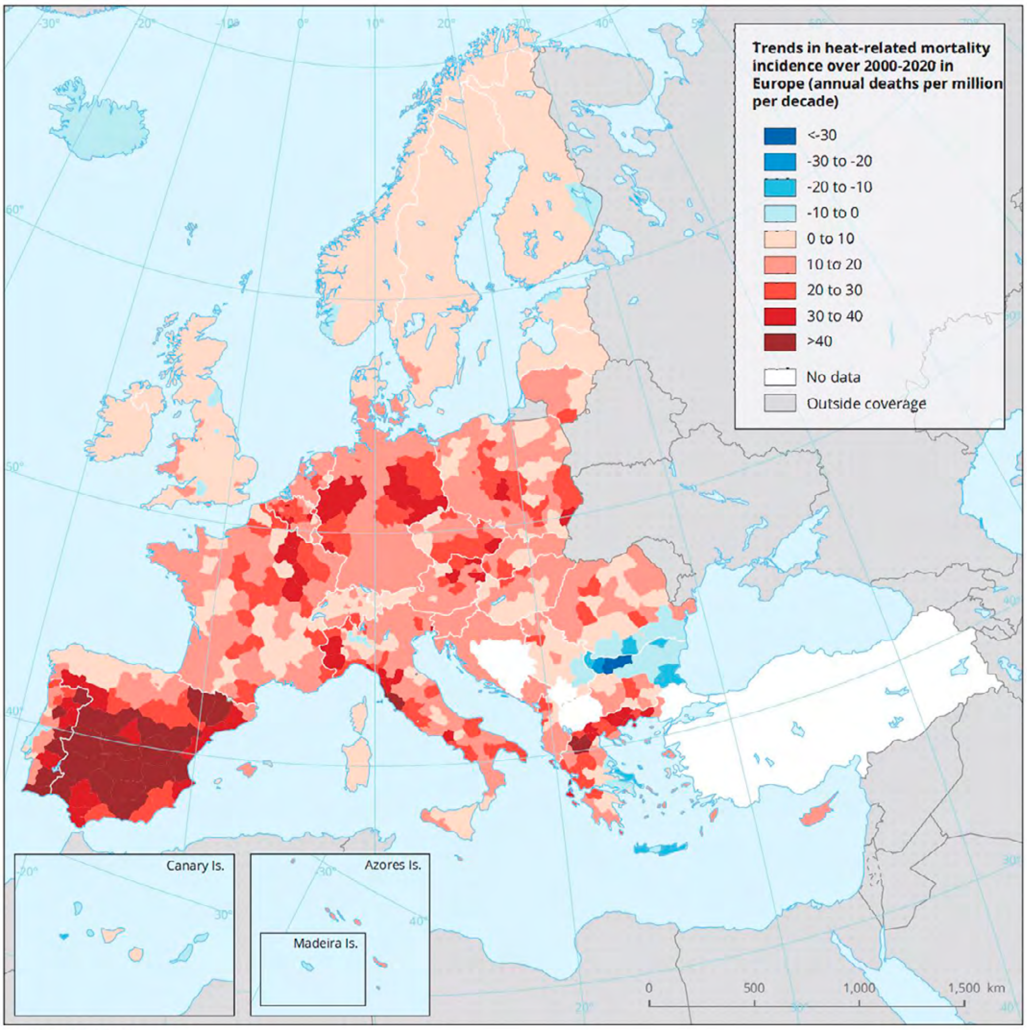

Figure 3. B) Trends in heat-related mortality incidence in the period 2000-2020 in Europe (annual deaths per million per decade). The smallest regions possible were used, depending on the spatial resolution of the mortality data in a given country, i.e., ranging from the NUTS 3 (areas with 150,000-800,000 inhabitants) to a single country
Source: van Daalen et al., 2022

ing biodiversity and economic losses (IPCC, 2022). Based on the research about the contribution of human-induced warming to the heat-related mortality in 732 locations (cities) from 43 countries over the period 1991-2018, it has been found that 37 % of warm-season heat-related deaths can be attributed to anthropogenic climate change (Vicedo-Cabrera et al., 2021). This heat-related mortality and morbidity have been increasing across Europe, particularly in southern Europe, and with a scenario of 3 °C temperature change, the projection predicts approximately 90,000 deaths of Europeans every year due to extreme heat events. Moreover, about half of hospitals and schools in European cities are in areas with strong UHI effects (higher than 2 °C), meaning that their vulnerable users and staff are exposed to high temperatures (EEA, 2022a). Figure 3 presents some general tendencies of heat risks and heat-related mortality in 16 selected cities, as well as across European regions.

According to the current report of the European Environmental Agency (EEA, 2022b), air pollution is the single largest environmental health risk in Europe, causing cardiovascular and respiratory diseases that lead to the loss of healthy years of life and, in the most serious cases, to premature deaths. For the area of Europe, it can be stated that the fine particulate matter (PM2.5 and PM10) represents a significant risk for air quality, which also confirms the goal of the European Commission to reduce the number of premature deaths caused by PM2.5 at least 55% until 2030 compared to 2005 levels. In 2020, according to the World Health Organization (WHO) standard (where the threshold is 5 μg/m^3), about 96% of the European population is exposed to a higher concentration of PM2.5 and based on the EU standard (where the threshold is 25 μg/m^3), less than 1% of the population is exposed, and this difference is a result of obvious distinct standards. Still, there are real air pollution risks based on the

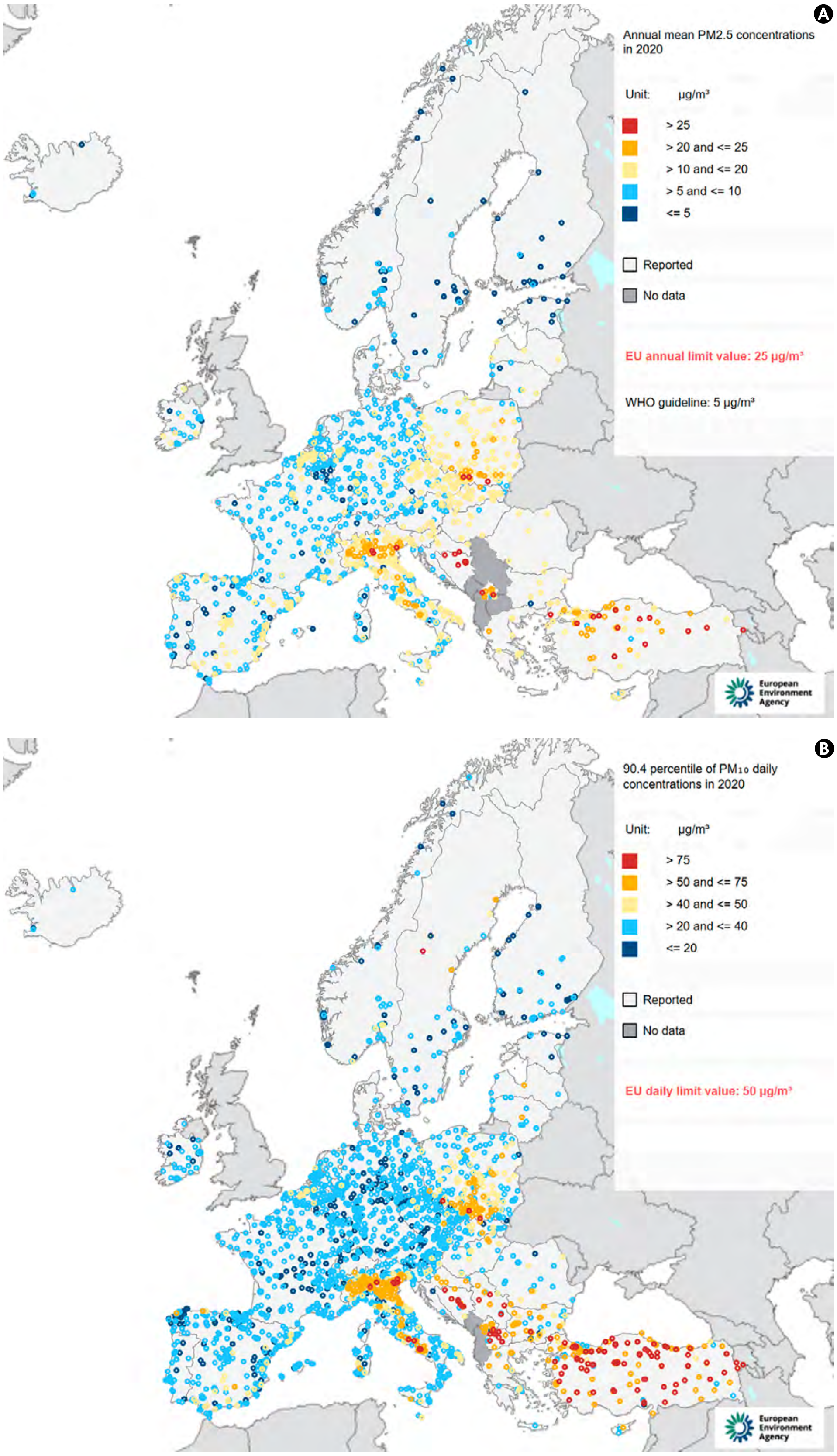

Figure 4. A) Concentration of PM2.5 in European countries for 2020 (validated data) in relation to the EU and WHO standards. Six countries reported PM2.5 concentration above the EU limit (25 µg/m3), and only Estonia did not report PM2.5 concentration higher than the WHO standard (5 µg/m3); B) Concentration of PM10 in European countries for 2020 (validated data) in relation to the EU and WHO standards. 20 countries reported PM10 concentration above the EU standard (50 µg/m3), and only Iceland did not report PM10 concentration above the WHO standard (15 µg/m3)
Source: https://www.eea.europa.eu/publications/status-of-air-quality-in-Europe-2022

fine particulate matter, particularly in some European regions, such as Central Europe, Southeast Europe and Italy, where combination of domestic heating, road traffic and some industrial branches cause higher concentrations of PM2.5 and PM10 (Figure 4) (EEA, 2022b).

The road traffic noise is one of the major environmental problems in Europe causing health and well-being issues for millions of people. It is estimated that about 113 million people are affected by long-term daytime and nighttime traffic noise levels of at least 55 dB(A). About 22 million people suffer chronic high annoyance and 6.5 million people suffer chronic high sleep disturbance. Furthermore, projections show that road traffic noise in urban areas, in the category of day-evening-nighttime – noise level at least 55 dB(A), will increase by 7.8 % in EU countries by 2030

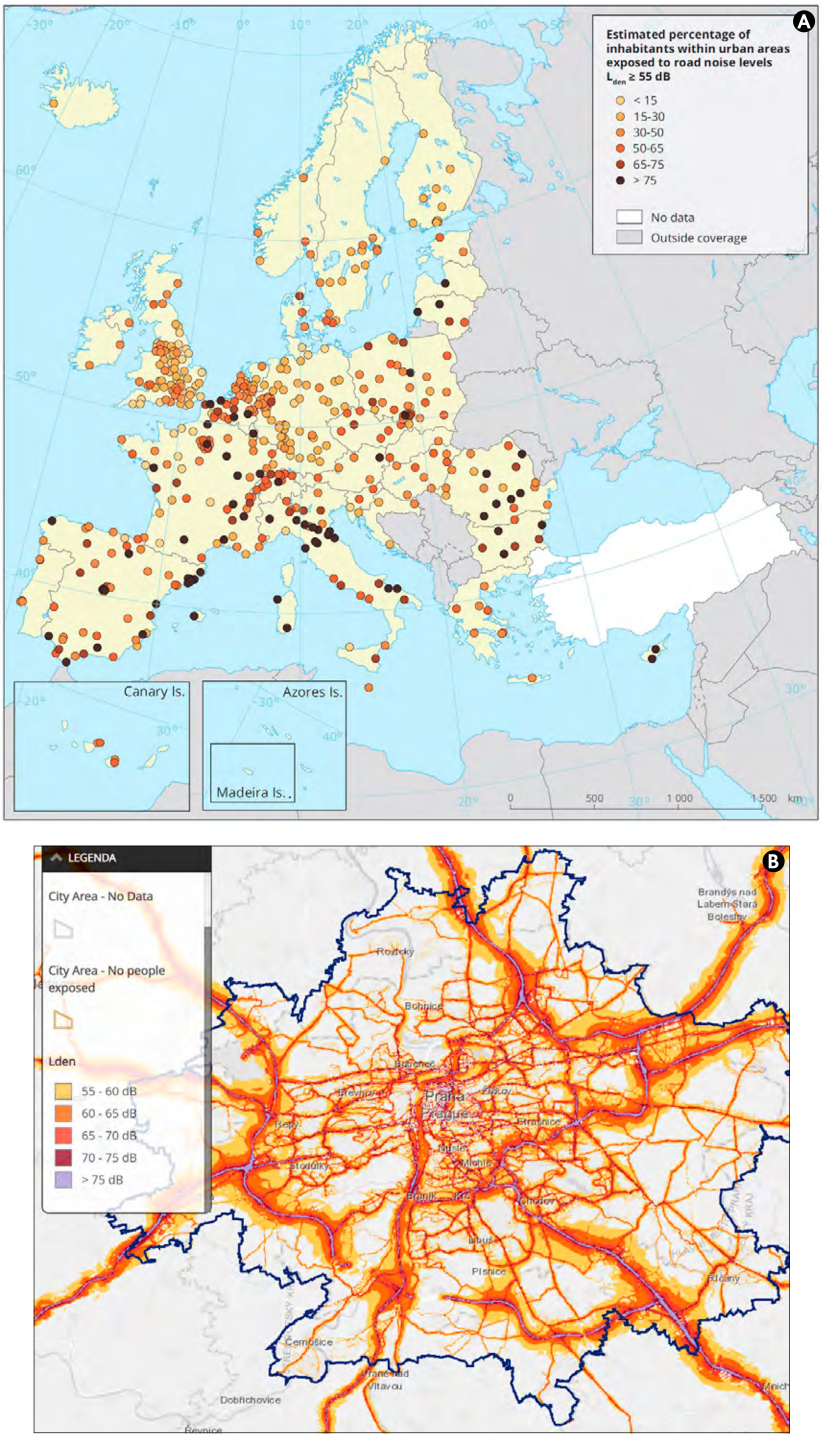

Figure 5. A) Estimated percentage of population in cities from EU and EEA (+ CH) countries that are exposed to road traffic noise levels L_{den} ≥ 55 dB in 2017; B) Urban area of Prague that is exposed to day-evening-nighttime average sound levels of L_{den} ≥ 55 dB from road traffic noise. In this exposed area of Prague lives about 876 000 inhabitants
Sources: EEA, 2020 and http://noise.eea.europa.eu

(compared to the level in 2017). Despite these problems, there are still delays in providing action plans, good quality spatial/temporal noise datasets and assessments from both urban and rural areas, and it suggests that countries have not taken serious actions to address noise pollution (EEA, 2020). More details about urban population exposed to the road traffic noise risk are presented on Figure 5.

What are the next steps

Effective urban and territorial planning by applying the New Urban Agenda and the Sustainable Development Goal - SDG 11 should be considered seriously in the urbanization policy. For example, integrating green infrastructure into the urban design will provide co-benefits for adapting to climate change, improving health or mitigating the effects of traffic by restoring and regenerating natural ecosystems in cities (UN, 2022). Furthermore, by implementing public transport and decreasing individual transport is main task for many urban challenges (spatial efficiency, noise mitigation, transport safety, GFG emissions, economic efficiency and also air quality). Implementing electric mobility has a positive influence of air quality and noise issues, however it does not bring solution to other urban problems mentioned above. For these measures and solutions to have a maximum result on the ground, it is necessary to further develop integrative and complex monitoring and assessments of environmental and social risks in cities. According to international projects and actions there are developed a few indices with various risk approaches and responses to different natural and social sectors. In Table 1 is presented more details on the concept and idea of these indices. However, based on the natural and anthropogenic processes that are occurring and will occur in the coming decades in urban areas, the creation of a "global/regional urban environmental risk index" that would simultaneously integrate the most important atmospheric effects on the environment, as which are thermal conditions (air and surface temperature), noise (dB(A)) and air quality (with focus on the fine particulate matter) (Table 1), could contribute to the creation of more effective adaptation measures and policies that will better response to further changes expected in cities during the 21st century.

Finally, we cannot think about developing new risk approaches or indices only, but we should also think about the availability of datasets and information. Hence, the FAIR (Findability, Accessibility, Interoperability, and Reusability) principle for data usability should be considered more in the future. Good examples could be more environmental observational platforms developed (COPERNICUS, OpenEO, NoisePlanet, OpenAQ, PM2.5 open data, ECMWF, etc.) that provide various spatial and temporal data across the globe. But we should focus also on platforms that gather data from specific sources, such as the Micrometeorological knowledge share platform (Micromet_KSP) that is currently developed by the COST Action project FAIRNESS[2] and will contain the datasets and metadata from urban and rural networks, which are not part of official national networks, and this kind of platforms could provide additional contributions to more detailed environmental risk assessments in cities.

Table 1. Review of the developed risk indices and possible further actions

Risk index	Risk approach	Response to sectors	Reference
European Green City Index	CO_2; Energy; Buildings; Transport; Water; Waste and land use; Air quality; Environmental governance	Environmental performance of 30 leading European cities	Economist Intelligence Unit, 2009
Global Urban Risk Index	• Natural hazards (earthquakes, landslides, floods, cyclones); • Exposure (covering people, buildings, transport infrastructure, economies, communities); • Vulnerability; • Losses (mortality, economy)	Different natural and social sectors in cities	Brecht et al., 2013
Urban heat risk index	• Location within the city; • Characteristics of the building; • Characteristics of people	• Physical; • Social; • Strategic – before hot weather; • Operational – during hot weather	ARUP, 2014

[2] More about the project: https://www.fairness-ca20108.eu/

Risk index	Risk approach	Response to sectors	Reference
"City co-benefits" by LSE Cities and C40 Cities	Health; Mobility; Buildings; Resources; Economy	- Traffic pollution; - Healthy lifestyles; - Smart transportation systems; - Flooding and building damage; - Valuing the size of the environmental goods market	Floater et al., 2016
Cities in Motion Index - CIMI	Human capital; Social cohesion; Economy; Governance; Environment; Mobility and transportation; Urban Planning; International profile; Technology	Sustainability issues and quality of life in cities	Berrone et al., 2022
Environmental Performance Index - EPI	• Environmental health (air quality, waste management, water & sanitation, heavy metals); • Climate (climate, change, mitigation); • Ecosystem vitality (biodiversity & habitat, ecosystem services, fisheries, agriculture, acid rain, water resources)	Sustainability issues on country level	Wolf et al., 2022
Further actions			
"Global/regional urban environmental risk index"	• Climate (air/surface temperature, thermal indices); • Noise pollution; • Air quality (PM2.5, PM10)	Comprehensive urban environmental issues	/

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