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# Symbolic and social boundaries of the integration of Russian immigrants in Czechia

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**ABSTRACT**

This article focuses on the integration process of Russian immigrants into Czech society. The integration of immigrants into Czech society is a key topic in the public debate as well as a political issue. Ukrainians, Slovaks, Vietnamese, and Russians are the most numerous groups within the half-million migrant population. Czechia is therefore predominantly attractive to non-EU immigrants. Representing highly educated and financially well-secured migrants who come as entire families, the Russians are distinct from other Eastern European immigrants. However, various factors hinder their integration. The article discusses the factors that shape symbolic and social boundaries in this integration process: (1) the development of Czech-Russian relationships that have been influenced by dramatic past events, (2) the representation of Russians in Czech media, (3) their specific socio-economic status, and (4) Czech immigration and integration policies. Negative experience, socio-economic inequalities, strict implementation of immigration policies towards third-country immigrants, and an unfavourable media discourse affect the attitudes of the majority toward the Russians and limit meaningful encounters.

**KEYWORDS**

symbolic and social boundaries; immigration and integration policies; media discourse; Russian immigrants; Czechia

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## 1. Introduction

With the rapid growth of immigrants in Czechia, the issue of their integration becomes important at the institutional level through the implementation of immigration policy, as well as at the social level due to its impact on public opinion in society. During the integration process, immigrants try to find their own way in different areas of life within a host country. Meanwhile, members of the majority may not hinder, but rather, they may aid and support societal newcomers. Hence, integration is considered a two-way as well as a reciprocal process (Bosswick, Heckmann 2006), where both immigrants and the majority may participate. On both sides, participation is necessarily conditioned by mutual interaction that mostly manifests in coexistence at the local level, where encounters between foreigners and members of the majority society come about most often.

Prague increasingly attracts foreigners and belongs to regions with their highest concentration (Czech Statistical Office 2019). Immigrants transform the capital of Czechia into a cosmopolitan city. The most numerous groups of up to half a million migrants in whole Czechia include Ukrainians (23%), Slovaks (21%), Vietnamese (11%), and Russians (7%)[1]. In this article, I focus on Russian immigrants living in Czechia. Russians are particularly distinct from other foreigners from Eastern Europe, especially in terms of their composition. They represent a group of highly educated, economically well-resourced immigrants of working age who migrate as whole families (Drbohlav et al. 2010; Drbohlav, Janská 2004).

According to the intergroup contact hypothesis (Pettigrew 1998; Allport 1954), in countries with larger numbers of immigrants, there are better opportunities for encountering and social interaction that improve the majority attitudes towards immigrants through prejudice reduction. Even though today the number of immigrants in Czechia is 14 times higher than in 1989 and is continuously growing, members of the Czech majority society, particularly of the older generation, still have negative attitudes towards foreigners. In contrast, the younger generation comes into contact with foreigners more so; and most of them have foreigners as work colleagues or schoolmates – a common circumstance today. Some of the reasons for this impact on the attitudes of the older majority generation are (1) a lack of experience with international migration in Czechia, and thus, locals have not become used to the presence of 'others' yet, and (2) relatively recent dramatic events in Czech history, such as the Soviet military intervention and occupation of Czechoslovakia, that are remembered by elders to this day. The results of the 2017 Eurobarometer survey show that, in a comparison of EU countries, Czechia is the country with the most negative attitudes towards immigrants. Concerning the situation inside Czechia, the assessment of majority attitudes indicates that 64 percent of Czechs consider immigrants a problem (Public Opinion Research Centre 2017). Interestingly, this indicator has never dropped below fifty percent over the past ten years, since 2003. With regard to Russians, the Czech majority manifests more antipathy than sympathy towards them, and, moreover, the attitude of Czechs towards the Russians has grown worse in recent years (Public Opinion Research Centre 2017).

Pettigrew (1998) argues that not only social contacts, but also cultural, economic, political factors, media discourse, and dramatic social events influence majority attitudes towards immigrants. Similarly, several different factors that contribute to making boundaries influence Czech attitudes towards Russians, and therefore, slow down or block integration processes. In this article, I discuss factors (historical, discursive, socio-economic, and institutional) that have a significant impact on the integration process of Russian immigrants into Czech society.

The aim of the article is to explore the context of the integration process through the concept of symbolic and social boundaries (Lamont, Molnár 2002) with an emphasis on (1) the historical development of Czech-Russian relationships, which has undergone both positive and negative events in the past; (2) representation of Russians in Czech media discourse; (3) the socio-economic status of Russians that distinguish them from 'others'; and (4) modes of Czech immigration and integration policies that disadvantage the legal status of Russians as third-country immigrants over EU immigrants. This article significantly contributes to understanding how symbolic and social boundaries between Russian immigrants and the Czech majority are created and influence everyday negotiation by limiting encounters that hinder the integration of immigrants. The results will be useful predominantly for integration policymakers in the setting, development, and improvement of integration activities for foreigners.

First, the article discusses the theoretical framework, which is built around the concept of symbolic and social boundaries (Lamont, Molnár 2002). After this, I briefly introduce the research methods. From the methodological point of view, in regard to research on the development of Czech-Russian relationships, I study the available literature on this subject. Next, an analysis of the Czech press serves as a methodical approach to investigating the discourse of media coverage concerning Russian immigrants. A description of the specific socio-economic status of Russian immigrants follows. Finally, there is an attempt to explain the institutional status of Russians through an analysis of the development of Czech immigration and integration policies. The article's main findings are in the following section, and in conclusion, there

1 According to data from the Directorate of the Alien Police Service from 31 December 2018.

is a summary of the research results and an explanation of how the discussed factors impact the attitudes of the majority towards Russians and, consequently, how they hinder the integration process of Russian immigrants into Czech society.

## 2. Theoretical and methodological frameworks

### 2.1 Symbolic and social boundaries

In this article, I use the concept of symbolic and social boundaries by Lamont and Molnár (2002) to describe barriers in the process of Russian integration into Czech society as well as to evaluate the incorporation process through the historically developed attitudes of the majority, media discourse, the specific socio-economic status of Russian immigrants, and the implementation of immigration policies. By categorising objects, people, practices, time, and space, people draw symbolic boundaries that help individuals and social groups identify each other and, at the same time, to determine their belonging within a particular group during the negotiation of everyday life (Lamont, Molnár 2002). Thus, symbolic boundaries contribute to the emergence and maintenance of a dichotomy of 'us' and 'them' or the in-group and the out-group.

Symbolic boundaries, however, could transform into social boundaries, which are broadly accepted in society (Lamont, Molnár 2002). Unequal access to resources, their distribution, and different social opportunities shape social boundaries in a society, which are 'objectified forms of social differences' (Lamont, Molnár 2002: 168). Social boundaries are often institutionalised (Bail 2008; Heizmann 2016) and policy-oriented (Neumann, Moy 2018), determining who in a society can or cannot access resources (material and non-material), define social opportunities (Lamont, Molnár 2002), and consolidate social inequalities. Even though symbolic and social boundaries are closely connected and 'should be viewed equally as real' (Lamont, Molnár 2002: 169), symbolic boundaries are a 'necessary but insufficient condition for the existence of social boundaries' (Lamont, Molnár 2002: 169).

Symbolic boundaries are formed discursively based on our subjective perceptions and are also influenced by representations from the outside. Today, the depiction of immigrants in media discourse plays an active role in shaping and reinforcing symbolic boundaries. Media might represent immigrants in different ways – positive, negative, or neutral. However, negative portrayals mostly contribute to the drawing of symbolic boundaries. Frames, where immigrants are linked with crime or terrorism, represent them as a threat to the receiving society, creating negative attitudes in the majority towards newcomers (Sohoni, Sohoni 2014; Caviedes 2015; Estrada et al. 2016) which limit mutual encounters and influence immigrant incorporation.

Boundaries may become exaggerated by frames based on stereotyping or which emphasise the 'otherness' of the immigrant (Estrada et al. 2016). In particular, defining who 'we' are and who 'they' are may lead to distinguishing society as 'us' and 'them'. As a result, there is no favourable environment where fruitful social interactions can arise. Importantly, the immigrant voice is generally almost always missing in media coverage as well. Immigrants belong to the 'others' as well as poor, handicapped people, sexual and ethnic minorities, who exclude from the 'normal values of Western culture' (Spivak 1999). Simultaneously immigrants belong to the discourse powerless salient social group, that less quoted or that have less to say (van Dijk 1988). As van Dijk (1988) asserts, people who are neglected in the press are people who are neglected in social life. According to van Dijk (1988: 140) 'there is not much difference between the free press of the Western countries or the more controlled press in most communist and many Third World countries'. Thus, by ignoring the opinion of immigrants, the media deprives them of justification, and, on the other hand, provides readers a biased view of immigrants.

How immigrants are described or labelled in media coverage creates public opinion and policy outcomes (Sohoni, Sohoni 2014; Bleich et al. 2015; Estrada et al. 2016); in other words, media discourse may have an impact on immigration policies. In particular, representations of restrictive immigration legislation in media contribute to the maintenance of symbolic boundaries, especially when readers rely principally on the media discourse in place of the original legislative resources or actual law texts (Estrada et al. 2016). Nevertheless, I will discuss immigration legislation as a separate dimension of boundary-making below.

According to Estrada et al. (2016), the government continues to be a key player in drawing boundaries among groups of immigrants and natives through immigration law-making. Social boundaries are manifested by restrictive immigration policies that 'draw a sharper line between "us" and "them", highlighting or brightening boundaries' (Heizmann 2016: 1793). Immigration legislation provides immigrants with unequal rights in comparison to those that citizens enjoy. Immigrants may have different rights even within one country. For instance, in the European context, there is a distinction between immigrants from the EU and non-EU countries and third countries (Heizmann, Böhnke 2018). This distinction between immigrants and natives results in the creation of social boundaries. However, for third-country immigrants living in the EU, there is an extra layer of social boundaries that define them as both as foreigners and as non-EU immigrants. Contrarily, integration policies endeavour to reduce inequalities and achieve equilibrium between immigrants and non-immigrants.

Here it is necessary to mention the importance of the time aspect, respectively the time of arrival and duration time that influence boundary-making. It is a difference in the time when migrant arrived in a new country, precisely it depends on how many migrants this country has? How more restrictive immigration policy towards newcomers? How many experiences locals have with living in a multicultural society and which attitudes they have towards foreigners? etc. Another important aspect is the duration time of the foreigner's stay. First, as time goes on, it comes about a mutual habit and adaptation, on both part, of foreigners and locals. Second, and more important is, with increasing a duration time in a new country, the migrant acquires more and more rights in society, and at the same time, has to overcome less and less boundaries.

This article examines symbolic boundaries found in the Czech media coverage of Russian immigrants. The perception of historical experiences with Russians as well as the current conditions of Czech-Russian relations influence the Czech media's representation of Russians. Moreover, Czechia, as a post-socialist country, is in transition and is still dealing with its heritage. Večerník (2002) points to the social transformations of Czech society, especially human mentality and behaviour patterns that are not completed yet (Sýkora, Bouzarovski 2012). Klvaňová (2018) concerns herself with the shaping of symbolic boundaries between Russian speaking immigrants and Czechs through an examination of collective memory – in particular, the cultural trauma caused by the Soviet military intervention and occupation of Czechoslovakia in 1968. She found that Czech society perceives immigrants from the former Soviet Union as 'colonizers', devolves responsibility for past acts of occupational violence to current immigrants, marks them as 'others', and keeps them at a distance due to the former dominance of the Soviet regime (Klvaňová 2018). Thus, cultural trauma in Czech society contributes to the stigmatisation of newcomers through past negative experiences and draws symbolic boundaries (Klvaňová 2018). Russia's current geopolitical behaviour (for example, its violation of international law in the annexation of another state's territory) also significantly influences the majority attitudes towards its citizens.

Social boundaries are primarily represented by an immigrant's socio-economic status. Most Russians come to Czechia with a high-level socio-economic status and try to keep or enhance it upon arrival. This points to the differences between Russian immigrants and other Russian-speaking foreigners from the East. On the other hand, Russians belong to third-country immigrants; thus, unlike immigrants from EU countries, they have much more difficult entry conditions, access to the labour market, and limited possibilities to use other state benefits (for instance, access to public health insurance, the right to vote, etc.). On that account, it is necessary to examine the implementation of Czech immigration and integration policies that shape social boundaries by distinguishing among immigrants from EU and non-EU countries and reinforces them at the institutional level. In the next section, I briefly discuss the research methods.

## 2.2 Research design

The article offers the results of three-part research. Firstly, a historical development overview of Czech-Russian relationships provides a summary of previous detailed academic research and studies built upon the memories of immigrant descendants, analyses of documents from historical archives, as well as a discussion of the current situation.

Secondly, the representation findings were discovered through an analysis of Russian immigrant coverage in the online version of Czech newspapers. The media analysis focused on four of the most read Czech national daily newspapers, such as *Lidové noviny*, *Deník*, *Blesk*, and *Reflex*, whose articles have been under observation throughout an eight-year period (2011–2018). The important reason for choosing these newspapers was the simple logical claim that the most read sources have a wider target audience which could be affected by reading its content.

Newspapers articles were searched using the keywords 'Russian' and 'Russians' on newspapers' websites which archives were available online. The keywords 'migrant' and 'immigrant' were not using for the purpose to reduce or eliminate the useless incidence of found articles that deal with immigrants in general. The selection of articles had to concern information about Russian immigrants as a main requirement. Each found article was read and its information value detected. Articles that did not directly deal with Russian immigrants living in Czechia were excluded. For instance, articles about tourism, sport, culture, and international politics. If the article contained relevant information, it was included in the database of articles in the form of a simple Excel spreadsheet. Articles were categorised by topic in order to ascertain what is written and spoken of in the Czech press in relation to Russian immigrants. The total number of found articles revealed whether the Russians are popular in the Czech media discourse or not. Subsequently, the following characteristics were identified for each article: geographic level (national, regional, local), type of narrative with the numbers of each type, and the possible participation of Russians.

Finally, the article offers (1) a discussion of the socio-economic status of Russian immigrants based on 2011 census data from Czech Statistical Office with emphasis on three features – income, education, and occupation – and (2) an assessment of their legal status via an evaluation of Czech immigration and integration policies, which was based on an overview of their general development from 1990 and any relevant changes. The analysis focuses specifically on immigrants from the third countries (including Russians) and their institutional position in society as a result of implemented immigration policies. To compare with EU immigrants, I discuss the limits and disadvantages of Czech immigration policies towards immigrants from non-EU countries that contribute to the creation of social boundaries in the integration process.

Nevertheless, there are some limitations of the study. The first part which deals with the historical development overview is limited by the lack of numbers of academic studies about Czech-Russian relationships. The Russians are not much explored immigrants' groups in Czechia for instance in contrast to Ukrainians or Vietnamese minorities. The analysis of media discourse about Russian immigrants based on the research of newspapers only – it is the second limitation of this research. It may be better to include the other media sources – TV, radio, and social networks on the Internet (e.g. Facebook, Twitter, Instagram, etc.). On the other hand, this would lead to the overshoot an extent of the article and would make it possible to create another independent article, hence the media discourse of this article is represented only by analysis of the press.

## 3. Results

### 3.1 Heritage of the past: Development of Czech-Russian relationships

Different historical events influence the current attitudes of Czechs towards Russian immigrants. Since the establishment of the Czechoslovak and Czech Republics, there have been three waves of Russian immigration. Sládek (2010) gave names to these waves according to the periods in which they took place: the First Republic wave (1918–1948), the socialist wave (1948–1989), and the post-socialist wave (1989–present). The individual waves differ from each other by volume and structure of immigrants, their motivation to move, and the attitudes of the Czech receiving society. Moreover, the migration history of Russians is characterised itself by alternating voluntary and involuntary migration periods.

Czech-Russian relationships arose in 1918, during the first Czechoslovak Republic, when Russian students, professors, scientists, and wealthier intelligentsia (Kopřivová 2001) were forced to flee from Tsarist Russia for political reasons (Sládek 2010) after the Bolshevik coup. Later, they were joined by Russian soldiers who did not want to return after the First World War, and therefore, stayed in Czechoslovakia. The largest concentration of Russian students and professors was in the capital of Czechoslovakia where most universities were located. Hence the reason 1920s Prague was nicknamed the 'Russian Oxford' (Sládek 2010). The newly established Czechoslovak state organised an unprecedented humanitarian action for Russians (the so-called 'Russian Action') that set up and secured not only the basic needs of the immigrants but also provided temporary asylum and the opportunity to study and work. The responsive Czechoslovak policy emphasised the cultural enrichment of Europe due to the presence of Russian refugees who carried with them the traditional Russian culture. The relationships between Czechs and Russians were mostly friendly at the beginning when all these actions appeared as a temporary situation. However, when Russians realised the way back was definitely closed, they had to accustom themselves to their new home while the Czechs had to come to terms with the permanent presence of new citizens and learn to live together. At this point, Russians started to build their own community, establishing societies, organisations, and institutions, some of which still function today (the Slavic Library in Prague, for instance). Sládek (1999) notes a disadvantage in the existence of these societies: the hermetic closeness of the Russians to the host society represented a major barrier to the process of their integration. Keeping their own Russian culture and traditions without an effort to assimilate to that of Czechs led to the shaping of symbolic boundaries by Russians themselves towards the receiving society.

Top among positive Czech-Russian relationships was a victory in World War II, and especially the liberation of Czechoslovakia by the Soviet Army; Czech people appreciated and were grateful towards Russian as well as Soviet soldiers. After the end of the Second World War in 1945, there was a certain euphoria in Czech-Russian relations. The significant influence of the Soviet Union helped the Communist Party gain political power in Czechoslovakia and establish a communist totality in 1948. Although according to Večerník (2002) the communist regime was not successful and could not enter deep inside into the Czech society, it significantly influenced the behaviour of the Czech population, and these negative experiences are still passed on from generation to generation. During socialism, Czechs and Russians were connected by a lot of common things, for instance, economic and cultural relations (Sládek 2010). Eventually, previous open and fruitful mutual everyday interaction and collaboration have changed into pragmatic economic cooperation (Kratochvíl et al. 2006), and subsequently, it has moved towards the negative influence of Soviet power. The subordination and the increasing dependence on the Soviet Union led to the gradual destruction and backwardness of the Czechoslovak economy, which once was one of the most advanced in post-war Europe.

Unfortunately, in 1968, the Prague Spring was followed by the tragic Soviet occupation of Warsaw Pact troops, which ruled Czechoslovakia under orders from Moscow from that point on. Gratitude to the Russians for the liberation of Czechoslovakia in the

Second World War was replaced by hatred towards any that had Russian roots due to the invasion. The negative experiences of the communist totality period form the foundation of the symbolic boundaries towards Russians and everything of Russian genesis. According to Klvaňová (2018), this collective trauma of communism in the majority society tends to reflect these events into the present and to devolve responsibility onto contemporary Russian and/or Russian-speaking immigrants.

After the events of 1989 took place, a third Russian migration wave began which continues to this day (Sládek 2010). At present, negative attitudes persist within Czech-Russian relations. And there are reasons for that. First, today's Russian immigrants inherit a 'collective guilt' for the 1968 occupation. A second reason reflects the typical xenophobic attitudes towards foreigners in general within Czech society. This negative reaction triggers a connection between Russians and the mafia, espionage, and perception of Russians as agents of Putin or the Kremlin.

Klvaňová (2018) also points to the potential threat of contemporary Russian imperialism, which is intensely perceived and monitored in Central and Eastern Europe. The Russian occupation of Crimea in 2014 and the subsequent war in the Donbas region evokes Czech memories of the 1968 invasion when every Czechoslovak was considered a victim and at the same time, every Russian had been perceived as a perpetrator (Klvaňová 2018). As a result of the deep-seeded post-communist collective trauma, contemporary Russia's geopolitical behaviour in the international arena is largely reflected by negative attitudes of the Czech majority towards Russian immigrants due to an equation of Russians with Russia. In August, Czech people annually remember the tragic events of 1968 – the 50th anniversary of the Soviet invasion of Czechoslovakia passed in 2018, stirring a great response in Czech public discourse. In the following section, the issues of the portrayal of Russians in Czech media will be discussed in more detail. Notwithstanding, it seems the more time passes, the more the events of 1968 have been made into a representative reminder of the post-communist trauma, thus sustaining the symbolic boundaries which are then reinforced and transferred onto the next generation.

The first and last waves of migration have much in common. Today, Russian students, intellectuals, and wealthy entrepreneurs choose Czechia as a migration destination, similarly to the first Czechoslovak Republic period. This tradition, however, today contains a significant critical point, where positive experiences from the past have been influenced by the negative events of the communism period. The communist regime and the Soviet occupation of Czechoslovakia have left a significant trail in the history of the Czechoslovak nation, which is still one of the primary causes behind the existence of symbolic boundaries in the process of negotiation between Czechs and Russians. The influence of these negative past experiences on the representations of Russians in the Czech media will be discussed in the following section.

### 3.2 Media coverage of Russian immigrants in the Czech press

The media discourse analysis found 68 articles: 30 in *Lidové noviny*, 19 in *Deník*, 11 in *Blesk*, and 8 in *Reflex*. Considering this fact, we can claim that Russian immigrants are not the dominant object of Czech newspaper coverage. In terms of geographical scale (Fig. 1), 37% of the articles reported on Russians in the Czech national context. The regional level was represented in 56% of the articles; most of them dealt with Russian immigrants in Prague and Karlovy Vary, which is explained by the significant concentration of Russians in these two cities. Written about less frequently were Russians in other Czech cities, such as Brno, Hradec Králové, and Kunovice. In terms of the local level, only 7% of articles in the case of Prague focused on Russian immigrants living in the districts of Bubeneč, Nové Butovice, Zličín, Stodůlky, Letňany, and Vršovice. In a comparison between national and local levels, the same findings were discovered by Lawlor (2015), claiming that media discourse on immigrants is generally much more nationalised and mostly neglects the local context. However, in my analysis, the regional level emerged and was represented more often (56%) than others.

The next finding in the discourse analyses concerns the participation of Russians in the media debate. The question is how often Russians are given the opportunity and space to express themselves in the Czech press? The media discourse analysis found only 16% of all articles include the opinions of Russian entrepreneurs, students, and journalists living in Czechia. Most of these articles are informative narratives, where Russians descript why Czechia is attractive to them. For instance, the high achiever Russian entrepreneur presents:

> Czechia is attractive to the Russians because there is a close mentality … Western European societies are very much based on tradition and are not influenced by communism. New traditions and relationships are now being built in Eastern Europe. Here, Russian integrates into society faster. In Western Europe, no matter how much money Russian has, he will always be a foreigner there. (Lidové noviny, 23.12.2018)

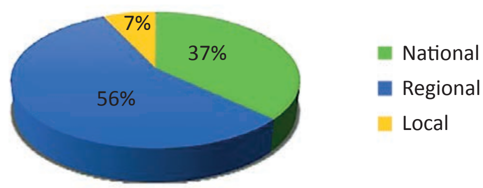


Fig. 1 Percentage of all articles by geographical levels.

Media which offers the majority an immigrant's perspective directly has significant value in the creation and improvement of an individual's perception as well as public opinion about immigrants in general. Thus, an immigrant voice in media discourse can be used as a tool in the elimination of symbolic and/or social boundaries as well as in the prevention of their formation.

Found articles about Russians covered various narratives (Tab. 1), the most often discussed is their cohesion with the majority (21%), entrepreneurship (16%), activity on the real estate market (15%), and criminality (15%). Articles dealing with everyday negotiations between Russians with Czechs never provided information about conflicts or tensions, but rather they represented non-conflictual social interactions. Nonetheless, it is remarkable that articles concerning the everyday life of Russians in Czechia several times (29%) made mention of the 1968 occupation. For instance, a resident from Carlsbad narrates about cohabitation Russians with locals, and about sometimes provocative behaviour from the Russian side:

> The Russians still claim that Carlsbad is beautiful and that they are very well here. And gradually the local people from Carlsbad are getting used to them. Nevertheless, the Russians can dial locals almost reliably. For example, when they (Russians) indulge in fireworks on August 21st or when the Russians defeat the Czechs in hockey. The locals here do not forgive that. (Deník, 10.12.2011)

This demonstrates that media discourse maintains and reinforces symbolic boundaries which were initially created by negative past experiences. In articles about the housing or real estate market, Russians were usually described as owners of expensive luxury apartments – mostly in Karlovy Vary but Prague as well. This title of the article is a very good example that captures the nature of fondness for luxury property: 'Russians love Czechia. Castles are cheaper here' (Lidové noviny, 15.11.2011) Czech media discourse largely accuses Russian immigrants of raising property prices in such a way that others cannot afford them. Less attention was paid to topics dealing with the presence of Russians in Czechia generally and which related to outdated stereotypes from time to time (12%).

Only 6% of found articles connected the Russians with espionage. This happened thanks to information within reports of the Security Information Service of Czechia (BIS), which mostly have a political context and are built on fears of Russia's geopolitical behaviour in the international arena (for more information about the securitisation of European media discourse see, for example, Caviedes 2015). 8% of the articles dealt with the Russian presidential elections, or rather they portrayed the participation and election preferences of Russians living abroad. Bleich et al. (2015: 861–862) noted that 'media outlets, especially print media in Europe, are often associated with particular political viewpoints'. As a result, an equation takes place between Russian immigrants living in Czechia and the political force in their motherland. These representations of Russians as spies create a particular perception within the majority society, which is accompanied by feelings of suspicion and mistrust towards the whole Russian immigrant population. This is yet another example of how boundaries can be created in the negotiation between the majority and immigrants. It is also worth mentioning that almost no attention was paid to the themes such as the Russian financial crisis (3%), debts (1%), church restitution (1%), discrimination (1%), and emigration from Russia (1%).

**Tab. 1** Percentage of all articles about Russian immigrants by narrative type.

| Narrative | % of articles |
|---|---|
| Cohesion with the majority, everyday life[1] | 21 |
| Entrepreneurship | 16 |
| Real estate market activity | 15 |
| Criminality | 15 |
| Stereotypes | 12 |
| Participation and election preferences of Russians abroad | 8 |
| Espionage | 6 |
| Russian financial crisis | 3 |
| Debts | 1 |
| Church restitution | 1 |
| Discrimination | 1 |
| Emigration | 1 |

Source: own research
[1] 29% of these narrative type articles mentioned the 1968 occupation.

Another interesting finding is that Czech print collectivises Russians when covering other Russian-speaking immigrants from former Soviet Union countries. Therefore, the narratives in these articles lead to a misrepresentation of reality, shaping media bias towards Russians. Only three articles of this sort were discovered in the research, but it is noteworthy that two of them deal with criminality. For instance, the title in Blesk newspaper introduces the crime as committed by Russians: 'Two Russians raided a money truck: They neutralized the drivers with tear gas', but the content of the article tells us that they were not actual Russians and instead were possibly Russian-speaking foreigners or even people who speak a language similar to Russian: 'According to witnesses, one of them was nervously and loudly telephoning in Russian or similar language' (Blesk, 22.6.2015).

The question is how many people read only titles with this distorted reality, which therefore create a negative public perception of Russians and shape the majority attitudes towards them? Bleich et al. (2015)

note that articles about immigrant individuals with a criminal or economic threat context can lead to representation of the whole group of immigrants as deeply problematic for society.

### 3.3 Socio-economic status of Russian immigrants in Czechia

A significant factor in the shaping of social boundaries is the socio-economic status (SES) of immigrants, which can be seen as a source of various inequalities. Russian immigrants living in Czechia are perceived by some scholars (e.g. Drbohlav et al. 2010; Janičko 2010) as an elite group of immigrants. They differ from the immigrants of other former Soviet countries in the following ways. First of all, there is a high level of education among Russians. Most of them (43%) carry a university degree, which exceeds the Czech national average by more than three times (Czech Statistical Office 2011). However, it should be added that foreigners from Western Europe and the United States also come with a high education level. Russians also care about the education of their children and pay close attention to it. Believing in the European education system, which in their opinion is better and cheaper than Russian, they send their children to study abroad. This is confirmed by an increase of share of Russian students attending Czech universities from 4.9% in 2007 to 12.9% in 2019 (Czech Statistical Office 2019). Russians are confident that a high level of education provides better opportunities in obtaining well-paying jobs and general well-being.

The next specific feature that characterises Russians in Czechia is their high economic activity and type of occupation. Most of them run a business or do a highly-skilled job in a position that corresponds to their education level. As 2011 census data shows, 16.2% of Russians are frequently employed in wholesale or retail; 13.1% in the real estate sector; almost 9% of Russians carry out qualified, scientific, and technical activities; 8% are in manufacturing, 7.5% in information and communication technologies; and 6.4% carry out administrative and support activities. This differs among Russians; for instance, Ukrainians, who are mostly employed in Czechia as construction workers or in manufactories, do lower-skilled jobs in comparison to the jobs they performed in their home country (Drbohlav, Janská 2004). Furthermore, it is typical of Russians to create an immigrant economy, which focuses on their compatriots or other Russian-speaking foreigners, allowing them to remain relatively independent and, at the same time, limiting their interaction with the Czech majority. In this case, Russians initiate the shaping of social boundaries themselves through the creation of their own small world with strong inner ties that help them to separate and close off from others, including Czechs.

Several studies show that Russian immigrants in Czechia are distinguished by their incomes not just from other foreigners but also from the Czech majority. For instance, a survey provided by Schebelle et al. (2015) found that Russians had the highest monthly income and lowest debt in comparison to Ukrainian and Vietnamese immigrants in Czechia. Vavrečková and Dobiášová (2015) discovered that in 2013 the average and median gross monthly salary of Russians in Czechia exceeded the average and median gross monthly salary of domestic inhabitants.

The specific features of Russian socio-economic status discussed above rank them among the most self-sufficient immigrants in Czechia, distinguishing them from others, including the Czech majority. This socio-economic division of 'us' and 'them' leads to a deepening of inequalities in society and, therefore, to the creation of social boundaries to which Russians contribute themselves.

### 3.4 Czech immigration policies

The history of Czech immigration policy is thirty years old. Some scholars (e.g. Barša, Baršová 2005; Drbohlav et al. 2010; Kušniráková, Čižinský 2011) distinguish five historical periods during which liberal and restrictive approaches cyclically alternated.

The first period took place between 1990 and 1996 when Czechia did not regulate or limit entry to its territory. This 'liberal tolerance' (Barša, Baršová 2005: 222) approach towards all foreigners in Czech immigration policy enabled free entry to the country but, as Drbohlav et al. (2009: 46) note, 'without a legal way for permanent residence or naturalization, except for marriage with a Czech citizen'.

Between 1996 and 1999, due to the deterioration of the socio-economic situation in Czechia as well as increasing numbers of illegal foreign workers, Czech immigration policy turned to a restrictive approach through a tightening of the rules. At the same time, Czechia became an EU candidate country and therefore sought to adapt its entry requirements accordingly. As a result, an amendment to Act No. 326/1999 Coll., on the Residence of Foreign Nationals in the Czech Republic, came into force, which complicated the lives of immigrants via the implementation of a visa requirement before entering Czechia (Drbohlav et al. 2009; Kušniráková, Čižinský 2011). Applications for a permanent residence permit were permissible after ten years of continuous stay in Czechia and only for the purpose of family reunification, employment/entrepreneurship, and humanitarian cases. In essence, this was the first step in creating institutionalised (Bail 2008; Heizmann2016) and politicised (Neumann, Moy 2018) social boundaries towards newcomers through the regulation of their entrance and residence.

The third period – 2000 to 2004 according to Barša and Baršová (2005) or 2006 in keeping with Kušniráková and Čižinský (2011) – was marked by a partial liberalisation. In 2004, Czechia joined the EU and the most important change in the Czech immigration policy came into force: a division of all immigrants into foreigners from EU and non-EU countries. Free entry, movement, and access to the Czech labour market was given to EU citizens and their family members – essential benefits distinct from immigrants coming from non-EU countries. It was the first significant change to bring disadvantages leading to institutionally rooted social boundaries, especially towards third-country immigrants (include Russians).

The next period, from 2005 to 2007 (Barša, Baršová 2005) or 2008 (Kušniráková, Čižinský 2011), was called a neoliberal immigration policy. A consequence of economic growth, Czechia was faced with a labour shortage, and the solution to this problem was the implementation of a green card as a way to attract a cheap labour force quickly (Drbohlav et al. 2010). The green card project existed from 2007 to 2009. As Drbohlav et al. (2010) note, Russians as well as foreigners from Vietnam, Moldavia, and Mongolia could not apply for a green card. Given the high socio-economic status of Russians, it was likely that they would not have been interested in this type of visa, which primarily targeted those doing low-skilled and poorly paid jobs. Despite this fact, this deprival of the opportunity to apply was the next brick in the wall of disadvantages and the drawing of social boundaries towards immigrants from Russia. In the middle of this period, in 2006, the length of a continuous stay in Czechia was shortened from ten to five years (Drbohlav et al. 2009).

The latest period of Czech immigration policy discussed in academic literature started in 2008 and continues to this day. Kušniráková and Čižinský (2011) call this time a neo-restrictive period during which entry and stay requirements have been tightened and entrance to Czechia for some nationals, such as Mongolians, Moldavians, Thais, Ukrainians, and Vietnamese, has been temporarily cancelled.

In 2011, the next amendment brought new, stricter application requirements. Every applicant must now provide proof of secure accommodation, health insurance, and funds for their stay in the country. Moreover, personal attendance when applying, as well as an interview with a police officer, makes the whole process longer and more apprehensive than before. Finally, the newly implemented permit card with biometric data increases expenditures for immigrants.

So as to attract a high-skilled labour force to Czechia, a blue card was later implemented and, in 2014, an employee card for all types of labour (including low-skilled) replaced the previous green card. According to the Ministry of Interior, there are two modes of the employee card: (1) *dual*, which contains residence and employment permits, and (2) *non-dual*, which offers a residence permit only – for foreigners with free access to the Czech labour market who (a) have obtained secondary, tertiary, tertiary professional, or university education in Czechia; (b) wish to be employed as a pedagogical/academic worker at a Czech university; or (c) have been posted to Czechia for the provision of services by his or her foreign employer based in some other EU state.

Two years later, in 2016, the next amendment to the Alien Act was implemented. Two types of permit residence newly came into existence: (1) a short-term visa for seasonal workers and (2) a long-term residence permit for investment purposes. However, there were also restrictive changes. For instance, a further restrictive step was taken in terms of acquiring a permanent residence permit by children in cases of family reunification when those eligible were underage children. Such an unhappy implementation of immigration policy leads to the division of family members and seriously impacts Russians, who often move with the whole family. Therefore, one of the most common migration strategies for financially-secure Russians is to send their child to be educated in Czechia first and then move to them.

In 2018, a recent amendment of the Alien Act brought some liberal changes related to students and scientists who, after finishing their studies, may remain in Czechia for nine months for the purpose of seeking employment or practising entrepreneurship – finally Czechia has considered the human capital of foreign nationals into which it invests considerable funds (a foreigner may study in Czech language free of charge and after graduation they now have free access to the national labour market). Today, at least in small steps, the permeability of social boundaries has begun to be relaxed, even though it is only for select groups of foreigners. Additionally, every foreigner has an obligation to complete an integration and adaptation course during the first year after their arrival in Czechia.

Another significant type of institutional inequality is related to the division in voting rights of immigrants who are living in Czechia. In accordance with the Election Acts (No. 491/2001 Coll., No. 62/2003 Coll.), EU citizens with a permanent residence permit have the right to vote in municipal elections as well as the European Parliament elections. On the other hand, citizens of third countries do not have any voting rights, except holders of Czech citizenship. It means not all immigrants who live long-term in Czechia have an equal possibility of influencing their living conditions in the receiving country. The government enables foreigners to come, work, and live in the country while limiting opportunities and withholding the right to change and enhance them until citizenship is obtained.

Even though Czechia does not have a self-standing integration law, its integration strategy has recently been intensively developing. The Ministry of the Interior drafted the first version of an immigrant integration policy in 2000 when the Alien Act came in force. Focusing on equal opportunities and non-discrimination, immigrant integration policy struggles towards similar rights for long-term residents as those received by Czech citizens. In 2006, 2011, and 2016, there were fundamental updates in the integration policy which paid attention primarily to social interaction between the majority population and immigrants by supporting good relations in everyday life negotiation. Since 2010, the Czech government has annually published an action plan which contains priorities, goals and means, and reports on the fulfilment of the action plan in the previous year.

## 4. Conclusion

This article has investigated the symbolic and social boundaries that hinder the integration process of Russian immigrants in Czechia. This study contributes to the literature on boundary-making, and particularly the case of Russian immigrants, in Czechia. The findings of this study are summarised henceforth. The significant factors that create boundaries discussed were (1) the development of Czech-Russian relationships, (2) the depiction of Russians in Czech media discourse, (3) the socio-economic status of Russian immigrants, and (4) the implementation of immigration and integration policies.

The positive attitudes towards the presence of Russians in Czechia as well as Czech-Russian collaboration were disturbed by the negative experiences during the communist regime. In particular, the invasion and military occupation of Czechoslovakia by the Soviet Army in 1968 left a dramatic footprint in the souls of the Czech people. Unfortunately, this collective trauma persists in the minds of elderly Czechs to the present day. As Klvaňová (2018) indicated, contemporary Russia's geopolitical behaviour saturates the negative majority attitudes due to a fear of history repeating itself. Collective trauma turns to collective guilt, for which current Russian immigrants are deemed responsible in Czechia. Memories of the negative historical events, as well as the majority perception of the current status, can influence the media depiction of Russians.

According to the media discourse analysis, 'Russian immigrants' are not a popular topic in the Czech press. However, the frequency is not so important in contrast to the narrative context, which created an overall impression on readers. In this regard, based on the most common narratives in the media, we can compile a typical image of a Russian immigrant in Czechia. Probably he will be an entrepreneur who operates in the real estate market and owns a large number of luxury apartments or castles, he is maybe involved in crime, or even he is a Russian spy; he gets along with the majority without any problems, even though he is sometimes able to provoke them, for example on the anniversary of the occupation of Czechoslovakia. A further result indicated that Russians rarely receive space in the Czech media to express their opinions, it means they belong to a powerless salient social group (van Dijk 1988) or in general to the 'others' (Spivak 1999; Estrada et al. 2016). And finally, the media use Russians as a general term, pertaining not only to foreigners from Russia but also other Russian-speaking immigrants; such a generalisation can lead to the distortion of reality.

In summary, negative experiences from the past feed the present majority perception through media representations, which help identify and determine in-group and out-group members. These practices contribute to the 'otherness' (Spivak 1999; Estrada et al. 2016) of Russians and enable the classification of people in society as 'us' and 'them' and draw symbolic boundaries (Lamont, Molnár 2002). Linking with a crime as well as a constant return to the past and a reminder of the events of 1968 classify Russians in Czech media as a threat. Thus, the power of media discourse has a significant impact on the creation and strengthening of symbolic boundaries in majority attitudes towards Russians that might lead to the reinforcement of negative attitudes (Sohoni, Sohoni 2014; Caviedes 2015; Estrada et al. 2016), limit their encounters, and therefore, obstruct their fruitful integration.

The higher education of Russians provides them the opportunity to get high-paying employment, and therefore, a better position on the social ladder. This combination of high education level and high economic activity ranks Russians as an elite immigrant group that differentiates them from others and the Czech majority as well, leading to the consolidation of social inequalities. It is a next example of the 'otherness' (Spivak 1999; Estrada et al. 2016), but in this case to which Russians contribute themselves. Thus, they are able to create social boundaries by their specificity.

However, Russians, as third-country immigrants, have an unequal legal status in comparison to foreigners from EU countries. The results of the research further show that the restrictive implementation of Czech immigration policy towards Russians, as well as other third-country immigrants, regulates their entrance, limits their access to the labour market, and defines them as 'they' or 'others'. As with the findings of previous studies (e.g. Heizmann, Böhnke 2018), a detailed investigation of Czech immigration policies confirms that there is an emphasis on legally privileged EU immigrants in comparison with immigrants from third countries who are legally disadvantaged. In sum, on the one hand, Russian immigrants create social boundaries themselves through their specific self-sufficient status that defines their social opportunities in society (Lamont, Molnár 2002). On the other hand, other sources of inequalities that lead to the creation of social boundaries are the implementation of immigration policies that are broadly accepted in society (Lamont, Molnár 2002).

Based on this study I suggest some concluding remarks that would help to make the process of integration easier for foreigners and fruitful for society in whole. First, members of the Czech majority society should intensify social contact with foreigners living in Czechia and behave towards newcomers with understanding and tolerance, regardless of their country of origin. Current immigrants cannot be responsible for past mistakes made by their predecessors. Moreover, in everyday negotiations and attitudes towards foreigners, it is incorrect to connect immigrants with political affairs taking place in their origin countries as they have left their motherland and live abroad. Second, the media should pay attention to how they represent immigrants who live among us and how that may impact their lives. At the same time, foreigners should be offered more avenues in which to express their opinions, and interest in them should be shown. In the process of building attitudes towards foreigners, readers should rely on their own experiences, not a mediated perception of news served by the media. Third, although it is difficult to imagine quick changes in legislation, Czech immigration and integration policies might adapt to all foreigners staying on its territory and intending to remain here.

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## References

Act No. 326/1999 Coll., on the Residence of Foreign Nationals in the Czech Republic.
Act No. 491/2001 Coll., on Elections to Municipal Councils and on Amendments to Some Acts.
Act No. 62/2003 Coll., on Elections to the European Parliament and on Amendments to Some Acts.
Allport, G. W. (1954): The Nature of Prejudice. Reading, MA: Addison-Wesley.
Bail, C. A. (2008): The Configuration of Symbolic Boundaries against Immigrants in Europe. American Sociological Review 73, 37–59, https://doi.org/10.1177/000312240807300103.
Baršová, A., Barša, P. (2005): Přistěhovalectví a liberální stát. Imigrační a integrační politiky v USA, západní Evropě a Česku. Masarykova univerzita, Mezinárodní politologický ústav, Brno, 205–255.
Barvíková, H. (2005): Ruští emigranti v Československu v letech 1918–1938. In: Exil v Praze a Československu 1918–1938. Pražská edice, Praha, 9–21.
Bleich, E., Bloemraad, I., de Graauw, E. (2015): Migrants, Minorities and the Media: Information, Representation, and Participation in the Public Sphere. Journal of Ethnic and Migration Studies 41, 857–873, https://doi.org/10.1080/1369183X.2014.1002197.
Bosswick, W., Heckmann, F. (2006): Integration of migrants: Contribution of local and regional authorities. European Foundation for the Improvement of Living and Working Conditions, Dublin.
Caviedes, A. (2015): An Emerging 'European' News Portrayal of Immigration? Journal of Ethnic and Migration Studies 41, 897–917, https://doi.org/10.1080/1369183X.2014.1002199.
Czech Statistical Office (2019): Foreigners in the Czech Republic. Prague.
Drbohlav, D., Janská, E. (2004): Current Ukrainian and Russian Migration to the Czech Republic: Mutual Similarities and Differences. In: Górny, A., Ruspini, P. (eds.): Migration in the New Europe, East-West Revisited. Palgrave Macmillan, London, 49–64.
Drbohlav, D., Lachmanová-Medová, L., Čermák, Z., Janská, E., Čermáková, D., Dzúrová, D. (2009): The Czech Republic: on its way from emigration to immigration country. IDEA Working Papers.
Drbohlav, D. et al. (2010): Migrace a (i)migranti v Česku. Kdo jsme, odkud přicházíme, kam jdeme? Praha, SLON.
European Comission (2017): Special Eurobarometer 469 – Integration of Immigrants in the European Union. https://ec.europa.eu/commfrontoffice/publicopinion/index.cfm/survey/getsurveydetail/instruments/special/surveyky/2169.
Heizmann, B. (2016): Symbolic boundaries, incorporation policies, and anti-immigrant attitudes: what drives exclusionary policy preferences? Ethnic and Racial Studies 39(10), 1791–1811, http://dx.doi.org/10.1080/01419870.2015.1124128.
Heizmann, B., Böhnke, P. (2018): Immigrant life satisfaction in Europe: the role of social and symbolic boundaries. Journal of Ethnic and Migration Studies 45(7), 1027–1050, https://doi.org/10.1080/1369183X.2018.1438252.
Janíčko, M. (2010): Pražští Rusové (The Prague Russians). Bachelor's thesis. Charles University in Prague, Department of Sociology.
Klvaňová, R. (2018): 'The Russians are back': Symbolic boundaries and cultural trauma in immigration from the former Soviet Union to the Czech Republic. Ethnicities 0(0), 1–20. https://doi.org/10.1177/1468796817752740.
Kopřivová, A. (2001): Střediska ruského emigrantského života v Praze (1921–1952). Praha: Národní knihovna ČR, Slovanská knihovna.
Kratochvíl, P., Cibulková, P., Beneš, V. (2006): Foreign policy, rhetorical action and the idea of otherness: The Czech Republic and Russia. Communist and Post-Communist Studies 39(4), 497–511, https://doi.org/10.1016/j.postcomstud.2006.09.002.
Kušniráková, T., Čižinský, P. (2011): Dvacet let české migrační politiky: Liberální, restriktivní, anebo ještě jiná? Geografie 116(4), 497–517, https://doi.org/10.37040/geografie2011116040497.
Lamont, M., Molnár, V. (2002): The Study of Boundaries in the Social Sciences. The Annual Review of Sociology 28, 167–195, https://doi.org/10.1146/annurev.soc.28.110601.141107.
Lawlor, A. (2015): Local and National Accounts of Immigration Framing in a Cross-national Perspective.

Journal of Ethnic and Migration Studies 41, 918–941, https://doi.org/10.1080/1369183X.2014.1001625.
Neumann, R., Moy, P. (2018): You're (Not) Welcome: The Impact of Symbolic Boundaries, Intergroup Contact, and Experiences with Discrimination on Immigration Attitudes. American Behavioral Scientist 62(4), 458–477, https://doi.org/10.1177/0002764218760370.
Pettigrew, T. F. (1998): Intergroup contact theory. Annual Review of Psychology, 49(1), 65–85, https://doi.org /10.1146/annurev.psych.49.1.65.
Sládek, Z. (1999): České prostředí a ruská emigrace (1918–1938). In: Běloševská, L.: Duchovní proudy ruské a ukrajinské emigrace v Československé republice (1919–1939). Slovanský ústav AV ČR, Praha, 7–46.
Sládek, K. (2010): Ruská diaspora v České republice: Sociální, politická a religiózní variabilita ruské migrace, Pavel Mervart, Červený Kostelec.
Sohoni, D., Sohoni, T. W. P. (2014): Perceptions of Immigrant Criminality: Crime and Social Boundaries. The Sociological Quarterly 55(1), 49–71, https:// doi.org/10.1111/tsq.12039.
Spivak, G. S. (1999): A Critique of Postcolonial Reason: Toward a History of the Vanishing Present. Cambridge: Harvard University Press.
Sýkora, L., Bouzarovski, S. (2012): Multiple transformations: Conceptualising the post-communist urban transition. Urban Studies 49(1), 43–60.
van Dijk, T. A. (1988): News analysis. Case studies of international and national news in the press. Lawrence Erlbaum Associates, Publishers, Hillsdale, New Jersey.
Vavrečková, J., Dobiášová, K. (2015): Začlenění ruské komunity do většinové společnosti (Incorporation of Russian community into majority society). Výzkumný ústav práce a sociálních věcí, v.v.i., Univerzita Karlova v Praze, Fakulta sociálních věd.
Večerník, J. (2002): Výzkum společenské transformace a česká sociologie (Transition Studies and Czech sociology). Sociologický časopis 38(1–2), 55–77.

# Flood susceptibility mapping in Erythropotamos river basin with the aid of Remote Sensing and GIS

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**ABSTRACT**

Erythropotamos is a tributary of river Evros and during the last decade its drainage basin flooded many times, causing extensive damage on properties. In order to assess flood susceptibility in the aforementioned study area, the inundated areas of floods that occurred in 2010, 2017 and 2018 were initially delineated with the aid of SAR (Synthetic Aperture Radar) imagery by applying an established flood delineation methodology. Subsequently, flood susceptibility mapping was conducted for the study area by applying the Analytical Hierarchy Process (AHP). Topographical, hydrological and meteorological factors were used and each one of them was classified into three (3) flood susceptibility categories (low, medium and high). The determination of the importance for each factor over the others, which is the main objective of this research, was decided according to the proportion of the 2010 inundated area, captured by ENVISAT/ASAR imagery, which intersected with each factor's high susceptibility class. Finally, the resulting flood susceptibility map was validated according with the inundated areas of the 2017 and 2018 flood events, captured by SENTINEL – 1 A/B imagery, indicating that approximately 60% of both of these areas intersected with the map's high susceptibility zone.

**KEYWORDS**

GIS; Susceptibility mapping; Analytical Hierarchy Process (AHP); floods; remote sensing

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## 1. Introduction

Floods can potentially cause fatalities, displacement of people and damage to the environment, to severely compromise economic development and to undermine the economic activities of every community that suffers the effects of these destructive environmental hazards (Patrikaki et al. 2018; Zhong et al. 2018; Birkholz et al. 2014; Mouratidis and Sarti 2013; Yésou et al. 2013; Astaras et al. 2011). During the last decade, such phenomena have also plagued Greece, with their majority occurring in the eastern part of the region of Thrace (Kazakis et al. 2015; Nikolaidou et al. 2015; Mouratidis 2011; Mouratidis et al. 2011). Most such cases are attributed to the river Evros, which is the natural borderline between Greece and Turkey, and, along with its tributaries, has burst its banks on several occasions during the aforementioned time period. Erythropotamos is one of Evros' tributaries and although, in many occasions, flood phenomena have been observed within its river basin, there is a lack of flood hazard assessment studies referring to this catchment.

During the last few decades, advances in remote sensing and GIS have helped flood hazard assessment to become more effective. Inundation and susceptibility mapping are among the main procedures that flood hazard assessment follows, in order to achieve its goals.

Regarding inundation mapping, SAR systems are particularly suitable, thanks to the synoptic view, the capability to operate in almost all-weather conditions and during both day-time and night-time, as well as the sensitivity of the microwave radiation to water (Pierdicca et al. 2013). Furthermore, various methods have been used within the literature to delineate flood water from SAR data. Change detection highlights the temporal changes in land cover by comparing the flood scene to a previous dry image (Li et al. 2018; Psomiadis 2016; Schlaffer et al. 2015). The difference between the images can be combined with other image segmentation techniques to identify areas producing an unusually low backscatter response, improving the reliability of the flood delineation when compared to the single image methodologies (Matgen et al. 2011).

Concerning flood susceptibility mapping, according to the current literature, the contemporary trend involves mostly the creation of ensemble models, which are based on the combination of

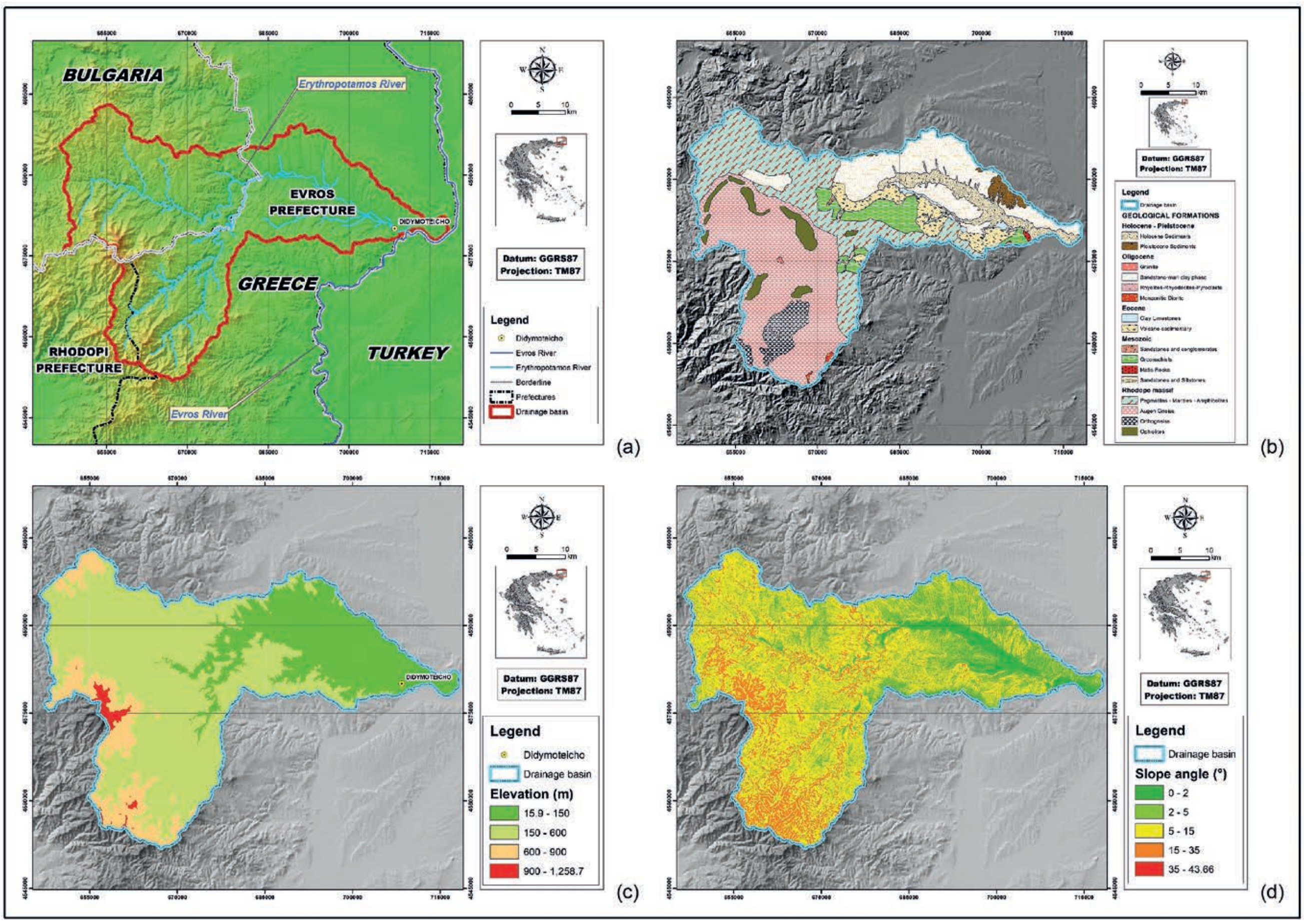


Fig. 1 a) Location of the study area (drainage basin of Erythropotamos), b) Geological formations within the drainage basin of Erythropotamos river (CoG 1989, I.G.M.E. 2002), c) Spatial distribution of elevation within the catchment of Erythropotamos river (E.E.A. 2017) and d) Spatial distribution of slope angle values within the drainage basin of Erythropotamos river.

different data-driven (machine learning), statistical or multi-criteria methods. This approach aims in achieving higher accuracy of the delineated susceptibility zones, in comparison with the flood susceptibility mapping methodologies that employ a single method or model (Costache et al. 2020; Kanani-Sadat et al. 2019; Wang et al. 2019; Khosravi et al. 2016). However, there is a plethora of methodologies that can be used in flood susceptibility assessment, such as statistical and data-driven approaches (Ettinger et al. 2016; Nandi et al. 2016; Tehrany et al. 2015; Tehrany et al. 2014; Pulvirenti et al. 2011). Among them, the analytic hierarchy process (AHP) (Kazakis et al. 2015; Stefanidis and Stathis 2013) is considered as the most widely used and, because of its simplicity, continues to be popular even in recent works (Lyu et al. 2018; Seejata et al. 2018; Tang et al. 2018). Additionally, this methodology has proved many times that it can handle sparse or poor quality data and that it can operate efficiently in regional studies (Chen et al. 2015, 2013; Wang et al. 2011).

The main aim of this research is to introduce a methodology that deals with the subjectivity that involves the determination of the hierarchy of factors in flood susceptibility mapping with the use of AHP. To this end, the proposed methodology employed the results of SAR-based inundation mapping that delineated the flood extent of the 2010 flood. Specifically, the hierarchy between the flood susceptibility factors was determined according to the proportion of the aforementioned inundated areas that intersected with each factor's high susceptibility class.

**Tab. 1** Distribution of elevation into categories according to Dikau's classification (Dikau 1989).

| Elevation | Description | Area (km²) | Percent (%) |
|---|---|---|---|
| <150 | Lowland | 429.6 | 26.543 |
| 150–600 | Hilly | 969.1 | 59.876 |
| 600–900 | Semi-mountainous | 197.3 | 12.190 |
| 900> | Mountainous | 22.5 | 1.390 |

**Tab. 2** Slope angle categorization within the study area according to Demek's classification (Demek 1972).

| Slope Angle (°) | Description | Area (km²) | Percent (%) |
|---|---|---|---|
| 0–2 | Plain to slightly sloping | 147.5 | 9.11 |
| 2–5 | Gently inclined | 390.3 | 24.11 |
| 5–15 | Strongly inclined | 864.9 | 53.44 |
| 15–35 | Steep | 215.7 | 13.33 |
| >35 | Precipitous | 0.1 | 0.01 |

## 2. Location of the study area

Erythropotamos is a tributary of Evros River, which is the longest river that runs solely in the interior of the Balkans, and its catchment covers an extent of 1,618.5 km$^2$. The largest part of its river basin belongs to Greece and particularly to the geographic region of Thrace in Northern Greece, while the rest of its drainage basin belongs to Bulgaria (Figure 1a).

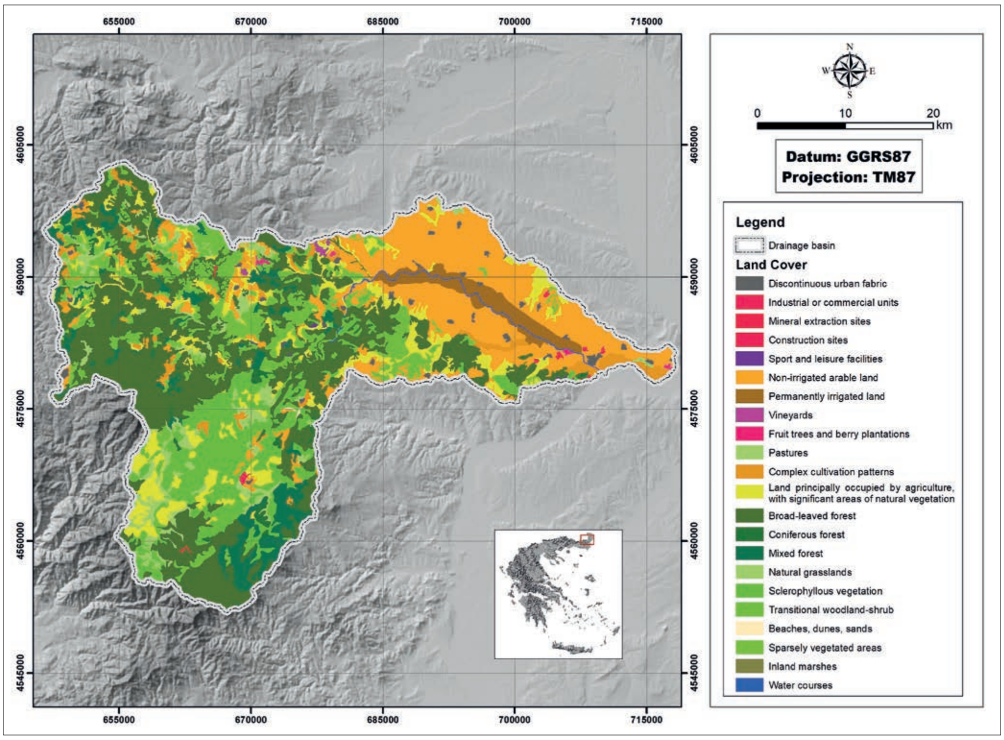


**Fig. 2** Spatial distribution of land cover in the catchment of Erythropotamos river (Copernicus 2017).

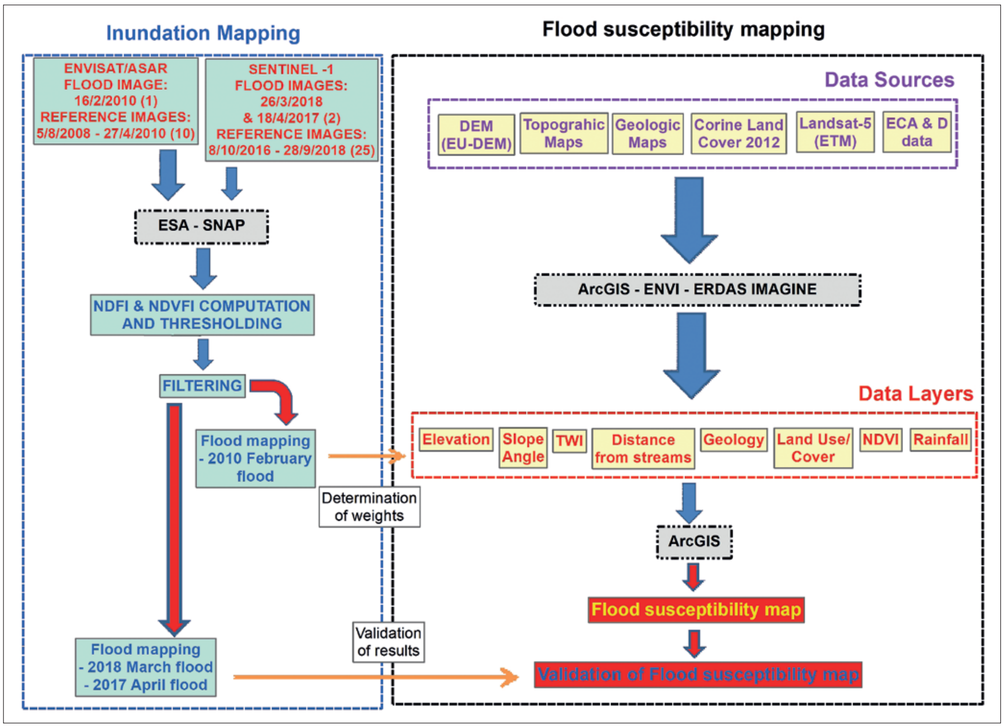


**Fig. 3** General flowchart of the applied methodology.

Regarding administrative distribution within national borders, the Greek part of Erythropotamos' river basin belongs to the Prefectures of Evros and Rhodopi.

The drainage basin of Erythropotamos River belongs to both the Circum – Rhodope geotectonic zone and the Rhodope massif. The geological formation that covers the largest part of the study area consists of orthogneissess and augen gneisses (Figure 1b).

Elevation in the drainage basin of Erythropotamos river ranges from 16 m to about 1,258 m above mean sea level (M.S.L.), and the largest part of the study area can be described as hilly according to Dikau's classification (Dikau 1989) (Figure 1c and Table 1). Additionally, the spatial distribution of slope angle values within the study area, indicates that most of its terrain belongs to the strongly inclined category (5°–15°) according to Demek's classification of slope angles (Demek 1972) (Figure 1d and Table 2).

Finally, based on information provided by the data layer of Corine Land Cover 2012 (Copernicus 2017), which, instead of the Corine Land Cover 2018 (Copernicus 2020) data layer, is chronologically closer to the gauged 2010 flood event, the catchment of Erythropotamos River is dominated by forests and semi natural areas (Figure 2). Along with agricultural areas, these two land cover categories occupy approximately the 98% of the total extent of the study area (Table 3).

**Tab. 3** Distribution of Land Cover within the river basin of Erythropotamos according to Corine Land Cover 2012 (Copernicus 2017).

| Land Cover | Area (km$^2$) | Percent (%) |
|---|---|---|
| Artificial surfaces | 18.4 | 1.137 |
| Agricultural areas | 586.2 | 36.219 |
| Forest and semi natural areas | 1007.9 | 62.274 |
| Wetlands | 0.1 | 0.006 |
| Water bodies | 5.9 | 0.365 |

## 3. Materials and methodology

The materials that were used and the methodology that was followed in order to achieve the aims of this study can be divided into two parts. The first involves inundation mapping with the use of SAR images, while the second part is concerned with flood susceptibility mapping with the use of AHP. The general flowchart is given in Figure 3.

### 3.1 Inundation mapping with SAR imagery

Eleven ENVISAT/ASAR and twenty seven SENTINEL – 1 A/B images of VV (Vertical transmit – Vertical receive) polarization were used to map the flood extents of the February 2010, April 2017 and March 2018 flood events. Their detailed product characteristics appear on Table 4.

The aforementioned SAR images were pre-processed with the aid of ESA's SAR satellite image analysis software SNAP (Sentinel Application Platform). Initially, they were calibrated to σ° backscatter coefficient values and despeckled using a 3 × 3 Gamma map filter. Regarding the co-registration step, the SAR

Tab. 4 Product information of ENVISAT/ASAR and SENTINEL – 1 A/B imagery.

| Satellite | ENVISAT | SENTINEL – 1 |
|---|---|---|
| Dates | Flood image: 16/2/2010 (1)<br>Reference images: 5/8/2008 to 27/4/2010 (10) | Flood images: 18/4/2017 & 26/3/2018 (2)<br>Reference images: 8/10/2016 to 28/9/2018 (25) |
| Spatial Resolution | 11.1 m × 11.1 m | 8.8 m × 8.8 m |
| Pass | Ascending | Descending |
| Mode | N/A | IW |
| Type | N/A | GRD |
| Level | 1 | 1 |
| Polarization | VV | VV |
| Relative Orbit | 14 | 109 |

images were co-registered with the use of EU-DEM, which is the Digital Surface Model (DSM) of European Environment Agency (EEA) member and cooperating countries that represents the first surface as illuminated by the sensors. It is a hybrid product based on SRTM and ASTER GDEM data fused by a weighted averaging approach (EEA 2017). Its horizontal spatial resolution is 1 arc second (approximately 25 m), while its absolute and relative vertical accuracy are 3.6 m and 5.3 m, respectively (Mouratidis et al. 2019).

The Change Detection And Thresholding (CDAT) methodology by Cian et al. (2018), based on the work of Long et al. (2014), was applied in order to delineate the inundated areas of the aforementioned flood events. This procedure involved the calculation of the Normalized Difference Flood Index (NDFI) and the Normalized Difference Flood in low Vegetation Index (NDFVI), which are based on the multi-temporal statistical analysis of two sets of images, one containing only the images before or after the event, and another one containing images both before or after the event and during the occurrence of the event. NDFI categorizes as flooded only areas that are temporarily covered by water, excluding permanent water bodies and non-water land cover classes. On the other hand, NDFVI was used in order to detect shallow water in low vegetation.

According to Cian et al. (2018) NDFI values that are greater than 0.7 and NDFVI values that are greater than 0.75 can be used to delineate inundated areas in open land and in low vegetation respectively. However, the resulting flooded areas require further processing according to the following criteria:

1. Flooded areas with extent smaller than the size of 10 pixels in NDFI and NDFVI images were excluded because they can be considered as spurious (Cian et al. 2018).
2. Pixels with $\sigma_{o(mean)}$ values less than 0.015 ($\sigma_{o(mean)} < 0.015$), which correspond to permanent water bodies, and pixels with $\sigma_{o(min)}$ values greater than 0.03 ($\sigma_{o(min)} > 0.03$) that represent pixels that consistently decrease their backscatter during the flood, indicating that something happened, but not enough to reach a $\sigma_{o(min)}$ value typical of water pixels, have to be filtered out from the resulting inundation maps (Cian et al. 2018).

Moreover, the adverse weather conditions during the 2010, 2017 and 2018 floods prevented satellite optical imagery and aerial vehicles from capturing the extents of the corresponding floods and thus validation of their SAR-based inundation mapping results was not feasible.

## 3.2 Flood susceptibility mapping with the use of AHP and with the aid of GIS and satellite imagery

The compilation of the susceptibility map can be achieved by conducting multi-criteria analysis (MCA), which involves the selection of criteria whose weights will be determined via the AHP. In this process, the selection of criteria is very important. A plethora of criteria has been used in previous research on flood susceptibility mapping (Hong et al. 2018; Lyu et al.

Tab. 5 Details regarding the data from which each factor was compiled.

| Primary input data | Original format | Map scale or spatial resolution | Source | Derived map |
|---|---|---|---|---|
| EU-DEM | Raster | 25 m × 25 m | EEA | Elevation |
| EU-DEM | Raster | 25 m × 25 m | EEA | Slope Angle |
| Corine Land Cover 2012 | Vector | Better than 100 m | Copernicus | Land Cover |
| EU-DEM | Raster | 25 m × 25 m | EEA | Drainage Density |
| EU-DEM | Raster | 25 m × 25 m | EEA | TWI |
| 1) Geologic Map of SE Rhodope – Thrace<br>2) Geologic map of Bulgaria | Raster | 1) 1:200,000<br>2) 1:50,000 | 1) 1:200,000 Institute of Geology and Mineral Exploration (IGME) of Greece<br>2) 1:50,000 Committee of Geology (CoG) | Geology |
| WorldClim | Raster | 825 m × 825 m | Fick et al. 2017 | Rainfall |
| EU-DEM | Raster | 25 m × 25 m | EEA | Distance from Streams |

2018; Seejata et al. 2018; Tang et al. 2018; Xiao et al. 2018; Zhao et al. 2018; Kazakis et al. 2015). Their main characteristics being that they should be connected with the physical process of the flood generation mechanism, they can be measured or quickly calculated for the whole study area and that they ought to have simple interpretability (Papaioannou et al. 2015).

According to Xiao et al. (2018) and Zhao et al. (2018), the factor's effect on the flood hazard and data availability, three types of indicators were considered in the present research, i.e. topographical, hydrological and meteorological. Specifically, topographical indicators (Xiao et al. 2018) provide information of the flow or stagnating of the water on the ground due to the impact of the terrain. In the current study they consist of elevation, slope angle and drainage density. On the other hand, hydrological indicators (Xiao et al. 2018) provide information of the intercept, infiltration and accumulation of the water and the river network. They consist of Topographic Wetness Index (TWI), distance from streams, land cover and geology. Finally, the meteorological indicators (Zhao et al. 2018) provide information on the spatial distribution of precipitation in the study area and were represented by the annual total rainfall.

The input data, their original format, the source from which the input data originated and their map scale or spatial resolution for each factor are synoptically presented in the following table (Table 5).

### 3.2.1 Topographical indicators

#### 3.2.1.1 Elevation

Elevation is considered as an important factor for floods, because flood-prone areas tend to occupy drainage basin areas with low elevation values. The data layer of elevation was derived from EU-DEM.

#### 3.2.1.2 Slope Angle

The slope angle data layer was produced by the EU-DEM data layer with the aid of raster-processing routines. Slope angle is also an important factor when it comes to discerning flood-prone areas, because areas in a river basin that occupy flat terrain surfaces tend to flood more easily than areas with more steep surface terrain.

#### 3.2.1.3 Drainage Density

The drainage density is defined as the total stream length per unit area, which can be calculated as shown in the following equation (1) (Zhou et al. 2014):

$$DD = \frac{1}{S}\sum_i L_i^S \quad (1)$$

$DD$ stands for drainage density, while $S$ represents the area of the grid and $L_i^S$ represents the length of river $i$ within the grid. Areas with high drainage density indicate high flood susceptibility.

### 3.2.2 Hydrological indicators

#### 3.2.2.1 Topographic Wetness Index (TWI)

This index according to Miliaresis (2011) belongs to the indices of soil erosion, since it is used to relate the effects of runoff with geomorphometry. It is used in order to assess soil moisture and it is defined by the Beven and Kirkby (1979) equation:

$$TWI = \ln\left(\frac{a}{\tan(\beta)}\right) \quad (2)$$

In equation (2), α stands for the local upslope area draining through a certain point per unit contour length and tan(β) is the local slope in radians. High values of TWI indicate areas more susceptible to flooding.

#### 3.2.2.2 Distance from streams

The drainage network of the drainage basin of Erythropotamos river has been produced by the EU-DEM data layer with the use of raster-processing routines (Voudouris et al. 2007). Furthermore, the distance from the streams of the drainage network data layer was compiled through the use of geoprocessing buffer routines. This factor is crucial to flood susceptibility mapping, because areas that are closer to streams are more likely to be inundated during a flood event.

#### 3.2.2.3 Geology

The synoptic geologic map of SE Rhodope – Thrace from the Institute of Geology and Mineral Exploration (IGME) of Greece, at a scale of 1:200,000 (I.G.M.E. 2002), was used in order to produce the part of the data layer that belongs to Greece. Accordingly, the geologic map of Bulgaria from the Department of Geophysical Prospecting and Geological Mapping of the Committee of Geology (CoG 1989), at a scale of 1:50,000, was used in order to produce the part of the data layer that belongs to Bulgaria.

Geology is considered a significant factor in determining flood-prone areas, because impermeable geological formations favor surface runoff. On the other hand, permeable geological formations favor infiltration.

#### 3.2.2.4 Land Cover

The data layer of Corine Land Cover 2012 (Copernicus 2017) was used to determine the land cover classes within the limits of the study area. It is worth mentioning that Corine Land Cover 2012 was chosen over Corine Land Cover 2018 (Copernicus 2020), because it depicts more closely the surface relief's land cover conditions during the 2010 flood, which was gauged by the station on Didymoteicho's bridge. Additionally, regarding the catchment of Erythropotamos River, the differences between the aforementioned data layers are insignificant since they cover a total extent of approximately 2 $km^2$. Vieux (2004) correlated land cover classes with Manning's n roughness coefficient (Table 6), which participates in Manning's formula:

$$V = \frac{1}{n} A r^{\frac{2}{3}} S^{\frac{1}{2}} \tag{3}$$

In equation (3), $V$ stands for discharge/flow ($m^3/s$), $n$ is Manning's roughness coefficient, $A$ is the "wetted" cross-sectional area ($m^2$), $r$ stands for the hydraulic radius and $S$ is the slope of hydraulic grade or the linear head loss (m/m). Moreover, Manning's $n$ roughness coefficient is inversely proportional to discharge, which means that low Manning's $n$ values correspond to high discharge values. In that way, areas susceptible to floods can be related to low Manning's $n$ values.

#### 3.2.3 Meteorological indicators

##### 3.2.3.1 Rainfall

The annual total rainfall layer was derived using raw data that were retrieved from the WorldClim database (Fick et al. 2017). The raw data involve monthly precipitation totals, which refer to the climatological period 1970–2000 and are available as an approximately 30 seconds by 30 seconds (approximately 824 by 824 m) grid (Fick et al. 2017). The total annual precipitation layer was constructed by summing all 12 monthly precipitation totals with the aid of map algebra. Subsequently, the aforementioned rainfall layer was converted to a point shapefile, from which the final rainfall data layer, with a spatial resolution of 25 m, was derived. The downscaling of the original WorldClim layer (824 × 824 m grid resolution) to the layer that was eventually used in the current analysis (25 × 25 m grid resolution), was performed by employing the universal kriging spatial interpolation method (Li et al. 2014). The interpolated values were the total annual precipitation values obtained at each point of the original WorldClim grid. The auxiliary variables used were elevation, slope, aspect and distance from the sea. The elevation data used was the EU-DEM obtained from the COPERNICUS Land Monitoring Services data portal (EEA 2017) and is provided on a 25 by 25 m grid. Slope and aspect were derived from the EU-DEM using the available raster-processing routines. Distance from the sea was also computed, by applying proximity analysis routines, at a spatial resolution of 25 m. Areas with high annual precipitation sums were considered as more prone to flooding.

**Tab. 6** Manning's *n* roughness coefficients for certain land cover types according to Vieux (2004).

| Land Cover | Manning's *n* coefficient |
|---|---|
| Artificial surfaces | 0.015 |
| Agricultural areas | 0.035 |
| Forest and semi natural areas | 0.100 |
| Wetlands | 0.700 |
| Water bodies | 0.030 |

### 3.3 Analytical Hierarchy Process (AHP)

#### 3.3.1 Determination of flood susceptibility classes for each factor

In order to apply the AHP methodology, which was introduced by Saaty (1980), the data layer of each factor was classified into three classes according to how prone each one of these classes was to flooding. Classes that are highly susceptible to flooding were assigned a rating of three (3), while those that are of medium susceptibility were assigned a rating of two (2) and those of low susceptibility were assigned a rating of one (1).

#### 3.3.2 Determination of the hierarchy between the flood susceptibility factors with the aid of the results of SAR-based inundation mapping

Having to deal with the subjectivity that often accompanies this step of AHP, the importance of each factor was determined according to the proportion of the inundated areas of the 2010 flood event (total area of 6.84 $km^2$ for both open water and shallow water in low vegetation) that intersected with each factor's high susceptibility class (Figure 4 and Table 7). This concept was based on the idea that a SAR image that is taken during a flood indicates the areas where flood water is concentrated. Moreover, the factors or indicators of flood susceptibility all coexist in these areas and it is known how each factor influences floods. For example it is known that, regarding e.g. slope angle, flat areas tend to flood more easily. Thus, the areas where flood water is concentrating are those where the most favourable conditions for most factors coexist, i.e. where the high susceptibility classes for most factors or indicators intersect. Subsequently, the more a high susceptibility class of a factor or indicator is encountered in inundated areas, the more influential this factor or indicator is in terms of flood susceptibility.

**Tab. 7** Proportion of the total inundated area of the 2010 flood event that intersects with each factor's high susceptibility class.

| Factor | Extent of inundated area ($km^2$) | Percent ratio (%) |
|---|---|---|
| Land Cover | 0.15 | 2.19 |
| TWI | 0.12 | 1.75 |
| Geology | 0.39 | 5.70 |
| Distance from streams | 3.44 | 50.29 |
| Rainfall | 0.01 | 0.15 |
| Slope Angle | 5.59 | 81.73 |
| Drainage Density | 0.99 | 14.47 |
| Elevation | 6.66 | 97.37 |

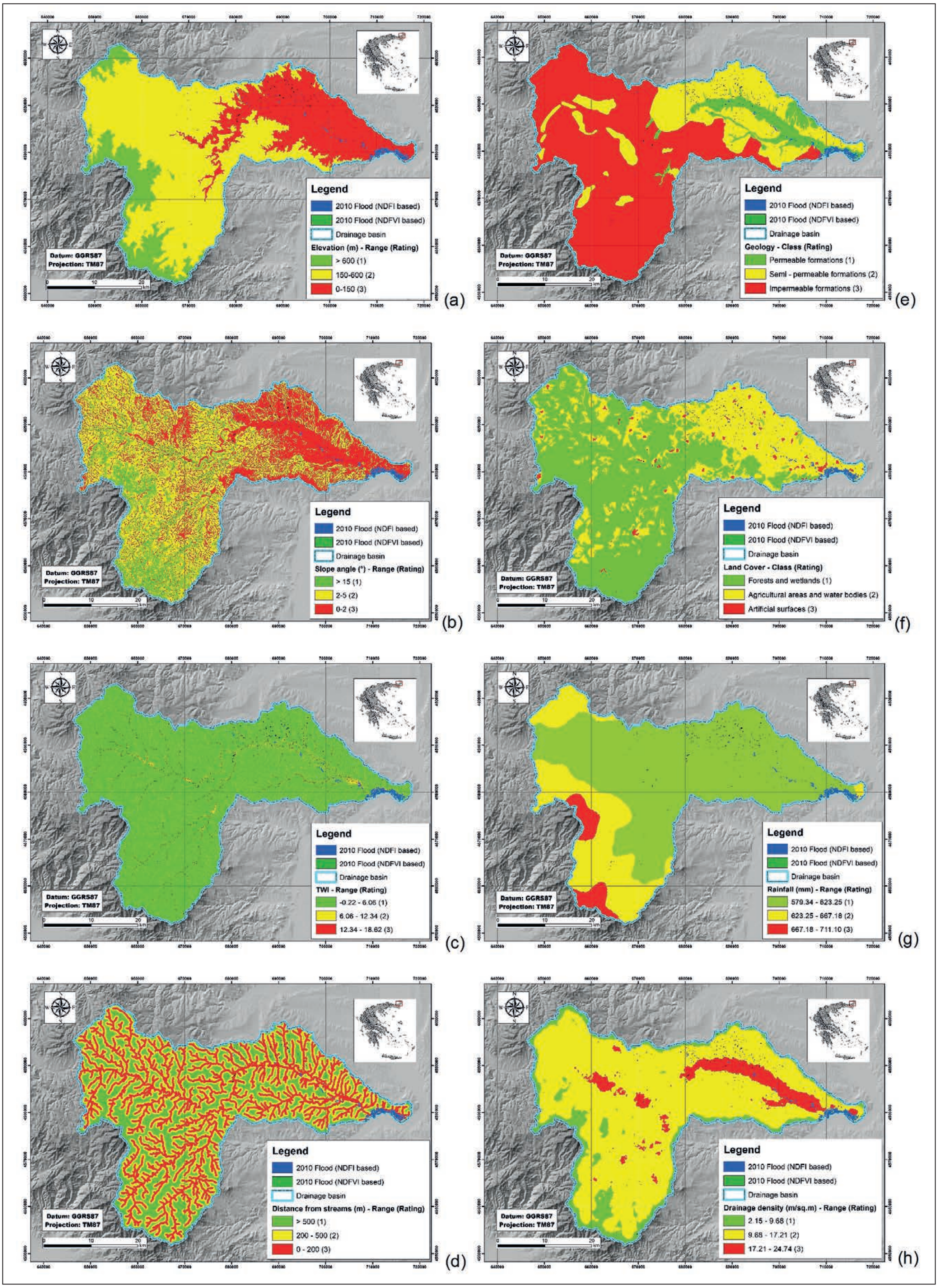


**Fig. 4** The data layer of the inundated areas of the 2010 flood event has been superimposed upon the flood susceptibility classes of the factors' data layers: a) Elevation, b) Slope angle, c) TWI, d) Distance from streams, e) Geology, f) Land cover, g) Rainfall and h) Drainage density.

**Tab. 8** Pairwise comparison of the factors that affect flood susceptibility.

| | Elevation | Slope angle | Distance from streams | Drainage Density | Geology | Land Cover | TWI | Rainfall |
|---|---|---|---|---|---|---|---|---|
| **Elevation** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| **Slope angle** | 1/2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| **Distance from streams** | 1/3 | 1/2 | 1 | 2 | 3 | 4 | 5 | 6 |
| **Drainage Density** | 1/4 | 1/3 | 1/2 | 1 | 2 | 3 | 4 | 5 |
| **Geology** | 1/5 | 1/4 | 1/3 | 1/2 | 1 | 2 | 3 | 4 |
| **Land Cover** | 1/6 | 1/5 | 1/4 | 1/3 | 1/2 | 1 | 2 | 3 |
| **TWI** | 1/7 | 1/6 | 1/5 | 1/4 | 1/3 | 1/2 | 1 | 2 |
| **Rainfall** | 1/8 | 1/7 | 1/6 | 1/5 | 1/4 | 1/3 | 1/2 | 1 |
| **Total** | 2.718 | 4.593 | 7.5 | 11.28 | 16.08 | 21.83 | 28.5 | 36 |

**Tab. 9** Calculation of the factor weights with the use of the arithmetic mean method.

| | Elevation | Slope angle | Distance from streams | Drainage Density | Geology | Land Cover | TWI | Rainfall | Mean |
|---|---|---|---|---|---|---|---|---|---|
| **Elevation** | 0.368 | 0.435 | 0.403 | 0.355 | 0.311 | 0.275 | 0.246 | 0.222 | 0.327 (32.7%) |
| **Slope angle** | 0.184 | 0.218 | 0.268 | 0.266 | 0.249 | 0.229 | 0.211 | 0.194 | 0.227 (22.7%) |
| **Distance from streams** | 0.123 | 0.109 | 0.134 | 0.177 | 0.187 | 0.183 | 0.175 | 0.167 | 0.157 (15.7%) |
| **Drainage Density** | 0.092 | 0.073 | 0.067 | 0.089 | 0.124 | 0.137 | 0.140 | 0.139 | 0.108 (10.8%) |
| **Geology** | 0.074 | 0.054 | 0.045 | 0.044 | 0.062 | 0.092 | 0.105 | 0.111 | 0.073 (7.32%) |
| **Land Cover** | 0.061 | 0.044 | 0.034 | 0.030 | 0.031 | 0.046 | 0.070 | 0.083 | 0.050 (5%) |
| **TWI** | 0.053 | 0.036 | 0.027 | 0.022 | 0.021 | 0.023 | 0.035 | 0.056 | 0.034 (3.4%) |
| **Rainfall** | 0.046 | 0.031 | 0.022 | 0.018 | 0.016 | 0.015 | 0.018 | 0.028 | 0.024 (2.4%) |

The 2010 flood extent was chosen for that purpose, because the measurements from the gauging station on Didymoteicho's bridge confirmed that during the date and time that the ENVISAT/ASAR's flood image was taken on 16/2/2010, Erythropotamos indeed flooded. Additionally, ENVISAT/ASAR's imagery has lower spatial resolution when compared with SENTINEL-1 A/B imagery. Since the aforementioned gauging station went out of order in 2012, the only way to collect information for the 2017 and 2018 flood events was to rely on statements from members of the Department of Civil Protection of the region of Evros (C. Papapostolou, Department of Civil Protection of the region of Evros, personal communication, 2018).

### 3.3.3 Pairwise comparison between the flood susceptibility factors and determination of their weights with the use of the arithmetic mean method

The factors were paired with each other and following that, each factor was given an arithmetic value between 1 and 8, according to its significance, in agreement with Table 7, when compared to the other factor, with which it formed the pair (Table 8). In the resulting matrix table, an arithmetic value of 8 indicates that a row factor is much more significant than the corresponding column factor with which it has been compared, while an arithmetic value of 1 means that both factors are equally significant. After the completion of Table 8, the arithmetic mean method has been applied to its results and the weights for each factor were calculated (Table 9).

To sum up, Table 10 presents synoptically the factors, the classes of flood susceptibility into which they were classified, the rating that was assigned for each class and the weight that was calculated for each factor via the application of AHP methodology (Kazakis et al. 2015).

### 3.3.4 Consistency ratio

In order to check the consistency of the eigenvector matrix of AHP, the consistency ratio was calculated according to the following formula:

$$CR = \frac{CI}{RI} \tag{4}$$

In mathematic formula (4), *CR* stands for consistency ratio, *CI* stands for consistency index, and *RI*

**Tab. 10** Synoptic table presenting the factors, their flood susceptibility classes, the rating that was assigned for each class and the weight for each factor that was assigned through AHP methodology.

| Factor | Class | Rating | Weight |
|---|---|---|---|
| Elevation (m) | >600 | 1 | 0.327 |
| | 150–600 | 2 | |
| | 0–150 | 3 | |
| Slope angle (°) | >15 | 1 | 0.227 |
| | 2–5 | 2 | |
| | 0–2 | 3 | |
| Distance from streams (m) | >500 | 1 | 0.157 |
| | 200–500 | 2 | |
| | 0–200 | 3 | |
| Drainage density ($m/m^2$) | 2.15–9.68 | 1 | 0.108 |
| | 9.68–17.21 | 2 | |
| | 17.21–24.74 | 3 | |
| Geology | Permeable formations | 1 | 0.073 |
| | Semi – permeable formations | 2 | |
| | Impermeable formations | 3 | |
| Land Cover | Forests and wetlands | 1 | 0.050 |
| | Agricultural areas and water bodies | 2 | |
| | Artificial surfaces | 3 | |
| TWI | −0.22–6.06 | 1 | 0.034 |
| | 6.06–12.34 | 2 | |
| | 12.34–18.62 | 3 | |
| Rainfall (mm) | 579.34–623.25 | 1 | 0.024 |
| | 623.25–667.18 | 2 | |
| | 667.18–711.10 | 3 | |

stands for random index. *RI* depends on the number of factor that are used to perform AHP and in our case, for an 8 by 8 matrix, *RI*= 1.41 (Saaty 1980), while *RI* can be calculated by the following equation:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{5}$$

In equation (5), λmax is the maximum eigenvalue of the comparison matrix and n is the number of factors. In the current study, $\lambda_{max} = 8.41$ and $n = 8$, therefore $CR = 0.042$. According to Saaty (1980), if *CR* is less than 0.1, then the weights' consistency is affirmed.

### 3.3.5 Calculation of flood susceptibilityand validation of the results

Finally, the data layers for each factor were added together in accordance with the mathematical equation (6):

$$S = \sum_{i=1}^{n} w_i * X_i \tag{6}$$

In equation (6), S is the value for each pixel of the final flood susceptibility map of the study area, $w_i$ is the weigh for each factor and $X_i$ are the rating values for each pixel according to the factor to which it is referred.

The resulting susceptibility map was validated by calculating, with the aid of geoprocessing routines, the proportion of the inundated areas of the April 2017 and March 2018 flood events that intersected with its high susceptibility areas. This procedure indicated that 59% and 58% of the inundated areas of the 2018 and 2017 floods respectively coincided spatially with the high flood susceptibility zones of the resulting map.

## 4. Results

According to the results that were produced by flood extent mapping, the inundated areas within Erytropotamos' drainage basin, regarding the 2010 flood event, cover a total of 6.84 $km^2$, while the inundated areas of the flood events that occurred on April 2017 and March 2018 cover a total extent of 18.23 $km^2$ and 20.60 $km^2$ respectively. The proportions of the inundated areas that were detected in open-land flooded areas and as shallow water in low vegetation areas are presented in more detail in Table 11.

Regarding susceptibility mapping, the resulting map was classified into three categories, which contained areas of high, medium, and low susceptibility (Figure 5). Moreover, the application of AHP methodology produced the criteria weight for each indicator. According to these results elevation was considered as the most important indicator with the weight value of 0.327, followed by the slope angle with the weight value of 0.227. Distance from stream and drainage density are respectively considered as the third and fourth most important criteria, and their weight values are 0.157 and 0.108, respectively. The weights of the remaining indicators are below 0.1, which indicates that they present less important than aforementioned four indicators. The criteria weight value of geology, land cover, TWI and rainfall are 0.073, 0.05, 0.034 and 0.024, respectively (Tables 8 and 9).

Finally, by superimposing the delineated areas of the April 2017 and March 2018 inundation mapping onto the resulting susceptibility map, with the aid of geoprocessing routines, calculations indicated that the largest part of the aforementioned estimated flood

**Tab. 11** Flood extents of the inundated areas for February 2010, April 2017 and March 2018 flood events.

| Flood event | NDFI based inundated area ($km^2$) | NDFVI based inundated area ($km^2$) | Total inundated area ($km^2$) |
|---|---|---|---|
| 2010 February | 6.49 | 0.35 | 6.84 |
| 2017 April | 17.52 | 0.71 | 18.23 |
| 2018 March | 19.28 | 1.32 | 20.60 |

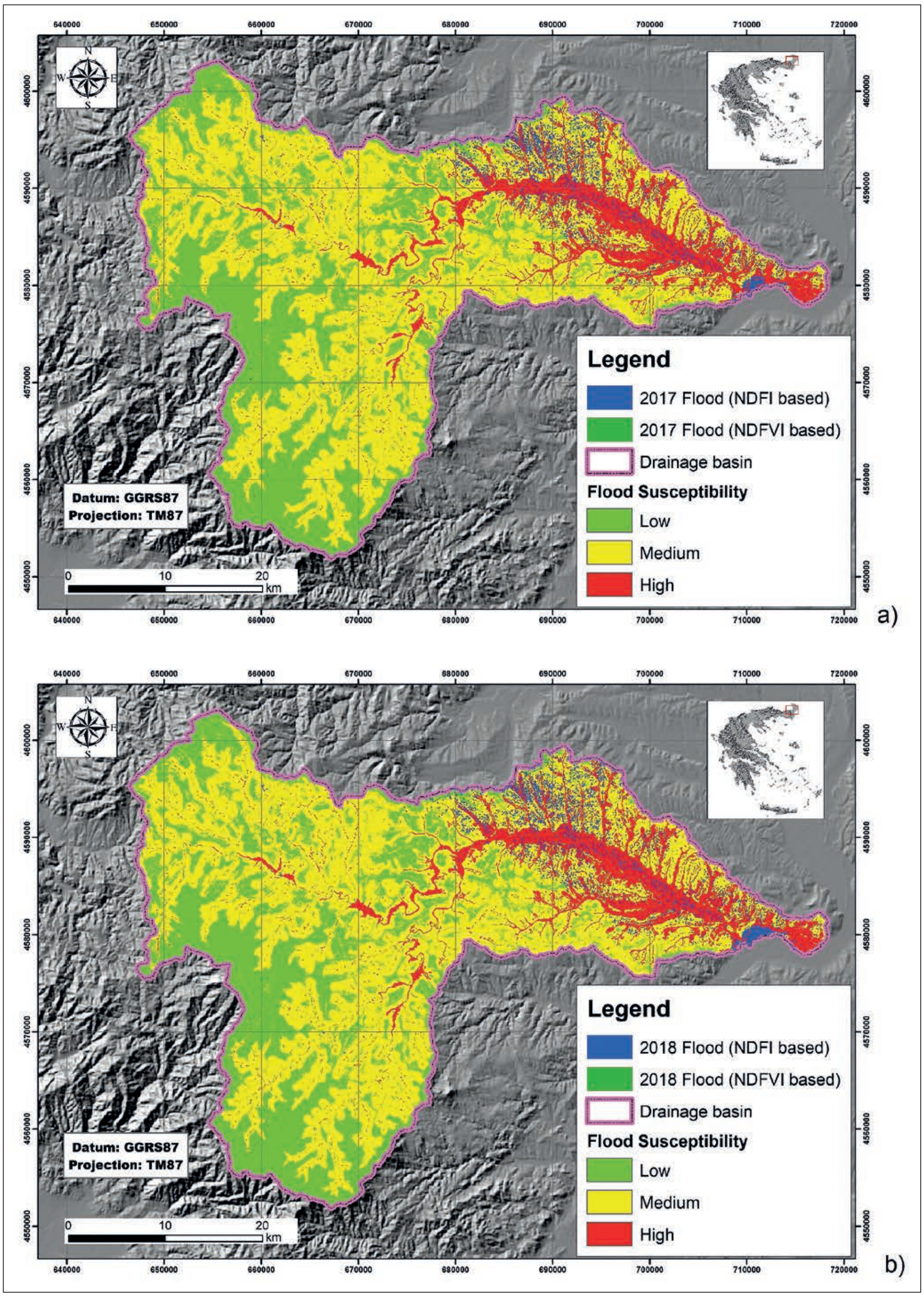


**Fig. 5** Flood susceptibility map upon which are superimposed: a) the data layer of the April 2017 inundated areas (both NDFI and NDFVI based), and b) the data layer of the March 2018 inundated areas (both NDFI and NDFVI based).

extents coincided with the areas of high and medium susceptibility of the resulting map (Figure 5). Regarding the April 2017 flood, from the total of 18.23 $km^2$ of the total inundated area in both open-land and in low vegetation, 10.6 $km^2$ (58.17%) intersected with the high flood susceptibility class. Additionally, high and medium susceptibility classes intersected with 17.54 $km^2$ (96.22%) of the resulting flood extent. Correspondingly, from the total of 20.60 $km^2$ of the March 2018 inundated area, 12.22 $km^2$ (59.33%) were included within the high flood susceptibility class, while high and medium susceptibility classes intersected with 19.73 $km^2$ (95.8%) of the resulting flood extent (Table 12).

## 5. Discussion

By comparing the flood extents of the flood events, it appeared that the inundated areas of 2010 are considerably smaller than the inundated areas of 2018 and 2017. The 2010 flood covered an extent of 6.84 $km^2$,

**Tab. 12** Area extent and percentage of the part of the March 2018 and April 2017 inundated areas, which intersect with high to medium classes of the susceptibility map.

| Flood susceptibility classes | Inundated area ($km^2$) | Percentage (%) |
|---|---|---|
| **2018 March flood** | | |
| High | 12.22 | 59.33 |
| High and medium | 19.73 | 95.80 |
| **2017 April flood** | | |
| High | 10.60 | 58.17 |
| High and medium | 17.54 | 96.22 |

in comparison with the inundated areas of the 2017 and 2018 flood events, which covered areas of 18.23 $km^2$ and 20.60 $km^2$ respectively; however, as it was mentioned earlier, validation of these results was not feasible due to unfavourable weather conditions. At first place, these differences in flood extents might indicate that the 2010 flood had probably a lower return period than the other two flood events. Furthermore, it is worth mentioning that according to the gauging station on Didymoteicho's bridge, the 2010 flood reached a peak discharge of 1,255.05 $m^3/s$, while, on the other hand, such gauges were not available for the 2017 and 2018 floods.

Regarding the uncertainties that exist in flood inundation mapping with the use of Remote Sensing and especially SAR, it has to be mentioned that such techniques and methodologies suffer mostly from speckle and from under or over-detection of flood extents especially in urban and vegetated areas. Currently there is no methodology that can overcome these difficulties entirely. However, flood inundation mapping is still considered appropriate for validation in cases of flood susceptibility and flood hazard mapping. (Giustarini et al. 2015a; Giustarini et al. 2015b; Schumann et al. 2015)

Concerning flood susceptibility mapping, there is a wide variety of works that utilize the AHP methodology for its implementation. The main differences and similarities of these works with the present research focus on the following points: 1) the factors that are employed by the research, 2) the determination of the importance between the factors that are used by the AHP procedure, 3) the dominant flood susceptibility factors of the study area and 4) the validation of the resulting flood susceptibility map.

The number and type of factors that are used in order to determine the spatial distribution of flood susceptibility, with the use of AHP, depend heavily on data availability (Xiao et al. 2018; Zhao et al. 2018). However, it can be observed that certain factors such as elevation, slope angle, land cover, lithology and distance from streams are used in the vast majority of works due to being easily produced via Digital Elevation Models (DEMs), geological maps and the various Corine Land Cover data layers. Other factors such as TWI (Arabameri et al. 2019; Das 2018; Tang et al. 2018), flow accumulation (Vojtek et al. 2019; Das 2018; Mahmoud et al. 2018; Kazakis et al. 2015), drainage density (Arabameri et al. 2019; Souissi et al. 2019; Vojtek et al. 2019; Das 2018; Mahmoud et al. 2018; Seejata et al. 2018) and rainfall (Souissi et al. 2019; Mahmoud et al. 2018; Seejata et al. 2018; Tang et al. 2018; Kazakis et al. 2015) appear in most works. On the contrary, curvature (Arabameri et al. 2019; Das 2018), NDVI (Normalized Difference Vegetation Index) (Arabameri et al. 2019), runoff/CN (Curve Numbers) (Vojtek et al. 2019; Mahmoud et al. 2018), SPI (Stream Power Index) (Arabameri et al. 2019) and groundwater depth (Souissi et al. 2019) appear rarely on flood susceptibility mapping works. Moreover, the number of the factors that are used in flood susceptibility mapping varies greatly (Mahmoud et al. 2018; Rahmati et al. 2015) with the most common number of factors ranging from seven to nine.

This paper tries to employ the most common and important factors that can be used in flood susceptibility mapping. Thus, flow accumulation was not included, since its data layer was indirectly employed by the TWI factor. Likewise, Stream Power Index (SPI) and Sediment Transport Index (STI) were not utilized because, according to Miliaresis (2006), these are, like TWI, indices of soil erosion with very similar mathematical expressions and thus they produce similar results. Curvature is considered to have a minor impact on the occurrence of a flood (Das 2018) and therefore it was not included in the factors that were utilized in the assessment of flood susceptibility. Additionally, Topographic position index (TPI) and Topographic roughness index (TRI) are rarely used in flood susceptibility mapping and even more rarely appear to be more important than the factors with which they are compared, so they were too omitted. Finally, the curve numbers (CN) data layer was not feasible to be compiled since there were no available maps depicting the spatial distribution of the hydrological soil groups.

The determination of the importance between the factors that are used in AHP when conducting flood susceptibility mapping can be achieved by applying various procedures. Many researches use sensitivity analysis in order to overcome the subjectivity of AHP (Souissi et al. 2019; Mahmoud et al. 2018; Tang et al. 2018), while weight linear combination is also a popular approach (Vojtek et al. 2019; Kazakis et al. 2015). There is also a great number of works that employ expert opinion in dealing with the hierarchy of factors (Das 2018; Seejata et al. 2018; Rahmati et al. 2015). However, the current trend involves the use of training algorithms over a part of the elements that will be used for the validation of the resulting susceptibility map, which usually involves a database of historical points where floods occurred (Arabameri et al. 2019). The present paper is introducing the use of the results of SAR-based inundation mapping, of a confirmed via gauges flood event, in the determination of the importance of the factors that affect flood susceptibility in AHP. Specifically, the aforementioned hierarchy was determined according to the part of the extent of the inundated area of the 2010 flood that intersected with each factor's highest susceptibility class, thus overcoming the subjectivity of AHP.

When it comes to the determination of the most important factor in flood susceptibility mapping, the results of AHP in various researches indicate that there is no factor to have clear dominance over other factors. Many papers indicate slope angle as the most important factor (Arabameri et al. 2019; Vojtek et al. 2019), while flow accumulation (Kazakis et al. 2015), elevation (Souissi et al. 2019) or even rainfall (Seejata et al. 2018) have been determined as the dominant flood susceptibility factors in certain regions and by certain methodologies. Likewise the present research determined elevation as the most important flood susceptibility factor, but it can be observed that the results depend heavily on both the procedure that is employed in the determination of the hierarchy of factors and the conditions that lie within the studied region.

Regarding the validation of the results of flood susceptibility mapping with the use of AHP, the vast majority of works involves the compilation of a historical database that includes, in the form of points, sites where according to eye-witnesses or Remote Sensing techniques floods occurred (Arabameri et al. 2019; Souissi et al. 2019; Vojtek et al. 2019; Mahmoud et al. 2018). The present work handles this matter by utilizing the results of SAR-based inundation mapping for specific flood occurrences. To this end, the inundated areas of the 2017 and 2018 floods, which were not involved in the determination of the importance between the factors in AHP, were used in order to provide the proportions of their respective flood extents that intersected with the high flood susceptibility zones of the resulting map. Furthermore, the resulting flood susceptibility map (Figure 5), indicated that the areas of high susceptibility are located on the eastern part of the study area, specifically in the first half of main stream and appear increased toward the basin mouth.

Moreover, the scores that were achieved by the validation of the susceptibility map were quite high. In particular, approximately 60% of the inundated areas from the April 2017 and March 2018 floods intersect with the high susceptibility zones of the map. The percentage rises to approximately 96% in the case that the aforementioned inundated areas intersect with the map's high to moderate susceptibility zones.

Finally, it is worth mentioning that the source data layers of the factors that were used in flood susceptibility mapping, in terms of scale and spatial resolution, were quite consistent since the majority of them were derived from EU-DEM that has a spatial resolution of 25 m. The data layers of geology and Corine Land Cover 2012 involved a smaller scale, while the data layer of rainfall had to be downscaled in order to reach the spatial analysis of the EU-DEM data layer. However, the aforementioned spatial variations of these data layers do not appear to have a significant effect on the resulting susceptibility map since they were ranked among the least important flood susceptibility factors (Table 10). Additionally, the extent of the study area involved a considerably large drainage basin, which, in terms of size, allowed the use of small scale data, which are widely used in likewise cases according to the existing literature regarding AHP flood susceptibility mapping (Kazakis et al. 2015).

## 6. Conclusions

The present research paper introduced the idea to use the extent of a flood that has been captured by SAR imagery in order to determine the importance between flood susceptibility factors and thus dealing with the subjectivity that involves the determination of the hierarchy of factors in AHP. The larger the part of the inundated area that intersects with the factor's high susceptibility zone, the more important the factor is considered over the others.

According to the results of the applied methodology, elevation was found to be the most dominant flood susceptibility factor in the catchment of Erythropotamos. However, this has to be further ascertained by considering more future flood events in the same area and by taking advantage of the current and prospective availability of SENTINEL-1 imagery data. Moreover, the resulting susceptibility map appeared to be in consistency with the, April 2017 and March 2018 flood extents, since the aforementioned inundated areas coincided mostly with the high flood susceptibility class of the resulting map.

It appears that the suggested methodology, regarding the determination of the hierarchy of flood susceptibility factors, via the results of SAR-based inundation mapping, in AHP produced some interesting results. Nevertheless, more thorough testing of this proposed methodology is required, while it also remains to be seen if its application on other drainage basins shall indicate each time another factor as more prevalent in flood susceptibility, thus maintaining the argument that the conditions that affect flood susceptibility are unique for each catchment.

## References

Arabameri, A., Rezaei, K., Cerdà, A., Conoscenti, C., Kalantari, Z. (2019): A comparison of statistical methods and multi-criteria decision making to map flood hazard susceptibility in Northern Iran. Science of the Total Environment 660, 443–458, https://doi.org/10.1016/j.scitotenv.2019.01.021.

Astaras, T., Oikonomidis, D., Mouratidis, A. (2011): Psifiakí Chartografía kai Geografiká Systímata Pliroforión [Digital Cartography and GIS]. Thessaloniki: Ekdóseis Dísigma [Disigma Publishing Group].
Beven, K., Kirkby, M. (1979): A Physically Based, Variable Contributing Area Model of Basin Hydrology. Hydrological Science Bulletin 24, 43–69, https://doi.org/10.1080/02626667909491834.
Birkholz, S., Muro, M., Jeffrey, P., Smith, H. M. (2014): Rethinking the relationship between flood risk perception and flood management. Science of the Total Environment 478, 12–20, https://doi.org/10.1016/j.scitotenv.2014.01.061.
Chen, Y., Liu, R., Barrett, D., Gao, L., Mingwei, Z., Renchullo, L., Emelyanova, I. (2015): A spatial assessment framework for evaluating flood risk under extreme climates. Science of the Total Environment 538, 512–523, http://dx.doi.org/10.1016/j.scitotenv.2015.08.094.
Chen, Y., Yu, J., Khan, S. (2013): The spatial framework for weight sensitivity analysis in AHP-based multi-criteria decision making. Environmental Modelling and Software 48, 129–140, https://doi.org/10.1016/j.envsoft.2013.06.010.
Cian, F., Marconcini, M., Ceccato, P. (2018). Normalized Difference Flood Index for rapid flood mapping: Taking advantage of EO big data. Remote Sensing of Environment 209, 712–730, https://doi.org/10.1016/j.envsoft.2013.06.010.
CoG (Committee of Geology) (1989). Geologic map of P.R. Bulgaria, Scale 1:50 000.
COPERNICUS, Europe's eyes on earth – land monitoring service. Available online: https://land.copernicus.eu/pan-european/corine-land-cover/clc-2012?tab=download (accessed on 25/11/2017).
COPERNICUS, Europe's eyes on earth – land monitoring service. Available online: https://land.copernicus.eu/pan-european/corine-land-cover/ clc2018 (accessed on 17/4/2020).
Costache, R., Pham, Q. B., Sharifi, E., Linh, N. T. T., Abba, S. I., Vojtek, M., Vojteková, J., Nhi, P. T. T., Khoi, D. N. (2020): Flash-Flood Susceptibility Assessment Using Multi-Criteria Decision Making and Machine Learning Supported by Remote Sensing and GIS Techniques. Remote Sensing 12(1), 106, https://doi.org/10.3390/rs12010106.
Das, S. (2019): Geographic information system and AHP-based flood hazard zonation of Vaitarna basin, Maharashtra, India. Arabian Journal of Geosciences 11, 576, https://doi.org/10.1007/s12517-018-3933-4.
Demek, J. (1972). Manual of detailed geomorphological mapping. Academia, Prague.
Dikau, R. (1989): The application of a digital relief model to landform analysis. In: J. F. Raper, ed. Three Dimensional Application in Geographical Information Systems. Taylor and Francis, London, 51–77.
European Environment Agency (EEA) (2017): Copernicus Land Monitoring Service – EU-DEM. Published 7/12/2017 from: https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-eu-dem.
Ettinger, S., Mounaud, L., Magill, C., Yao-Lafourcade, A.-F., Thouret, J.-C., Manville, V., Negulescu, C., Zuccaro, G., De Gregorio, D., Nardone, S., Uchuchoque, J.A.L., Arguedas, A., Macedo, L., Llerena, N. M. (2016): Building vulnerability to hydro-geomorphic hazards: estimating damage probability from qualitative vulnerability assessment using logistic regression. Journal of Hydrology 541, 563–581, https://doi.org/10.1016/j.jhydrol.2015.04.017.
Fick, S. E., Hijmans, R. J. (2017): Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37(12), 4302–4315, https://doi.org/10.1002/joc.5086.
Giustarini, L., Chini, M., Hostache, R., Pappenberger, F., Matgen, P. (2015a). Flood hazard mapping combining hydrodynamic modeling and multi annual remote sensing data. Remote Sensing 7(10), 14200–14226, https://doi.org/10.3390/rs71014200.
Giustarini, L., Vernieuwe, H., Verwaeren, J., Chini, M., Hostache, R., Matgen, P., Verhoest, N.E.C. De Baets, B. (2015b): Accounting for image uncertainty in SAR-based flood mapping. International Journal of Applied Earth Observation and Geoinformation 34, 70–77, https://doi.org/10.1016/j.jag.2014.06.017.
Hong, H., Panahi, M., Shirzadi, A., Ma, T., Liu, J., Zhu, A-X., Chen, W., Kougias, I., Kazakis, N. (2018): Flood susceptibility assessment in Hengfeng area coupling adaptive neuro-fuzzy inference system with genetic algorithm and differential evolution. Science of the total Environment 621, 1124–1141, https://doi.org/10.1016/j.scitotenv.2017.10.114.
I.G.M.E. (Institute of geology and mineral exploration) (2002): Synoptic geologic map of SE Rhodope – Thrace, Scale 1:200 000, Xanthi.
Kanani-Sadat, Y., Arabsheibani, R., Karimipour, F., Nasseri, M. (2019): A new approach to flood susceptibility assessment in data-scarce and ungauged regions based on GIS-based hybrid multi criteria decision-making method. Journal of Hydrology 572, 17–31, https://doi.org/10.1016/j.jhydrol. 2019.02.034.
Kazakis, N., Kougias, I. Patsialis, T. (2015): Assessment of flood hazard areas at a regional scale using an index-based approach and Analytical Hierarchy Process: application in Rhodope–Evros region, Greece. Science of the Total Environment 538, 555–563, https://doi.org/10.1016/j.scitotenv.2015.08.055.
Khosravi, K., Nohani, E., Maroufinia, E., Pourghasemi, H. R. (2016): A GIS-based flood susceptibility assessment and its mapping in Iran: a comparison between frequency ratio and weights-of-evidence bivariate statistical models with multi-criteria decision-making technique. Natural Hazards 83, 947–978, https://doi.org/10.1007/s11069-016-2357-2.
Li, J., Heap, A. (2014): Spatial interpolation methods applied in the environmental sciences: A review. Environmental Modelling and Software 53, 173–189, https://doi.org/10.1016/j.envsoft.2013.12.008
Li, Y., Martinis, S., Plank, S., Ludwig, R. (2018): An automatic change detection approach for rapid flood mapping in Sentinel-1 SAR data. International Journal of Applied Earth Observation and Geoinformation 73, 123–135, https://doi.org/10.1016/j.jag.2018.05.023.
Long S., Fatoyinbo, T. E., Policelli, F. (2014): Flood extent mapping for Namibia using change detection and thresholding with SAR. Environmental Research Letters 9, 35002–35009, https://doi.org/10.1088/1748-9326/9/3/035002.

Lyu, H. M., Sun, W. J., Shen, S. L., Arulrajah, A. (2018): Flood risk assessment in metro systems of mega-cities using a GIS-based modeling approach. Science of the Total Environment 626, 1012–1025, https://doi.org/10.1016/j.scitotenv.2018. 01.138.

Mahmoud, S., Gan, T. Y. (2018): Multi-criteria approach to develop flood susceptibility maps in arid regions of Middle East. Journal of Cleaner Production 196, 216–229, https://doi.org/10.1016/j.jclepro.2018.06.047.

Matgen, P., Hostache, R., Schumann, G. J. P., Pfister, L., Hoffmann, L. Savenije, H. H. G. (2011): Towards an automated SAR-based flood monitoring system: lessons learned from two case studies. Physics and Chemistry of the Earth 36 (7–8), 241–252, https://doi.org/10.1016/j.pce.2010.12.009.

Miliaresis A. (2006). Eidikés Efarmogés sto AcGIS. [Specialized applications in ArcGIS]. Ekdóseis «ION» [ION Publishing Group], Athens.

Mouratidis A. (2011): Contribution of Earth Observation data and GIS to mapping and managing flood evens in Greece. Final Report of "GEOGIS floods" research project funded by the John S. Latsis Public Benefit Foundation.

Mouratidis, A., Ampatzidis, D. (2019): European Digital Elevation Model (EU-DEM) validation against extensive Global Navigation Satellite Systems data and comparison with SRTM and ASTER-GDEM in Central Macedonia (Greece). ISPRS, International Journal of Geo-Information 8(3), 108, https://doi.org/10.3390/ijgi8030108.

Mouratidis, A., Nikolaidou, M., Doxani, G., Lampiri, M., Sarti, F. Tsakiri-Strati, M. (2011): Flood studies in Greece using Earth Observation data and Geographical Information Systems. Geological Remote Sensing Group (GRSG) Annual General Meeting, 7–9 December 2011, ESA /ESRIN, Frascati, Italy.

Mouratidis, A., Sarti, F. (2013): Flash-Flood Monitoring and Damage Assessment with SAR Data: Issues and Future Challenges for Earth Observation from Space Sustained by Case Studies from the Balkans and Eastern Europe. In: Krisp J., Meng L., Pail R., Stilla U., eds. Earth Observation of Global Changes (EOGC). Lecture Notes in Geoinformation and Cartography. Springer, Berlin, Heidelberg, 125–136, https://doi.org/10.1007/978-3-642-32714-8_8.

Nandi, A., Mandal, A., Wilson, M., Smith, D. (2016). Flood hazard mapping in Jamaica using principal component analysis and logistic regression. Environmental Earth Sciences 75, 465, https://doi.org/10.1007/s12665-016-5323-0.

Nikolaidou, M., Mouratidis, A., Doxani, G., Oikonomidis, D., Tsakiri-Strati, M., Sarti, F. (2015): An on-line flood database for Greece supported by Earth Observation data and GIS. Proceedings of the 10th International Congress of the Hellenic Geographical Society, 22–24 October 2014, Thessaloniki, Greece, 671–688.

Papaioannou, G., Vasiliades, L., Loukas, A. (2015): Multi-criteria analysis framework for potential flood prone areas mapping. Water Resoures Management 29, 399–418, http://dx.doi.org/10.1007/s11269-014-0817-6.

Patrikaki, O., Kazakis, N., Kougias, I., Patsialis, T., Theodosiou, N. Voudouris, K. (2018): Assessing flood hazard at river basin scale with an index-based approach: The case of Mouriki, Greece. Geosciences 8(50), 1–13, https://doi.org/10.3390/geosciences8020050.

Pierdicca, N., Pulvirenti, L., Chini, M., Guerriero, L. Candela, L. (2013): Observing floods from space: Experience gained from COSMO-SkyMed observations. Acta Astronautica 84, 122–133, http://dx.doi.org/10.1016/j.actaastro. 2012.10.034.

Psomiadis, E. (2016): Flash flood area mapping utilising SENTINEL-1 radar data. Proceedings of SPIE, 10005, https://doi.org/10.1117/12.2241055.

Pulvirenti, L., Pierdicca, N., Chini, M., Guerriero, L. (2011): An algorithm for operational flood mapping from Synthetic Aperture Radar (SAR) data using fuzzy logic. Natural Hazards and Earth System Sciences 11, 529–540, https://doi.org/10.5194/nhess-11-529-2011.

Rahmati, O., Zeinivand, H., Besharat, M. (2015): Flood hazard zoning in Yasooj region, Iran, using GIS and multi-criteria decision analysis. Geomatics, Natural Hazards and Risk 7(3), 1000–1017, https://doi.org/10.1080/19475705.2015.1045043.

Saaty, T. L. (1980): The Analytic Hierarchy Process. McGraw-Hill, New York.

Schlaffer, S., Matgen, P., Hollaus, M. Wagner, W. (2015): Flood detection from multi-temporal SAR data using harmonic analysis and change detection. International Journal of Applied Earth Observation and Geoinformation 38, 15–24, http://dx.doi.org/10.1016/j.jag.2014.12.001.

Schumann, G. J. P., Moller, D. K. (2015): Microwave remote sensing in flood inundation. Physics and Chemistry of the Earth 83–84, 84–95, https://doi.org/10.1016/j.pce.2015.05.002.

Seejata, K., Yodying, A., Wongthadam, T., Mahavik, N., TantaneE, S. (2018): Assessment of flood hazard areas using Analytical Hierarchy Process over the Lower Yom Basin, Sukhothai Province. Procedia Engineering 212, 340–347, https://doi.org/10.1016/j.proeng.2018.01.044.

Souissi, D., Zouhri, L., HammamI, S., Msaddek, M. H., Zghibi, A., Dlala, M. (2019): GIS-based MCDM – AHP modelling for flood susceptibility mapping of arid areas, southeastern Tunisia. Geocarto International, https://doi.org/10.1080/10106049.2019.1566405.

Stefanidis, S., Stathis, D. (2013): Assessment of flood hazard based on natural and anthropogenic factors using analytic hierarchy process (AHP). Natural Hazards: Journal of the International Society for the Prevention and Mitigation of Natural Hazards, Springer;International Society for the Prevention and Mitigation of Natural Hazards 68, 569–585, https://doi.org/10.1007/s11069-013-0639-5.

Tang, Z., Zhang, H., Yi, S., Xiao, Y. (2018): Assessment of flood susceptible areas using spatially explicit, probabilistic multi-criteria decision analysis. Journal of Hydrology 558, 144–158, https://doi.org/10.1016/j.jhydrol.2018.01.033.

Tehrany, M. S., Pradhan, B., Jebur, M. N. (2014): Flood susceptibility mapping using a novel ensemble weights-of-evidence and support vector machine models in GIS. Journal of Hydrology 512, 332–343, https://doi.org/10.1016/j.jhydrol.2014.03.008.

Tehrany, M. S., Pradhan, B., Mansor, S., Ahmad, N. (2015): Flood susceptibility assessment using GIS-based support vector machine model with different kernel types.

Catena 125, 91–101, https://doi.org/10.1016/j.catena.2014.10.017.
Vieux, B. E. (2004). Distributed Hydrologic Modelling using GIS. Kluwer Academic Publishers, Netherlands, 123–124.
Voudouris, K., Mavrommatis, T. Antonakos, A. (2007): Hydrologic balance estimation using GIS in Korinthia prefecture, Greece. Advances in Science and Research 1, 1–8, https://doi.org/10.5194/asr-1-1-2007.
Vojtek, M., Vojteková, J. (2019): Flood Susceptibility Mapping on a National Scale in Slovakia Using the Analytical Hierarchy Process. Water 11, 364, https://doi.org/10.3390/w11020364.
Wang, Y., Hong, H., Chen, W., Li, S., Pamucar, D., Gigovic, L., Drobnjak, S., Bui, D. T., Duan, H. (2019): A Hybrid GIS Multi-Criteria Decision-Making Method for Flood Susceptibility Mapping at Shangyou, China. Remote Sensing, 11, 62, https://doi.org/10.3390/rs11010062.
Wang, Y., Li, Z. Tang, Z. (2011): A GIS-based spatial multi-criteria approach for flood risk assessment in the Dongting Lake Region, Hunan, Central China. Water Resources Management 25, 3465–3484, https://doi.org/10.1007/s11269-011-9866-2.
Xiao, Y., Yi, S., Tang, Z. (2018): Integrated flood hazard assessment based on spatial ordered weighted averaging method considering spatial heterogeneity of risk preference. Science of the Total Environment 599–600, 1034–1046, https://doi.org/10.1016/j.scitotenv.2017.04.218.
Yésou, H., Sarti, F., Tholey, N., Mouratidis, A., Clandillon, S., Huber, C., StudeR, M., De Fraipont, P. (2013): Addressing emergency flood mapping and monitoring of inland water bodies with sentinel 1-2. Expectations and perspectives. Living Planet Symposium, 9–13 September 2013, Edinburgh, UK, ESA SP-722.
Zhao, G., Pang, B., Xu, Z., Yue, J., Tu, T. (2018): Mapping flood susceptibility in mountainous areas on a national scale in China. Science of the Total Environment 615, 1133–1142, https://doi.org/10.1016/j.scitotenv.2017.10.037.
Zhong, S., Yang, L., Toloo, S., Wang, Z., Tong, S., Sun, X., Crompton, D., Fitzgerald, G., Huang, C. (2018): The long-term physical and psychological health impacts of flooding: A systematic mapping. Science of the Total Environment 626, 165–194, https://doi.org/10.1016/J.SCITOTENV.2018.01.041.
Zhou, Z., Psomiadis, E., Dercas, N. (2014): Analysis of the drainage density of experimental and modelled tidal networks. Earth Surface Dynamics 2, 105–116, https://doi.org/10.5194/esurf-2-105-2014.

# A comparison of actual evapotranspiration estimates based on Remote Sensing approaches with a classical climate data driven method

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**ABSTRACT**

The knowledge of actual evapotranspiration at farm level is a prerequisite for irrigation planning, farm management, to increase production and reduce water consumption. To accomplish this, comprehensive and accurate assessment methods should be applied. In order to evaluate accurately evapotranspiration processes we compared lysimeter evapotranspiration data with MODIS (Aqua and Terra satellites) and LANDSAT (SEBAL algorithm) satellite images as well as with the FAO Penman-Montith method. The findings indicate the low error rate, high correlation (1) and appropriateness of SEBAL in estimating actual evapotranspiration. The error values MAD, MSE and RMSE between lysimeter and the SEBAL algorithm were 0.59, 0.36 and 0.60 respectively. The second best performance was established for the FAO Penman-Montith method. The obtained error values MAD, MSE and RMSE between the lysimeter and FAO-Penman-Montith method are 0.91, 1.29 and 1.13, respectively.

**KEYWORDS**

actual evapotranspiration; SEBAL algorithm; Landsat; MODIS; Penman-Montith; Wheat; lysimeter

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## 1. Introduction

Water need is one of the most important parameters in crop cultivation and in terms of planning the irrigation calendar. Water Source deficit estimations are one of the major challenges in dry and semi-arid regions like Iran which is due to the low amount of precipitation (248 mm), high temperatures (average temperature 18 °C, which is 3 °C higher than the global average) long dry season (in some areas up to 8 months), high evaporation, inappropriate cultivation pattern and irregular irrigation methods (Alizadeh 2016; Zakerinejad and Masoudi 2019). In the current condition, the phenomenon of global warming and the occurrence of severe and continuous droughts and desertification aggravate the problem (Zakerinejad and Maerker 2015). Consequently, due to the high impact of evapotranspiration processes in plant and water resources management we assess different models for the Iranian conditions. Especially, we focus in our study on the main crop cultivation in Iran, which is namely wheat.

Evapotranspiration is highly affecting the hydrological cycle and water balance equations. Measuring, calculating and estimating the evapotranspiration volume are essential in water resource management. Different methods exist on the marked such as: direct measurements (Lysimeter), multiple models like Priestley-*Taylor*, Jensen-Haise, Thornth-Waite, Blaney-Criddle, FAO-Pennman Monteith, Hargreaves-Samani, Turc, Making and Ritchie (Allen et al. 1998; Zare Haghi et al. 2016). In addition, evapotranspiration can be estimatedusing remotely sensed data and respective modelling approaches such as SEBI, SEBAL, S-SEBI, SEBS, METRIC, S-TSEB and P-TSEB (Alizadeh et al. 2016). Moreover, the MODIS sensor also measures evapotranspiration, that is represented in a 8-day composite dataset.

The results of many studies in different countries like China, Poland, Slovakia, Iraq, and Brazil indicate that the SEBAL algorithm is suitable to estimate evapotranspiration even in areas with climate data shortage (Santos et al. 2017; Ndou et al. 2018; Li et al. 2013; Santos 2017; Jaber 2016; Jian 2015; Bezerra 2015; Sun 2011). The MODIS evapotranspiration product provides significant information on variations of evapotranspiration over a wide area. Extensive research has been done in this context by e.g. Yu et al. (2019), Rasmussen et al. (2014), or Sun et al. (2012).

In this context, the results obtained through the SEBAL algorithm where compared with experimental methods like Hargrevi-Samani, Blaney-Criddle, FAO Penman-Monteith, Metric, SWAT and lysimeter data in countries like Turkey, India and some cities in Iran (Zanjan, Mazandaran, Neyshabur). Particularly, the SEBAL algorithm has been compared with actual lysimeter data showing small errors, which mainly related to the determination of the cold and hot pixels. The low value of MSE, MAE, MAD, and RMSE obtained in different other studies sustain the findings mentioned above (e.g. Karbasi et al. 2016; Ghorbani et al. 2015; Morshedi et al. 2016; Rezaei Banafsheh et al. 2014; Kamali and Nazari 2018; Atasever and Ozkan 2018; Fu et al. 2018; Rawat et al. 2017). The results obtained by Wagle et al. (2017) on the operation of five of surface energy balance SEB, models of (SEBAL), (METRIC), (SEBS), (S-SEBI (SSEBop)) for evapotranspiration of sorghum prediction indicate that the S-SEBI, SEBAL and SEBS outperform METRIC and SSEBop models with higher accuracy.

In this study we estimate evapotranspiration through: i) the SEBAL algorithm, ii) the FAO-Penman-Montith method and iii) MODIS evapotranspiration products and compare the obtained results con observed lysimeter data. The study area is located in the Shahrekord plain that is characterized by a temperate climate and wheat cropping as dominant agricultural production.

## 2. Study area

The Centre of Shahrekord plain is located at 32°29' to 32°38' N and 50°46' to 50°55' E at 2066 m above sea level (Fig. 1). The annual average precipitation of the plain is 330 mm and the annual temperature average is of 12 °C. The test farm is located at Farrokhshahr Agricultural Meteorological Research Center (AMRC). The farm is equipped with a drainage lysimeter with a diameter of 3 m and area of 7.60 $m^2$ and a cover consisting of 1200 wheat seeds. This farm is one of the experimental farms that estimats the actual evapotranspiration data through the SEBAL algorithm and we compare the results with that of the nearest wheat farm (Fig. 1).

## 3. Method and materials

The method applied in this study is comparative and illustrated in the following.

### 3.1 Method

According to the available databases, the observational data (lysimeter) is used a reference data. We estimate the evapotranspiration processes following the SEBAL algorithm given by Eq. 1–20, and the FAO-Penman-Monteith model reported by Eq. 21. To test the accuracy of these models and select the optimal model the RMSE Eq. 23, MES Eq. 24, MAD Eq. 25 and R Eq. 22 indexes are calculated.

### 3.2 Materials

The data bases consist of three data groups: i) meteorological data collected from Farokhshahr station

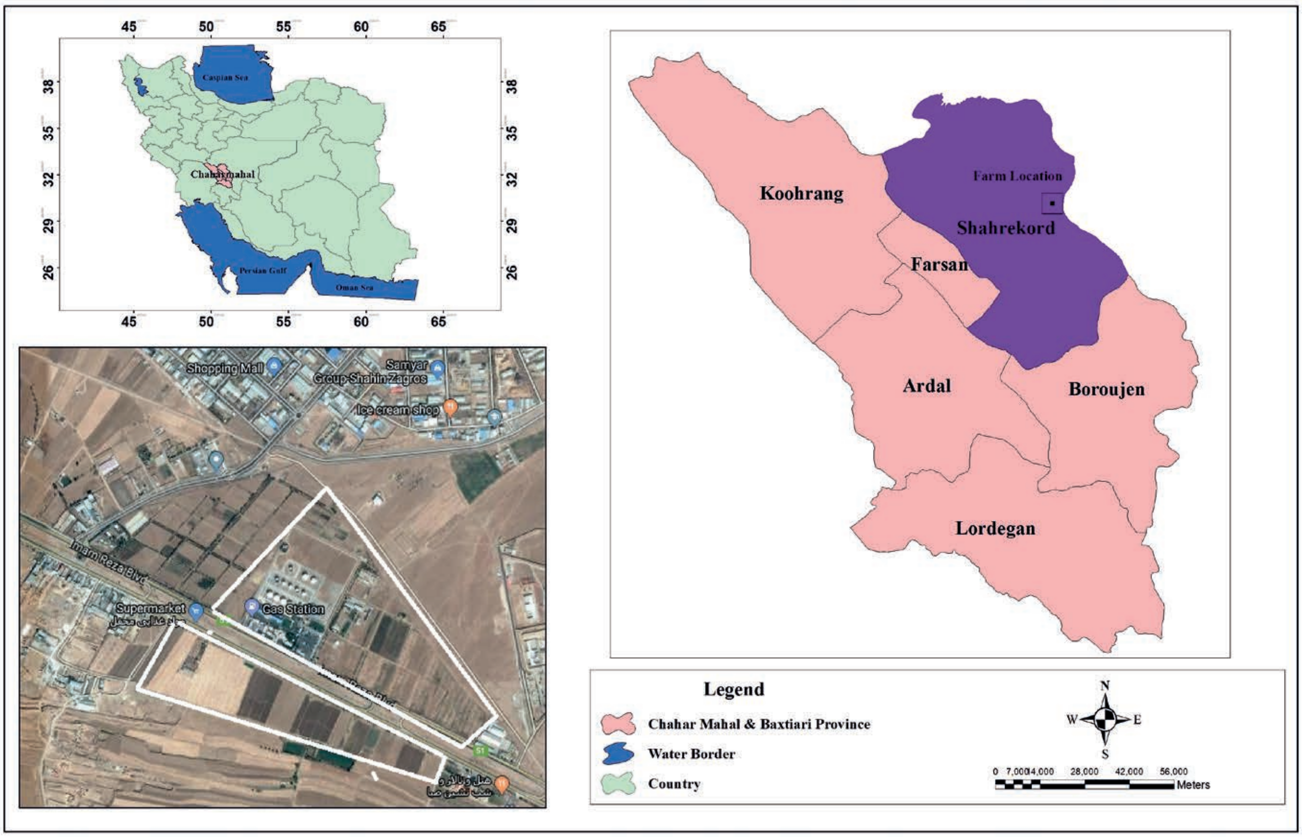


Fig. 1 Geographical location of the study area and sample farm.

which include average, minimum and maximum temperature, average, minimum and maximum precipitation, relative humidity (RH), wind speed, sunny hours, ii) evapotranspiration data measured by the lysimeter, iii) Landsat satellite images (2016–2017), and vi) the MODIS evapotranspiration product (2016–2017) Table 1.

Tab. 1 Specification of the applied satellite images (LANDSATandMODIS).

| Image type | Imaging time(D/M/Y) | Julian Day |
|---|---|---|
| Landsat7 | 25/07/2017 | 205 |
| Landsat7 | 22/05/2017 | 143 |
| Landsat7 | 11/11/2016 | 314 |

### 3.2.1 SEBAL algorithm

In the SEBAL model, ET is computed from satellite images and weather data using the surface energy balance. Since the satellite image provides information for the overpass time only, SEBAL computes an instantaneous ET flux for the image time. The ET flux is calculated for each pixel of the image as a “residual” of the surface energy budget equation:

$$\lambda ET = R_n - G - H \quad (1)$$

Where $\lambda ET$ is the latent heat flux ($W/m^2$), $R_n$ is the net radiation flux at the surface ($W/m^2$), G is the soil heat flux ($W/m^2$), and H is the sensible heat flux to the air ($W/m^2$).

The surface energy budget equation is further explained in part 4 of this section.

The net radiation flux at the surface ($R_n$) represents the actual radiant energy available at the surface. It is computed by subtracting all outgoing radiant fluxes from all incoming radiant fluxes (Figure 2) as illustrated in the surface radiation balance equation:

$$R_n = (1 - \alpha)R_{s\downarrow} + R_{L\downarrow} - R_{L\uparrow} - (1 - \varepsilon_0)R_{L\downarrow} \quad (2)$$

Where $R_{s\downarrow}$ is the incoming shortwave radiation ($W/m^2$), α is the surface albedo (dimensionless), $R_{L\downarrow}$ is the incoming long wave radiation ($W/m^2$), $R_{L\uparrow}$ is the outgoing long wave radiation ($W/m^2$), and $\varepsilon_o$ is the surface thermal emissivity (dimensionless) (Waters et al. 2002).

**Surface Albedo (α):** The albedo at the top of the atmosphere is compute as follows:

$$\alpha_{toa} = \Sigma(\omega_\lambda \times \rho_\lambda) \quad (3)$$

Where $\rho_\lambda$ is the reflectivity and $\omega_\lambda$ is a weighting coefficient for each band compute as follows:

$$\omega_\lambda = \frac{ESUN_\lambda}{\sum ESUN_\lambda} \tag{4}$$

Where *ESUN* is elevation of the sun. Albedo is defined as the ratio of the electromagnetic radiation reflected from the surface of the soil and the plant to the incident light emitted by the sun. Surface albedo is computed by correcting the $\alpha_{toa}$ for atmospheric transmissivity:

$$\alpha = \frac{\alpha_{toa} - \alpha_{path-radiance}}{\tau_{sw}^2} \tag{5}$$

Values for $\alpha_{path\_radiance}$ range between 0.025 and 0.04 and for SEBAL we recommend a value of 0.03 based on Bastiaanssen (1998).

$\tau_{sw}$ includes the transmissivity of both direct solar beam radiation and diffuse (scattered) radiation to the surface. We calculate $\tau_{sw}$ assuming clear sky and relatively dry conditions using an elevation-based relationship from FAO-56:

$$\tau_{sw} = 0.75 \times 2 \times 10^{-5} \times z \tag{6}$$

Where z is the elevation above sea level (m).

**Incoming Shortwave Radiation ($R_{S\downarrow}$):** Incoming shortwave radiation is the direct and diffuse solar radiation flux that actually reaches the earth's surface ($W/m^2$). Its value is computed as follows:

**Tab. 2** Component of atmospheric transmissivity.

| Station | $\tau_{sw}$ | $\tau^2_{sw}$ | z (m) |
|---|---|---|---|
| Shahrekord | 0.79 | 0.62 | 2066 |

**Tab. 3** Component of $R_{S\downarrow}$ Equation.

| Date | $G_{CS}$ (w/m²) | cos θ | $d_r$ | $\tau_{sw}$ | $R_{S\downarrow}$ (w/m²) |
|---|---|---|---|---|---|
| 2016/11/11 | 1367 | 0.79 | 1.02 | 0.79 | 871.68 |
| 2017/05/22 | 1367 | 0.93 | 0.97 | 0.79 | 981.65 |
| 2017/07/25 | 1367 | 0.91 | 0.96 | 0.79 | 954.29 |

$$R_{s\downarrow} = G_{CS} \times \cos\theta \times d_r \times \tau_{sw} \tag{7}$$

Where $G_{sc}$ is the solar constant (1367 $W/m^2$), cos θ is the cosine of the solar incidence angle as defined above, $d_r$ is the inverse squared relative earth-sun distance, and $\tau_{sw}$ is the atmospheric transmissivity. The value $R_{S\downarrow}$ is computed for the days specified.

Sun Elevation = 37.84438276 (Metadata file) → θ = 90 − 37.84438276= 52.15561724 → cos θ = 0.79

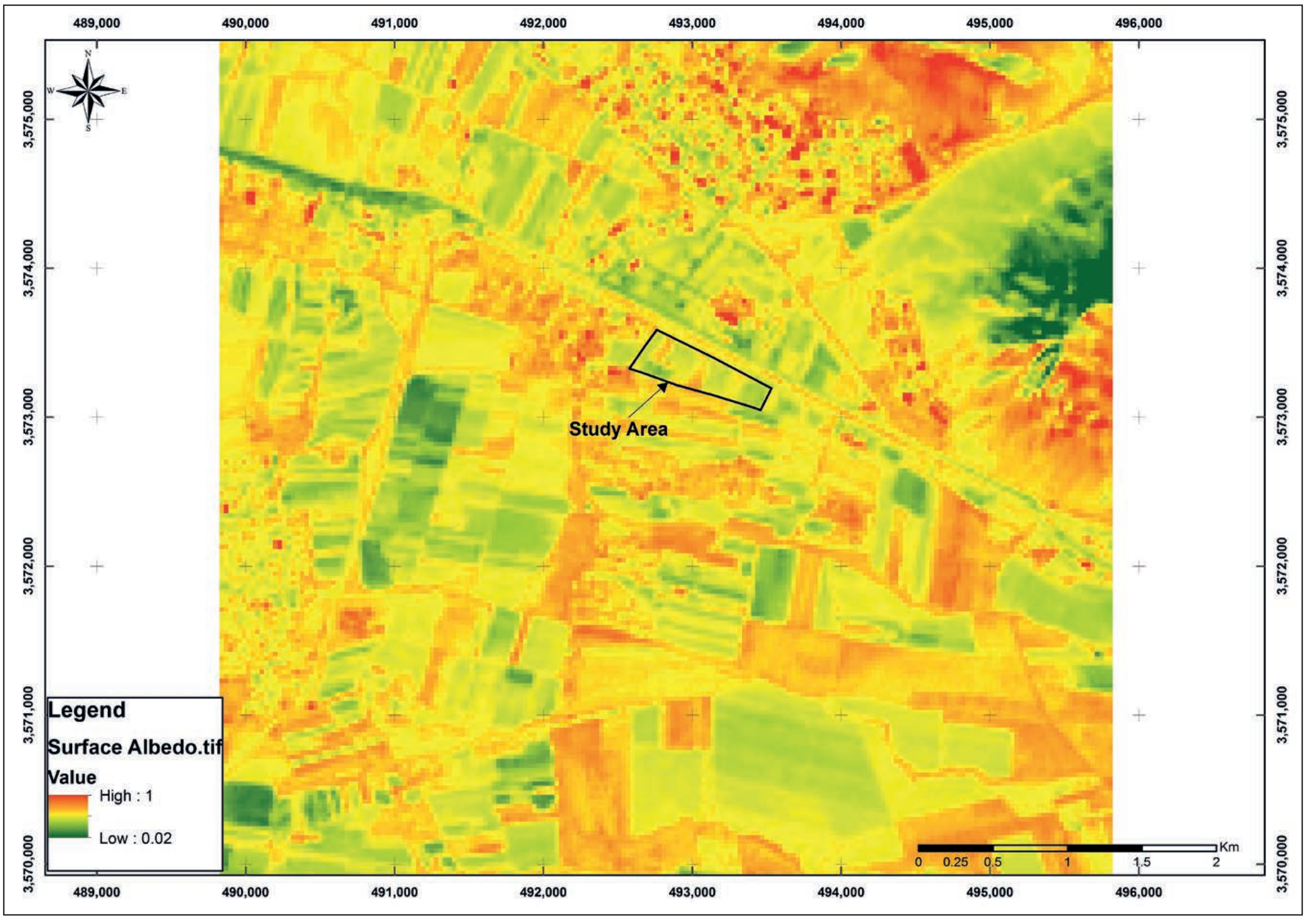


**Fig. 2** Surface Albedo of wheat farm (2016/11/11).

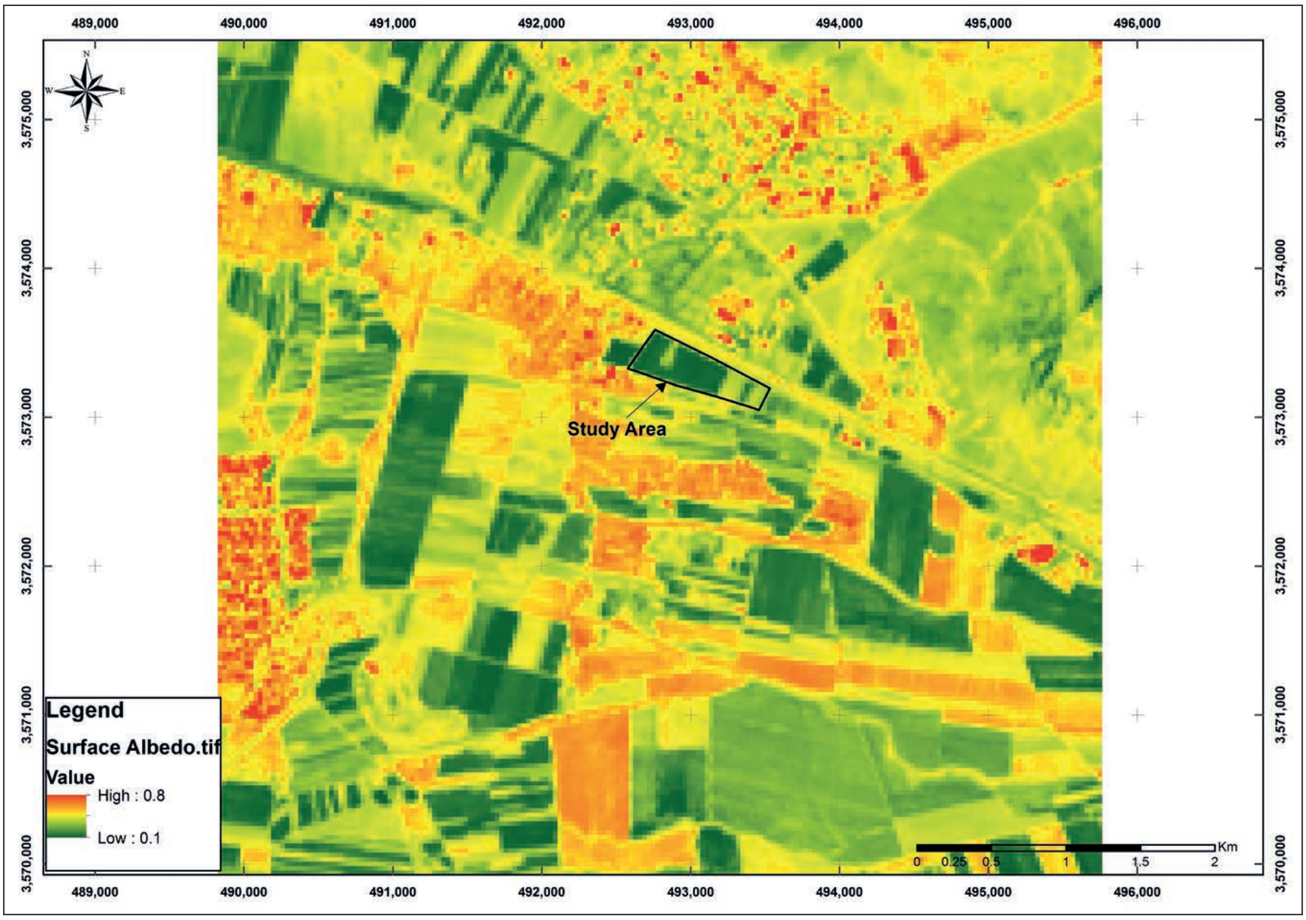


Fig. 3 Surface Albedo of wheat farm (2017/22/05).

Sun Elevation = 68.00616546 (Metadata file) → θ = 90 − 68.00616546= 21.99383 → cos θ = 0.93

Sun Elevation = 65.69948076 (Metadata file) → θ = 90 − 65.69948076 = 24.300522 → cos θ = 0.91

**Outgoing Long wave Radiation ($R_{L\uparrow}$):** The outgoing long wave radiation is the thermal radiation flux emitted from the earth's surface to the atmosphere ($W/m^2$). It is computed in SEBAL through the following steps:

1. Computation of vegetation indices of Normalized Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI), and Leaf Area Index (LAI)

The NDVI is the ratio of the differences in reflectivities for the near-infrared band (5) () and the red band (4) () to their sum:

$$NDVI = (R_1 - R_2)/(R_1 + R_2) \quad (8)$$

The NDVI is a sensitive indicator of the amount and condition of green vegetation. Values for NDVI range between −1 and +1. Green surfaces have a NDVI between 0 and 1 and water and cloud are usually less than zero.

The SAVI is an index that attempts to "subtract" the effects of background soil from NDVI so that impacts of soil wetness are reduced in the index. It is computed as:

$$SAVI = (1 + L)(R_1 - R_2)/(R_1 + R_2) \quad (9)$$

Where; L is a constant for SAVI. If L is zero, SAVI becomes equal to NDVI. A value of 0.5 frequently appears in the literature for L.

The LAI is the ratio of the total area of all leaves on a plant to the ground area represented by the plant. It is an indicator of biomass and canopy resistance. LAI is computed for southern Idaho using the following empirical equation:

$$LAI = -\frac{\frac{\ln(0.69 - SAVI_{ID})}{0.59}}{0.91} \quad (10)$$

Where; $SAVI_{ID}$ is the SAVI calculated from Equation (9).

2. Computation of Surface emissivity (ε)

Surface emissivity (ε) is the ratio of the thermal energy radiated by the surface to the thermal energy radiated by a blackbody at the same temperature.

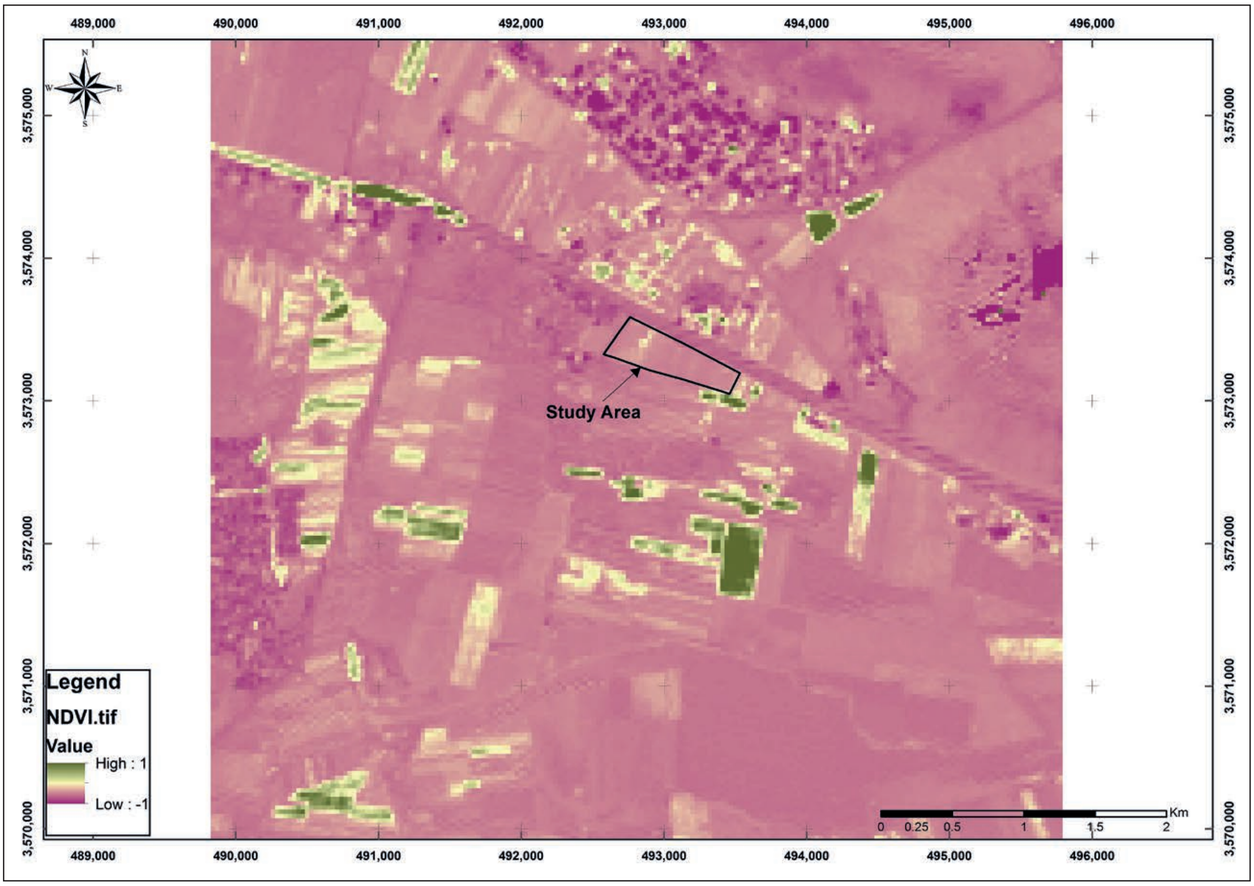


Fig. 4 NDVI of wheat farm (2016/11/11).

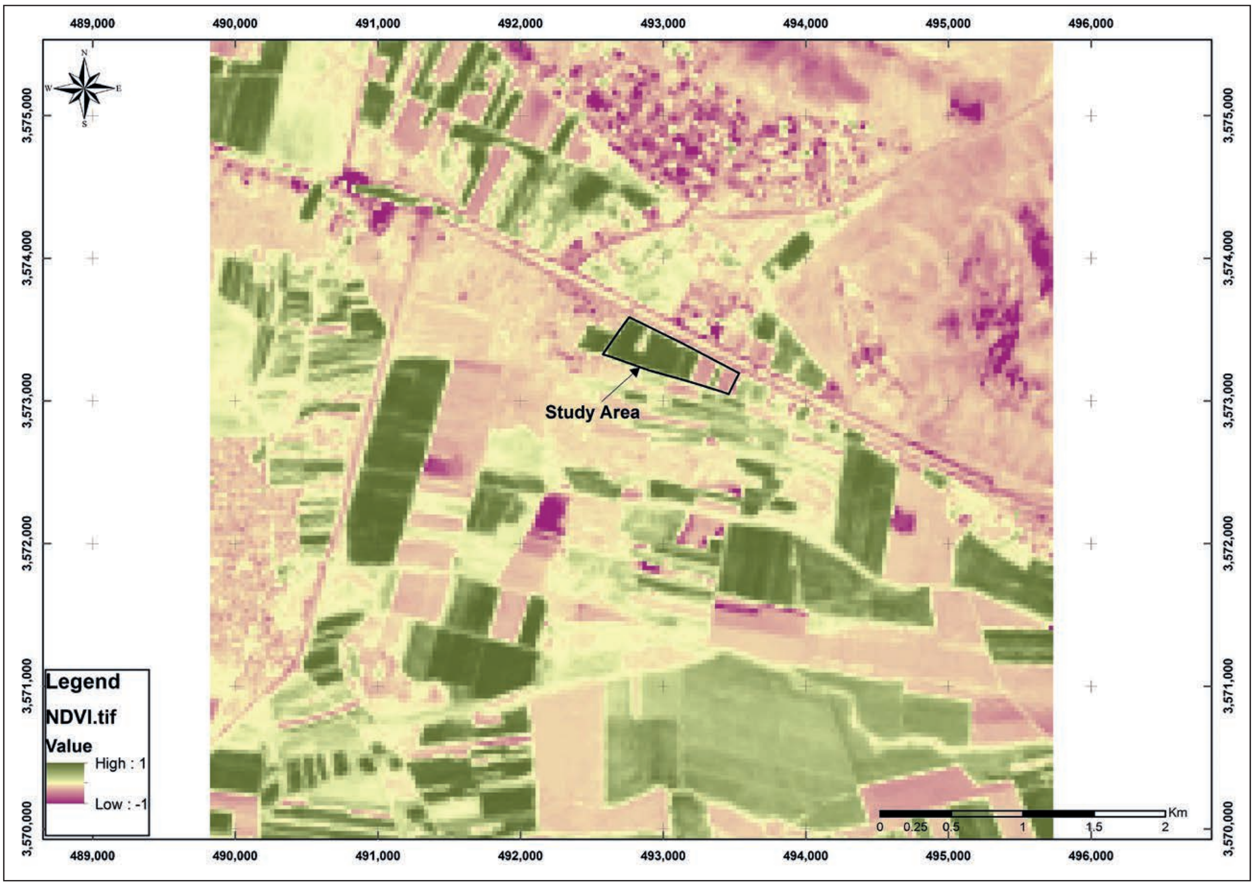


Fig. 5 NDVI of wheat farm (2017/22/05).

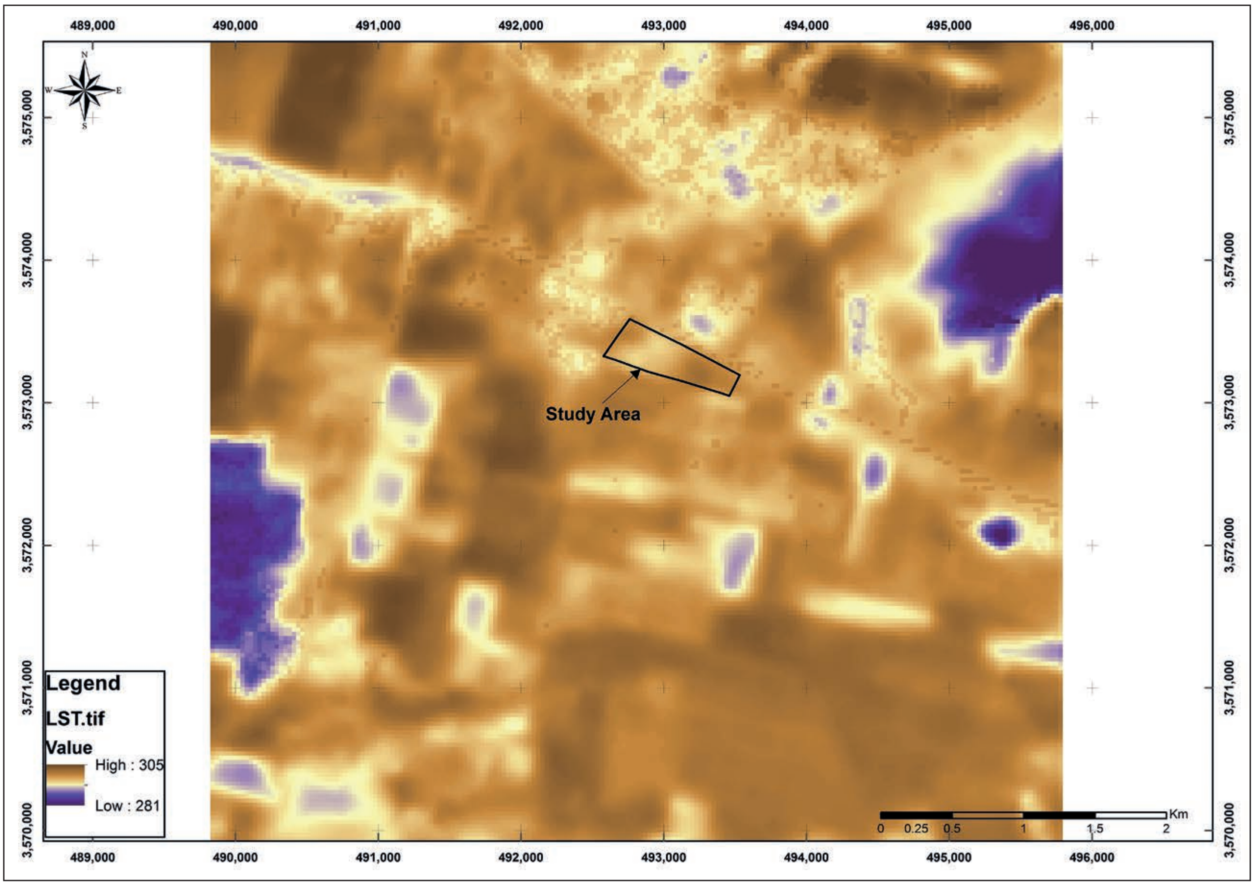


Fig. 6 LST of wheat farm (2016/11/11).

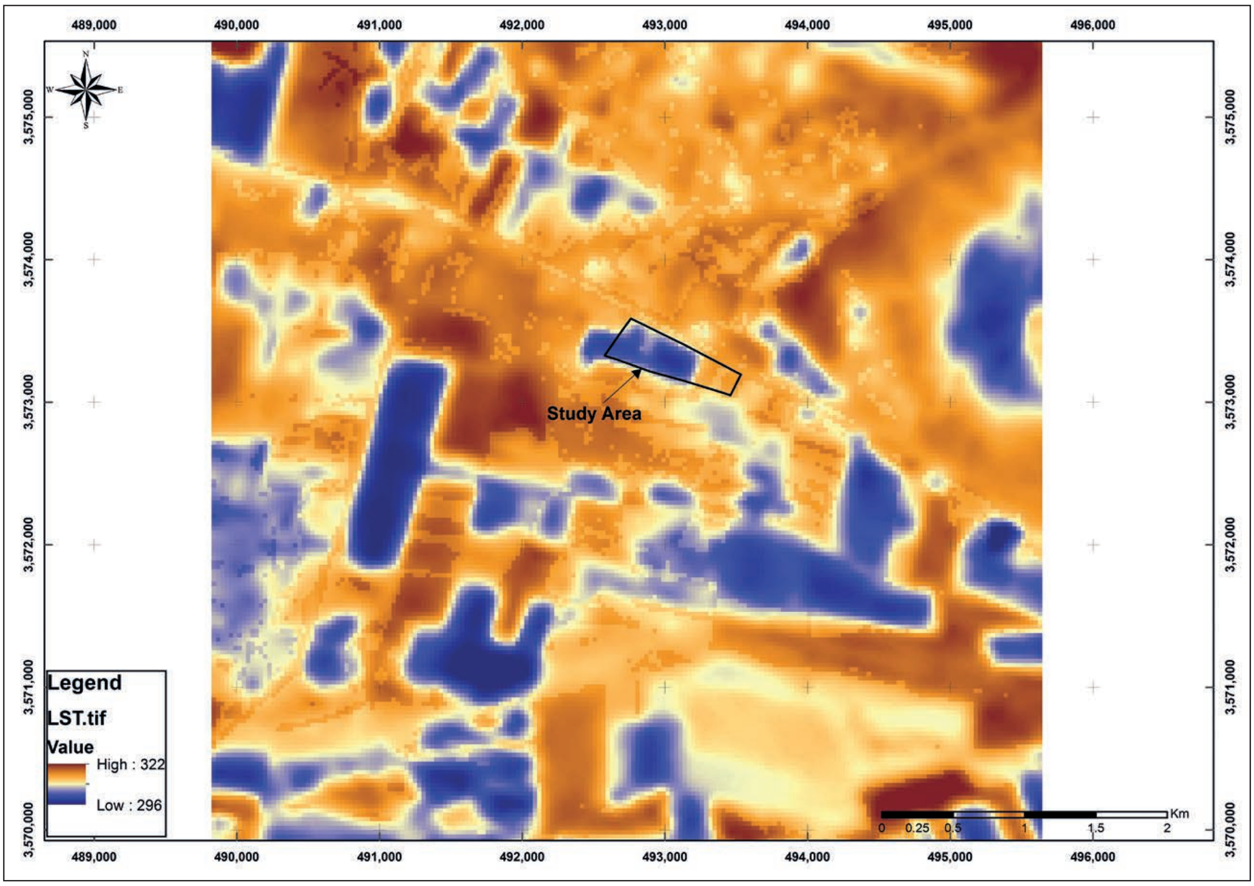


Fig. 7 LST of wheat farm (2017/22/05).

3. Computation of corrected thermal radiance (Rc)

The corrected thermal radiance ($R_c$) is the actual radiance emitted from the surface.

4. Computation of surface temperature (Ts)

The surface temperature (Ts) is compute using the following equation:

$$T_s = \frac{TB}{\left[1+\left(\lambda \times \frac{TB}{c2}\right) \times \ln(e)\right]} \quad (11)$$

Where TB is the Brightness Temperature, wavelength of emitted radiance (the value of λ for bands 6 the Landsat 4,5,7 is 11.45.), e is emissivity, c2 = h × c/s =1.4388 × $10^{-2}$ m K, where h = Planck's constant (6.62607015 × $10^{-34}$ J s), s = Boltzmann constant (1.380649 × $10^{-23}$ J/K), c = velocity of light (2.998 × $10^{8}$ m/s). The value of e is obtained from this relation 0.004 × Pv +0.986, where Pv = NDVI – $NDVI_{min}$/$NDVI_{max}$ –$NDVI_{min}$.

Brightness Temperature is obtained from the following relation:

$$TB = \frac{K_2}{ln\left(\frac{K_1}{L_\lambda}+1\right)} \quad (12)$$

Where $K_1$ and $K_2$ are constants for Landsat images, $L_\lambda$ ($L_\lambda = M_L Q_{cal} + A_L$) spectral radiance where $M_L$ is band-specific multiplicative rescaling factor from metadata, $Q_{cal}$ is quantized and calibrated standard product pixel value and $A_L$ is band-specific additive rescaling factor from metadata.in this paper from Brightness Temperature and wavelength of emitted radiance recorded by the sensor (thermal band) is used.

5. Computation of Outgoing Long wave Radiation ($R_L$↑)

This is computed using the Stefan-Boltzmann equation:

$$R_{L\uparrow} = \varepsilon_0 \times \sigma \times T_S^4 \quad (13)$$

Where $\varepsilon_0$ is the "broad-band" surface emissivity (dimensionless), σ is the Stefan-Boltzmann constant (5.67 × $10^{-8}$ W/$m^2$/$K^4$), and $T_s$ is the surface temperature (K).

**Choosing the "Hot" and "Cold" Pixels:** The "cold" pixel is selected as a wet, well-irrigated crop surface having full ground cover by vegetation. The surface temperature and near-surface air temperature are assumed similar at this pixel. The "hot" pixel is selected as a dry, bare agricultural field where ET is assumed zero.

**Incoming Long wave Radiation ($R_{L\downarrow}$):** The incoming long wave radiation is the downward thermal radiation flux from the atmosphere (W/$m^2$). It is computed using the Stefan-Boltzmann equation:

**Tab. 4** Constant of K for Equation 12.

| Landsat | K1 | K2 |
|---|---|---|
| Landsat 8 band 10,11 | 666.09 | 1282.71 |

**Tab. 5** Components of the $R_{L\downarrow}$ Equation for different days.

| Date | $T_\alpha^4$ (K) | $\varepsilon_0$ | $R_{L\downarrow}$ (W/$m^2$) |
|---|---|---|---|
| 2016/11/11 | 284.09 | 0.74 | 275.30 |
| 2017/05/22 | 296.15 | 0.74 | 326.47 |
| 2017/07/25 | 295.70 | 0.74 | 323.30 |

$$R_{L\downarrow} = \varepsilon_0 \times \sigma \times T_\alpha^4 \quad (14)$$

Net surface radiation ($R_n$) is calculated is computed using Equation (2).

**Soil Heat Flux (G):** Soil heat flux is the rate of heat storage into the soil and vegetation due to conduction. Estimates of G/$R_n$ for agriculture surfaces is between 0.05–0.15.

$$\frac{G}{R_n} = \frac{T_s}{\alpha} \times [0.0032 \times \alpha + 0.0062 \times \alpha^2] \times [1 - 0.978 \times NDVI^4] \quad (15)$$

**Sensible Heat Flux (H):** Sensible heat flux is the rate of heat loss to the air by convection and conduction, due to a temperature difference. It is compute using the following equation for heat transport:

$$H = \frac{D \times C_D \times dt}{r_{ah}} = \rho \times C_\rho \times dt/r_{ah} \quad (16)$$

Where ρ is air density (kg/$m^3$), $c_p$ is air specific heat (1004 J/kg/K), dT (K) is the temperature difference ($T_1$ – $T_2$) between two heights ($z_1$ and $z_2$), and $r_{ah}$ is the aerodynamic resistance to heat transport (s/m). $z_1$ is the height just above the zero plane displacement (d ≅ 0.67 × height of vegetation) for the surface or crop canopy and $z_2$ is some distance above the zero plane displacement, but below the height of the surface boundary layer. Based on experimental analysis, values of 0.1 meter for $z_1$ and 2.0 meters for $z_2$ are assigned. Temperature difference (dt) is given as dT = $Tz_1$ – $Tz_2$. The air temperature at each pixel is unknown, along with explicit values for $Tz_1$and $Tz_2$. Therefore, only the difference dT is utilized. SEBAL computes dT for each pixel by assuming a linear relationship between dT and $T_s$: dt = b + a$T_s$, where b and a are the correlation coefficients and $T_S$ is the land surface temperature. a is obtained by subtracting the dT (dt hot pixel – dt cold pixel) and the LST (LST hot pixel – LST cold pixel). Using Envi software, first the hot and cold pixels are separated according to vegetation and temperature of the pixels and the dt are calculated based on the difference of two hot and cold pixels: a = (dt hot pixel – dt cold pixel) / (LST hot pixel – LST cold pixel). b is obtained by multiplying –a in LST hot pixel and dt hot pixel: b = (–a) × LST(hot) + dt(hot).

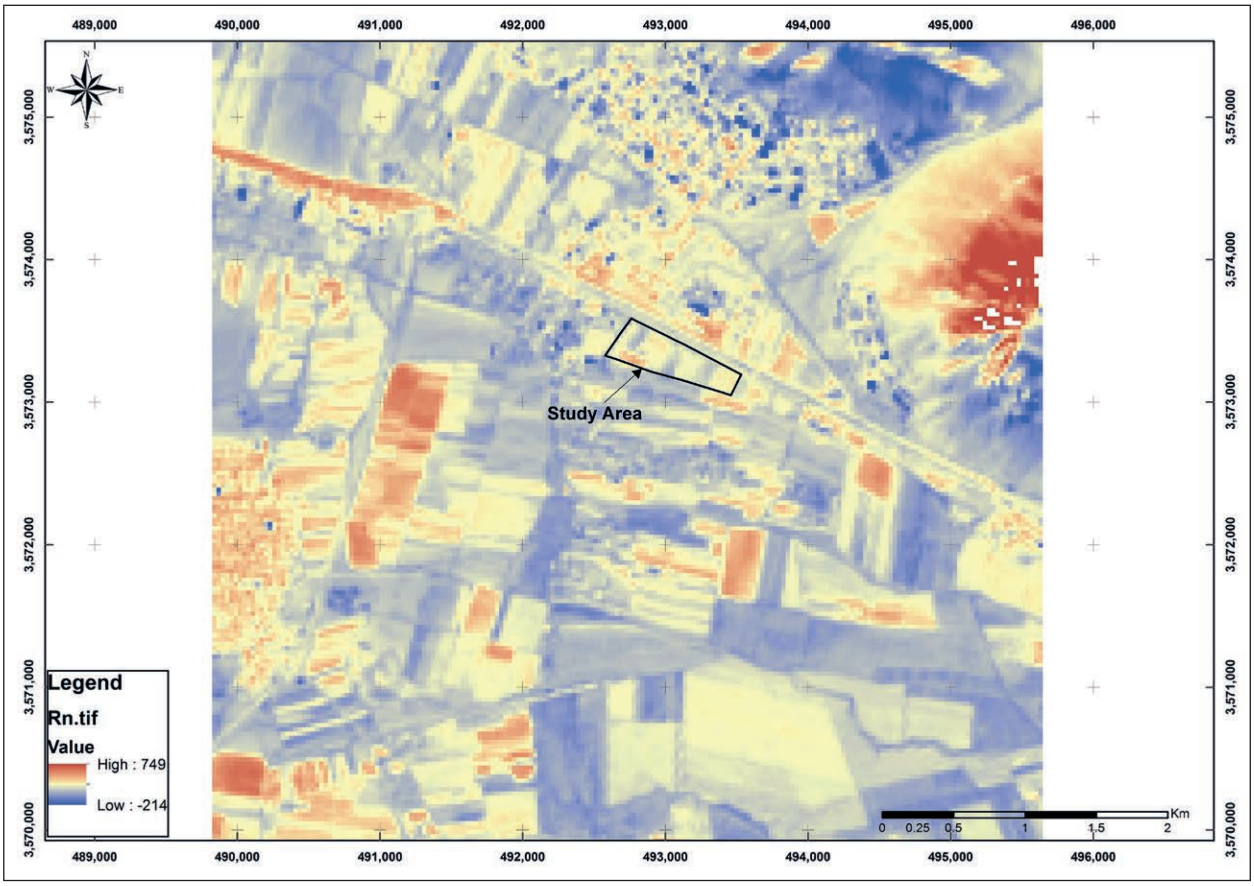


Fig. 8 Rn of wheat farm (2016/11/11).

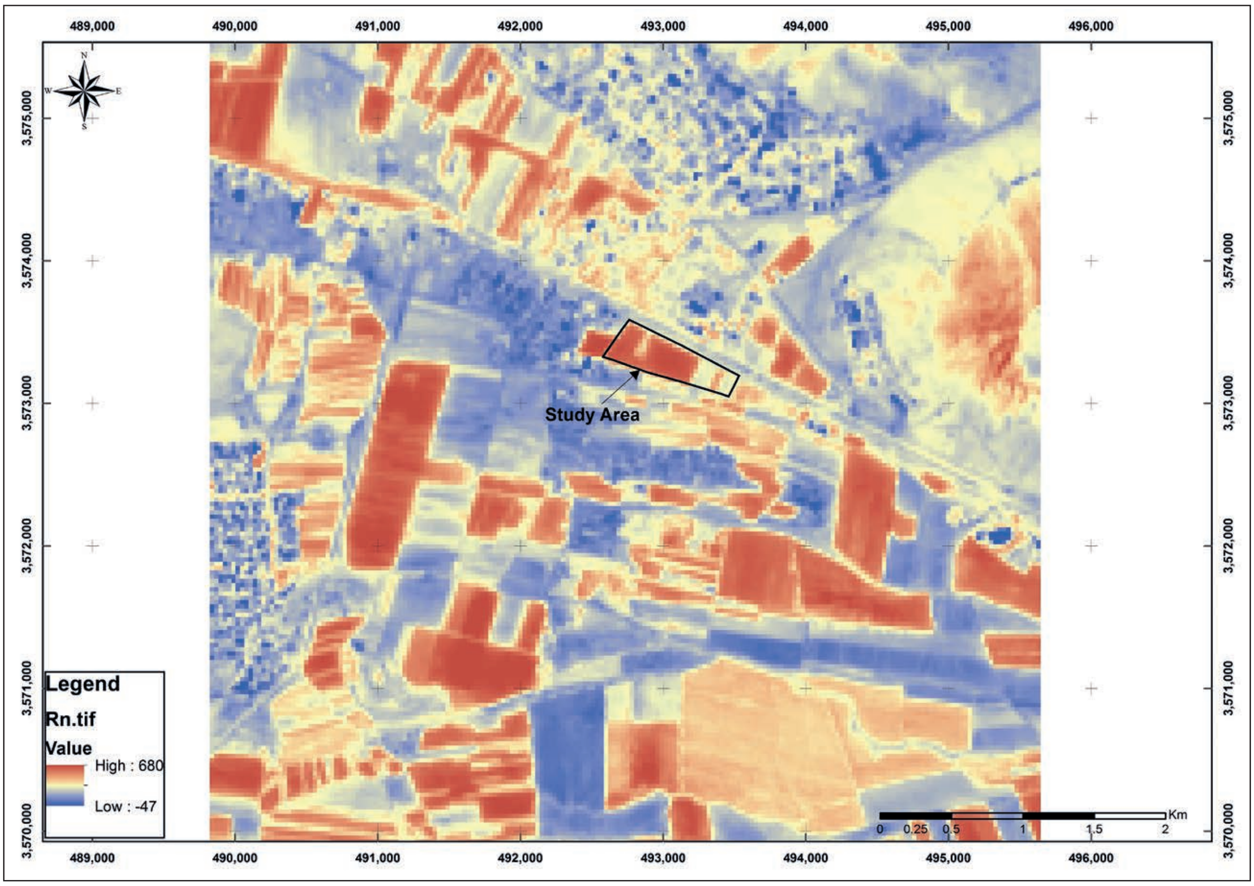


Fig. 9 Rn of wheat farm (2017/22/05).

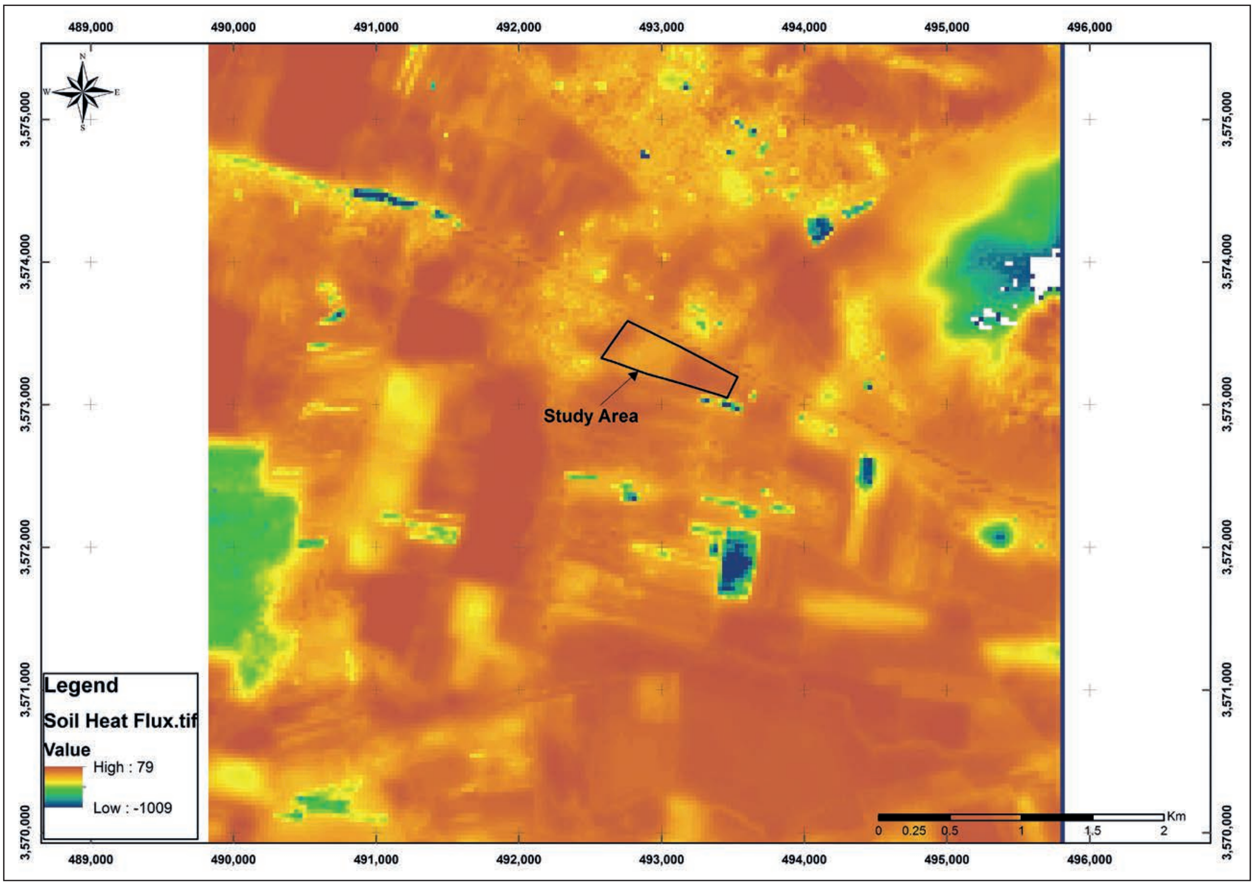


Fig. 10 Soil Heat Flux of wheat farm (G) (2016/11/11).

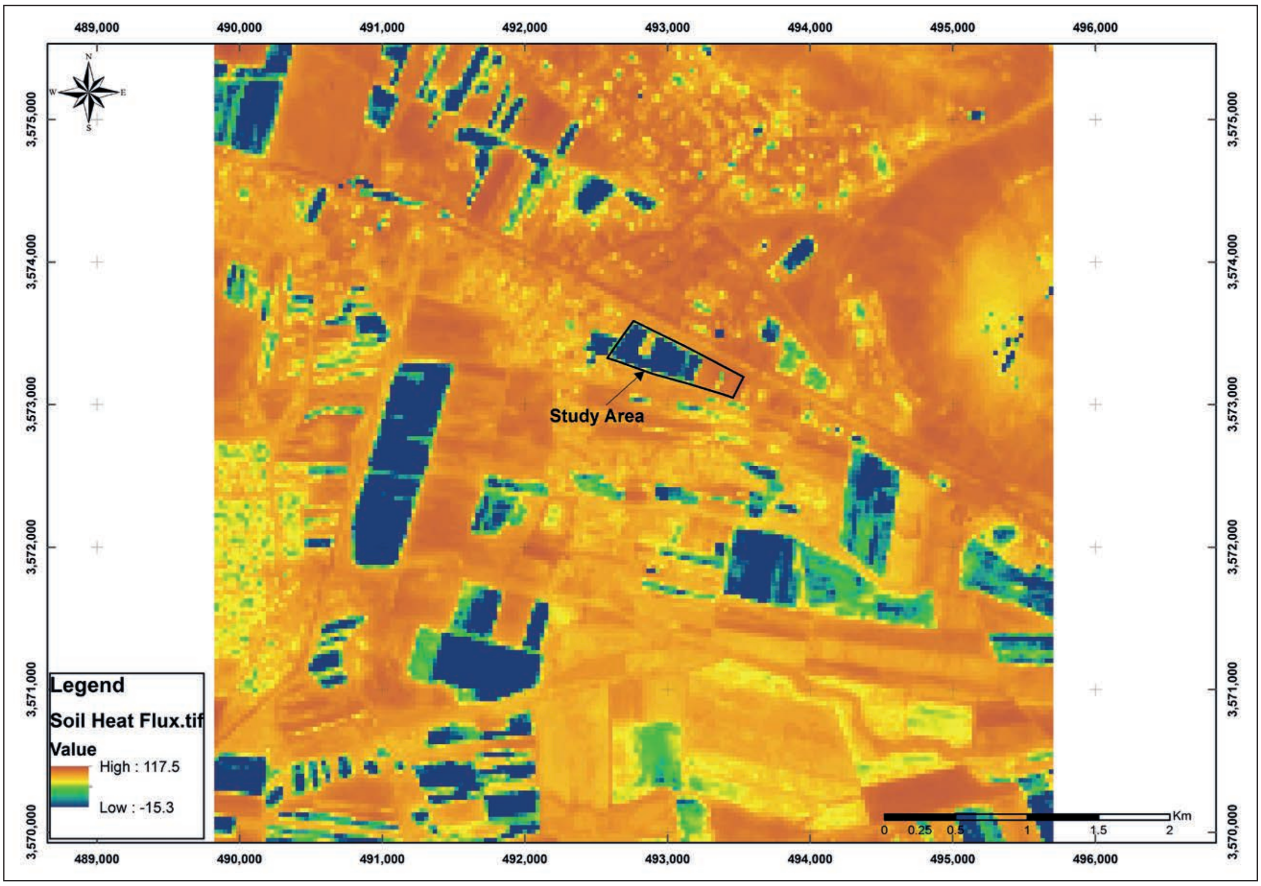


Fig. 11 Soil Heat Flux (G) of wheat farm (2017/22/05).

By replacing the unknowns in the *dt* equation, the temperature difference of $z_1$ and $z_2$ is obtained.

Latent Heat Flux ($\lambda ET$), Instantaneous ET ($ET_{inst}$), and Reference ET Fraction ($ET_rF$) computation Latent heat flux is the rate of latent heat loss from the surface due to evapotranspiration. It can be computed for each pixel using the following Equation:

$$\lambda ET = R_n - G - H$$

Where $\lambda ET$ is an instantaneous value for the time of the satellite overpass ($W/m^2$).

An instantaneous value of ET in equivalent evaporation depth is computed as:

$$ET_{inst} = 3600\frac{\lambda ET}{\lambda} \quad (17)$$

Where $ET_{inst}$ is the instantaneous ET (mm/hr), 3600 is the time conversion from seconds to hours, and $\lambda$ is the latent heat of vaporization or the heat absorbed when a kilogram of water evaporates (J/kg) is computed as:

$$\lambda = [2.501 - 0.00236(T_S - 273)] \times 10^6 \quad (18)$$

**Tab. 6** Results obtained from compute of  for different dates.

| Date | $ET_{inst}$ |
|---|---|
| 2017/07/25 | 0.15 |
| 2017/05/22 | 0.20 |
| 2016/11/11 | 0.03 |

The Reference ET Fraction ($ET_rF$) is defined as the ratio of the computed instantaneous ET ($ET_{inst}$) for each pixel to the reference ET ($ET_r$) computed from weather data:

$$ET_rF = \frac{ET_{inst}}{ET_r} \quad (19)$$

Daily values of ET ($ET_{24}$) are often more useful than instantaneous ET.

$$ET_{24} = ET_rF \times ET_{r-24} \quad (20)$$

Where $ET_{r\text{-}24}$ is the cumulative 24-hour $ET_r$ for the day of the image. This is calculated by adding the hourly $ET_r$ values over the day of the image (Waters et al. 2002).

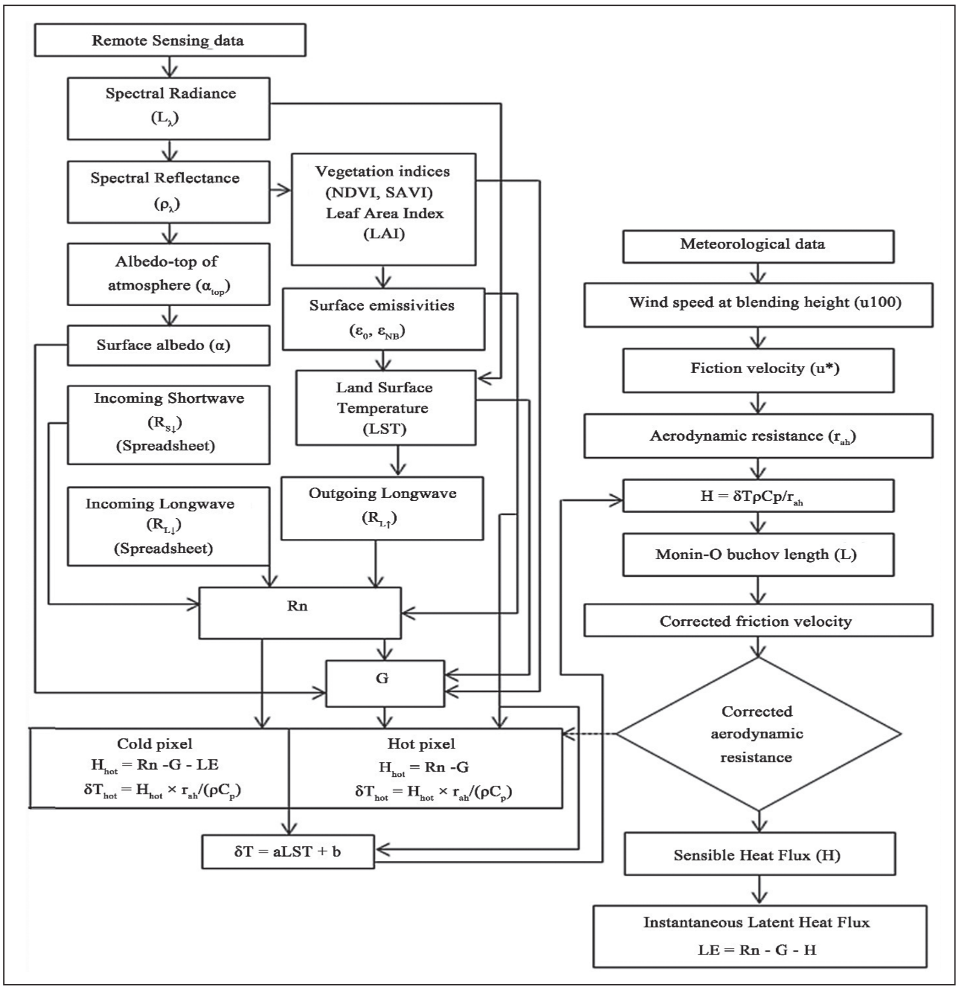


**Fig. 12** Flow chart of the computational steps of SEBAL algorithm (Bezerra et al. 2015).

### 3.2.2 FAO Penman-Monteith method

Evapotranspiration is obtained through Eq. 17 (National Irrigation and Drainage Committee 2008):

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{t+273}u_2(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34\,u_2)} \quad (21)$$

Where:

$ET_0$ is the reference evapotranspiration (mm/day),

$R_n$ is the pure radiation entering the surface of the plant (MJ/m$^2$/day),

G is the soil heat flux (MJ/m$^2$/day),

T is the mean daily air temperature at 2 meters (°C),

$u_2$ is the average daily wind speed at 2 m height (m/s),

$e_s$ is the saturation vapor pressure (kPa),

$e_a$ is the real vapor pressure (kPa),

$e_s - e_a$ is the lack of saturation vapor pressure (kPa),

$\Delta$ is the slope of the vapor pressure curve (kPa/°C),

$\gamma$ is the constant coefficient.

### 3.2.3 MODIS evapotranspiration product

Evapotranspiration product is an 8-day composite dataset produced at 500-meter (m) pixel resolution. The algorithm used for the Evapotranspiration data product collection is based on the logic of the Penman-Monteith equation, which includes inputs of daily meteorological reanalysis data along with Moderate Resolution Imaging Spectroradiometer (MODIS) remotely sensed data products such as vegetation property dynamics, albedo, and land cover. The download data set is the MODIS evapotranspiration product for Aqua Satellite MYD16A2 and for Terra Satellite MOD16A2. The MOD16A2 and MYD16A2 layers provide the following products:

i) The composited Evapotranspiration (ET),
ii) Latent Heat Flux (LE),
iii) Potential ET (PET),
iv) Potential LE (PLE) along with a quality control layer.

The pixel values for the two Evapotranspiration layers (ET and PET) are the sum of all eight days within the composite period and the pixel values for the two Latent Heat layers (LE and PLE) are the average of all eight days within the composite period.

### 3.2.4 Model evaluation

To assess model performance a comparison is run between observations obtained from applying the three models and the SEBAL algorithm. These indicators include R (Eq. 18), RMSE (Eq. 19), MSE (Eq. 20) and MAD (Eq. 21), as follows:

$$R = \frac{\sum_{i=1}^{n}(x_i - \bar{x})\cdot(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - x)^2 \cdot \sum_{i=1}^{n}(y_i - \bar{y})^2}} \quad (22)$$

$$RMSE = \left[\frac{\sum_{n=i}^{n}(P_i - O_i)^2}{N}\right]^{0.5} \quad (23)$$

$$MSE = \frac{1}{N}\sum_{n=i}^{n}(P_i - O_i)^2 \quad (24)$$

$$MAD = \frac{\sum_{i}^{n}|P_i - O_i|}{N} \quad (25)$$

In all these error detection indexes is the modeled data and is the observational data and N is the data count.

## 4. Results

In total the Chaharmahal and Bakhtiari province is covered by circa 248,000 hectares of agricultural land, 79,854 hectares of these are located in the Shahrekord plain, of which, 58,553 hectares are under irrigation cultivation and 21,301 hectares are under rain fed cultivation. In total (in Shahrekord city), there are 29,917 hectares under cultivation of crops and 21,759 hectares dedicated to vegetable and garden farming.

According to the available statistics, the average productivity of agricultural water use of the province is 0.87 kg/m$^3$ while it should be increased to 1.51 kg/m$^3$ in the Iranian 5-years program and to 1.9 kg/m$^3$ in the Iranian 10-years planning. The water resources of this province decrease by 46 million m$^3$ in average, annually (Ministry of Agriculture 2016).

Due to global warming, water demand and related tensions regarding water supply increased. Being aware of the fact that the knowledge about the actual evapotranspiration is essential in water supply and management in this research, we assess the productivity and determine the appropriate pattern of proportional water resources under the present day climatic and hydrological conditions.

### 4.1 Lysimeter

Evapotranspiration obtained for the initial growth period is 1.2 mm/day. The evapotranspiration volume increases with the advance of the growth period and the highest evapotranspiration (4.09) is related to the active growth period of the plants. Although the highest temperature is recorded at the end of the growth period, the evapotranspiration volume of this stage is lower (Table 8).

### 4.2 FAO Penman-Monteith method

The FAO Penman-Monteith estimates, before applying the crop factor, the highest evapotranspiration volume (7.43 mm/day) in the harvest time (2017/07/25). Because at this time of the growth period, the plant is completely ripe and no irrigation takes place. The largest volume of the plant consists of seed and chaff.

Consequently, to estimate the most accurate evapotranspiration volume, the volumes obtained from the FAO Penman-Monteith model are corrected through crop coefficients as shown in Tables 7 and 8. After applying the crop coefficient, the maximum evapotranspiration volume is obtained for active plant growth time. The minimum evapotranspiration volume is recorded in the initial period of growth.

**Tab. 7** Estimated Evapotranspiration without crop coefficient rate.

| Date | Vegetable coefficient | FAO Penman-Monteith method (mm/day) |
|---|---|---|
| 11/11/2016 | 0.40 | 1.60 |
| 22/05/2017 | 1.19 | 3.72 |
| 25/07/2017 | 0.50 | 2.30 |

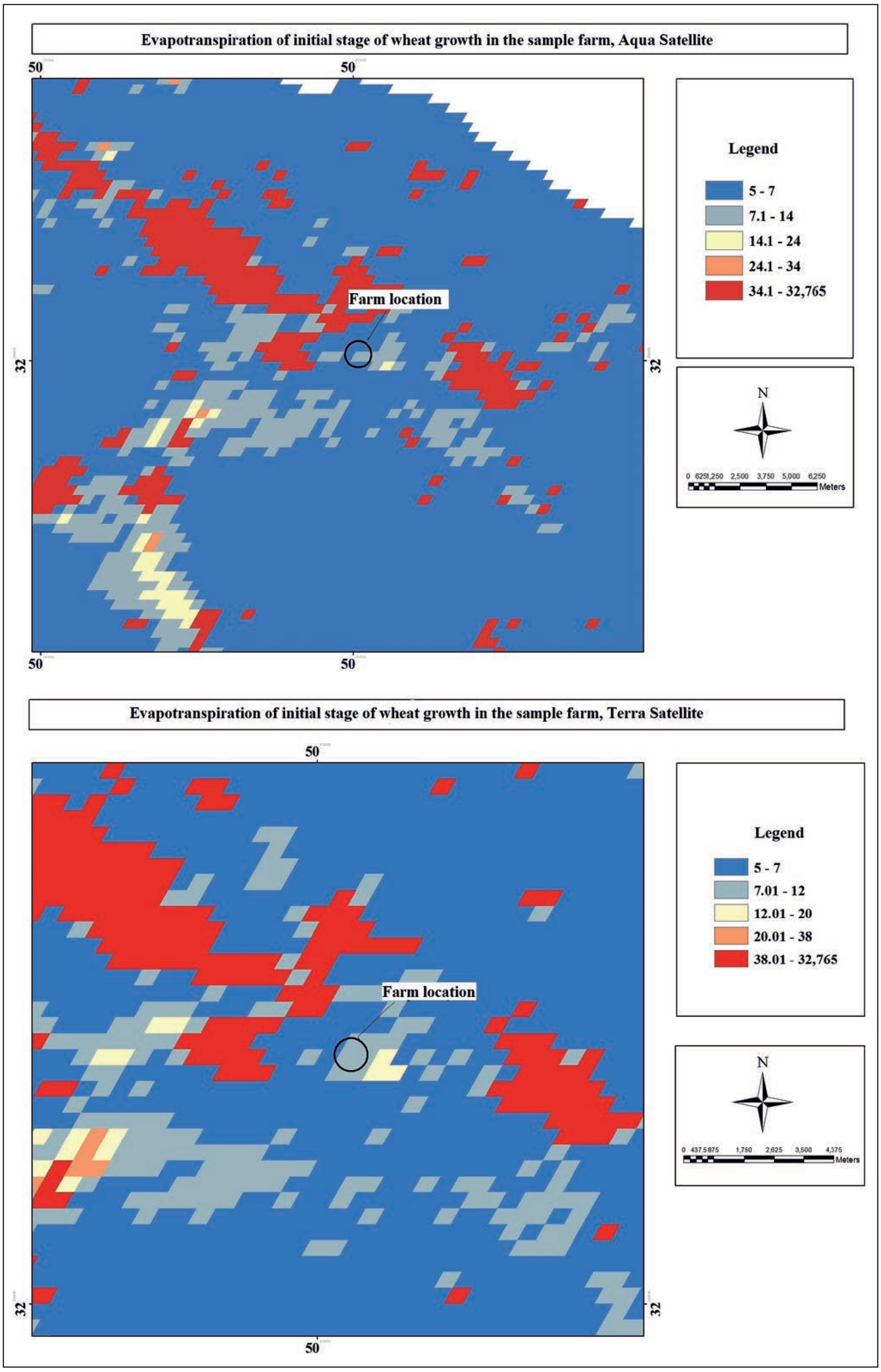


**Fig. 13** Evapotranspiration of initial stage of wheat growth.

## 4.3 MODIS evapotranspiration product

The results of the study of variations of wheat evapotranspiration on the sample plots through MODIS images show that the maximum evapotranspiration of wheat in the field occurred in the middle growth stage. The average evapotranspiration at this stage is 1.13 mm/day based on Aqua satellite and 1.09 mm/day on the Terra satellite (Table 8). The final stage of wheat growth with 0.59 mm evapotranspiration per day for Aqua satellites and 0.58 mm evapotranspiration per day for Terra satellites had the highest evapotranspiration after the middle wheat growth stage. The lowest evapotranspiration occurs in the initial stages of growth (Figures 13–14).

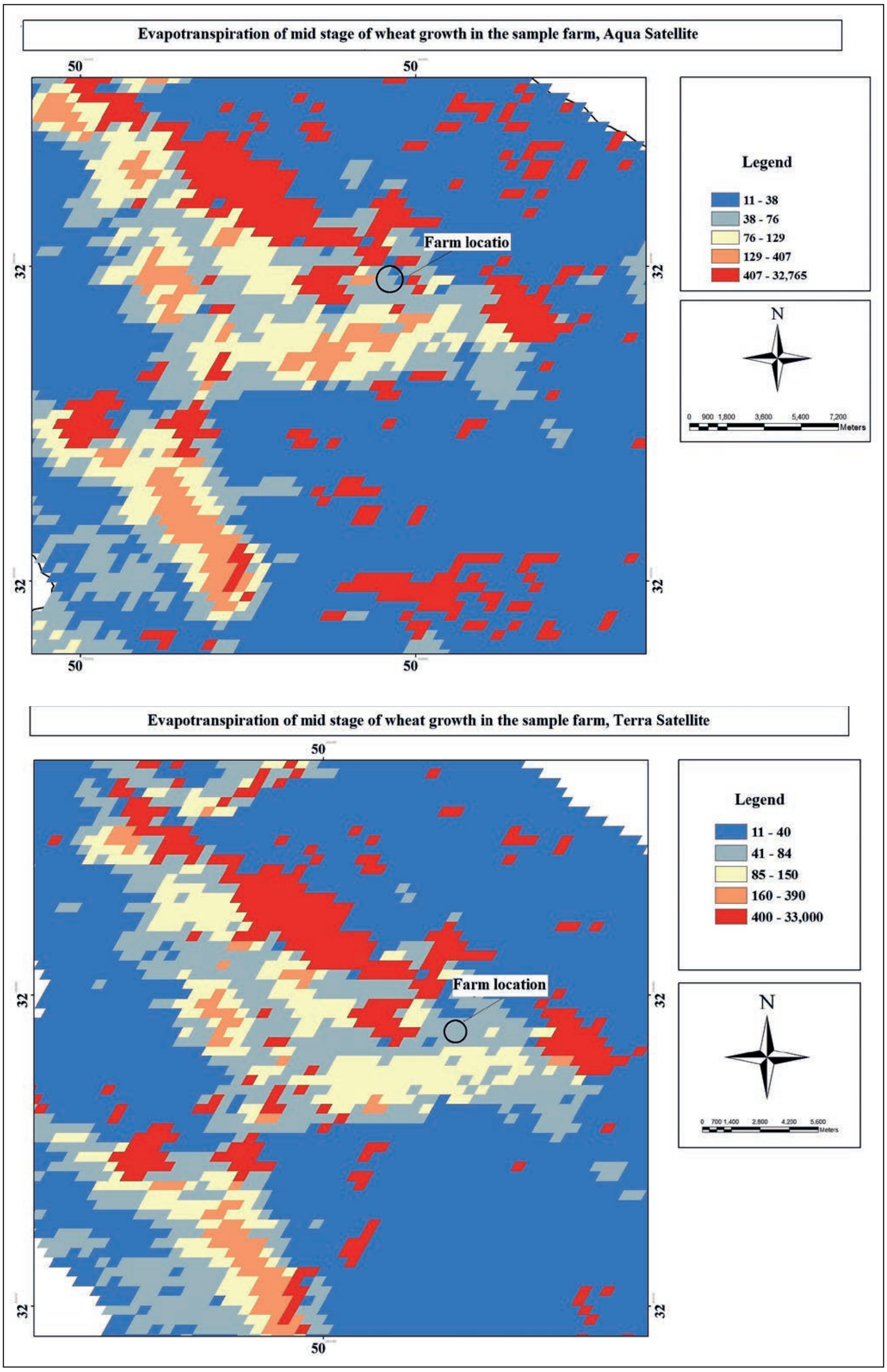


Fig. 14 Evapotranspiration of mid stage of wheat growth.

### 4.4 SEBAL algorithm

The obtained SEBAL parameters are illustrated in Table 9. As observed in figures (4–5, 8–9 and 16–17), the NDVI, $R_n$ and ET are expressed in hot and cold pixels indicting one of the critical functions of this algorithm.

### 4.5 Data evaluation

The results of the error comparison and the correlation coefficient of the above-cited methods are tabulated in Table 10. We show that the SEBAL algorithm together with satellite imagery and the FAO Penman-Monteith method, after applying the vegetation

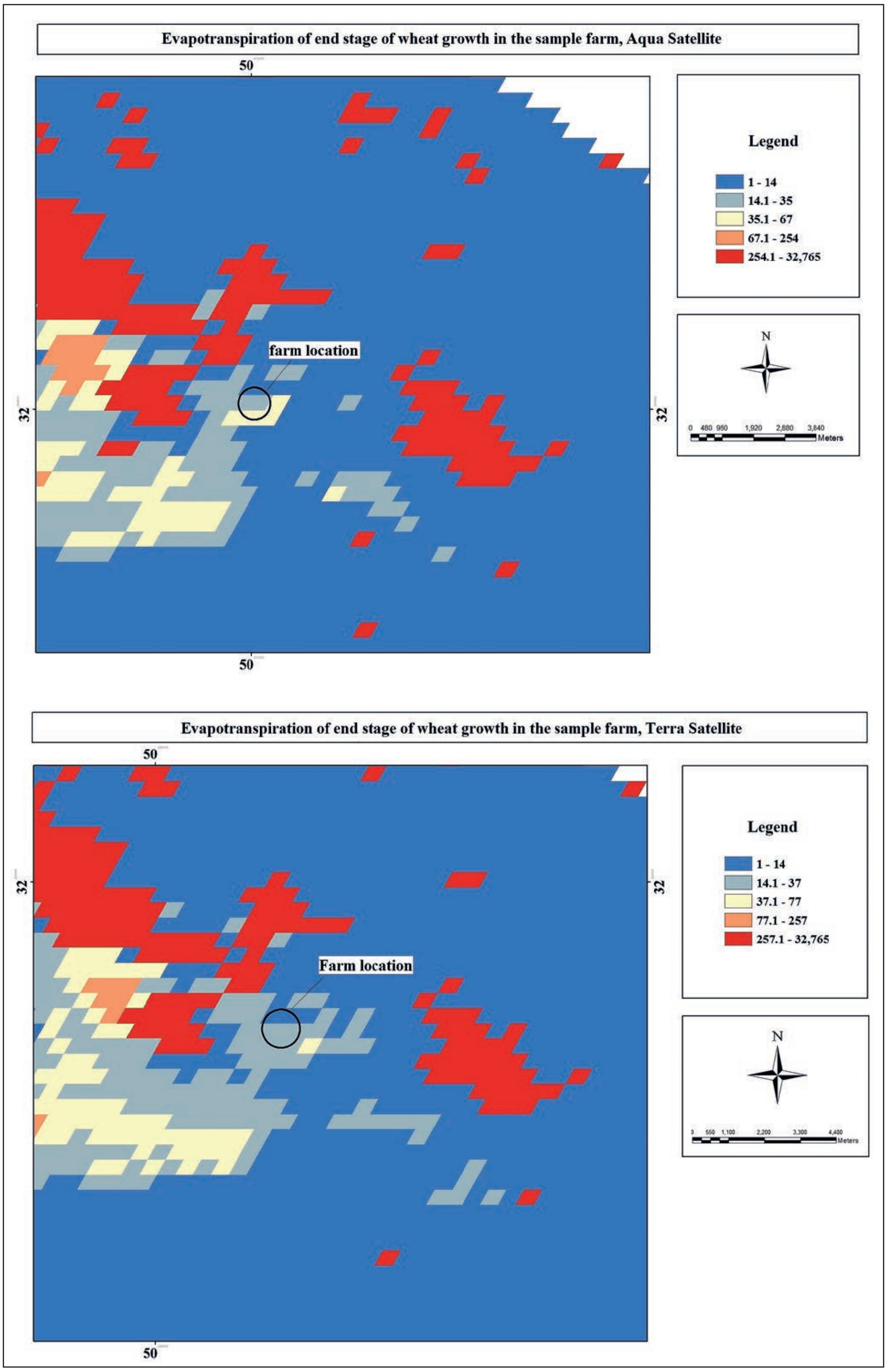


Fig. 15 Evapotranspiration of end stage of wheat growth.

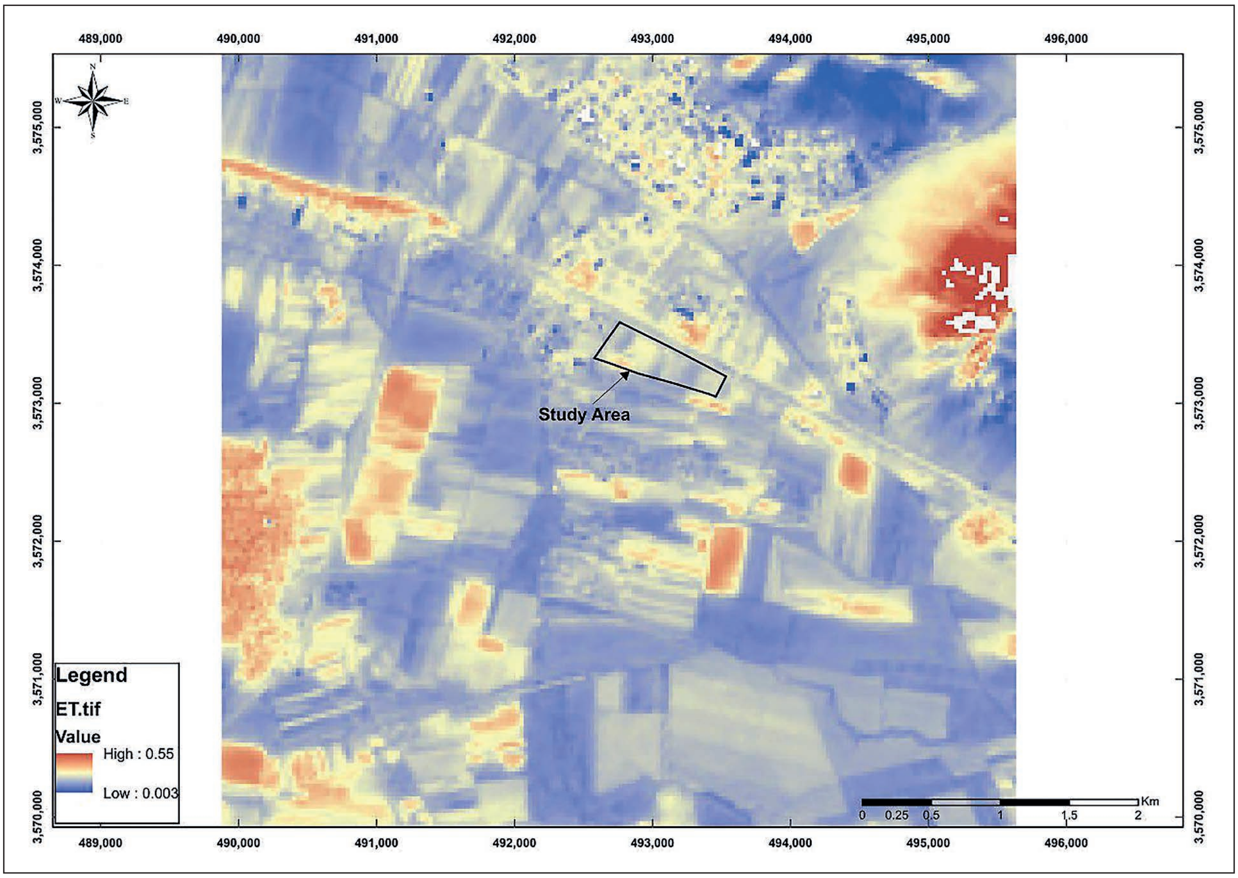


Fig. 16 Instantaneous ET of wheat farm (2016/11/11).

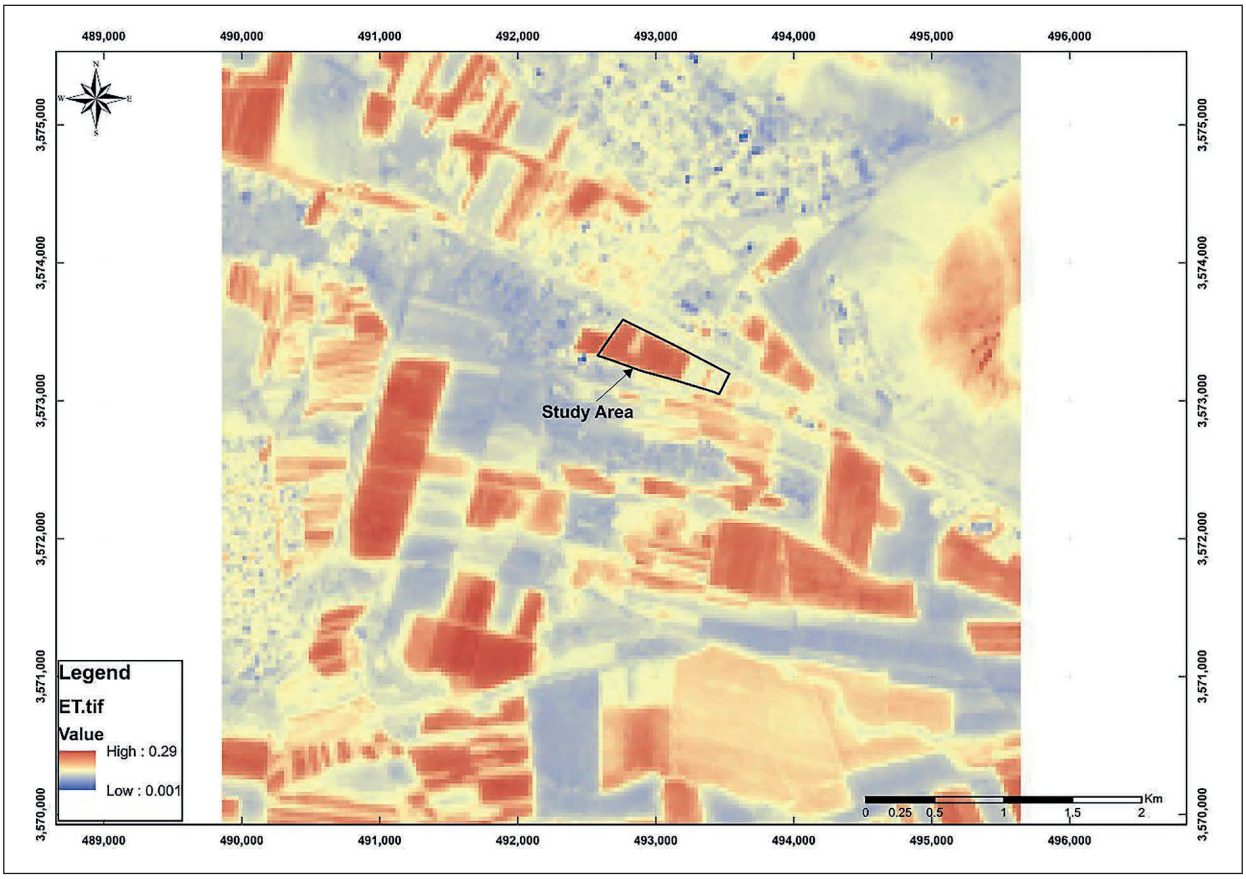


Fig. 17 Instantaneous ET of wheat farm (2017/22/05).

Tab. 8 Estimated Evapotranspiration with crop coefficient rate (mm/day).

| Date | Lysimeter | FAO Penman-Monteith method | MODIS evapotranspiration product | |
|---|---|---|---|---|
| | | | Aqua | Terra |
| 11/11/2016 | 1.20 | 0.64 | 0.15 | 0.15 |
| 22/05/2017 | 4.09 | 4.42 | 1.13 | 1.09 |
| 25/07/2017 | 3.01 | 1.15 | 0.59 | 0.58 |

Tab. 10 Comparison of Lysimeter with Estimation of Evapotranspiration Methods.

| Evaluation criteria | SEBAL algorithm | FAO Penman -Monteith | MODIS evapotranspiration product | |
|---|---|---|---|---|
| | | | Aqua | Aqua |
| R | 1 | 0.86 | 0.98 | 0.98 |
| MAD | 0.59 | 0.91 | 2.14 | 2.16 |
| MSE | 0.36 | 1.29 | 5.24 | 5.34 |
| RMSE | 0.60 | 1.13 | 2.29 | 2.31 |

Tab. 9 Results obtained from the farm for SEBAL algorithm index.

| Date | NDVI | Rn ($W/m^2$) | Ts (K) | H ($W/m^2$) | G ($W/m^2$) | Evp (mm/day) |
|---|---|---|---|---|---|---|
| 11/11/2016 | 0.27 | 515.19 | 297.42 | 428.00 | 67.80 | 0.72 |
| 22/05/2017 | 0.66 | 569.53 | 307.30 | 419.00 | 55.00 | 4.80 |
| 25/07/2017 | 0.41 | 567.58 | 295.80 | 361.23 | 70.78 | 3.60 |

coefficient, are considered the best methods for situations where sufficient instruments are not provided in obtaining evapotranspiration through the installation of the Lysimeter.

Although the correlation between the evapotranspiration measured through MODIS images and Lysimeter is high (0.98), the error between their different outputs is also quite high. The error of evapotranspiration measured by the Aqua Satellite in comparison to the Lysimeter data is less than for the Terra satellite products.

## 5. Conclusion

Agriculture development and food security are threatened by a decrease in rainfall, rising temperatures, droughts, a decrease in water table level and an increase in evaporation. Evapotranspiration is an effective parameter in providing water balance and food security because of its contribution in determining plant water need. Accurate estimations of the water needs and water supply for plants, especially for wheat, as a strategic product in Iran, are of major interest.

Evapotranspiration estimations by experimental methods and different algorithms as used in this paper is an important step forward especially in data scarce areas. However, a careful validation of the different methods should be carried out using observed data e.g. from Lysimeter. The evapotranspiration estimations obtained through the experimental models and the SEBAL algorithm revealed that the SEBAL algorithm have highest correlation and the least error with the observed Lysimeter data. The error values of MSE is 0.36, of is MAD is 0.59, and of the RMSE is 0.60 in terms of the SEBAL algorithm. Comparable good values we found for the FAO penman Monteith method with MSE equal to 1.29, an MAD of 0.91, and a RMSE of 1.13 compared to the lysimeter output.

In general, the results of this study indicate that applying remote sensing and satellite images, allows estimating evapotranspiration volume in areas with data deficits. The results reported in this study reveal particularly, a high correlation between the SEBAL algorithm and the lysimeter data. Consequently, we suggest using data derived with the SEBAL algorithm in areas with similar environmental conditions where no data are available and as input information for a further assessment of hydrological process dynamics. We show that the results of this study can be applied in studies of water resources management and appropriate irrigation management on farm level.

## References

Allen, R. G., Pereira, L. S., Raes, D., Smith, M. (1998): Crop evapotranspiration – Guidelines computing crop water requirements. FAO Irrigation and drainage paper No. 56, FAO.

Alizadeh, A. (2011): Principles of Applied Hydrology. 33rd ed. Imam Reza University, Mashhad.

Atasever, U. H., Ozkan, C. (2018): A New SEBAL Approach Modified with Backtracking Search Algorithm for Actual Evapotranspiration Mapping and On-Site Application. Journal of the Indian Society of Remote Sensing 46, 1213–1222, https://doi.org/10.1007/s12524-018-0816-9.

Bezerra, B. G., Da Silva, B. B., Dos Santos, C. A. C., Bezerra, G. R. C. (2015): Actual Evapotranspiration Estimation Using Remote Sensing: Comparison of SEBAL and SSEB Approaches. Advances in Remote Sensing 4, 234–247, https://doi.org/10.4236/ars.2015.43019.

Fu, Q., Liu, W., Li, T., Liu, D., Cui, S. (2018): Study of the water saving potential of an irrigation area based on a remote sensing evapotranspiration model. Arabian Journal of

Geosciences 183, 1–10, https://doi.org/10.1007/s12517-018-3504-8.
Ghorbani, A., Faramarzi, M., Karami, J., Gholami, N., Sobhani, B. (2015): Comparative Evaluation of SEBAL and Metric algorithms in Estimating Evapotranspiration (Case Study: Malayer City). Journal of Spatial Planning 19, 184–153. (In Persian).
Jaber, H. S., Mansor, S., Pradhan, B., Ahmad, H. (2016): Evaluation of SEBAL Model for Evapotranspiration Mapping in Iraq Using Remote Sensing and GIS. International Journal of Applied Engineering Research 11, 3950–3955,
Jian-Ying, Y., Xu-Rong, M., Zhi-Guo, H., Chang-Rong, Y., Hui, J, Feng-Hua, Z. H., Qin L. (2015): Water consumption in summer maize and winter wheat cropping system based on SEBAL model in Huang-Huai-Hai Plain, China. Journal of Integrative Agriculture 14(10), 2065–2076, https://doi.org/10.1016/S2095-3119(14)60951-5.
Kamali, M. I., Nazari, R. (2018): Determination of maize water need using remote sensing data and SEBAL algorithm. Agricultural Water Management 209, 197–205, https://doi.org/10.1016/j.agwat.2018.07.035.
Karbasi, M., Moghaddam, M., Nikbakht, J., Kaviani, A. (2016): Estimation of actual evapotranspiration of the plant using SEBAL Algorithm (Case Study: Khoramdareh Region in Zanjan Province). Journal of Ecohydrology 3, 427–437. (In Persian). https://doi.org/10.22059/IJE.2016.60031.
Li, Zh., Liu, X., Ma, T., Kejia, D., Zhou, Q., Yao, B., Niu T. (2013): Retrieval of the surface evapotranspiration patterns in the alpine grassland–wetland ecosystem applying SEBAL model in the source region of the Yellow River, China. Ecological Modelling 270, 64–75, http://dx.doi.org/10.1016/j.ecolmodel.2013.09.004.
Meyabadi, A., Alizadeh, A., Sanaynejad, S. H., Ghahreman, B., Davari K. (2017): Evaluation of SEBAL Algorithm for Estimation of actual Evapotranspiration of Neyshabour – Rokh Basin Using SWAT Model. Journal of Water Research in Agriculture 30(4), 525–541. (In Persian). https://doi.org/10.22092/JWRA.2017.109014.
Morshedi, A., Tabatabaee, S. H., Naderi, M. (2016): Validation of Estimation of Evapotranspiration from SEBAL and Hargreaves-Samani Models Using Lysimeter Data. Water and Soil Journal (Science and Technology Agricultural) 23, 367–376 (In Persian), https://doi.org/10.22067/jsw.v30i2.39762.
Ministry of Agriculture (2016).
National Irrigation and Drainage Committee (2008).
Ndou, N. N., Palamuleni, L. G., Ramoelo, A. (2018): Modelling depth to groundwater level using SEBAL-based dry season potential evapotranspiration in the upper Molopo River Catchment, South Africa. Egyptian Journal of Remote Sensing and Space Science 21, 237–248, https://doi.org/10.1016/j.ejrs.2017.08.003.
Pourmohammadi, S., Rezaanian, M. T., Mokhtari, M. H., Rahimian, M. H. (2010): Determination and zoning of actual evapotranspiration by remote sensing technique and SEBAL algorithm (Case study: Menshad watershed in Yazd province). Iranian Journal of Watershed Management Science and Engineering 13, 21–30. (In Persian).
Rasmussen, M. O., Sørensen, M. K., Wu, B., Yan, N., Qin, H., Sandholt, I. (2014): Regional-scale estimation of evapotranspiration for the North China Plain using MODIS data and the triangle-approach. International Journal of Applied Earth Observation and Geoinformation 31, 143–153, https://doi.org/10.1016/j.jag.2014.03.017.
Rawat, K. S., Bala, A., Singh, S. K., Pal R. K. (2017): Quantification of wheat crop evapotranspiration and mapping: A casestudy from Bhiwani District of Haryana, India. Agricultural Water Management 187, 200–209, http://dx.doi.org/10.1016/j.agwat.2017.03.015.
Rezaei Banafsheh, M., Jahanbakhsh, S., Valizadeh Kamran, K. (2014): Estimation of Actual Evapotranspiration in Sefidrood Basin with Satellite. Image Processing 13(44), 241–262.
Santos, C. A. G., Silva, R. M. D., Silva, A. M., Neto, R. M. B (2017): Estimation of evapotranspiration for different land covers in a Brazilian semi-arid region: A case study of the Brígida River basin, Brazil. Journal of South American Earth Sciences 74, 54–66, http://dx.doi.org/10.1016/j.jsames.2017.01.002.
Sun, Zh., Gebremichael, M., Ardö, J., Nickless A., Caquet, B., Merboldh, L., Kutschi W. (2012): Estimation of daily evapotranspiration over Africa using MODIS/Terra and SEVIRI/MSG data. Atmospheric Research 112, 35–44, https://doi.org/10.1016/j.atmosres.2012.04.005.
Sun, Zh., Wei, B., Su, W., Shen W., Wang, Ch., You, D., Liu Zh. (2011): Evapotranspiration estimation based on the SEBAL model in the Nansi Lake Wetland of China, Mathematical and Computer Modelling 54, 1086–1092, https://doi.org/10.1016/j.mcm.2010.11.039.
Wagle, P., Bhattarai, N., Gowda P. H., Kakani, V. G. (2017): Performance of five surface energy balance models for estimating daily evapotranspiration in high biomass sorghum. ISPRS Journal of Photogrammetry and Remote Sensing 128, 192–203, http://dx.doi.org/10.1016/j.isprsjprs.2017.03.022.
Waters, R., Allen R., Tasumi M., Trezza R., Bastiaanssen W. (2002): S E B A L (Surface Energy Balance Algorithms for Land) Advanced Training and User's Manual, Idaho Implementation.
Yu, B., Shang S., Zhu, W., Gentine P., Cheng Y. (2019): Mapping daily evapotranspiration over a large irrigation district from MODIS data using a novel hybrid dual-source coupling model. Agricultural and Forest Meteorology 276–277, https://doi.org/10.1016/j.agrformet.2019.06.011.
Zare Haghi, D., Neyshabouri, M. R., Majnooni-Heris, A., Jalilian, Z. (2016): Planning, Water and Soil Science, 26(1–2), 1–30.
Zakerinejad, R., Maerker, M. (2015): An integrated assessment of soil erosion dynamics with special emphasis on gully erosion in the Mazayjan basin, southwestern Iran. Journal of Natural Hazards 79, 25–50, https://doi.org/10.1007/s11069-015-1700-3.
Zakerinejad, R., Masoudi, M. (2019): Quantitative mapping of desertification risk using the modified MEDALUS model: a case study in the Mazayejan Plain, Southwest Iran. AUC Geographica 54(2), 232–239, https://doi.org/10.14712/23361980.2019.20.

# Are the Czech or Slovak regions “closer to Europe”? Pro-Europeanness from a subnational perspective

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**ABSTRACT**
Based on the 2003–2019 electoral data, this article evaluates the level of pro-Europeanness in Czechia and Slovakia at the regional and sub-regional levels during and after their EU accession period. The TOPSIS multi-criteria evaluation method and cluster analysis were used to quantify the pro-European levels and to create the subsequent categories of territorial units. The results show support for the ideas of European integration primarily in large urban regions (Prague, Brno, Bratislava, Košice), territorial units with a higher concentration of ethnic minorities, larger scale agricultural activities (southwestern Slovakia), and a high degree of religiosity (northeastern Slovakia). The low level of pro-Europeanness was predominant in the less developed north-western Czechia and parts of Moravia. In Slovakia, the Eurosceptic regions were mostly located in the northwest, where the values of statism, egalitarianism and nationalism have a strong tradition. This approach can be used to identify areas of weak support for the EU project at a spatially disaggregated level in other EU countries.

**KEYWORDS**
Pro-Europeanness; TOPSIS method; EU referendum; European Parliament elections; subnational level; Czechia; Slovakia

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## 1. Introduction

Czechia, Slovakia and eight other mainly post-socialist countries of Central and Eastern Europe, joined the European Union on May 1, 2004. In the periods before and after accession, the moods in the two countries in relation to the European integration project differed based on time, location, and the political and socio-economic conditions. Public support for the country's accession to the EU, as well as the referendum turnout itself differed for both countries, depending on their intraregional specifics. The same can be said for the period after May 1, 2004, in the case of the territorial specificities of turnout and votes for Eurosceptic parties in the European Parliament (EP) elections.

We have seen a gradual shift of Euroscepticism toward the centre of European politics since the 1990s. Nevertheless, it gained stronger influence after both enlargement and elections in 2004. For the new member states, there was high public support for the European Union project; however, it began to decline after accession. In addition to contextual factors such as the financial and migration crises, changes in the rhetoric of several political actors could have contributed to the rise of Euroscepticism. The extreme right-wing political parties learned from the past and instead of proclaiming radical views (including xenophobia, racism and anti-Semitism) they moved on to a somewhat milder and more tolerant populism and thus Euroscepticism was addressed to a wider electorate (Goodwin 2011). The bearers of pro-European values or Euroscepticism include citizens on the one hand, and their political representatives, political parties and specific candidates on the other.

The main objective of this contribution is to identify the degree of pro-Europeaness of the public in Czechia and Slovakia at the time of accession to the EU and afterwards at the hierarchically lower, regional and sub-regional (district) levels, to create a typification of partial territorial units according to the long-term pro-European orientation and to characterize the groups formed on the basis of its indicators. For this reason, we apply TOPSIS multi-criteria decision making method regarding the value distance of given territorial unit to the most positive and most negative value within the set of units under study. We also try to outline possible factors related to pro-Europeanness at the regional and district levels, discussing with findings of previous studies on electoral behaviour (e.g. Krivý et al. 1996; Madleňák 2012; Pink 2012; Voda 2015; Kostelecký et al. 2016; Przybyla 2019). Thus, the aim is to map the "Europeanity" of the sub-national units of these countries, which is particularly important in relation to running an effective, place-specific campaign focusing on EU relevance and benefits, the meaningful dissemination of its promotional activities, and in the context of regional (cohesion) policy, also due to the proper direction of real assistance from European structural and investment funds. Indeed, if we want to avoid disintegration processes within the EU and the threat of its gradual decomposition, just in those regions which are characterized by the highest degree of Euroscepticism, the EU's contribution to the future should be the most visible. This is prevented by the knowledge of "problematic" regions and the reasons that can cause Euroscepticism at the regional and sub-regional levels.

## 2. Theoretical background

The dominant concept of understanding European politics, in the case of European elections, is the second-order national election theory (Reif and Schmitt 1980). European Parliament elections were characterized as national elections taking place simultaneously in all the member states of the European Community. These are less important elections held in the shadow of major (general) national elections and are dominated by the same parties that focus more on national interests than European issues or on the position of the national parties to the EU (Hix and Marsh 2011). Nevertheless, the results of the national and European elections are still different. Second-order elections do not lead to national government formation and are therefore of less interest to voters, the media and political actors. This leads voters to make a different decision than if the national elections were organized on the same day (Hix and Marsh 2011). The electorate votes on the basis of what they think about the country's economic situation, the government's performance or the topics that move domestic politics at that moment (Carrubba and Timpone 2005; De Vries et al. 2011). For this reason, the campaigning and tactics of political parties in second-order elections are motivated by national themes (Reif and Schmitt 1980; Cabada 2010). Also, media coverage of these elections is usually limited. Furthermore, immediately after the election and the end of the campaign, the European Parliament returns to obscurity (Lodge 2010). In the analysis of the first European elections (1979), there is emphasized the fact that one of the main aspects of the second-order elections is that there is less at stake (Reif and Schmitt 1980). The election does not involve the national parliament or the government, and the electorate is not highly motivated to participate in the election or to vote differently than they would if national elections were held. The second order election theory predicts that elections to the European Parliament follow three main formulas: a lower rate of participation (lower turnout), a more positive outcome for small and new parties, and a loss of support for government parties stemming from the location of general elections in the national election cycle (Reif and Schmitt 1980; Hix and Marsh 2007). The validity of the theory in the context of post-socialist countries has been addressed by several authors, e.g. Linek et al.

(2007), Šaradín (2008), Havlík and Hoskovec (2009), Cabada (2010), Klíma and Outlý (2010), Kovář (2013), Kovář and Kovář (2014).

In order to understand the perception of the nature of the European Parliament elections by the political actors themselves (parties, politicians and voters), the connection of these elections with the concept of Europeanization must be recognized. Europeanization is defined as a process of changing the direction and content of politics in such a way that the political and economic dimensions of the European Community influence the structure of national politics, and shape the content and scope of national policies (Landrech 2002). It is clear that European issues have an increasing effect on political debates at the national level, but the response of national party systems is very limited, without a more significant formation of (new) parties built on a "European basis". In this context, it is worth mentioning the term "European cleavage", around which the pre-election struggle of the political actors involved in the existing social structure should ideally be shaped (ideally, real awareness of the dimension of the "Europeanness" concerning these elections). The term European cleavage, in contrast to the more traditional concept of cleavages (Lipset and Rokkan 1967), can in principle be defined as a concept for and against a territorial integration project within Europe (the EU as a centrally oriented and bureaucratic superstate, with a common economic or financial (monetary, fiscal or budgetary) policy on the one hand, or as a concept of a more lenient bundle of states, for example on a customs union basis or the existence of a common market, on the other). According to Bartolini (2007), this term can be understood on three levels: general (for and against the EU as a territorial integrator = independence / integration dimension), constitutive (the cultural level – who can access, division of competences between EU institutions and member states themselves, community decision-making mechanism) and isomorphic (ideological issues – liberalism, protectionism, welfare state, immigration policy, civil rights, etc.). We could assume that those who evaluate the process of European integration in their particular life as a disappointment tend to ignore the European Parliament elections, or they use the protest vote against the mainstream parties and support Eurosceptic political forces of an extreme right- or left-wing orientation.

The question remains regarding how much of the electorate and the political parties in the European Parliament elections place an emphasis on addressing internal political issues and how much the current challenges of European integration or the content of European policies themselves matter. There is, however, evidence that the Eurosceptic and pro-European parties place importance on European issues, and this approach has ideological and practical significance in terms of better electoral results. An election campaign for the European Parliament features a mix of domestic and European issues, which was confirmed in the first direct elections in 1979 (Blumer 1983; Charlot 1986). Nevertheless, their importance varies from election to election and from place to place. In general, however, the importance of European themes gains momentum over time, but this is in contrast to the declining voter participation in the European elections. Traditional issues, such as research and development, food security, environment, foreign policy, immigration, and economic and industrial policy may be considered as "more European" (Budge 2001; Robert Schuman Foundation 2004). Nevertheless, the current pan-European themes of the given period, such as, the economic and financial crisis, Greece's debt crisis, Brexit, migration, reviving debates on the concept of a two-speed Europe, the future of EU regional policy, etc., as well as the hot topics of the domestic political scene, or analyses of election results in key European integration countries play a no less important role in this context.

In general, five basic forms of party Euroscepticism can be identified (Kopecký and Mudde 2002; Taggart and Szczerbiak 2002). The first category concerns major and government parties with a critical attitude towards the definition of European policies as regards the functioning and direction of the Community itself. This moderate form concerns the attitude of the social democratic parties toward the inadequate implementation of the socially oriented EU program, while the stronger form is represented by conservative or neoliberal parties who call for less regulation and intervention by EU institutions. It therefore has a more ideological character. The second type of Euroscepticism also concerns government parties and deals with the European integration project in terms of a reasonable (or necessary) degree of Brussels interventions in policies implemented at the national level. It is therefore a pragmatic debate on the division of competences and agendas between EU institutions and member states. The third type of Euroscepticism is represented by a radical opposition to mainstream and government parties, in the sense of protest and enforcing one's own, far-right or far-left-oriented ideology, in the sense of maintaining national interests and identity on the one hand, and protesting against excessive liberalization of the public sector and economic relations with negative social consequences on the other. The fourth category of Euroscepticism is aimed at fundamentally restoring the functioning of the Community as a whole, the policy of exiting or refusing entry to the EU. However, in principle, parties of this type do not have a significant political impact on the domestic scene, but, somewhat paradoxically, in some countries they enjoy a more prominent role particularly in the European Parliament elections. The last type of Euroscepticism is relatively marginal in terms of political representation and time span, and is often connected to specific persons or "single use" parties. These formations do not require a fundamental reform of relations within the EU but rather focus on subtle topics such as transparency and accountability for the staff of EU institutions, effective use of EU resources, salaries of MEPs, etc.

## 3. Methodology

In the empirical part of the paper, we use two types of electoral geographic data: the referenda on the country's accession to the EU in 2003 ("yes to EU") and the European Parliament elections held in 2004, 2009, 2014 and 2019. In the second, we also work with the results of the Eurosceptic parties. We put them into this group based on the work of several authors and electoral programs of the parties themselves. In the case of the Czech political situation, we used several studies for the inclusion of the parties (Bradová and Šaradín 2004; Baun et al. 2006; Fiala et al. 2006; Linek et al. 2007; Havlík 2008; Havlík and Vykoupilová 2008; Hloušek and Pšeja 2009; Hricová 2009; Havlík 2010; Kovář 2014). In the case of Slovakia, we also used relevant literature for this purpose (Gyárfášová and Velšic 2004; Gyárfášová 2007). We refer to geographical context of electoral support for the parties in European elections (Plešivčák 2015) and the spatial differentiation of the extreme right support (Mikuš and Gurňák 2016; Mikuš et al. 2016). The character of the electorate was the decisive criterion for the inclusion of a political party among the group of Eurosceptic parties. Recessive parties were not taken into account. Given the above division of parties into types according to the degree of Euroscepticism and their relevance within the party system, we would like to mention the cases when the inclusion of parties to the Eurosceptic, or their exclusion, was a problematic matter. We emphasize that in classifying the parties, we primarily took into account the nature of the party's electorate rather than the official rhetoric of its then leaders. Among other parties, in the case of the Czechia, we also considered KSČM (2004–2019) and Úsvit (2014) to be the Eurosceptic parties (more precisely parties with a predominantly Eurosceptic electorate), although some authors label them soft Eurosceptic (Havlík and Kaniok 2006; Kaniok and Havlík 2016). The electorate of these two parties is indeed quite different from another party often associated with Eurospeticism, ODS (Občanská demokratická strana, *eng. Civic Democratic Party*). In the case of this party, we finally decided to not include it in the Eurosceptic Party Group, based on several arguments (Baun et al. 2006), as this party can rather be perceived as "pro-European with reservations". Given the ODS electorate, which is largely characterized by more educated voters living in the urban environment more in favour of the EU project, we have chosen not to include the party into the Eurosceptic group. In the case of Slovakia, there was a problem with ĽS-HZDS and SNS, parties that even expressed support for the EU at the time ("at the last minute"); but ĽS-HZDS's policies in office as well as the profile of the then and later electorate, along with SNS and later especially ĽS-NS (Ľudová strana – Naše Slovensko, *eng. People's Party – Our Slovakia*) proved to be Eurosceptic to the largest extent when comparing all of the major political parties in Slovakia (Gyárfášová 2007). Even in the case of the European Union membership referendum in 2003, a low turnout (52%) demonstrably confirmed the fact that Euroscepticism in Slovakia was also present in the past (in comparison with the current ĽS-NS at the time of the impending membership in a more latent form). We do not consider it to be strictly correct and the only possible to refer to the divisions of various authors in this matter, as e.g. Hynčica and Šárovec (2018) describe the SaS as a Eurosceptic party, while a large part of its electorate supports the EU project. We also consider it relatively subjective to perceive parties such as KDH or SMER-SD (Henderson 2008) as Eurosceptic, even for the 2004 European Parliament elections. With these examples we wanted to illustrate the fact that the classification of parties as Eurosceptic is really a very problematic and to some extent subjective matter, in which different authors can work with different set of Eurosceptic parties in research, as a certain degree of subjectivity of classification is not possible to avoid.

For each election of the period under study (2004–2019), we identified the following parties as Eurosceptic parties:

### Czechia

***2004 European Parliament Elections*** – DS (Dělnická strana, *eng. Workers' Party*), KSČM (Komunistická strana Čech a Moravy, *eng. Communist Party of Bohemia and Moravia*), NARKOA (Národní koalice, *eng. National Coalition*), NEZ (Nezávislí, *eng. Independent*), RMS (Republikáni Miroslava Sládka, *eng. Republicans of Miroslav Sládek*)

***2009 European Parliament Elections*** – DS, KSČM, Libertas.cz, NS (Národní strana, *eng. National Party*), SSO (Strana svobodných občanů, *eng. Party of Free Citizens*), SPR-RSČ (Sdružení pro republiku – Republikánská strana Československa, *eng. Association for the Republic – Republican Party of Czechoslovakia*), Suverenita (*eng. Sovereignty*)

***2014 European Parliament Elections*** – Česká suverenita (formerly Suverenita, *eng. Czech Sovereignty*), DSSS/SPE (formerly Dělnická strana, Dělnická strana sociální spravedlnosti/Ne diktátu Bruselu!, *eng. Workers' Party of Social Justice/No to Brussels Dictate!*), KSČM, KSČ (Komunistická strana Československa, *eng. Communist Party of Czechoslovakia*), ND (Ne Bruselu – Národní demokracie, *eng. No to Brussels – National Democracy*), RSČMS (Republikánská strana Čech, Moravy a Slzska, *eng. Republican Party of Bohemia, Moravia and Silesia*), SSO, SZR-NE (Strana zdravého rozumu – Nechceme Euro, *eng. Party of Common Sense – We Don't Want the Euro*), Úsvit přímé demokracie (*eng. Dawn of Direct Democracy*)

***2019 European Parliament Elections*** – ANS (Aliance národních sil, *eng. Alliance of National Forces*), APAČI (Alternativa pro Českou republiku, *eng. Alternative for Czech Republic*), Česká suverenita, Svobodní/Radostné Česko (*eng. Independents/Joyful Czechia*), ČSNS/Patrioti ČR (Česká strana národně sociální/Patrioti České republiky, *eng. Czech National Social Party/Patriots of Czech Republic*), KOAL (Konzervativní alternativa, *eng. Conservative Alternative*), KSČM, Moravané (*eng. Moravians*), První republika (*eng. First Republic*), SNČR (Strana nezávislosti České republiky, *eng. Independence Party of the Czech Republic*), DSSS/NF (Dělnická strana sociální spravedlnosti/Národní fronta, *eng. Workers' Party of Social Justice/National Front*), SPD – Tomio Okamura (formerly Úsvit přímé demokracie, Svoboda a přímá demokracie – Tomio Okamura, *eng. Freedom and Direct Democracy – Tomio Okamura*), SPR-RSČ, Rozumní/ND (formerly SZR, *eng. Reasonables*/Národní demokracie, formerly Právo a Spravedlnost, *eng. National Democracy*)

## Slovakia

***2004 European Parliament Elections*** – KSS (Komunistická strana Slovenska, *eng. Communist Party of Slovakia*), ĽS-HZDS (Ľudová strana – Hnutie za demokratické Slovensko, *eng. People's Party – Movement for Democratic Slovakia*), SĽS (Slovenská ľudová strana, *eng. Slovak People's Party*), SNS/PSNS (Slovenská národná strana/Pravá Slovenská národná strana, *eng. Slovak National Party/True Slovak National Party*)

***2009 European Parliament Elections*** – KSS, ĽS-HZDS, SNS

***2014 European Parliament Elections*** – KSNS (Kresťanská slovenská národná strana, *eng. Christian Slovak National Party*), KSS, ĽS-NS (Ľudová strana – Naše Slovensko, *eng. People's Party – Our Slovakia*), NaS-NS (Národ a Spravodlivosť – naša strana, eng. *Nation and Justice – Our Party*), SĽS, SNS, Úsvit (eng. Dawn), Vzdor – strana práce (*eng. Defiance – Labour Party*)

***2019 European Parliament Elections*** – Kotleba – ĽSNS (formerly Ľudová strana – Naše Slovensko, *eng. Kotleba – People's Party Our Slovakia*), KSS/Vzdor – strana práce, SĽS Andreja Hlinku (formerly SĽS, eng. *eng. Slovak People's Part of Andrej Hlinka*), SME RODINA – Boris Kollár (*eng. We Are Family – Boris Kollár*), SNJ-sv (formerly KSNS, Slovenská národná jednota – strana vlastencov, *eng. Slovak National Unit – Patriot Party*), SNS

We wanted to approach the issue from a positive perspective, based on support for the EU project (Euro-optimistic), and not Euro-sceptically. Therefore, we decided to work with the index of pro-Europeanness. When constructing, in addition to supporting EU accession by Referendum 2003, we considered supporting Eurosceptic parties, as is commonly used. We could not automatically work "with the rest" (100 per cent minus the support for the Eurosceptic parties) as a % for pro-Europeanness, as a much wider group of parties would include much more heterogeneous political entities (in relation to the level of EU support) than for parties defined as Eurosceptic. The settings of the model calculation in the TOPSIS method technically solve this "discrepancy" (index of pro-Europeanness vs. votes for Eurosceptic parties) very easily and is based on evaluating the influence of input variables with sensitivity to their orientation (increasing value of something "negative" means a decrease in the value of index of pro-European and vice versa. The researcher sets the desired orientation of the variable – for our research a positive orientation in supporting the country's accession to the EU, and a negative orientation in supporting the Eurosceptic parties, which in both cases means increasing the value of the index of pro-Europeanness).

The variables entering the index of pro-Europeanness thus were as follows:

a) Votes for accession to the 2003 European Union referendum (%) – *the more the better*
b) Votes for Eurosceptic parties in the 2004 European Parliament elections (%) – *the less the better*
c) Votes for Eurosceptic parties in the 2009 European Parliament elections (%) – *the less the better*
d) Votes for Eurosceptic parties in the 2014 European Parliament elections (%) – *the less the better*
e) Votes for Eurosceptic parties in the 2019 European Parliament elections (%) – *the less the better*

We obtained data for the state, regional and district levels from the databases of the Czech Statistical Office and the Statistical Office of the Slovak Republic (Czech Statistical Office 2019; Statistical Office of the Slovak Republic 2019).

We use the TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution) to evaluate the position of the regions and districts under study in mutual comparison based on the values of the set of indicators mentioned above. This method generates score for the index of pro-Europeanness to rank the mentioned territorial units. For the need of the empirical part of the paper, we decided to use this method, which in relation to the objectives of the work can be assessed as adequate (for this reason, it was not necessary to use other methods, e.g. factor analysis). Given that in this part of the paper we decided to evaluate a set of variables indicating the degree of pro-Europeanness across the regions and districts of Czechia and Slovakia, the use of TOPSIS method as one of the multicriteria evaluation tools can be considered desirable. In addition, if we work with several territorial units, in this case 20 at the regional and 149 at the district level, the use of this method is the right choice, because in the case of a given territorial unit it takes into account the level of each input variable to ideal and to the least desirable value within the set of units (i.e. with respect to the value of the most successful and the least successful region or district).

Accelerators increasing the value of the pro-Europeanness index were the high values of indicator *a* (the higher the better) and the low values of indicators *b-e* (the lower the better). When calculating index (in scale from 0 to 1), each input indicator (*a-e*) was equally weighted, by 1/5 (0.2).

The TOPSIS method (Hwang and Yoon 1981) is considered one of the most classical multi-criteria decision making methods (Opricovic and Tyeng 2004; Shih et al. 2007; Manokaran et al. 2011).

It constitutes a collection of shortcut methods designed to minimize the distance from the ideal solution. These methods use an ideal variant as the object of aspiration. The selected "best" compromise variant is then the one which according to the selected metrics is the closest to the ideal option.

It provides a complete ordering of all variants. To resolve the problem, the multi-criteria decision matrix as well as the weight vector of individual criteria has to be determined. The main principle of this method is to identify the variant that is closest to the positive ideal solution, and farthest from the negative ideal solution.

The calculation procedure is as follows.

1. To calculate the normalized multi-criteria decision matrix

   $R = (r_{ij})$

   using the formula:

   $$r_{ij} = \frac{y_{ij}}{\left(\sum_{i=1}^{p}(y_{ij})^2\right)^{\frac{1}{2}}},\ i = 1, 2, \ldots, p,\ j = 1, 2, \ldots, k$$

   *After this transformation, the columns in the matrix are vectors of unit size by Euclidean metrics.*

2. To calculate the weighted multi-criteria decision matrix

   $W = (w_{ij})$

   how the *j*-th column is multiplied by the appropriate weight, as follows

   $w_{ij} = (v_j r_{ij})$

3. To determine the positive ideal solution

   $H_j = (\max_i w_{ij}),\ j = 1, 2, \ldots, k$

   and the negative ideal solution

   $D_j = (\min_j w_{ij}),\ j = 1, 2, \ldots, k$

4. To calculate the distance from the positive ideal solution by using the formula as follows:

   $$d_i^+ = \left(\sum_{j=1}^{k}\left(w_{ij} - H_j\right)^2\right)^{\frac{1}{2}},\ i = 1, 2, \ldots, p,$$

   and from the negative ideal solution by using the formula below:

   $$d_i^- = \left(\sum_{j=1}^{k}\left(w_{ij} - D_j\right)^2\right)^{\frac{1}{2}},\ i = 1, 2, \ldots, p,$$

   *The Euclidean distance measure was utilised to calculate the distance.*

5. To calculate the relative distance from the negative ideal solution by using the formula below:

   $$c_i = \frac{d_i^-}{d_i^+ + d_i^-},\ i = 1, 2, \ldots, p$$

Variants are then arranged in descending order according to the $c_i$ values.

Subsequently, we used the cluster method to create groups of districts based on the pro-Europeanness index (Hastie et al. 2016). The increasing amount of data and information has led to the need to develop methods to clarify and classify them. In addition to other classification methods, cluster analysis has begun to be used. This method produces a certain number of clusters, with objects in one cluster having similar properties, and objects in different clusters having as many different properties as possible.

The input for cluster analysis is represented by *N* objects denoted by indexes $1 < i < N$, which have *d* features indexed as $1 < j < d$. These data are used to write to the $N \times d$ matrix:

$$X = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1d} \\ x_{21} & x_{22} & \cdots & x_{2d} \\ \vdots & \vdots & \ddots & \vdots \\ x_{N1} & x_{N2} & \cdots & x_{Nd} \end{pmatrix}$$

Line *d*-dimensional vector $x_i$ is a vector of the *i*-th object, while element $x_{ij}$ denotes the value of the *j*-th feature of the *i*-th object.

The cluster analysis is comprised of four general steps. 1. Selecting and extracting the features, 2. Selecting the algorithm, 3. Verifying accuracy, 4. Evaluating the results.

The IBM SPSS Statistics 22 programme was used to conduct the clustering. As a result of clustering, based on the values of the index of pro-Europeanness, five groups of districts with internal similarity were generated.

# 4. Analysis, results and findings

## 4.1 Levels of Territorial Units

### 4.1.1 Regions

At the regional level, we analysed 22 spatial units, 14 regions in Czechia and eight regions in Slovakia (Fig. 1). These units also represent the NUTS 3 level. Their territorial and population size is markedly different, as the smallest region has an area of only 496.10 km$^2$ (the city of Prague as a separate NUTS 3 region) while the largest has an area of 11,014.97 km$^2$ (Central Bohemia Region). In Slovakia, the smallest region is the Bratislava Region (2,052.5 km$^2$), and the largest is the Banská Bystrica Region (9,454.4 km$^2$). In terms of population, the city of Prague is the smallest region in terms of area, but it has largest population (1,301,135 inhabitants) in Czechia, while the Karlovy Vary Region has the smallest population (data as of December 31, 2018, 295,686 inhabitants). In Slovakia, the differences between regions are also smaller in this indicator, as the region with highest number of inhabitants with permanent residence is the Prešov Region (825,022), and the region with the lowest number of inhabitants is the Trnava Region (563,591 as of December 31, 2018). The areas with the greatest population density are the city of Prague (2,622 inhabitants/km$^2$) in Czechia and the Bratislava Region (321 inhabitants/km$^2$) in Slovakia. On the contrary, the South Bohemian Region (63 inhabitants/km$^2$) and the Banská Bystrica Region (68 inhabitants/km$^2$) are the least inhabited areas.

### 4.1.2 Districts

At the district level, we worked with 149 units, 77 in Czechia and 72 in Slovakia (Fig. 2, Tab. 1). In the case of Slovakia, the municipal districts of Bratislava (5) and Košice (4) were connected to one district in the entire city in order to strengthen the comparative value of the analysis with the other districts of the countries. The largest district in Czechia is the district of Klatovy in the Plzeň Region, with an area of 1,945.69 km$^2$, while the Levice district in the Nitra Region (1,551.1 km$^2$) is the largest in Slovakia. On the other hand, the Brno-město district (230.22 km$^2$) is the smallest in Czechia and the Kysucké Nové Mesto district (173.7 km$^2$) is the smallest in Slovakia. In Czechia, the city of Prague has the largest population (1,301,135 inhabitants); on the contrary, the Jeseník district in the Olomouc Region has the smallest population (38,330 inhabitants as of December 31, 2018). The most populous area in Slovakia is the city of Bratislava (432,864 inhabitants), while the Medzilaborce district in the Prešov region is the least populous (11,896 inhabitants as of December 31, 2018). In terms of population density, Prague (2,622 inhabitants/km$^2$) dominates in Czechia, while the Prachatice district in the South Bohemian Region (37 inhabitants/km$^2$) is the least populated. In Slovakia, Bratislava (1,177 inhabitants/km$^2$) has the

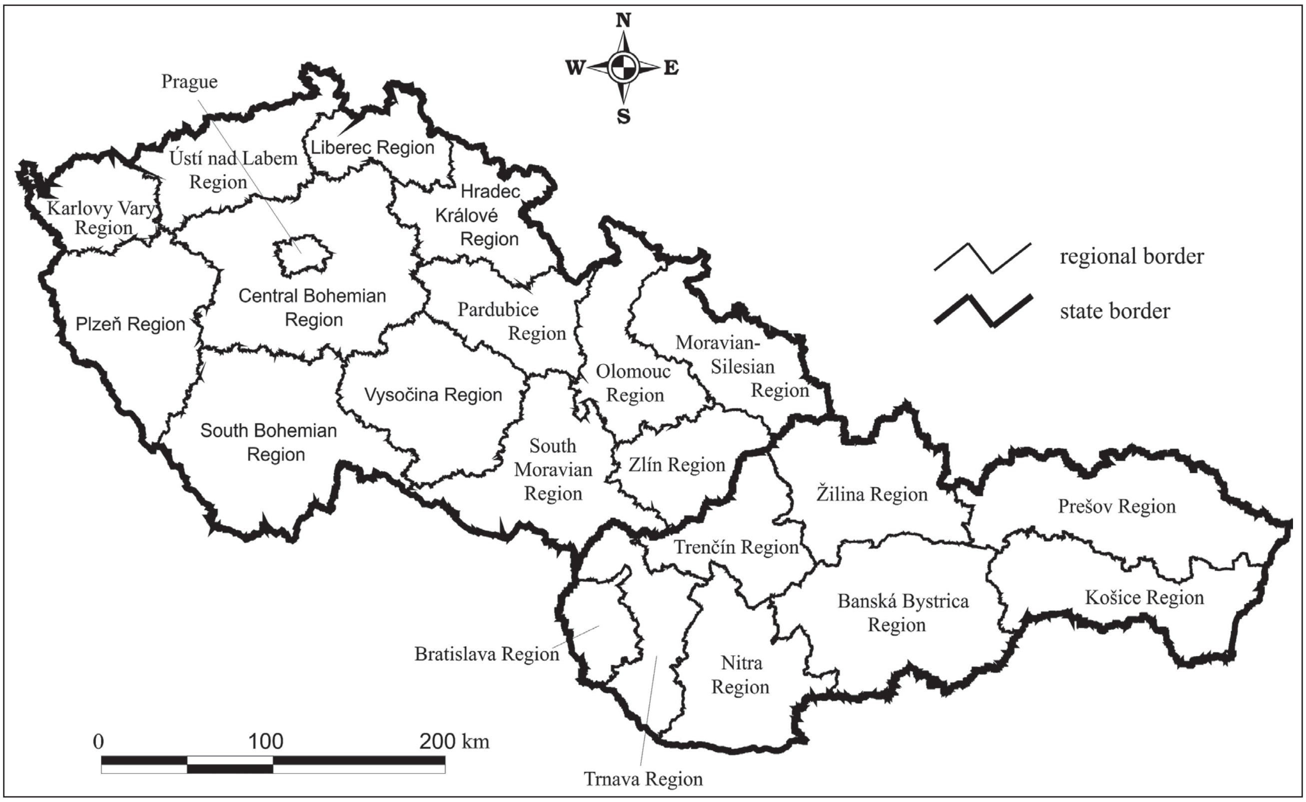


Fig. 1 Territorial composition of NUTS 3 regions in Czechia and Slovakia.
Source: Czech Statistical Office, Statistical Office of the Slovak Republic (2019).

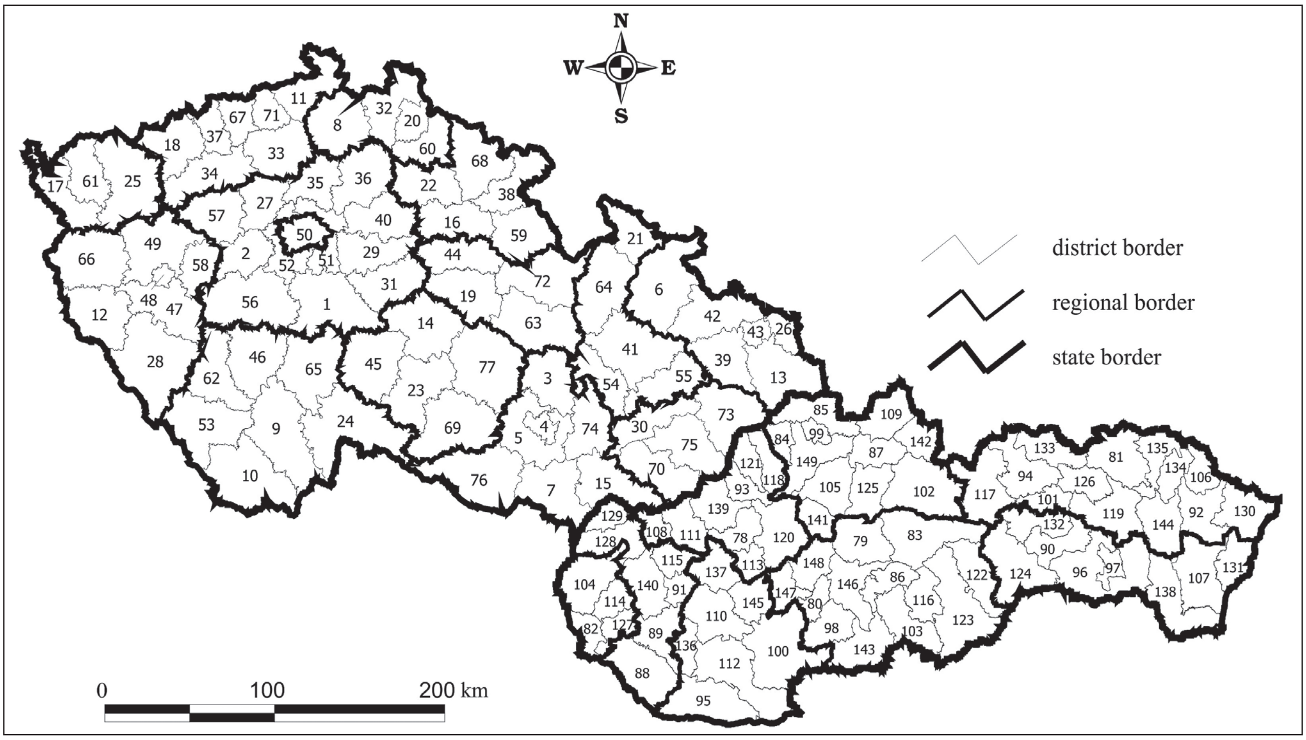


**Fig. 2** Territorial composition of districts in Czechia and Slovakia.
Source: Czech Statistical Office, Statistical Office of the Slovak Republic (2019).

**Tab. 1** Order number of districts in Czechia and Slovakia.

| Order Number | District | Region | Country |
|---|---|---|---|
| 1 | Benešov | Central Bohemian Region | Czechia |
| 2 | Beroun | Central Bohemian Region | Czechia |
| 3 | Blansko | South Moravian Region | Czechia |
| 4 | Brno-město | South Moravian Region | Czechia |
| 5 | Brno-venkov | South Moravian Region | Czechia |
| 6 | Bruntál | Moravian-Silesian Region | Czechia |
| 7 | Břeclav | South Moravian Region | Czechia |
| 8 | Česká Lípa | Liberec Region | Czechia |
| 9 | České Budějovice | South Bohemian Region | Czechia |
| 10 | Český Krumlov | South Bohemian Region | Czechia |
| 11 | Děčín | Ústí nad Labem Region | Czechia |
| 12 | Domažlice | Plzeň Region | Czechia |
| 13 | Frýdek-Místek | Moravian-Silesian Region | Czechia |
| 14 | Havlíčkův Brod | Vysočina Region | Czechia |
| 15 | Hodonín | South Moravian Region | Czechia |
| 16 | Hradec Králové | Hradec Králové Region | Czechia |
| 17 | Cheb | Karlovy Vary Region | Czechia |
| 18 | Chomutov | Ústí nad Labem Region | Czechia |
| 19 | Chrudim | Pardubice Region | Czechia |
| 20 | Jablonec nad Nisou | Liberec Region | Czechia |
| 21 | Jeseník | Olomouc Region | Czechia |
| 22 | Jičín | Hradec Králové Region | Czechia |
| 23 | Jihlava | Vysočina Region | Czechia |
| 24 | Jindřichův Hradec | South Bohemian Region | Czechia |
| 25 | Karlovy Vary | Karlovy Vary Region | Czechia |
| 26 | Karviná | Moravian-Silesian Region | Czechia |
| 27 | Kladno | Central Bohemian Region | Czechia |
| 28 | Klatovy | Plzeň Region | Czechia |
| 29 | Kolín | Central Bohemian Region | Czechia |
| 30 | Kroměříž | Zlín Region | Czechia |
| 31 | Kutná Hora | Central Bohemian Region | Czechia |
| 32 | Liberec | Liberec Region | Czechia |
| 33 | Litoměřice | Ústí nad Labem Region | Czechia |
| 34 | Louny | Ústí nad Labem Region | Czechia |
| 35 | Mělník | Central Bohemian Region | Czechia |
| 36 | Mladá Boleslav | Central Bohemian Region | Czechia |
| 37 | Most | Ústí nad Labem Region | Czechia |
| 38 | Náchod | Hradec Králové Region | Czechia |
| 39 | Nový Jičín | Moravian-Silesian Region | Czechia |
| 40 | Nymburk | Central Bohemian Region | Czechia |
| 41 | Olomouc | Olomouc Region | Czechia |
| 42 | Opava | Moravian-Silesian Region | Czechia |
| 43 | Ostrava-město | Moravian-Silesian Region | Czechia |
| 44 | Pardubice | Pardubice Region | Czechia |
| 45 | Pelhřimov | Vysočina Region | Czechia |
| 46 | Písek | South Bohemian Region | Czechia |
| 47 | Plzeň-jih | Plzeň Region | Czechia |
| 48 | Plzeň-město | Plzeň Region | Czechia |
| 49 | Plzeň-sever | Plzeň Region | Czechia |
| 50 | Praha* | Prague | Czechia |
| 51 | Praha-východ | Central Bohemian Region | Czechia |

| Order Number | District | Region | Country |
|---|---|---|---|
| 52 | Praha-západ | Central Bohemian Region | Czechia |
| 53 | Prachatice | South Bohemian Region | Czechia |
| 54 | Prostějov | Olomouc Region | Czechia |
| 55 | Přerov | Olomouc Region | Czechia |
| 56 | Příbram | Central Bohemian Region | Czechia |
| 57 | Rakovník | Central Bohemian Region | Czechia |
| 58 | Rokycany | Plzeň Region | Czechia |
| 59 | Rychnov nad Kněžnou | Hradec Králové Region | Czechia |
| 60 | Semily | Liberec Region | Czechia |
| 61 | Sokolov | Karlovy Vary Region | Czechia |
| 62 | Strakonice | South Bohemian Region | Czechia |
| 63 | Svitavy | Pardubice Region | Czechia |
| 64 | Šumperk | Olomouc Region | Czechia |
| 65 | Tábor | South Bohemian Region | Czechia |
| 66 | Tachov | Plzeň Region | Czechia |
| 67 | Teplice | Ústí nad Labem Region | Czechia |
| 68 | Trutnov | Hradec Králové Region | Czechia |
| 69 | Třebíč | Vysočina Region | Czechia |
| 70 | Uherské Hradiště | Zlín Region | Czechia |
| 71 | Ústí nad Labem | Ústí nad Labem Region | Czechia |
| 72 | Ústí nad Orlicí | Pardubice Region | Czechia |
| 73 | Vsetín | Zlín Region | Czechia |
| 74 | Vyškov | South Moravian Region | Czechia |
| 75 | Zlín | Zlín Region | Czechia |
| 76 | Znojmo | South Moravian Region | Czechia |
| 77 | Žďár nad Sázavou | Vysočina Region | Czechia |
| 78 | Bánovce nad Bebravou | Trenčín Region | Slovakia |
| 79 | Banská Bystrica | Banská Bystrica Region | Slovakia |
| 80 | Banská Štiavnica | Banská Bystrica Region | Slovakia |
| 81 | Bardejov | Prešov Region | Slovakia |
| 82 | Bratislava* | Bratislava Region | Slovakia |
| 83 | Brezno | Banská Bystrica Region | Slovakia |
| 84 | Bytča | Žilina Region | Slovakia |
| 85 | Čadca | Žilina Region | Slovakia |
| 86 | Detva | Banská Bystrica Region | Slovakia |
| 87 | Dolný Kubín | Žilina Region | Slovakia |
| 88 | Dunajská Streda | Trnava Region | Slovakia |
| 89 | Galanta | Trnava Region | Slovakia |
| 90 | Gelnica | Košice Region | Slovakia |
| 91 | Hlohovec | Trnava Region | Slovakia |
| 92 | Humenné | Prešov Region | Slovakia |
| 93 | Ilava | Trenčín Region | Slovakia |
| 94 | Kežmarok | Prešov Region | Slovakia |
| 95 | Komárno | Nitra Region | Slovakia |
| 96 | Košice – okolie | Košice Region | Slovakia |
| 97 | Košice* | Košice Region | Slovakia |
| 98 | Krupina | Banská Bystrica Region | Slovakia |
| 99 | Kysucké Nové Mesto | Žilina Region | Slovakia |
| 100 | Levice | Nitra Region | Slovakia |
| 101 | Levoča | Prešov Region | Slovakia |
| 102 | Liptovský Mikuláš | Žilina Region | Slovakia |
| 103 | Lučenec | Banská Bystrica Region | Slovakia |
| 104 | Malacky | Bratislava Region | Slovakia |
| 105 | Martin | Žilina Region | Slovakia |
| 106 | Medzilaborce | Prešov Region | Slovakia |
| 107 | Michalovce | Košice Region | Slovakia |
| 108 | Myjava | Trenčín Region | Slovakia |
| 109 | Námestovo | Žilina Region | Slovakia |
| 110 | Nitra | Nitra Region | Slovakia |
| 111 | Nové Mesto nad Váhom | Trenčín Region | Slovakia |
| 112 | Nové Zámky | Nitra Region | Slovakia |
| 113 | Partizánske | Trenčín Region | Slovakia |
| 114 | Pezinok | Bratislava Region | Slovakia |
| 115 | Piešťany | Trnava Region | Slovakia |
| 116 | Poltár | Banská Bystrica Region | Slovakia |
| 117 | Poprad | Prešov Region | Slovakia |
| 118 | Považská Bystrica | Trenčín Region | Slovakia |
| 119 | Prešov | Prešov Region | Slovakia |
| 120 | Prievidza | Trenčín Region | Slovakia |
| 121 | Púchov | Trenčín Region | Slovakia |
| 122 | Revúca | Banská Bystrica Region | Slovakia |
| 123 | Rimavská Sobota | Banská Bystrica Region | Slovakia |
| 124 | Rožňava | Košice Region | Slovakia |
| 125 | Ružomberok | Žilina Region | Slovakia |
| 126 | Sabinov | Prešov Region | Slovakia |
| 127 | Senec | Bratislava Region | Slovakia |
| 128 | Senica | Trnava Region | Slovakia |
| 129 | Skalica | Trnava Region | Slovakia |
| 130 | Snina | Prešov Region | Slovakia |
| 131 | Sobrance | Košice Region | Slovakia |
| 132 | Spišská Nová Ves | Košice Region | Slovakia |
| 133 | Stará Ľubovňa | Prešov Region | Slovakia |
| 134 | Stropkov | Prešov Region | Slovakia |
| 135 | Svidník | Prešov Region | Slovakia |
| 136 | Šaľa | Nitra Region | Slovakia |
| 137 | Topoľčany | Nitra Region | Slovakia |
| 138 | Trebišov | Košice Region | Slovakia |
| 139 | Trenčín | Trenčín Region | Slovakia |
| 140 | Trnava | Trnava Region | Slovakia |
| 141 | Turčianske Teplice | Žilina Region | Slovakia |
| 142 | Tvrdošín | Žilina Region | Slovakia |
| 143 | Veľký Krtíš | Banská Bystrica Region | Slovakia |
| 144 | Vranov nad Topľou | Prešov Region | Slovakia |
| 145 | Zlaté Moravce | Nitra Region | Slovakia |
| 146 | Zvolen | Banská Bystrica Region | Slovakia |
| 147 | Žarnovica | Banská Bystrica Region | Slovakia |
| 148 | Žiar nad Hronom | Banská Bystrica Region | Slovakia |
| 149 | Žilina | Žilina Region | Slovakia |

Notes: * whole city as a one district for this purpose
Source: Czech Statistical Office, Statistical Office of the Slovak Republic (2019).

highest population density, while the Medzilaborce district (27 inhabitants/km$^2$) has the lowest population density.

## 4.2 Results and Findings

### 4.2.1 Regions

*Pro-Europeanness Index*

At the regional level (Fig. 3), the highest pro-Europeanness index values (ranging from 0.700 to 0.906) reflecting five variables in total (votes for accession in the 2003 European Union membership referendum, votes for Eurosceptic parties in the 2004–2019 European Parliament elections) were recorded by Bratislava followed by other four regions from Slovakia (Trnava, Nitra, Košice and Prešov). A level of 0.700 was almost achieved also by the capital region of Czechia, Prague. Other two regions from Slovakia (Banská Bystrica and Žilina) reached the values of index from 0.500 to 0.600. The values between 0.400–0.500 were obtained by two regions from Czechia (Zlín and South Moravia) and the last Slovak region, Trenčín. On the contrary, the lowest values of the index (0.029–0.294) were reported by the Ústí nad Labem Region, the Karlovy Vary Region and the Moravian-Silesian Region in Czechia. Of the last twelve regions, all are from Czechia.

Considering regional perspective, one of the highest spatial concentrations were recorded also in regions of Prague, Bratislava and Košice, i.e. centres that have been more successful in the post-socialist transformation, with higher economic performance, localization of significant foreign investment, a population with higher education and socio-economic status, supporting, in general, liberal political parties. Highest values also applied to regions using EU agricultural subsidies and promoting a policy of guaranteeing the rights of ethnic minorities (especially the Trnava Region and the Nitra Region in Slovakia), or typical of an approach toward the values of Christian Democracy (the Zlín Region in Czechia and the Prešov Region in Slovakia). On the contrary, the lowest values were recorded in the Czech regions with a peripheral position geographically and socio-economically (Ústí nad Labem Region and Karlovy Vary Region), with increased support for the far-left or far-right parties and the Slovak region with a traditionally egalitarian, etatist and nationalist electorate (Trenčín Region).

### 4.2.2 Districts

We came up with other interesting findings for the pro-Europeanness index at the district level.

*Pro-Europeanness Index*

The resulting index shows considerable spatial differences (Fig. 4). In the districts with the highest values of the index, the Slovakian districts absolutely dominate, with the first being Dunajská Streda (0.994) and second Komárno (0.903). Other districts with high values of index are located exclusively in the southwest of Slovakia. These districts, with geographical proximity to the capital, enjoy a significant position in the agro-sector and a strong Hungarian minority. In the case of Czechia, the highest values were reached by districts of Prague (Praha-západ, Praha and Praha-východ) and the city district of the second largest city of the country, Brno (Brno-město). On the contrary, districts with the lowest values (below 0.200) are located in west Bohemia in the Ústí nad

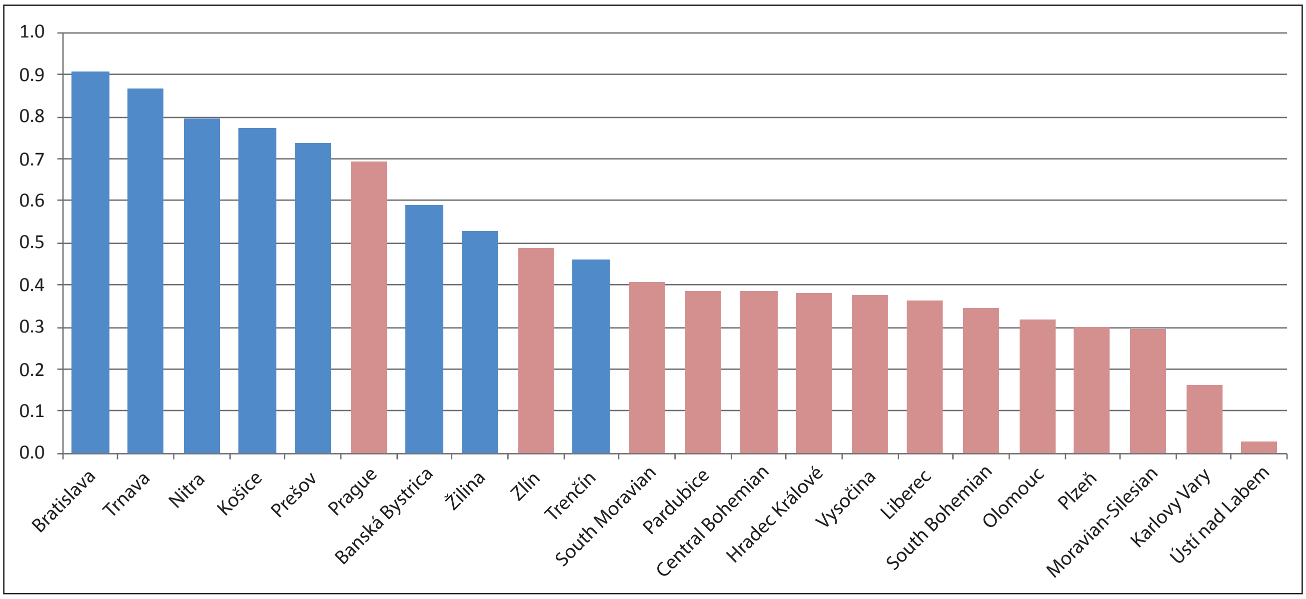


**Fig. 3** NUTS 3 regions of Czechia and Slovakia by Index of Pro-Europeaness.
Note: Light greyindicates the Czech regions, dark gray indicates the Slovak regions.
Source: Czech Statistical Office, Statistical Office of the Slovak Republic (2019), author's research.

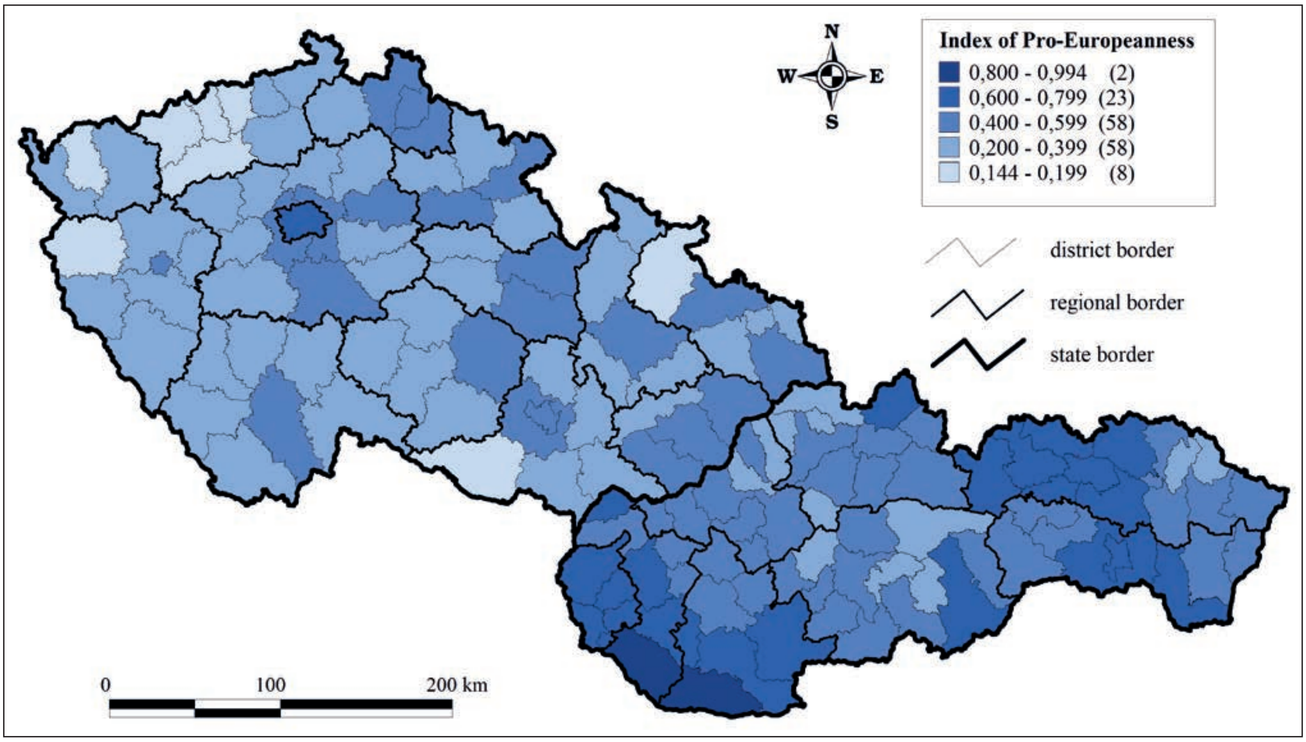


**Fig. 4** Districts of Czechia and Slovakia by Index of Pro-Europeaness.
Source: Czech Statistical Office, Statistical Office of the Slovak Republic (2018), author's research.

Labem Region (Most 0.144, Louny 0.156, Chomutov 0.164 and Teplice 0.171), the Plzeň Region (Tachov 0.161) and the Karlovy Vary Region (Sokolov 0.190). This group of districts is completed by couple from Moravia – Bruntál (0.151, Moravian-Silesian Region) and Znojmo (0.168, South Moravian Region). This group of districts is characterized by a relatively high unemployment rate and relatively low wages, with support for left-wing, far-left or far-right parties (Havlík and Voda 2016; Maškarinec 2017, 2019). In Slovakia, the districts with the lowest values are located in the northwestern corner of the country in the Žilina Region (Kysucké Nové Mesto, Čadca and Bytča) typical of long-term support for the values of egalitarianism, etatism and nationalism (Plešivčák 2011; Madleňák 2012).

### 4.2.3 Clusters

By using the cluster method, we derived five categories based on the values of the pro-Europeanness index (Fig. 5).

The first category, named *"districts of markedly pro-European orientation"*, consists of only two spatial units, both located in Slovakia. The districts belonging to this cluster are located in southwest Slovakia (Dunajska Streda and Komárno), with a traditional position of agriculture and a strong Hungarian minority. Compared to the national mean (Fig. 6), this group recorded strong support for country's accession to the EU (+14.06 *pp*) and very low support for Eurosceptic parties (−16.92 *pp*).

The second cluster, named *"districts of significantly pro-European orientation"* is comprised of 19 districts, of which all are located in Slovakia again. The largest concentration of these districts can be found in the area located in the southwest corner of the country (Bratislava, Šaľa, Galanta, Senec, Nové Zámky) and in the Prešov Region in the northeast (a compact belt of the six districts – Poprad, Kežmarok, Levoča, Stará Ľubovňa, Bardejov, Sabinov and Prešov) continuing to the Košice Region in the east of Slovakia (Košice and Trebišov). This cluster also includes three largest towns of Slovakia (Bratislava, Košice and Prešov). Compared to the national average (Fig. 6), this category declared a strong support for accession in the EU referendum (+12.71 *pp*) and lower support for Eurosceptic parties in the EU elections (−7.99 *pp*).

The third category of districts is described as *"districts of mildly pro-European orientation"*. It consists of 30 spatial units, the larger part of which (23) is located in Slovakia. The main concentration is recognized in the regions of Bratislava, Trnava and Nitra in the southwest of Slovakia with seven districts overall (Pezinok, Malacky, Trnava, Senica, Nitra, Piešťany and Hlohovec). The second compact area can be identified in the north of the country in the eastern part of the Žilina Region (Dolný Kubín, Tvrdošín, Martin, Liptovský Mikuláš and Ružomberok). This concentration is comprehensively complemented by four adjacent districts, from the Banská Bystrica Region (Banská Bystrica, Zvolen, Veľký Krtíš and Lučenec). The third concentration of districts of this type is

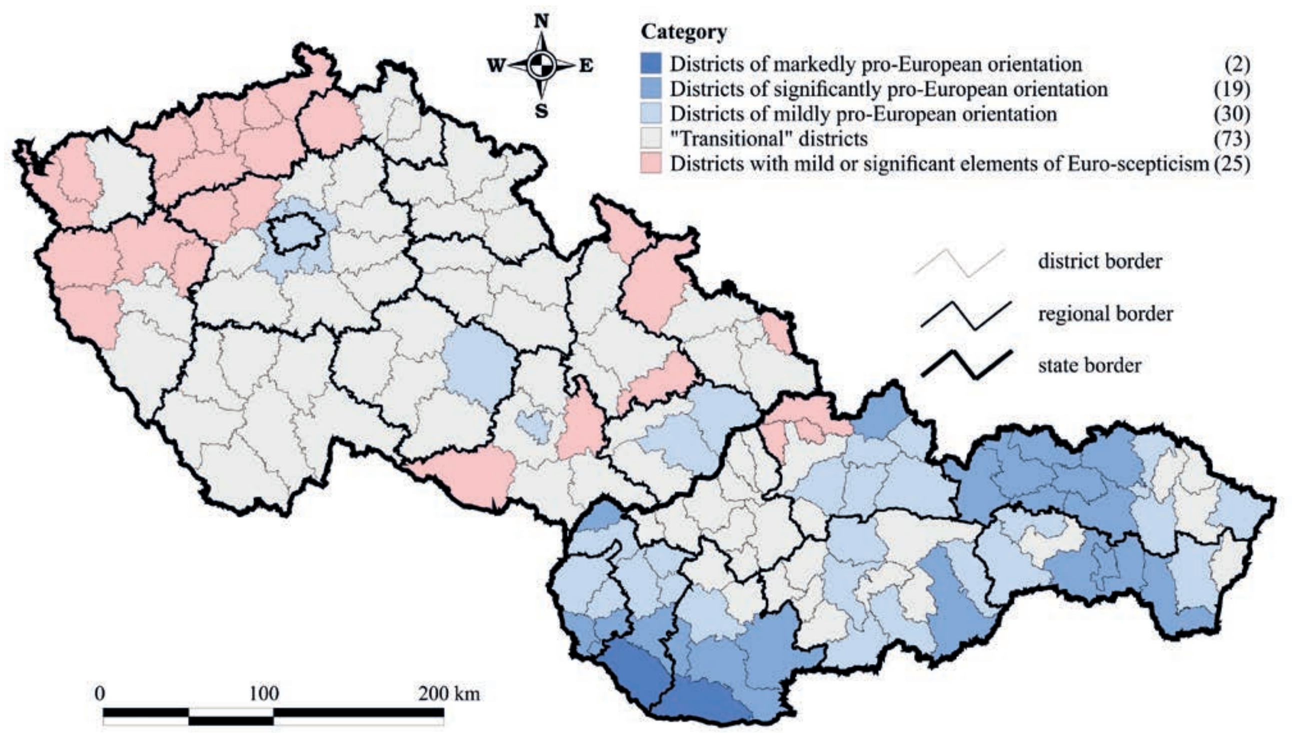


**Fig. 5** Categories of districts in Czechia and Slovakia clustered by Index of Pro-Europeaness.
Source: Czech Statistical Office, Statistical Office of the Slovak Republic (2019), author's research.

located in the eastern part of Slovakia in the regions of Banská Bystrica (Revúca), Košice (Rožňava, Spišská Nová Ves and Mihcalovce) and Prešov (Snina, Vranov nad Topľou and Svidník). In Czechia, the only cluster of districts of mildly pro-European orientation can be found in the capital region (districts of Prague). One district is located in the east of the Vysočina Region (Žďár nad Sázavou), three in Moravia in South Moravian Region (Brno-město) and Zlín Region (Zlín, Vsetín). Two largest cities of Czechia (Prague and Brno) fell into this category. This group is characterized by (Fig. 6) slightly above-average support for EU accession (+2.44 *pp*) and lower support for the Eurosceptic parties in EU elections (−4.06 *pp*).

The fourth group of districts, which is the most numerous of all clusters, we labelled *"transitional" districts*. Cluster analysis marked 73 spatial units (almost a half of all districts), of which 48 (66%) are located in Czechia. The largest concentration of districts of this type can be identified in the central and eastern Bohemia. In Slovakia, the most compact area is situated in all territory of Trenčín Region and adjacent districts. This category of districts is characterized by (Fig. 6) slightly below average support for EU accession (−3.51 *pp*) and mildly higher support for Eurosceptic parties in EU elections (+2.15 *pp*).

The last group consists of districts characterized by the notable degree of Euroscepticism (*"districts with mild or significant elements of Euroscepticism"*). Of the total number of 149 districts, 25 fall into this category, with 22 (88%) from Czechia. Most are located in the Ústí nad Labem Region (7 of 7), the Plzeň Region (4 of 7) and the Moravian-Silesian Region (3 of 7). Most of them, mainly from the Ústí nad Labem Region and the Moravian-Silesian Region, have certain socio-economic problems (relatively high unemployment, and low wages), favouring left-wing, far-left and recently protest parties to some extent. The most visible concentration is located in the northwest of Czechia, encompassing the regions of Liberec (Česká Lípa), Ústí nad Labem (Děčín, Ústí nad Labem, Teplice, Litoměřice, Most, Louny and Chomutov), Central Bohemia (Rakovník and Kladno), Karlovy Vary (Sokolov and Cheb) and Plzeň (Domažlice, Tachov, Plzeň-sever and Rokycany). In the historical regions of Moravia and Silesia, there are six such districts, namely Znojmo, Vyškov (South Moravian Region), Přerov (Olomouc Region), Jeseník, Bruntál and Karviná (Moravian-Silesian Region). Within Slovakia, districts of this type are located exclusively in the northwest of the territory in the Žilina Region (Bytča, Čadca, Kysucké Nové Mesto), where they formed a compact concentration. This area is known for its traditional support of nationalist parties, and the values of etatism and egalitarianism. Compared to the national average (Fig. 6), this cluster of districts is characterized by a markedly below average approval for EU accession (−6.44 *pp*) and an outstanding support for the Eurosceptic parties in EU elections (+8.25 *pp*).

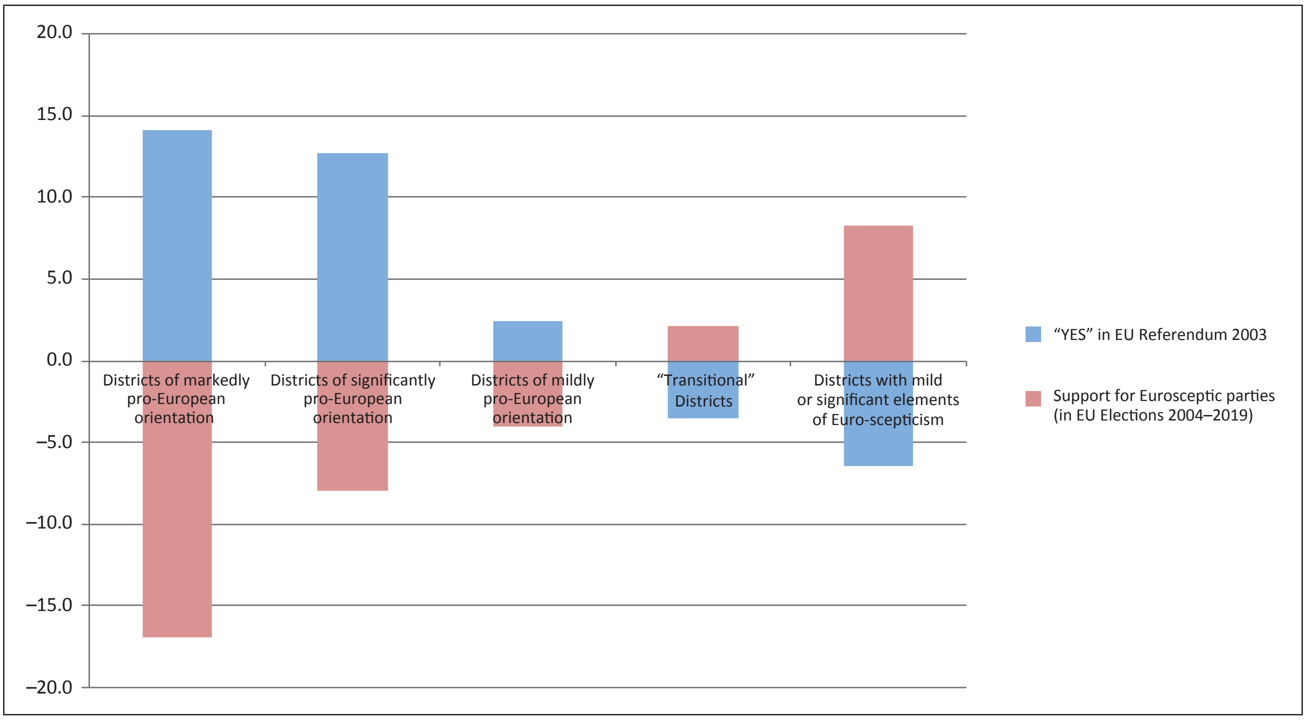


**Fig. 6** Categories of districts in Czechia and Slovakia clustered by Index of Pro-Europeaness – selected EU electoral characteristics.
Note: Difference from average value for Czechia and Slovakia, difference is measured by percentage points.
Source: Czech Statistical Office, Statistical Office of the Slovak Republic (2019), author's research.

## 5. Discussion

Some regions of Czechia and Slovakia are characterized by increased turnout and low level of Euroscepticism in the case of European issues (referendum, elections), while others are more passive in voting or support Eurosceptic parties to a great extent. The most frequent reasons for not participating in European parliamentary elections include disappointment with politics, non-alignment with the electoral program of any of the parties, and a lack of political commitment as such (Greffet 2007). In the debate on interest in voting in European elections as well as support for Eurosceptics, it is also important to mention the voter's relationship to the idea of Euro-citizenship (Frognier 2000), the project of European integration, Europeanism, the degree of awareness related to the role of the EU and the benefits of membership (Blondel et al. 1997) and the visibility of the EU in ordinary life (Irwin 1995). Voters of regions benefiting more from EU membership, e.g. through structural funds, have a higher tendency to participate in the European Parliament elections and support Euro-optimist parties (Jesuit 2003). In the case of Czechia, reasons for voter (non)participation were investigated by Linek (2013), in Slovakia by Gyárfášová (2019).

It turns out that the current wave of Euroscepticism or populism is better understood by the far-right subjects (in Czechia in particular by SPD and in Slovakia by ĽSNS). They are able to attract manual workers who previously almost unreservedly supported the left (Bale 2010). Nevertheless, in Czechia, the far-left KSČM has been enjoying significant support in the case of elections to the European Parliament, though currently of declining trend. Economic problems and migratory pressures are causing uncertainty in Europe and create a breeding ground for populists (Charvát 2007). Quite a number of authors have recently addressed the causes of support for far-right parties in Czechia and Slovakia (e.g. Kluknavská 2012, 2013; Gregor 2015; Mikuš et al. 2016). In general, increase in Euroscepticism can be linked to ongoing globalization (Salo 2014). It has created a group of "bereaved" who are losing certainty and feeling vulnerable to the current liberalization, worrying about their economic future and growing cultural diversity. Eurosceptics does not necessarily have to be a result of populism, but also as a legitimate part of the political arena that represents those "bereaved" by globalization (Salo 2014). It is said about the new European cleavage of social polarization based on the existence of various life and material opportunities (in our research, especially socio-economic status, civil and minority rights) perceived by different actors with different interests depending on the process of territorial integration (Bartolini 2007).

## 6. Conclusions

Considering the NUTS 3 regions of both countries (14 in Czechia and 8 in Slovakia) in terms of the final index of pro-Europeanness and regional cleavage, the highest values were achieved by the regions of the largest cities (Prague in the Czechia, Bratislava and Košice in Slovakia) typical of a more educated, urban population with a higher socio-economic status, more economically efficient and more successful in post-socialist transformation, with a higher concentration of large, especially foreign investment, and a predominant right-wing (or central/liberal) electorate. The second case of a pronounced tendency towards the EU project is represented by regions using EU subsidies under its largest agricultural policy, also dependent on the supranational policy securing the rights of ethnic minorities (especially the Trnava Region and the Nitra Region in Slovakia) or known for values of Christian Democracy (the Zlín Region in Czechia and the Prešov Region in Slovakia). On the contrary, the lowest values of the pro-Europeanness index were registered in the socio-economically and geographically peripheral regions of Czechia, with increased support for far-left, far-right and protest parties (the Ústí nad Labem Region, the Karlovy Vary Region and the Moravian-Silesian Region) and parts of Slovakia with a population traditionally close to the values of egalitarian, etatism and nationalism (the Trenčín Region).

At the district level (149 districts in total, 77 from Czechia and 72 from Slovakia), it was found that in the top two categories (*"districts of markedly pro-European orientation"* and (*"districts of significantly pro-European orientation"*), with the highest values of the index of pro-Europeanness, the Slovak districts (mainly from the southwest) dominated over Czech districts. On the contrary, 88% districts of the last category (*"districts with mild or significant elements of Euroscepticism"*) came from Czechia, with the absolute lowest values being registered for districts from Ústí nad Labem Region (northwestern Bohemia).

By using the cluster method, we derived five categories of districts across the countries based on the values of the pro-Europeanness index. The first three "evidently pro-European" groups (*"districts of markedly, significantly or mildly pro-European orientation"*) consists of 51 spatial units, 86% of them located in Slovakia. The districts of these clusters are characterized by a clear support for accession to the European Union and low support for Eurosceptic parties in European Parliament elections. Several districts of this type are urban (districts of Prague, Brno-město in Czechia, and Bratislava, Košice and Prešov in Slovakia), while others are located in southwest Slovakia (Senec, Dunajska Streda, Komárno and Nové Zámky) where there is relatively significant agricultural production and a strong concentration of the Hungarian minority. On the opposite side, there are districts with mild or significant elements of Euroscepticism, with significantly lower support for EU accession relevant support for Eurosceptic parties when EU elections take place. Of the 25 spatial units in this category, 22 are from the Czechia. The highest concentration was found mainly in the Ústí nad Labem Region, the Karlovy Vary Region and the Moravian-Silesian Region, i.e. in regions with relatively significant socio-economic difficulties (relatively high unemployment and low wages), with increasing support for radical (left-wing or right-wing) and protest (anti-system) parties. Within Slovakia, districts of this type are located in the northwest of the territory in the Žilina Region (Bytča, Čadca, Kysucké Nové Mesto), which traditionally support nationalist parties and espouse values of etatism and egalitarianism.

In general, ideas of European integration and Euro-optimism as such in Czechia and Slovakia are more common among the urban electorates (Prague, Brno, Bratislava, Košice), areas with a higher concentration of a particular ethnic group, with significant agricultural production (southwest of Slovakia), which in this case is probably related to the status of the EU as a guarantor (higher instance for protection) of civil and minority rights, and a provider of agro-subsidies. In the case of Euroscepticism, the Czech districts and regions prevail, especially from the peripheral northwest and the Moravian-Silesian border areas. In this context, relatively important socio-economic problems (in comparison with the national average high unemployment and low wages) can be mentioned. Part of the electorate can "blame" the EU (membership) for them (or at least in the form of a penalty for their failure to solve them) and thus, on a practical level, can prefer populist (radical, anti-system) and Eurosceptic parties. In the case of Slovakia, regions located to the northwest without significant socio-economic problems, but with the traditional vote for (ultra)nationalists (ĽSNS, formerly voting for SNS), egalitarian and etatist-minded political movements (SMER-SD, formerly voting for HZDS), were shown as least pro-European oriented. The obtained results are in accordance with the findings of previous studies from the Czech (Pink 2012; Voda 2015; Kostelecký et al. 2016; Koubek 2019) and Slovak literature (e.g. Krivý et al. 1996; Plešivčák 2011; Madleňák 2012; Przybyla 2019) on the historical and socio-economic causes affecting the spatial distribution of election results.

This study provides new insights into the "geography of pro-Europeanness" over a relatively long period of time (2003–2019), at the sub-national level of regions and districts of two countries that in the past formed a single state, applying a methodology not used before to assess the territorial context of EU integration support. This work also provides information for policy- and decision-makers on the regions in which EU assistance should be targeted to sustain (restore) the meaningfulness of both the idea of European integration and EU membership in those parts of the countries that are currently most critical to the EU project, and thus to stop encouraging Euroscepticism across the EU, starting with its partial regions.

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## References

Bale, T. (2010): If You Can't Beat Them Join Them? Explaining Social Democratic Responses to the Challenge from the Populist Radical Right in Western Europe. Political Studies 58(3), 410–426, https://doi.org/10.1111/j.1467-9248.2009.00783.x.

Bartolini, S. (2007): Cleavages. In: Encyclopaedia of European Elections. Ed. Y. Déloye, M. Bruter. Palgrave Macmillan, Basingstoke, 43–51.

Baun, M., Durr, J., Marek, D., Šaradín, P. (2006): The Europeanization of Czech Politics: The Political Parties and the EU Referendum. Journal of Common Market Studies 44(2), 249–280, https://doi.org/10.1111/j.1468-5965.2006.00622.x.

Blondel, J., Sinnott, R., Svensson, P. (1997): Representation and Voter participation. European Journal for Political Research 32(2), 243–272, https://doi.org/10.1023/A:1006832419724.

Blumer, J. G. (1983): Communicating to Voters. London, Sage.

Bradová, E., Šaradín, P. (2004): Volební kampaň. In: Volby do Evropského parlamentu v České republice. Ed. P. Šaradín. Periplum, Olomouc, 179–207.

Budge, I. (2001): Mapping Policy Preferences: Estimates for Parties, Electors and Governments (1945–1998). Oxford, Oxford University Press.

Cabada, L. (2010): Volby do Evropského parlamentu jako volby druhého řádu: reflexe voleb v nových členských zemích EU ze středovýchodní Evropy. Working Papers Fakulty mezinárodních vztahů 4(11), 5–26.

Carrubba, C., Timpone. R. (2005): Explaining vote switching across first-order and second order elections: evidence from Europe. Comparative Political Studies 38(3), 260–281, https://doi.org/10.1177/0010414004272693.

Czech Statistical Office. (2019): Elections Database (2003–2019). Prague, Czech Statistical Office.

De Vries, C., van der Brug, W., van Egmond, M., van der Eijk, C. (2011): Individual and contextual variation in EU issue voting: The role of political information. Electoral Studies 30(1), 16–28, https://doi.org/10.1016/j.electstud.2010.09.022.

Fiala, P., Hloušek, V., Pitrová, M., Pšeja, P. (2006): Evropeizace politických stran a zájmových skupin: základní problémy a směry analýzy. Politologický časopis 13(1), 3–26.

Frodnier, A.-P., (2000): Identité et participation électorale: pour une approche européenne des élections européennes. In: Le vote des Quinye. Les élections européennes du 13 juin 1999. Ed. G. Grunberg, P. Perrineau, C. Ysmal, C. Presses de Sciences, Paris, 75–94.

Goodwin, M. (2011): Right Response: Understanding and Countering Populist Extremism in Europe. London, Chatham House.

Greffet, F. (2007): Abstention. In: Encyclopaedia of European Election. Y. Déloye, M. Bruter. Palgrave Macmillan, Basingstoke, 1–6.

Gregor, K. (2015): Kto sú Kotlebovi voliči? Preskupovanie voličov v Banskobystrickom kraji v rokoch 2009 až 2014. Sociológia – Slovak Sociological Review 47(3), 235–252.

Gyárfášová, O. (2007): Jak volili Slováci ve volbách do EP v roce 2004 v kontextu veřejného vnímání Evropské unie. In: Volby do Evropského parlamentu 2004. L. Linek, J. Outlý, G. Tóka, A. Batory. Sociologický ústav AV ČR, Praha, 279–292.

Gyárfášová, O. (2019): Public's perception of the EU and turnout in the EP election. In: Euroflection. Eds. N. Bolin, K. Falasca, M. Grusell and L. Nord. Mittuniversitetet, Sundsvall, 56–56.

Gyárfášová, O. Velšic. M. (2004): Volebné správanie slovenských voličov v prvých eurovoľbách a širšie súvislosti vnímania členstva v EÚ. Bratislava, Inštitút pre verejné otázky.

Hastie, T., Tibshirani, R. Friedman, J. (2016): The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Second Edition (Springer Series in Statistics). Berlin, Springer.

Havlík, V. (2008): Jak je měřit? Přístupy a metody analýzy postojů politických stran k evropské integraci. Central European Political Studies Review 10(4), 340–369.

Havlík, V. (2010): České politické strany a evropská integrace: Evropeizace, evropanství, euroskepticismus? Brno, Masarykova univerzita.

Havlík, V., Hoskovec, L. (2009): Krajské volby v České republice v kontextu konceptu voleb druhého řádu. Analýza vybraných aspektů voleb do krajských zastupitelstev v letech 2000–2008. European Electoral Studies 4(1), 22–47.

Havlík, V., Kaniok, P. (2006): Euroskepticismus a země střední a východní Evropy. Brno, Mezinárodní politologický ústav Masarykovy univerzity.

Havlík, V., Voda, P. (2016): The Rise of New Political Parties and Re-Alignment of Party Politics in the Czech Republic. Acta Politologica 8(2), 119–144.

Havlík, V., Vykoupilová, H. (2008): Two dimensions of the Europeanization of election programs: The case of the Czech Republic. Communist and Post-Communist Studies 41(2), 163–187, https://doi.org/10.1016/j.postcomstud.2008.03.007.

Henderson, K. (2008): The Slovak Republic: Eurosceptics and Phoney Europhiles. In: The Party Politics of Euroscepticism, Vol. 1 Case Studies and Country Surveys. Eds. A. Szczerbiak and P. Taggart. Oxford University Press, Oxford, 277–294.

Hix, S., Marsh, M. (2007): Punishment or Protest? Understanding European Parliament Elections. The Journal of Politics 69(2), 495–510, https://doi.org//10.1111/j.1468-2508.2007.00546.x.

Hix, S., Marsh, M. (2011): Second-order effects plus pan-European political swings: An analysis of European Parliament elections across time. Electoral Studies 30(1), 4–15, https://doi.org/10.1016/j.electstud.2010.09.017.

Hloušek, V., Pšeja, P. (2009): Europeanization of Political Parties and the Party System in the Czech Republic. Journal of Communist Studies and Transition Politics

25(4), 513–539, https://doi.org/10.1080/13523270903310902.
Hricová, H. (2009): Česká republika. In: Eurovolby 2009: Prostor pro evropeizaci politických stran ve středovýchdoní Evropě. L. Cabada, V. Hloušek. Aleš Čeněk, Plzeň, 41–66.
Hwang, C. L., Yoon, K. (1981): Multiple Attribute Decision Making: Methods and Applications. New York, Springer-Verlag, https://doi.org/10.1007/978-3-642-48318-9.
Hynčica, P., Šárovec, D. (2018): Slovenské politické strany optikou konceptu novosti. Acta Fakulty filozofické Západočeské univerzity v Plzni 10(2–3), 7–34, https://doi.org/10.24132/actaff.2018.10.2-3.1
Charlot, M. (1986): The June 1984 European Elections. Paris, Publications de la Sorbonne.
Charvát, J. (2007): Současný politický extremismus a radikalismus. Praha, Portál.
Irwin G. (1995): Second-order or third-rate?: Issues in the campaign for the elections for the European Parliament 1994. Electoral Studies 14(2), 183–199, https://doi.org/10.1016/0261-3794(95)96843-7.
Jesuit, D. (2003): The Regional Dynamics of European Electoral Politics: Participation in National and European Contests in the 1990s. European Union Politics 4(2), 139–164, https://doi.org/10.1177/1465116503004002001.
Kaniok, P., Havlík, V. (2016): Populism and euroscepticism in the Czech Republic: Meeting friends or passing by? Romanian Journal of European Affairs 16(2), 20–35.
Klíma, M., Outlý, J. (2010): Volby do Evropského parlamentu 2009. V vybrané otázky přípravy, průběhu a výsledků voleb. Plzeň, Aleš Čeněk.
Kluknavská, A. (2012): Krajne pravicové strany v parlamentných voľbách 2012 naSlovensku. Rexter – časopis pro výzkum radikalismu, extremismu a terorismu 10(1), 1–35.
Kluknavská, A. (2013): Od Štúra k parazitom: Tematická adaptácia krajnej pravice v parlamentných voľbách na Slovensku. Politologický časopis 20(3), 258–281, https://doi.org/10.5817/PC2013-3-258.
Kopecký, P., Mudde, C. (2002): The Two Sides of Euroscepticism: Party Positions on European Integration in East Central Europe. European Union Politics 3(3), 297–326, https://doi.org/10.1177/1465116502003003002.
Kostelecký, T., Mikešová, R., Poláková, M., Čermák, D., Bernard, J., Šimon, M. (2016): Geografie výsledků parlamentních voleb: prostorové vzorce volebního chování v Česku 1992–2013. Praha, Sociologický ústav AV ČR.
Koubek, J. 2019. Volební chování českých velkoměst v historické perspektivě se zaměřením na výsledky levice. Praha, Masarykova demokratická akademie.
Kovář, J. (2013): The Supply Side of Second-Order Elections in the Czech Republic: A Light at the End of the Tunnel? Romanian Journal of European Affairs 13(1), 57–82.
Kovář, J. (2014): Europeizace volebních programů pro volby do EP. Politické vedy 17(3), 32–67.
Kovář, J., Kovář, K. (2014): Representation of Women in Second-order Elections: The Czech Republic and Slovakia Compared. Perspectives on European Politics and Society 15(1), 1–18, https://doi.org/10.1080/15705854.2013.793533.
Krivý, V., Feglová, V., Balko, D. (1996): Slovensko a jeho regióny: sociokultúrne súvislosti volebného správania. Bratislava, Nadácia Médiá.
Ladrech, R. (2002): Europeanization and Political Parties: Towards a Framework for Analysis. Party Politics 8(4), 389–403, https://doi.org/10.1177/1354068802008004002.
Linek, L. (2013): Kam se ztratili voliči? Vysvětlení vývoje volební účasti v České republice v letech 1990–2010. Brno, Centrum pro studium demokracie a kultury.
Linek, L., Outlý, J., Tóka, G., Batory, A. (2007): Volby do Evropského parlamentu 2004. Praha, Sociologický ústav AV ČR.
Lipset, S. M., Rokkan, S. (1967): Party Systems and Voter Alignments: Cross–national Perspectives. London, Collier-Macmillan.
Lodge, J. (2010): The 2009 elections to the European Parliament. Basingstoke, Palgrave Macmillan.
Madleňák, T. (2012): Regionálna diferenciácia volebného správania na Slovensku (1998–2010). Bratislava, Veda.
Manokaran, E., Subhashini, S., Senthilvel, S., Muruganandham, R., Ravichandran, K. (2011): Application of multi criteria decision making tools and validation with optimization techniquecase study using TOPSIS, ANN & SAW. International Journal of Management & Business Studies 1(3), 112–115.
Maškarinec, P. (2017): A Spatial Analysis of Czech Parliamentary Elections, 2006–2013. Europe-Asia Studies 69(3), 426–457, https://doi.org/10.1080/09668136.2017.1313962.
Maškarinec, P. (2019): The rise of new populist political parties in Czech parliamentary elections between 2010 and 2017: the geography of party replacement. Euroasian Geography and Economics 60(5), 511–547, https://doi.org/10.1080/15387216.2019.1691928.
Mikuš, R., Gurňák, D. (2016): Rómska otázka ako jeden z mobilizačných faktorov volebnej podpory krajnej pravice na Slovensku a v Maďarsku. Geographia Cassoviensis 10(1), 29–46.
Mikuš, R., Gurňák, D., Máriássyová, A. (2016): Analýza volebnej podpory Mariána Kotlebu ako reprezentanta krajnej pravice v krajských voľbách 2013. Sociológia 48(1), 48–70.
Opricovic, S., Tzeng, G. H. (2004): Compromise solution by MCDM methods: a comparative analysis of VIKOR and TOPSIS. European Journal of Operational Research 156(2), 445–455, https://doi.org/10.1016/S0377-2217(03)00020-1.
Pink, M. (2012): Volební mapy České a Slovenské republiky po roce 1993: vzorce, trendy, proměny. Brno, Centrum pro studium demokracie a kultury.
Plešivčák, M. (2011). Regionálny obraz korelačnej závislosti medzi volebnými preferenciami a vybranými sociálnymi charakteristikami populácie Slovenska. Regionální studia 5(1), 2–16.
Plešivčák, M. (2015): First Two Elections to the European Parliament in Slovakia: Turnout and Results in Regional Perspective. Evropská volební studia 10(1), 14–32.
Przybyla, V. (2019): Vliv vybraných demografických charakteristik na volební chování na Slovensku v meziválečném období. Geografický časopis 71(2), 181–199, https://doi.org/10.31577/geogrcas.2019.71.2.10.

Reif, K., Schmitt, H. (1980): Nine second-order national elections: a conceptual framework for the analysis of European election results. European Journal of Political Research 8(1), 3–44, https://doi.org/10.1111/j.1475-6765.1980.tb00737.x.
Robert Schuman Foundation (2004): Survey on Evaluation of competences at the European and national levels (in EU member states), 28–30 April 2004.
Salo, S. (2014): Eurosceptics in the 2014 EP Elections. Protest Parties Mobilized on National Cleveages Between Globalization Winners and Losers. Helsinki, Finnish Institute of International Affairs.
Shih, H. S., Shyurb, H. J., Lee, E. S. (2007): An extension of TOPSIS for group decision making. Mathematical and Computer Modelling 45(7–8), 801–813, https://doi.org/10.1016/j.mcm.2006.03.023.
Statistical Office of the Slovak Republic (2019): Elections and Referenda Database (2003–2019). Bratislava, Statistical Office of the Slovak Republic.
Šaradín, P. (2008): Teorie voleb druhého řádu a možnosti jejich aplikace v České republice. Olomouc, Univerzita Palackého v Olomouci.
Taggart, P., Szczerbiak, A. (2002): The Party Politics of Euroscepticism in EU Member and Candidate States. Brighton, Sussex European Institute.
Voda, P. (2015): Jaká je role postkomunismu? Volební geografie České a Rakouské republiky v letech 1990–2013. Brno, Centrum pro studium demokracie a kultury.

# Which subjects contribute to the teaching of cross-curricular topic Environmental Education at elementary schools in Czechia?

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**ABSTRACT**

This article summarizes the results of the research focused on the realization of the cross-curricular subject Environmental Education (CCSEE) at elementary schools (pupils' age 6–15 years) in Czechia. The introduction of cross-curricular subjects into the Czech educational system is linked to curricular reform and it has been implemented in Czech schools since 2007. CCSEE is one of the six currently implemented cross-curricular topics. The main objective of the present study is to determine which school subjects are involved in its implementation. The study was conducted through an internet questionnaire and responses were received from 640 schools. Data were processed by basic statistical methods. A school typology depending on the subjects involved in implementing EE was developed with the help of cluster analysis. The research shows that EE is implemented through most subjects, but their representation varies considerably for individual schools.

**KEYWORDS**

curricula; elementary school; geographical education; environmental education; cross-curricular subject; Czechia

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## 1. Introduction

One of the changes brought to the Czech schools by Framework Educational Programs (FEPs) was the introduction of cross-curricular subjects. The cross-curricular subject Environmental Education (CCSEE) is one of them. The aim of the research presented here was to find out which school subjects are involved in the implementation of CCSEE in schools and to what extent, and whether it is possible to trace certain typical "models" of CCSEE implementation in terms of the involvement of individual school subjects. According to our professional orientation, we were especially interested in the role of geography in fulfilling the objectives of EE.

The development of EE in Czechia is clearly summarized by Máchal (2000) and Činčera (2013a, 2014). Putting into the international context is discussed in more detail in Činčera (2013b). The roots of EE can be found in the activities of volunteer organizations already in the interwar period of Czechoslovakia. These activities were followed by organizations working with children and youth in the 1970s (especially the Czech Union for Nature Conservation and the Brontosaurus Movement). The first centers of environmental education (Máchal 2000) were later established from these and other organizations.

However, the implementation of EE into formal (school) education was delayed in comparation with some countries of northern and western Europe. At present, the basic framework for EE at schools is based on the State Program of EE in the Czech Republic (approved in 2000). When planning EE implementation goals, schools are based on valid curricular documents (especially from FEP or school educational programs – see below), from the Methodological Guideline of the Ministry of Education, Youth and Sports on ensuring EE, from the regional concept of EE and their action programs, and from the analysis of specific school conditions. The CCSEE coordinator is designated at individual schools and is responsible for the fulfillment of EE objectives according to FEP. More authors mention that its evaluation is very important for the development of EE (Verma and Dhull 2017; Ssozi 2012; Ferguson 2008; Grodzińska-Jurczak 2004; Nam 1995).

CCSEE got into Czech curriculum documents in 2007, in connection with the implementation of FEP (Jeřábek and Tupý 2007), which replaced the curriculum previously used. CCSEE is one of six currently implemented cross-curricular subjects. However, in the context of actual FEP revision, the future of cross-curricular topics is uncertain and actualy discussed.

According to Činčera (2005), the inclusion of CCSEE as a cross-curricular subject represents a major shift in its understanding in Czechia. Thus, EE started to be understood as a real cross-subject issue that integrates both the natural and human sciences. The expected outcomes for cross-curricular subjects (including CCSEE) were then elaborated in detail later (see Pastorová et al. 2011; Činčera 2011).

In practice, CCSEE can be implemented in schools either by integrating it into the educational content of existing school subjects, by creating a separate school subject or through project teaching (cross-curricular projects, project days). The individual forms may be combined with each other. The same situation is in Slovakia (Kelcová 2009). The opposite example is Great Britain (specifically England), where The Environemtal Curriculum gives examples of the implementation of EE in individual subjects (Green 2018).

Thus, all teachers in the school may theoretically participate in the implementation, but the situation in the individual schools may be quite different and the actual situation has not yet been closely monitored. This paper summarizes the results of research conducted at Czech elementary schools (primary schools) and focused on determining the degree of involvement of individual subjects in fulfilling the objectives of the EE, respectively. implementation of CCSEE.

In the past, this issue was only partially monitored, as part of the analysis carried out by Daňková et al. (2009). A wide range of aspects of EE goals implementation at schools was also addressed by a detailed study of Činčera et al. (2016), however, the rate of involvement of individual subjects was not realized in mentioned study. Finding out which subjects are involved in the implementation of EE can show whether EE really has a cross-curricular character and thus fulfills its potential.

EE can be realized in various forms and in various school subjects. The potential for implementing CCSEE objectives, introduced by FEPs (see Jeřábek and Tupý 2007), have practically all school subjects, but in different degrees. The interdisciplinary concept of EE prevails (Aikens et al. 2016). Number of concrete examples of linking environmental issues with other subjects, including fewer common ones, was described in the literature (see below).

In general, Godemann (2008) deals with integration and transdisciplinary concepts of environmental issues in a comprehensive way, which also summarizes the main principles of working with information in such a teaching approach. The importance of an interdisciplinary approach to EE is also highlighted by Jančaříková (2009).

The traditional is linking of EE with nature science education, especially with biology, physical geography and chemistry (Mwendwa 2017; Florentina and Barbu 2015; Ryplová and Reháková 2011; Řezníčková 2009). Aikens and McKenzie (2016) also state that most of the topics used in environmental education belong to the natural sciences, but recent studies are beginning to address the social sciences. Education in these school subjects enables pupils to know principles of natural processes, introduces them to the diversity of nature, and to understanding of the human activity impact on the natural environment.

Yet some dichotomy can be observed in this respect as well. While nature science education was mainly motivated by the need to create a sufficiently strong scientific and technical base to accelerate innovation and strengthen competitiveness around the mid-20th century, EE which emerges in the 1960s as a response to the environmental crisis is in favor of the aim is to develop the environmental literacy necessary to understand the broader contexts from which these problems have arisen and are solved within them (Wals et al. 2014).

The possibilities of interconnection of EE with mathematics and physics, including concrete examples, are presented by Sýkora (2007), Melichar et al. (2006) and Palivec (2013). The possibilities of integrating EE and social sciences in the curriculum are addressed by the example of Nigeria by Adedayo and Olawepo (1997), Ferstl and Parkan (2007) summarize the possibilities of linking to history teaching.

Numerous suggestions for linking environmental issues with language and literature teaching was provided by Bowers (2010), which emphasizes the importance of using appropriate concepts in teaching environmental topics and introduces misconceptions that may result from the use of inexact terms. Possible reasons for children's concepts and misconceptions discusses Pavlátová (2019). Kubrická and Hromádka (2015) provided specific examples of the use of environmental topics for teaching English. The possibilities of linking EE with language and literature teaching are mentioned by Howard (2010), Lustyantie (2015) and Soetaert et al. (1996).

The importance of linking different forms of artistic activities with EE is dealt with by Dielman (2013). Navrátil (2012) presents on concrete examples the possibilities of fulfilling the goals and development of key competences of EE according to FEP, through artistic activities.

Various examples how to utilize works of art in geography and EE are also presented by Parkinson (2009), Vočadlová (2009) or Kučera (2012). Halocha (2008), Trojanová (2009), Řezníčková a Boháček (2010), Sánchez (2013), Quigley et al. (2014) show the possibilities of developing the skills of acquiring geographical or environmental information from image sources or photographs. Several options for integrating environmental topics can also be found in music education (Campos 2013; Váňová et al. 2007; Jurmu 2005) or in connection with drama education (McNaughton 2004). Integration with physical education can be realized primarily through field activities (Dechano and Shelley 2004).

## 2. Research methodology

Data collection was carried out by anonymous on-line questionnaire, which was addressed to the EE coordinators at most of all elementary schools in Czechia. The questionnaire was created according to the principles for quantitative research (Gavora 2010; Chráska 2007).

The first part of the questionnaire was focused on the basic informations about the respondent (length of practice, sex, approbation), the second part was focused on the implementation of CCSEE. The questionnaire was sent out by a pilot survey (around 20 respondents), after this phase some items were changed or clarified. From the total number of primary schools to which the questionnaire was sent out (3203), we received responses from 640 respondents, after removing a few incomplete answers (return of about 20%). The headmasters of the schools listed in the Atlas of Education database (http://atlasskolstvi.cz) were asked to send a request for forwarding to the EE school coordinator.

The length of teaching practice addressed by the EE coordinators varied from 1 year to 54 years. The average length of practice was 19.1 years, most respondents were women (86%). The most frequent qualifications of respondents were biology, geography, chemistry, mathematics and physical education. Often repeated were different combinations of these school subjects.

The main part of the questionnaire consisted of items aimed at determining the rate of participation of individual school subjects in the implementation of CCSEE. For each school subject, respondents chose one of the following options: not involved or the subject is not taught at our school (0), very little (1), moderate (2), significantly (3), a core subject for achieving CCSEE objectives (4). A coefficient was assigned to each option (see above). This coefficient multiplied the frequency of individual responses in each category and the average was calculated. Thus it was found out how each subject participates in the realization of CCSEE.

The total dataset was divided into two parts, the first with answers of teachers who teach only at Stage 1 of elementary school ($n = 153$) and the second part with answers of teachers from complete (nine-year) elementary schools – with both Stage 1 and Stage 2 ($n = 487$).

To find out a typology of schools according to incorporation of the EE topics into the curriculum, it was necessary to choose the proper method. The metod would divide the objects (i.e. individual schools or better the answers of respondents from individual schools) into categories first according to composition of particular school subjects that comprise EE topics and second according to intensity of presence of EE topics (i.e. extent of the EE curriculum) within these subjects. Therefore, the multidimensional statistical method of hierarchical clustering was found as the most suitable for application. The method enables to divide the objects into categories according to mutual both similarity and dissimilarity of their characteristics. The analysis was conducted in the statistical software SPSS.

The clustering of non-standardized variables was conducted. The variables were not standardized because all of them represent the same type of respondents' answers, originating from the same time period, therefore they don't vary in their values. During the hierarchical clustering the method of Average linkage between groups was applied to obtain maximal similarity within the groups together with the maximal dissimilarity between groups. The linkage of the variables (value of their distance) was measured with utilization of Pearson correlation intervals. Their utilization ensures that the structural similarity of the answers is preferred – in this case the proportion of frequency in appreciation of EE topics between individual school subjects by the respondents.

Since the number of input variables (i.e. number of school subjects) was too wide for such type of analysis, several groups of school subjects were created. At Stage 1, the appreciation of basic biology (originally *přírodověda*), homeland studies (originally *vlastivěda*) and elementary teaching (originally *prvouka*) was observed. At Stage 2 biology, geography and health education were distinguished separately. The other subjects were grouped into: science subjects (physics, chemistry, mathematics), languages (mother language, foreign language), humane science subjects (history, civics), artistic and practical subjects (music, fine arts, physical education).

The number of 3 clusters was selected as the most representative number of clusters in the dataset of teachers at Stage 1 and 5 clusters in the dataset of teachers at complete elementary schools. The clusters were tested about their independency at 95% confidence interval through comparison of their means by method One Way ANOVA.

## 3. Results of Research

The degree of involvement of individual school subjects in the implementation of EE objectives at primary schools with Stage 1 only, is shown in Figure 1. The predominance of science-related subjects is evident, but the role of fine arts and homeland studies (a subject with mainly geographical and historical content) is also significant.

The situation in complete (nine-year) elementary schools is shown in Figure 2. Biology is the most important subject in these schools, but geography, which is the second most important subject in this respect, also plays a significant role.

The educational objectives of CCSEE can be fulfilled not only in already existing school subjects, but also through a special separate school subject. One of the questions in the questionnaire survey was therefore focused on using this option. Results show that it is used by 114 schools (18%). In about half of the cases the title of the subject contains the word *ecology* or *ecological*. In the remaining cases it is a modification of the subject of natural history or a practically conceived subject focused mainly on the realization of scientific experiments, research-oriented teaching, etc.

A simple typology of schools was based on the contribution to CCSEE goals fulfilling, assessed by respondents. The aim of this typology is to try to classify schools according to curriculum strategies of implementation EE goals.

Applying multivariate analytical statistical methods (cluster analysis) it was possible to distinguish 3 different clusters of elementary schools with the Stage 1 only according to the strategy of integrating

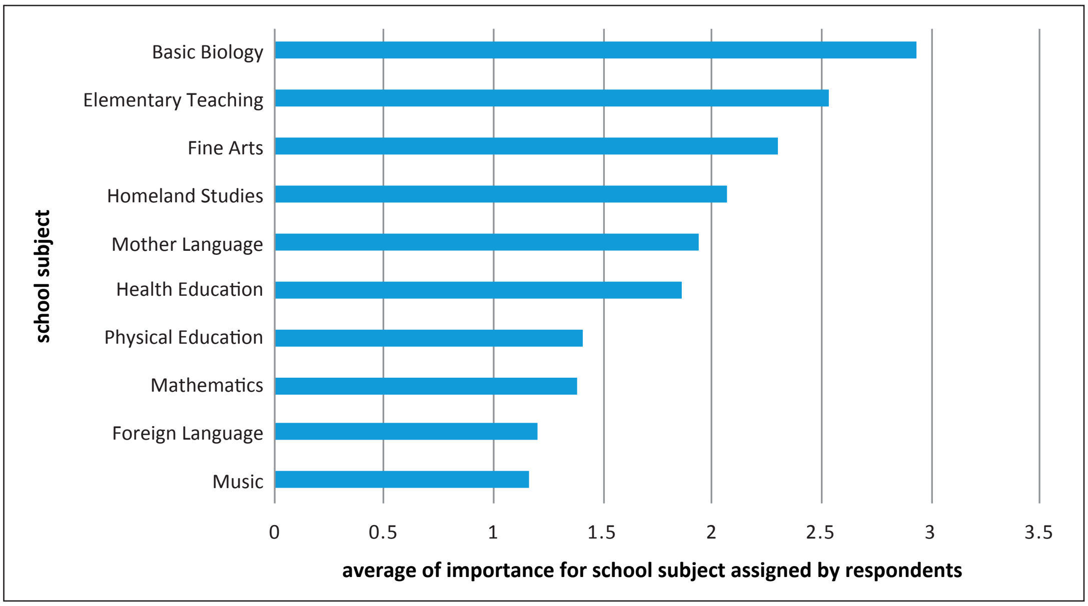


**Fig. 1** The involvement of school subjects in the implementation of EE objectives at primary schools with Stage 1 only.

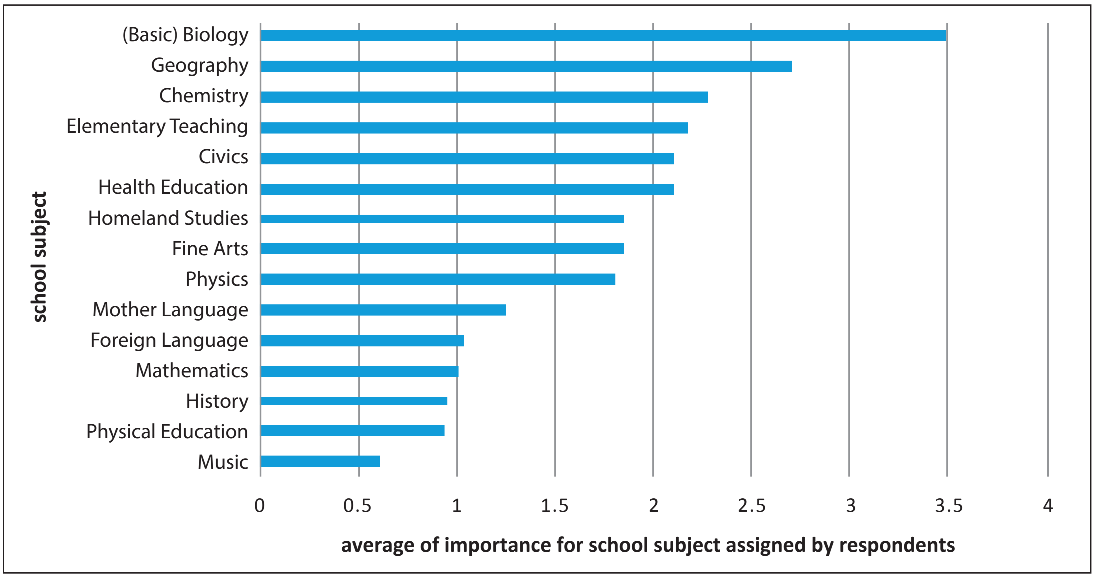


**Fig. 2** The involvement of school subjects in the implementation of EE objectives at complete (nine-year) elementary schools.

the CCSEE into the curriculum. The first cluster includes those schools where the subject of basic biology contributes unambiguously to the implementation of CCSEE and in other school subjects this issue is almost not represented. Respondents in the second (most numerous) clusters assigned to the basic biology and previous school subject elementary teaching the same contribution. Homeland studies was also mentioned, but its role was less apparent. The third cluster is marked by a sharp decrease in the importance of basic biology for the implementation of CCSEE against the previous two. Elementary teaching and homeland studies contribute most to the CCSEE implementation. Nonetheless, respondents in the third cluster differ significantly, showing high values of the standard deviation (Table 1).

Five different clusters can be defined in a sample of complete elementary schools (Table 2). To better understand the types of EE inclusion strategies, we have identified them with working names (Table 3). The unifying element of the first cluster (*separate subject*) is the existence of a specific separate school subject for the implementation of CCSEE, although the valuation of other subjects varies widely within the set (see standard deviation values). Conversely, the second cluster (*natural-geographic*) includes schools where a separate subject of EE does not exist. Basic biology or biology and geography contribute most to CCSEE implementation. The third cluster (*science subjects*) also includes schools, where a separate subject focused on EE is not taught, but the role of basic biology or biology and geography is not prevailing. The wider group of natural science (mostly the importance of the subject of chemistry) and health education are the most involved in the implementation of CCSEE. However, this is the smallest cluster with a very low number of respondents (only 15). The fourth cluster was called *socio-health*. Although the importance of biology prevails, and also geography contributes to the realization of CCSEE, there is one of the highest evaluations of the contribution of human science subjects and health education to other statements. The last cluster was named *complex* because it was very difficult to determine the dominance of any subject in

**Tab. 1** Descriptive statistics of clusters of schools with teaching at the Stage 1 only.

| Cluster | Number of schools in cluster (N) | Average of importance for school subject assigned by respondents | | | |
|---|---|---|---|---|---|
| | | separate subject | basic biology | homeland studies | elementary teaching |
| 1 | 37 | 0.200 | 3.500 | 0.000 | 0.000 |
| 2 | 79 | 0.000 | 3.600 | 2.900 | 3.600 |
| 3 | 37 | 0.600 | 0.900 | 2.300 | 2.700 |
| | | standard deviation | | | |
| 1 | | 0.917 | 0.605 | 0.000 | 0.000 |
| 2 | | 0.000 | 0.481 | 0.938 | 0.485 |
| 3 | | 1.495 | 1.308 | 1.283 | 1.309 |

**Tab. 2** Descriptive statistics of clusters of complete (nine-year) elementary schools.

| Cluster | Number of schools in cluster (N) | Average of importance for school subject assigned by respondents | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | separate subject | (basic) biology | geography | nature science subjects | languages | human science subjects | artistic and practical subjects | health education |
| 1 | 131 | 3.100 | 3.400 | 2.500 | 1.600 | 1.000 | 1.400 | 1.400 | 1.900 |
| 2 | 161 | 0.000 | 3.900 | 3.100 | 1.800 | 0.900 | 1.400 | 1.500 | 2.000 |
| 3 | 15 | 0.000 | 2.700 | 2.300 | 2.400 | 1.400 | 1.200 | 1.500 | 2.300 |
| 4 | 155 | 0.100 | 3.200 | 2.400 | 1.600 | 1.400 | 1.800 | 2.100 | 2.600 |
| 5 | 25 | 0.200 | 3.300 | 3.000 | 1.900 | 1.500 | 1.600 | 2.300 | 0.600 |
| | | standard deviation | | | | | | | |
| 1 | | 1.687 | 0.814 | 0.777 | 0.713 | 0.652 | 0.612 | 0.931 | 1.073 |
| 2 | | 0.000 | 0.292 | 0.715 | 0.608 | 0.558 | 0.616 | 0.878 | 0.968 |
| 3 | | 0.000 | 0.704 | 0.704 | 0.506 | 0.632 | 0.320 | 0.694 | 0.617 |
| 4 | | 0.636 | 0.703 | 0.797 | 0.633 | 0.560 | 0.641 | 0.965 | 0.791 |
| 5 | | 0.800 | 0.678 | 0.539 | 0.615 | 0.736 | 0.621 | 0.818 | 0.757 |

**Tab. 3** Elementary schools types according to a curricular strategy of realization of CCTEE in individual subjects at complete (nine-year) elementary schools.

| Cluster | Characteristics of type | Working title | Share from studied sample |
|---|---|---|---|
| 1 | schools with an separate subject environmental Education/EE, dominant in its contribution to realization of CCTEE, although the appreciation of the others subjects on the participation on CCTEE realization differs a lot | Separate subject | 27% |
| 2 | biology and geography are the most significant in realization of CCTEE, separate subject EE is not taught | Biological–Geographical | 33% |
| 3 | various science subjects (chemistry the most of all) and health education as well contribute to realization of CCTEE, separate subject EE is not taught | Science Subjects | 3% |
| 4 | biology or geography are the most significant in realization of CCTEE, nevertheless the highest appreciation of humane sciences (civics the most of all) and health education is noticeable | Humane–Health educational | 32% |
| 5 | various subjects contribute to realization of CCTEE, including languages and fine arts, nevertheless it is difficult to determine one dominant subject, on the contrary, health education does not contribute to the realization of CCTEE at all | Complex | 5% |

CCSEE implementation. Biology and geography have been the most appreciated in this cluster, but values of languages and artistic and practical subjects (fine arts, physical education, music) are also very high in comparison with other clusters (although their meaning is very variable according to the standard deviation), and also science and social science subjects. This cluster is also relatively small (25 schools).

It seems that if the separate school subject of EE is not directly established, the biology and geography subjects contribute most to the implementation of CCSEE at Stage 2 of elementary school. Only when their role is weak, does health education, or chemistry and civics, hold this position.

## 4. Discussion

The research confirmed that CCSEE could be implemented in all school subjects. However, from the point of view of teachers some subjects seem more appropriate for its implementation. It can be seen from the results obtained that at the first level the primary role in the realization of CCSEE is played by the elementary teaching and natural science. This is due to the fact, that this subject is closely related to EE and also to the fact, that the EE is in Czechia still perceived as a synonym for ecology or ecological education (Máchal 2000), even among EE coordinators (Činčera 2013b). This is also confirmed by the finding that if a separate subject dedicated to EE is being taught at school, in half of the cases it include words *ecology* or *ecological* in its title. This corresponds to the results of Aikens et al. (2016), who also found that biological topics predominate in the implementation of EE.

At Stage 2 the second most important subject according to the share in the realization of CCSEE is geography. This subject (together with history, whose role in the implementation of CCSEE objectives did not prove too significant) follows the homeland studies that is taught at the Stage 1 and belongs among the most important subjects in terms of CCSEE implementation. The importance of geography in the implementation of EE mentions also Mwendwa (2017).

An analysis of the EU curriculum by Stokes et al. (2001) suggests that if EE is integrated into individual school subjects, it is most often in geography, science (the dominant role is played by biology, then chemistry and physics) and civics. This finding largely corresponds to the results of our research. In some countries, subjects labeled as technologies, which do not have a direct equivalent in the Czech education system, are also involved, their content and approach being spread across multiple subjects.

The importance of (basic) biology, geography and homeland studies, as well as civics and health education, was also confirmed by the results of cluster analysis. We can say that both natural and human science subjects are involved in the implementation of CCSEE. It corresponds to the understanding of EE according to Činčera (2005). Aikens et al. (2016) also cite that the importance of the social sciences for the realization of EE is slowly growing.

The results obtained are partly consistent with the results of Daňková et al. (2009), according to which the objectives of EE were fulfilled most often in chemistry (71% of schools), geography, civics, biology and subjects of Stage 1 (about one third of the schools surveyed). Similarly, Ruda (2010) mentions that pupils most often meet the adjective *environmental* in biology or natural history, geography and foreign language.

The observed share of schools with a separate optional subject focused on EE (18%) roughly corresponds to the results of the analysis carried out by Daňková et al. (2009), according to which a single subject was taught to 14% of schools surveyed. However, the creation of a separate subject for the implementation of EE may not always be a good solution, as stated by Verma and Dhull (2017).

The aim of the presented research was to find out which subjects are involved in the implementation of CCSEE, but the specific forms and methods of teaching and the specific environmental topics taught have not been studied. This is one of the significant limitations of our study. However, these aspects are described in more detail in the studies of Bartoš and Matějček (2015) and Činčera et al. (2016), while the information about implementation of EE into individual subjects was just missing.

Another limit is the research sample. Although most schools in the Czechia were contacted, the return on the questionnaire was only partial. The representativeness of the results is thus limited to the schools that were willing to participated in the research. The informative value of the research is also limited by the fact that the results (due to various reasons) express only the view of teachers, which may differ from the real situation.

The choice of the way for the creation of clusters of the elementary schools may limit the results as well, because the outcoming groups from the clustering depend partly also on the method.

Important limits of research could also result from the ambiguity of the concept of EE itself. It is possible that teachers may have included in their responses activities that do not meet the objectives of EE or, conversely, did not have included activities that meet these objectives, even though they are not called as EE.

## 5. Conclusions

This research is the first comprehensive study primarily focused on the implementation of CCSEE in terms of the representation of individual subjects at Czech elementary schools. Results show that CCSEE is implemented at most Czech schools through most of existing subjects, but their representation and participation rates vary considerably across schools.

Approximately 18% of schools involved in our research have a separate subject dedicated to EE, which in some schools is dominant in terms of achieving CCSEE objectives, elsewhere it is only one of the subjects that fulfill these goals.

According to respondents, the subjects taught at Stage 1 are mostly represented by the elementary teaching, basic biology and homeland studies (school subjects focused on basic natural principles and their integration into the context of near neighbourhood of pupils. The relatively balanced role of these subjects in meeting CCSEE objectives at Stage 1 was also confirmed by the results of cluster analysis. The situation at the Stage 2 is a little more varied. However, similarly oriented subjects as biology and geography, also play a dominant role in fulfilling CCSEE objectives.

In addition to schools where the CCSEE goals are fulfilled dominantly by biology and geography (or are supplemented by a separate environmentally focused school subject), the results of cluster analysis have shown that other models of CCSEE implementation can exist at Czech elementary schools in practice. A more frequent case is the division of this role among a wider range of science subjects (chemistry, physics and mathematics, or health education, in addition to [basic] biology and/or geography), with less common subjects in almost all subjects, including artistic and practical ones, social sciences, languages, etc.

Although the implementation of Framework Educational Programs through CCSEE has reinforced the possibility of implementing EE in different subjects, including less traditional ones, the results of the survey show that a wider range of subjects is used only sporadically for this. We consider this finding a significant challenge for discussion.

From the geographical education point of view, the results are important especially as a confirmation of the importance of geography in the fulfillment of the objectives of the EE, respectively CCSEE. The fact that geography is one of the most important school subjects in terms of fulfilling these goals needs to be reflected more in particular in the preparation of future teachers of geography and in the further training of teachers, but also in textbooks and other didactic aids production, while specifying the expected outputs, evaluation of realized curriculum and its results, or in preparation of field competitions (for example Geographical Olympiad).

In addition to confirming the importance of geography for the implementation of EE topics (mentioned above), we consider the main result of our research to confirm the ability to meet the goals of EE through all school subjects. It demonstrates the usefulness of the concept of EE as a cross-curricular theme. Another important conclusion of our study, however, is the finding that the implementation of EE topics in many subjects is rather weak and occurs only in a relatively small number of asked schools.

During the processing of the results, several new questions emerged (see Table 4). Let these questions are taken as a contribution to the next discussion and as incentives for further research.

Tab. 4 Proposal of research questions for further research.

| |
|---|
| – Which subjects do pupils associate with EE most often? |
| – Which forms of teaching predominate in the implementation of EE in individual subjects? |
| – How different is the real concept of teaching EE topics compared to curricular documents? |
| – To what extent is it appropriate to teach EE as a separate subject (especially in terms of meeting the objectives of EE)? |
| – How are teachers of various approbations prepared for the implementation of EE topics? |
| – How EE implementations vary in different countries (international comparison)? |
| – Which EE implementation models can be considered as inspiring examples of good practice? |

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## References

Adedayo, A., Olawepo, J. A. (1997): Integration of environmental education in social science curricula at the secondary school level in Nigeria: Problems and prospects. Environmental Education Research 3(1), 83–93, https://doi.org/10.1080/1350462970030107.

Aikens, K., Mckenzie, M., Vaughter, P. (2016): Environmental and sustainability education policy research: A systematic review of methodological and thematic trends. Environmental Education Research 22(3), 333–359, https://doi.org/10.1080/13504622.2015.1135418.

Bartoš, J., Matějček, T. (2015): Rozvíjení environmentálních postojů z pohledu učitelů na 2. stupni základních škol. Envigogika 10(2), https://doi.org/10.14712/18023061.475.

Bowers, C. (2010): How language limits our understanding of environmental education. Environmental Education Research 7(2), 141–151, https://doi.org/10.1080/13504620120043144.

Campos, H. G. (2013): La música y lo ambiental. Decisio, 12(34), 52–58.

Činčera, J. (2005): Environmentální výchova. Ale jaká? Pedagogická orientace 15(3), 17–24.

Činčera, J. (2011): Doporučené očekávané výstupy pro environmentální výchovu. Envigogika 6(2), https://doi.org/10.14712/18023061.59.

Činčera, J. (2013a): Střediska ekologické výchovy mezi teorií a praxí. Praha, Brno: Agentura Koniklec, Brontosauří ekocentrum Zelený klub, Masarykova univerzita.

Činčera, J. (2013b): Paradigmatická proměna domácího pojetí environmentální výchovy. Pedagogika 63(2), 182–197.

Činčera, J. (2014): Environmentální výchova: cesty a křižovatky. Trenčín: Špirála.

Činčera, J., Jančaříková, K., Matějček, T., Šimonová, P., Bartoš, J., Lupač. J., Broukalová, L. (2016): Environmentální výchova z pohledu učitelů. Brno: Masarykova Univerzita, BEZK, Agentura Koniklec.

Daňková, L. et al. (2009): Analýza stavu environmentálního vzdělávání, výchovy a osvěty. Praha: Pavučina.

Dechano, L. M., Shelley, F. M. (2004): Using sports to teach geography: Examples from Kansas City. Journal of Geography 103(5), 185–191, https://doi.org/10.1080/00221340408978599.

Dielman, H. (2013). El arte en la educación para la sustentabilidad. Decisio, 12(34), 11–16.

Farmer, J., Knapp, D., Benton, G. M. (2007): An elementary school environmental education field trip: Long–term effects on ecological and environmental knowledge and attitude development. Journal of Environmental Education 38(2), 33–42, https://doi.org/10.3200/JOEE.38.3.33-42.

Ferguson, T. (2008): 'Nature' and the 'environment' in Jamaica's primary school curriculum guides. Environmental Education Research 14(5), 559–577, https://doi.org/10.1080/13504620802345966.

Ferstl, R., Parkan, F. (2007): Environmentální výchova ve výuce dějepisu. Metodika pro 2. stupeň ZŠ a víceletá gymnázia. Praha: Univerzita Karlova, Pedagogická fakulta.

Florentina, M., Barbu, M. (2015): An inter-disciplinary approach in teaching geography, chemistry and environmental education. Procedia – Social and Behavioral Sciences 180(1), 660–665, https://doi.org/10.1016/j.sbspro.2015.02.175.

Gavora, P. (2010): Úvod do pedagogického výzkumu. Brno: Paido.

Godemann, J. (2008): Knowledge integration: A key challenge for transdisciplinary cooperation. Environmental Education Research 14(6), 625–641, https://doi.org/10.1080/13504620802469188.
Green, J. (Eds.). (2018): The Environmental Curriculum – Opportunities for Environmental Education across the Secondary Curriculum Key Stages 3 and 4. Bath, NAEE (UK).
Halocha, J. (2008): Geography in the frame: Using photographs. Teaching Geography, 33(1), 19.
Grodzińska-Jurczak, M. (2004): Forum: Environmental Education in Poland: Its Present Status. International Research in Geographical and Environmental Education 13(3), 251–257, https://doi.org/10.1080/10382040408668519.
Howard, P. (2010): Pedagogy and the poetic: Nurturing ecological sensibility through language and literature. Canadian Journal of Environmental Education 15(1), 185–197.
Chráska, M. (2007): Metody pedagogického výzkumu. Praha, Grada.
Jančaříková, K. (2009): Hledání optimální podoby realizace environmentální výchovy na prvním stupni ZŠ. Envigogika 4(1), https://doi.org/10.14712/18023061.36.
Jeřábek, J., Tupý, J. (Eds.). (2007): Rámcový vzdělávací program pro základní vzdělávání. Praha: Výzkumný ústav pedagogický.
Jurmu, M. C. (2005): Implementing musical lyrics to teach physical geography: A simple model. Journal of Geography 104(4), 179–186, https://doi.org/10.1080/00221340508978633.
Kelcová, M. (Eds.) (2009): Štátny vzdelávací program Environmentální výchova (Prierezová téma). Štátny pedagogicky ustav.
Kubrická, J., Hromádka, Z. (2015): Environmentální prvky v učebnici anglického jazyka. Envigogika 10(4), https://doi.org/10.14712/18023061.488.
Kučera, Z. (2012): Obraz jako zdroj rozmanitých informací. Geografické rozhledy 21(3), 18–20.
Lustyantie, N. (2015): Environmental education in the language and literature learning in elemetary education. International Journal of Research Studies in Education 4(3), 4–12, https://doi.org/10.5861/ijrse.2015.991.
Máchal, A. (2000): Průvodce praktikou ekologickou výchovou. Brno: Rezekvítek.
McNaughton, M. J. (2004): Educational drama in the teaching of education for sustainability. Environmental Education Research 10(2), 139–154, https://doi.org/10.1080/1350462042000198140.
Melichar, J., Hamerská, G., Fořtová, P. (2006): Soubor matematických úloh pro 1. stupeň základní školy – environmentální výchova. Ústí nad Labem: Univerzita J. E. Purkyně v Ústí nad Labem, Pedagogická fakulta.
Mwendwa, B. (2017): Learning for Sustainable Development: Integrating Environmental Education in the Curriculum of Ordinary Secondary Schools in Tanzania. Journal of Sustainability Education 12, https://doi.org/10.25073/0866-773X/65.
Nam, S. J. (1995): Environmental Education in Primary and Secondary Schools in Korea: current developments and future agendas. Environmental Education Research 1(1), 109–122, https://doi.org/10.1080/1350462950010109.
Navrátil, O. (2012): Prostor mezi environmentálním uměním a výchovou. Envigogika 7(2), https://doi.org/10.14712/18023061.72.
Palivec, Z. (2013): Průřezové téma Environmentální výchova ve výuce fyziky (Diplomová práce). České Budějovice: Jihočeská univerzita, Pedagogická fakulta.
Parkinson, A. (2009): Think inside the box. Miniature landscapes. Teaching Geography 34(3), 120–121.
Pastorová, M. et al. (2011): Doporučené očekávané výstupy: Environmentální výchova v základním vzdělávání – metodická podpora. Praha: Výzkumný ústav pedagogický.
Pavlátová, V. (2019). Dětská pojetí vybraných environmentálních fenoménů u žáků 1. a 2. stupně základní školy. Envigogika 14(1), https://doi.org/10.14712/18023061.585.
Quigley, C. F., Miller, Z. D., Dogbey, J., Che, M. S., Hallo, J. (2014): No one should destroy the forest: Using photo-based vignette interview to understand Kenyan teachers views of the environment. International Journal of Science Education 36(17), 2937–2957, https://doi.org/10.1080/09500693.2014.940024.
Ruda, A. (2010): Adjektivum „environmentální“ jako zaklínadlo geografického vzdělávání. In: Geografie pro život ve 21. století. In: Šumberová, M.: Sborník příspěvků z XXII. sjezdu České geografické společnosti pořádaného Ostravskou univerzitou v Ostravě 31. srpna – 3 září (s. 400–407). Ostrava: Ostravská univerizata v Ostravě.
Ryplová, R., Reháková, J. (2011): Přínos badatelsky orientovaného vyučování (BOV) pro environmentální výchovu: případová studie implementace BOV do výuky na ZŠ. Envigogika 6(3), https://doi.org/10.14712/18023061.65.
Řezníčková, D. (2009): The transformation of geography education in Czechia. Geografie 114(4), 316–331, https://doi.org/10.37040/geografie2009114040316.
Řezníčková, D., Boháček, T. (2010): Čtení fotografií optikou geografa. Geografické rozhledy 19(4), 18–19.
Sánchez, D. M. G. (2013): De la tierra evocada a la tierra presentada. La fotografía como medio para la educación ambiental. Decisio 12(43), 46–51.
Siwek, T. (2010): Současná geografie očima českých geografů. Geografie 115(4), 361–376, https://doi.org/10.37040/geografie2010115040361.
Soetaert, R., Top, L., Eeckhout, B. (1996): Art and literature in environmental education: Two research projects. Environmental Education Research 2(1), 63–70, https://doi.org/10.1080/1350462960020106.
Ssozi, L. (2012): Embedding Education for Sustainability in the School Curriculum: the contribution of Faith Based Organisations to Curriculum Development. Journal of Sustainability Education, vol. 3.
Stokes, E., Edge, A., West, A. (2001): Environmental education in the systems of the European Union. Final Report. London: Environment Directorat-General of the European Commission.
Sýkora, V. (2007): Environmentální výchova v práci učitele matematiky. Praha: Univerzita Karlova, Pedagogická fakulta.

Trojanová, A. (2009): Využití land artu ve výuce. Geografické rozhledy 18(4), 20.
Váňová, H., Tichá, A., Herden, J. (2007): Environmentální výchova ve výuce hudební výchovy v základním vzdělávání. Praha: Univerzita Karlova, Pedagogická fakulta.
Verma, G., Dhull, P. (2017): Environmental education as a subject in schools. International Journal of Advanced Research 5(8), 1547–1552, https://doi.org/10.21474/IJAR01/5214.
Vočadlová, K. (2009): Obrazy jako archiv přírodních změn. Geografické rozhledy 18(5), 24–26.
Wals, A. E. J., Brody, M., Dillon, J., Stevenson, R. B. (2014): Convergence between science and environmental education. Science 344(6184), 583–584, https://doi.org/10.1126/science.1250515.

# Investigations and monitoring of deep-seated rock slides in feasibility studies for dam reservoirs

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**ABSTRACT**
This contribution presents a brief overview of investigation and monitoring methods which may help to detect and localise deep-seated rock slides in the surroundings of reservoirs. The identification and localisation of critical slopes and ancient/pre-existing rock slides in the early stage of a project (i.e. feasibility study) is essential to avoid endangering the planned infrastructure project and if necessary, adapting the project. The knowledge about deep-seated rock slides has increased over the decades. In particular, new insight was gained about rock slide geometry, kinematics, temporal deformation behaviour, hydrogeology and geomechanics. Major technical and methodical improvements have been made in recent years concerning the successful application of terrestrial and airborne based remote sensing tools to measure 2D/3D slope deformations on surface and to develop high-resolution digital terrain models for detailed geomorphological-geological mapping and geological-geometrical model design.

**KEYWORDS**
deep-seated rock slides; in-situ investigation; monitoring; dams; reservoirs

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## 1. Introduction

Worldwide, active and inactive deep-seated rock slides are frequently observed in low-strength rock masses such as foliated metamorphic rocks (Riemer 1995). Generally, these rock slides often affect entire slopes, reach volumes of millions of $m^3$, and usually belong to the compound type of rock slides (Hungr et al. 2014). Active or reactivated over longer periods of time slowly moving rock slides can adversely affect infrastructure such as high- and railway lines, reservoir dams, pressure pipes, pipelines, and settlements due to differential and localised displacements of the ground surface and subsurface (Huang et al. 2016; Gu et al. 2017). Because of the typical slow base activity of many rock slides, they are sometimes either not recognised or their damage potential is underestimated. Even for slow movements the damage can be considerable and the life-cycle of a structure can be reduced, accompanied with a great economic loss (Barla et al. 2010; Petley 2013). In some rare cases there is also the danger of total slope failure and acceleration to extremely high velocities, which in the worst case, can cause dramatic consequences. Reactivation of ancient or pre-existing rock slides or parts thereof is frequently observed and can be triggered by various factors comprising e.g. reservoir infilling or drawdown, toe erosion by flooding, extreme precipitation and snow melt, dynamic loading by earthquakes, construction of a cut slope, or loading the slope in the upper area. Due to the large volume the stabilisation of deep-seated rock slides is difficult, very costly or not feasible at all. In many cases mitigation measures based on groundwater management due to the construction of drainage drifts are possible but the success to reduce the deformation rate is not always guaranteed. Therefore, the identification of critical slopes and ancient rock slides which can endanger the planned infrastructure in an early stage of the project (i.e. feasibility study) is essential. During this early phase a cost-effective adaptation of the project may be possible in many cases.

In the past, thousands of dams and reservoirs were built worldwide and according to the global reservoir and dam database (GRanD) more than 7,000 dams greater than 15 m in height or with a reservoir volume of more than 0.1 $km^3$ are documented (see Fig. 1, Lehner et al. 2011). In addition, about 3,700 hydropower reservoirs and dams (FHReD) are under construction or in an advanced planning stage. The large number of new dam and reservoir projects for different utilisations require comprehensive planning and hazard assessment of the reservoir slopes, especially early when a feasibility study is performed. This may avoid future landslide induced construction and operation problems.

This contribution presents a brief overview of data and methods which can help to detect, localise, characterise and assess ancient deep-seated rock slides in the surroundings of large dam reservoir projects. In addition, it supports the planning of additional in-situ investigation and monitoring campaigns which are

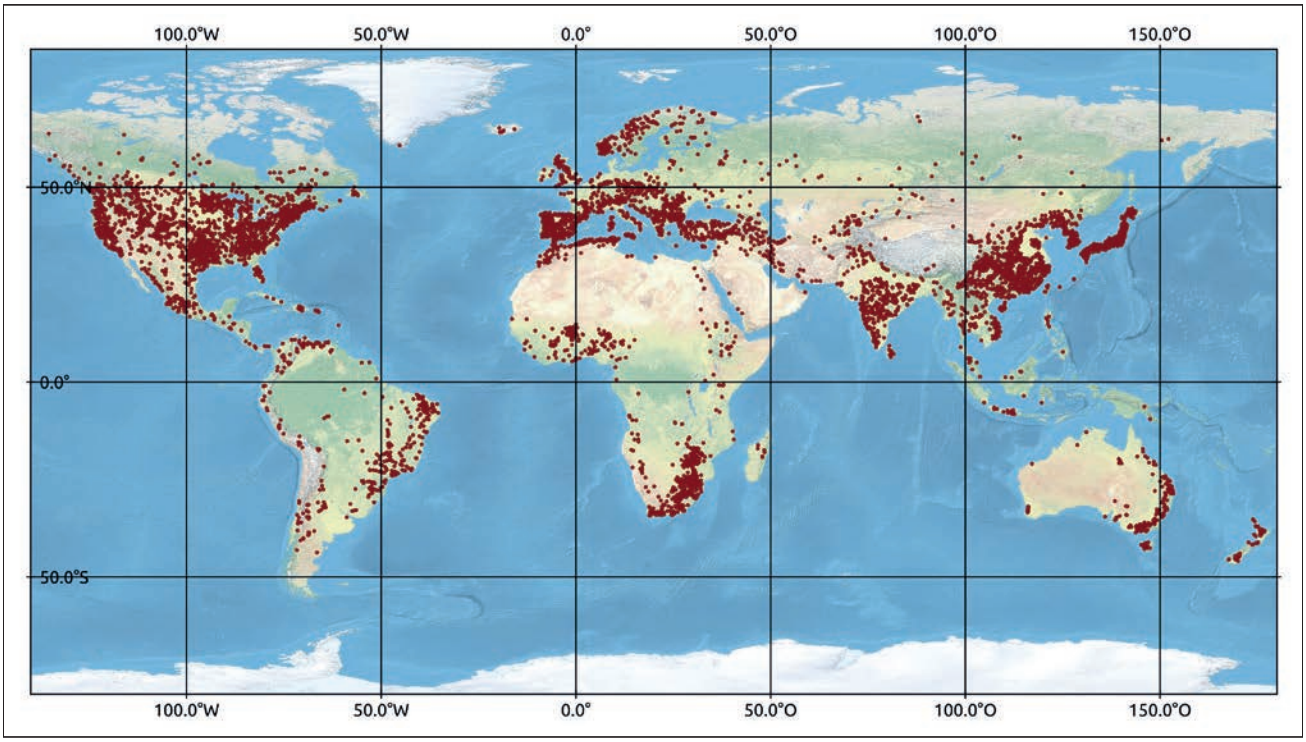


Fig. 1 Global distribution of (dam) reservoirs larger than 0.1 $km^3$ (red dots, Global Reservoir and Dam Database V1.3 [GRanD, globaldamwatch.org], data from Lechner et al. 2011, earth map by Natural Earth. Free vector and raster map data @ naturalearthdata.com).

fundamental for subsequent slope stability analyses and hazard assessments.

## 2. Geodata for rock slide identification and localisation

In many cases, deep-seated rock slides are not obvious because of their low activities and vegetation cover. A multi-disciplinary approach is required to analyse both size/geometry as well as the movement behaviour of the rock slide consequently. Before beginning with a detailed and expensive field investigation campaign a comprehensive desk study using a geographical information system (GIS) is useful. Therefore, high-resolution digital elevation or terrain models (DEM, DTM) usually obtained from airborne laser scanning (ALS) campaigns and supplemented by multi-temporal high-quality aerial images from airborne and UAV campaigns are needed for the project area. Because of the importance of high-resolution DEMs for landslide analyses these data should be a standard nowadays (Tab. 1). However, there are still recently published studies with reference to landslides and reservoirs with no high-quality DEMs being presented, but rather a focus is given on linear subsurface investigations by boreholes. Only by combining both, geomorphological-geological mapping on surface based on high-resolution DEMs (obtained by laser scanning or photogrammetry) and subsurface investigations a proper three-dimensional rock slide model can be obtained. Commonly, deep-seated rock slides are characterised by the formation of different slabs with variable sizes, movement velocities, and internal shear zones (Fig. 2). Geomechanically, these shear zones are of primary concern for stability analyses or predictions relating to future deformations. The material is the result of cataclasis and fragmentation of the rock during shearing and possesses soil-like mechanical and hydraulic properties. Stability and deformation behaviour of the rock slides is influenced by hydro-mechanical properties of these zones. Scarps mapped at ground surface should be correlated with basal and internal shear zones encountered in the subsurface (e.g. in drillings) to get a better understanding of the dimensions and geometry of the rock slide mass. GIS processed DEMs

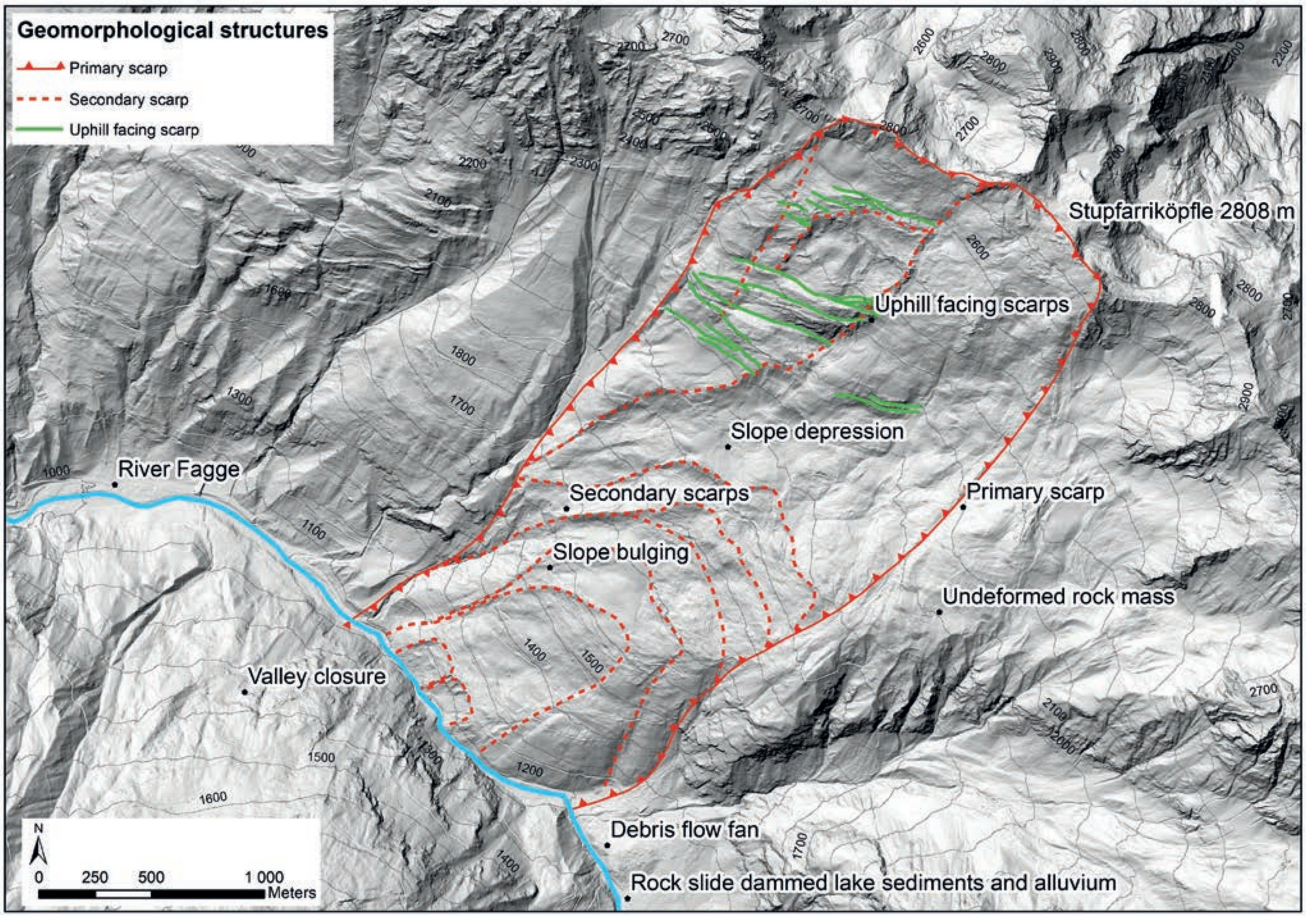


Fig. 2 Hillshade of a deep-seated rock slide in metamorphic rock showing the main, secondary and uphill facing scarps of sliding slabs, and rock slide dammed lake sediments in the upstream (Stupfarri rockslide in the Kaunertal valley, Austria, DEM source: TIRIS – Amt der Tiroler Landesregierung).

Tab. 1 Types of geodata for rock slide identification and localisation.

| Type of data | Description | Method |
|---|---|---|
| Digital elevation / terrain model | High-resolution DEM/DTM with a raster size ≤ 1 m | Airborne and terrestrial laser scanning, UAV – based photogrammetry |
| Ortho-images | Digital high-resolution ortho-images, raster size < 20 cm, ideally multi-temporal | Optical imagery by plane, helicopter or UAV |
| Optical satellite images | Optical imagery with a resolution of 10–60 m over land and coastal waters, e.g. Sentinel 2, for a general survey only | Optical imagery satellite based |
| Topographic maps | Ground relief, drainage, forest cover, administrative areas, populated areas, transportation routes and facilities, man-made features | Cartographical mapping methods |
| Regional geological maps | Pre-existing maps of the region (Scale 1:50,000 to 1:200,000) | Geological field mapping |
| Detailed geological maps | Detailed geological mapping of the project area (Scale 1:1000 to 1:10,000) | Geological field mapping |
| Landslide inventory maps | Pre-existing maps of landslide types and features according to accepted classification systems | Combination of desk study and field survey |
| Historic records | Age data and chronology of landslides | Field survey, archives, age-dating |

e.g. one-light-source or multi-directional hillshades, applying advanced filtering techniques, slope roughness and inclination are the basis to perform accurate and detailed geomorphological and geological terrain analyses and mappings (Reuter et al. 2009). Primary aim of a desk study is to detect structures and slope geometries which resulted from gravitational slope deformations. In particular, multi-directional hillshades highlight the terrain surface very plastically. Typically, primary and secondary scarps, uphill facing scarps, extensional cracks, slope bulging and depressions, the boundary between the rock slide and the undeformed rock mass, increased fracture density and rock mass loosening, etc. are clear indicators for deep-seated slope movements (see Fig. 2). Additionally, optical satellite images, pre-existing geological and topographical maps can be analysed during the desk study with the purpose of planning the field survey.

## 3. Geological-geomorphological field survey

The subsequent geological-geomorphological field survey is based on the high-resolution DEMs and high-quality ortho-images and include the verification of the observations from the desk study as well as the field-based mapping of geological (e.g. soil, rock, faults, joint network, springs and streams) and geomorphological features which are not obvious in remote sensing data (Table 1). According to the mapping results the areal extent of a rock slide (i.e. head scarps, lateral flanks and further landslides features, see WP/WLI UNESCO Working Party on World Landslide Inventory 1993) and surface boundaries of slabs are determined which enable a first and rough estimation of the thickness. The spatial extension, the shape of the primary scarps and the internal structures of the rock slide provide information about the kinematics (e.g. translational, rotational, compound failure). Mapping of all features (including slabs) is essential because of the complex geometry i.e. slab formation and movement behaviour of some rock slides (e.g. Zangerl et al. 2010). Further, it allows the classification of the evolution and activity stage in some cases.

## 4. Deformation monitoring

The choice of the investigation methods to monitor the deformation behaviour of a rock slide depends on project requirements and local circumstances. Depending on the particular project phase, surface and/or subsurface measurements are needed which again should be performed continuously (e.g. to detect acceleration phases and their triggers) or episodically only. The slow movement rates of only a few millimetres or centimetres per year of some rock slides in combination with small time constraints given by many early project specifications are the reasons why accurate deformation monitoring systems with low detection limits are required. Conclusively, depending on the monitoring method, rock slide velocity and size, a sufficiently long measuring period, sometimes more than a year, need to be planned to obtain significant data. For example, the detection of slope displacements for a 1000 m high rock slide slope with an annual displacement rate of mm to a few cm is challenging when reliable deformation data above the measuring accuracy should be attained in a short period. For some projects, there is a mismatch between the time span prescribed for project planning and the time span needed to get reliable information about the rock slide activity. Furthermore, it is important to note that the activity behaviour of a rock slide can change during the live-cycle of an infrastructure and the occurrence of unexpected acceleration phases should be considered.

Large rock slides are a challenge for monitoring due to the large measuring distances, but recent developments of remote sensing techniques provide new useful tools (Tab. 2). Satellite-based radar interferometry (InSAR) can be applied to measure areal slope deformations when vegetation cover is low and slope exposure is ideal with regard to satellite movement (Casagli et al. 2017; Zhang et al. 2013). A particular advantage of this remote sensing method is the possibility to detect deformations as far back as to the nineties, since from that time radar-images are available.

For larger rock slide velocities (i.e. decimeters to metres per year) airborne-based photogrammetric and laser scanning methods are available should be applied to get dense point clouds and high-resolution DEMs. If multi-temporal scanning and imaging was done displacement maps can be obtained. New advanced methods based on image processing and feature tracking of terrain breaklines enable the extraction of 3D displacement vectors of the surface (Fey et al. 2015; Jaboyedoff et al. 2012; Razak et al. 2011).

Terrestrial radar interferometry (TRI, GB-InSAR) can also be applied by installing the system on the ground mostly opposite of the slope to be monitored. The radar interferometry method is able to detect and quantify deformations from repeat monitoring setups of extremely slow moving rock walls and slopes (millimetres per year) to slow/moderate movements (metres per day) acquired during episodic and continuous measurement campaigns (Bardi et al. 2014; Caduff et al. 2015; Crosta et al. 2013; Cruden and Varnes 1996).

Terrestrial laser scanning (TLS) represents a further useful method for spatial change detection analyses and deformation monitoring (Fey and Wichmann 2017; Jaboyedoff et al. 2012). The long-range TLS method enable contact-free measurements of the terrain, and depending on the distance, is able to measure slope deformations of decimetres per year. Although TLS is less accurate than GB-InSAR, it has the advantage that measurements can also be carried out in forested and vegetated areas by getting the terrain surface recorded.

UAV-based photogrammetry is a cost- and time-effective method which can be applied to monitor rock slide deformations in a sparsely vegetated area by the acquisition of multi-temporal high-resolution images (Cardenal et al. 2008). Image matching and correlation algorithms deliver time-series of surface deformation models which enable the determination of movement directions, velocity fields, volume balances and geomorphological terrain changes (Casagli et al. 2017). Although this method is fast and inexpensive, a major disadvantage is that areas with dense vegetation cover cannot be successfully recorded.

Traditional total station or differential global positioning system (GNSS) measurements are reliable methods to obtain 3D displacement vectors of individual targets installed on a rock slide (Carla et al. 2019). When these systems are automated they form robust permanent monitoring and warning systems. Generally, pointwise inclination data of 3D displacement vectors are particularly useful to develop preliminary kinematical models of a rock slide (i.e. rotational or planar sliding mechanism).

Results from exploration campaigns confirmed that rock slide deformation accumulates primarily along basal and internal shear zones (Noveraz 1996; Zangerl et al. 2015). Detection of these shear zones is crucial to establish a sound geometrical model and to determine the extension of the rock slide into the depths. Thus line-shaped measurements along a vertical borehole by inclinometer devices, installed for episodic or continuous (i.e. in-place systems) measurement are needed (Stark and Choi 2008). During installation a solid mechanical infill between the inclinometer tube and the fractured rock mass is required to transmit the shear displacements to the tube and to obtain accurate measurements. In order to get interpretable measurement results sufficient long time intervals should be planned between the baseline and the follow-up measurements for very slow and deep-seated rock slides. Incorrect conclusions of measured data are quite common, especially for deep installations, and therefore a critical assessment considering the geological model and the application of systematic error correction methods is recommended (Mikkelsen 2003; Willenberg et al. 2003).

**Tab. 2** Selected slope deformation monitoring methods.

| Method | Description |
|---|---|
| Airborne laser scanning (ALS) | Survey by UAV or aircraft, dense point clouds, area-based data, can penetrate vegetation cover, detection of displacements in the range of dm to m |
| Terrestrial laser scanning (TLS) | By tripod from ground, dense point cloud, area-based data, can penetrate vegetation cover, detection of displacements in the range of cm to dm |
| Satellite-based InSAR | Areal displacement, sensitive to vegetation cover, detection of displacements in the range of cm to dm |
| Terrestrial radar-interferometry | Areal displacement, sensitive to vegetation cover, permanent monitoring, detection of displacements in the range of mm to m |
| UAV-Photogrammetry | Areal displacement, sensitive to vegetation cover, detection of displacements in the range of cm to dm |
| GNSS, Tachymetry, Levelling | Manually or automatically, pointwise measurement with reflectors, 3D displacement vectors, detection of displacements in the range of mm to cm |
| Inclinometer | Drillings and tube installations needed, exact detection and localisation of active shear zones (rupture planes), detection of displacements in the range of mm to cm, rapid loss of the inclinometer device through shearing of the borehole, expensive, preliminary rock slide model required to define borehole location and depth correct, detection of displacements in the range of mm to dm |

## 5. Geological-geotechnical subsurface characterization

Subsurface in-situ investigations are usually not part of an initial feasibility study but may become important when potential dam foundation sites need assessment concerning the occurrence of ancient deep-seated rock slides. Therefore, a more detailed study is required to investigate the geological and hydrogeological characteristics of rock slides. Although costly, subsurface investigations based on core drillings with borehole loggings in combination with inclinometer measurements and/or investigation drifts are required to improve the rock slide model obtained solely from surface data and to localise the basis/thickness of the rock slide mass and shear zones. If the rock slide is inactive or extremely slow inclinometer measurements are not able to localise shear zones, at least not within a reasonable period of time. Under such conditions a detailed geological core logging is needed provided that the drilling quality is high and the core recovery high. Core drillings into deep-seated rock slides are technically challenging and should be done by experienced drilling companies to maximize the gain in knowledge. Fluctuations of the rock quality designation values (RQD) between low and high, increased fracture densities, weathering and coating of fracture surfaces, and sections of fault-zone like totally crushed material (clay to gravel grain fraction) are typical characteristics of rock slide masses (Zangerl et al. 2010, 2014, 2015). Very low RQD values are usually observed around the basal contact or in the surrounding of internal shear zones. It should be noted that the degree of internal rock mass fragmentation and loosening of a rock slide is often related to the accumulated amount of slope displacements.

Geophysical investigations based on advanced data processing allows a further improvement of the geological-geometrical model. Seismic methods by combining reflection, refraction and tomography provide usually meaningful results of the subsurface, but require a qualitative interpretation of the results, ideally by joint analyses with borehole data (Brückl and Brückl 2006; Brückl et al. 2006; Frei and Keller 2000).

## 6. Hydrogeological characterization

If a dam reservoir is planned in a rock slide prone area information about the hydrogeological situation is particularly mandatory. This is especially true since the reservoir may influence the groundwater flow system within the slope differently (Strauhal et al. 2016; Zangerl et al. 2015). Monitoring of piezometric heights in boreholes is suggested to assess groundwater flow systems and time-depending pore pressure distributions, as well as the hydro-mechanical coupled characteristics (Crosta et al. 2014). Typically, the complex and heterogeneous hydrogeological situation of a rock slide suggests the installation of several monitoring piezometers at various locations in the slope (Moore 1999). Groundwater may occur in highly fractured sections which can hardly be predicted in many cases. Furthermore, hydrogeological rock mass parameters such as hydraulic conductivity or storativity values at in-situ scale can be determined for example by borehole-based hydraulic packer tests, both for the bedrock and the rockslide mass. Again, a high number of tests is required because of the typically heterogeneous nature due to fracturing and fragmentation of deep-seated rock slides. These parameters are required to analyse and forecast the future impact of initial reservoir impounding and level fluctuations on slope behaviour. The detection of water barriers with low hydraulic conductivities, such as compacted till covers or thick fault gouge-shear zones is highly relevant in this context, given that they could have a strong impact on time-depending groundwater fluctuations.

## 7. Discussion and Conclusion

In the future the number of large-scale dam and reservoir projects will increase. Many of them will be planned in rock slide-prone areas. In an early planning stage comprehensive feasibility studies for dam reservoirs are essential to avoid stability problems of dam foundations or reservoir slopes. All the ancillary data and methods mentioned above focus on the detection and localisation of ancient i.e. pre-existing deep-seated rock slides which can adversely affect infrastructure in the surrounding of dam reservoirs. Experiences show that multidisciplinary approaches including high-resolution digital elevation models beside deformation models and instrumented core drillings are the basis for a successful identification and assessment. Data from geomorphological-geological surveys, surface and subsurface investigations, if possible, and deformation measurements are needed for a comprehensive feasibility study i) to identify, localise and map ancient rock slides and landslide-prone areas, ii) to establish preliminary geological-geometrical rock slide models by considering its complexity due to the formation of different slabs, iii) to assess the present activity of the rock slides, and iv) to provide data for subsequent more detailed planning and investigation. All these data form the basis for further project planning and risk assessments, whereby the importance of a high-resolution digital elevation model with a raster size <1 m must be emphasized. The early stage of a dam reservoir project is also ideal for hydrogeological, geomechanical and hydro-mechanical coupled numerical modelling (Alonso and Pinyol 2011). All of the abovementioned data should be implemented in detailed numerical models to analyse the potential impact of the first infillings, water level draw downs and later infillings of a planned reservoir on the pore pressure distribution and the resulting change in slope behaviour. Both stationary and transient modelling should be carried out because of the various filling stages of a reservoir. Despite the complex three-dimensional landslide geometries and heterogeneous and anisotropic characteristics, this step is usually done by two-dimensional models currently. Further developments in this context are expected in the future.

Deep-seated rock slides which were newly formed as first-time failures are not considered herein. Potential first-time slope failures are much more difficult to locate and the assessment of the spatial extent and thickness is therefore a challenge and require additional efforts and methodical approaches.

## References

Alonso, E. E., Pinyol, N. M. (2011): Landslides in reservoirs and dam operation. In: Dam Maintenance and Rehabilitation II, Romeo García et al. (eds.), 2nd International Congress on Dam Maintenance and Rehabilitation, Zaragoza, Spain, Taylor and Francis Group, London, 3–27, https://doi.org/10.1201/9780415616485-3.

Bardi, F., Frodella, W., Ciampalini, A., Bianchini, S., Del Ventisette, C., Gigli, G., Fanti, R., Moretti, S., Basile, G., Casagli, N. (2014): Integration between ground based and satellite SAR data in landslide mapping: The San Fratello case study. Geomorphology 223, 45–60, https://doi.org/10.1016/j.geomorph.2014.06.025.

Barla, G., Antolini, F., Barla, M., Mensi, E., Piovano, G., (2010): Monitoring of the Beauregard landslide (Aosta Valley, Italy) using advanced and conventional techniques. Engineering Geology 116, 218–235, https://doi.org/10.1016/j.enggeo.2010.09.004.

Brückl, E., Brückl, J. (2006): Geophysical models of the Lesachriegel and Gradenbach deep-seated mass movements (Schober range, Austria). Engineering Geology 83(1–3), 254–272, https://doi.org/10.1016/j.enggeo.2005.06.035.

Brückl, E., Brunner, F.K., Kraus, K. (2006): Kinematics of a deep seated landslide de-rived from photogrammetric, GPS and geophysical data. Engineering Geology 88, 149–159, https://doi.org/10.1016/j.enggeo.2006.09.004.

Caduff, R., Schlunegger, F., Kos, A., Wiesmann, A. (2015): A review of terrestrial radar interferometry for measuring surface change in the geosciences. Earth Surf. Process, Landforms 40, 208–228, https://doi.org/10.1002/esp.3656.

Cardenal, J., Mata, E., Perez-Garcia, J. L., Delgado, J., Andez, M., Gonzalez, A., Diaz-de-Teran, J. R. (2008): Close range digital photogrammetry techniques applied to landslide monitoring. International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences 37 (Part B8).

Carlà, T., Tofani, V., Lombardi, L., Raspini, F., Bianchini, S., Bertolo, D., Thuegaz, P., Casagli, N. (2019): Combination of GNSS, satellite InSAR, and GBInSAR remote sensing monitoring to improve the understanding of a large landslide in high alpine environment. Geomorphology 335, 62–75, https://doi.org/10.1016/j.geomorph.2019.03.014.

Casagli, N., Frodella, W., Morelli, S. et al. (2017): Spaceborne, UAV and ground-based remote sensing techniques for landslide mapping, monitoring and early warnin. Geoenvironmental Disasters 4(9), https://doi.org/10.1186/s40677-017-0073-1.

Crosta, G. B., di Prisco, C., Frattini, P. et al. (2014): Chasing a complete understanding of the triggering mechanisms of a large rapidly evolving rockslide. Landslides 11, 747–764, https://doi.org/10.1007/s10346-013-0433-1.

Cruden, D. M., Varnes, D. J. (1996): Land-slide Types and Processes. In: Turner, A. K. et al. (eds.), Landslides: Investigation and Mitigation, 36–75, Washington.

Fell, R., Hungr, O., Leroueil, S., Riemer, W. (2000): Geotechnical engineering of the stability of natural slopes, and cuts and fills in soil. GeoEng2000 – International Conference on Geotechnical and Geological Engineering, Aust. Geomech. Soc., Melbourne, Australia.

Fey, C., Rutzinger, M., Wichmann, V., Prager, C., Bremer, M., Zangerl, C. (2015): Deriving 3D displacement vectors from multi-temporal airborne laser scanning data for landslide activity analyses. GisSience and Remote Sensing 52, 437–461, https://doi.org/10.1080/15481603.2015.1045278.

Fey, C., Wichmann, V. (2017): Long-range terrestrial laser scanning for geomorphological change detection in alpine terrain – handling uncertainties. Earth Surface Processes and Landforms 42, 789–802, https://doi.org/10.1002/esp.4022.

Frei, W., Keller, L. (2000): Hybride Seismik – eine verbesserte Methode zur Verwertung des Aus-sagepotentials seismischer Daten. Bull. angew. Geol. 5(2), 229–236.

Gu, D. M., Huang, D., Yang, W. D. et al. (2017): Understanding the triggering mechanism and possible kinematic evolution of a reactivated landslide in the Three Gorges Reservoir. Landslides 14, 2073–2087, https://doi.org/10.1007/s10346-017-0845-4.

Huang, Q., Wang, J., Xue, X. (2016): Interpreting the influence of rainfall and reservoir infilling on a landslide. Landslides 13, 1139–1149, https://doi.org/10.1007/s10346-015-0644-8.

Hungr, O., Leroueil, S., Picarelli, L. (2014): The Varnes classification of landslide types, an update. Landslides 11, 167–194, https://doi.org/10.1007/s10346-013-0436-y.

Jaboyedoff, M., Oppikofer, T., Abellan, A., Derron, M. H., Loye, A., Metzger, R. (2012): Use of LIDAR in landslide investigations: A review. Natural Hazards, 61, 1–24, https://doi.org/10.1007/s11069-010-9634-2.

Lehner, B., Liermann, R. C., Revenga, C., Vörösmarty, Ch., Fekete, B., Crouzet, P., Döll, P., Endejan, M., Frenken, K., Magome, J., Nilsson, C., Robertson, J. C., Rodel, R., Sindorf, N., Wisser, D. (2011): High-resolution mapping of the world's reservoirs and dams for sustainable river-flow management. Frontiers in Ecology and the Environment 9(9), 494–502, https://doi.org/10.1890/100125.

Mikkelsen, P. E. (2003): Advances in Inclinometer Data Analysis. In: Symposium of Field Measurements in Geomechanics. Oslo, Norway, 555–567, https://doi.org/10.1201/9781439833483.ch73.

Moore, D. P. (1999): Rock slopes and reservoirs – lessons learned. Canada: 13. Annual Vancouver Geotechnical Society Symposium; Vancouver, BC (Canada), Vancouver Geotechnical Society, 1–18.

Noverraz, F. (1996): Sagging or deep-seated creep: fiction or reality? In: Senneset (Ed.), 7th International Symposium on Landslides. Balkema, Rotterdam, 821–828.

Petley, D. N. (2013): Global losses from landslides associated with dams and reservoirs, in: International Conference on Vajont 1963–2013: Thoughts and Analyses after 50 years since the Catastrophic Landslide, edited by: Genevois, R. and Prestininzi, A., Italian Journal of Engineering Geology and Environment, Book Series 6, 63–71.

Razak, K. A., Straatsma, M. W., van Westen, C. J., Malet, J.-P., de Jong, S. M. (2011): Airborne laser scanning of forested landslides characterization: Terrain model quality and visualization. Geomorphology 126(1–2), 186-200, https://doi.org/10.1016/j.geomorph.2010.11.003.

Reuter, H. I., Hengl, T., Gessler, P., Soille, P. (2009): Chapter 4 – Preparation of DEMs for geomorphometric analysis. Developments in Soil Science 33, 87–120, https://doi.org/10.1016/S0166-2481(08)00004-4.

Riemer, W. (1995): Keynote paper: Landslides and reservoirs. In: D. H. Bell (Ed), 6th International Symposium on Landslides, Christchurch, Balkema, Rotterdam, 1973–2004.

Strauhal, T., Loew, S., Holzmann, M., Zangerl, C. (2016): Detailed hydrogeological analysis of a deep-seated rockslide at the Gepatsch reservoir (Klasgarten, Austria). Hydrogeology Journal 24, 349–371, https://doi.org/10.1007/s10040-015-1341-3.

Stark, T. D., Choi, H. (2008): Slope inclinometers for landslides. Landslides 5, 339, https://doi.org/10.1007/s10346-008-0126-3.

WP/WLI UNESCO Working Party on World Land-slide Inventory (1993): Multilingual Landslide Glosary. The Canadian Geotechnical Society, BiTech Publishers Ltd. Richmond, Canada.

Willenberg, H., Evans, K. F., Eberhardt, E., Loew, S. (2003): Monitoring complex rock slope instabilities – correction and analysis of inclinometer/extensometer surveys and integration with surface displacement data. In: F. Myrvoll (ed.), 6th International Symposium on Field Measurements in Geomechanics, Oslo: Balkema, 393–400, https://doi.org/10.1201/9781439833483.ch52.

Zangerl, C., Eberhardt, E., Perzlmaier, S. (2010): Kinematic behaviour and velocity characteristics of a complex deep-seated crystalline rock slide system in relation to its interaction with a dam reservoir. Engineering Geology 112, 53–67, https://doi.org/10.1016/j.enggeo.2010.01.001.

Zangerl, C., Holzmann, M., Perzlmaier, S., Engl, D., Strauhal, T., Prager, C., Steinacher, R., Molterer, S. (2014): Characterisation and kinematics of deep-seated rock slides in foliated metamorphic rock masses. In: Lollino, G., Giordan, D., Thuro, K., Carranza-Torres, C., Wu, F., Marinos, P., Delgado, C. (eds.), Engineering geology for society and territory 2. Springer, Heidelberg, Germany, 571–577, https://doi.org/10.1007/978-3-319-09057-3_94.

Zangerl, C., Holzmann, M., Perzlmeier, S., Strauhal, T. (2015): Geomechanics and Hydrogeology of Deep-seated Rock Slides in the Surroundings of Large Reservoirs. In: The International Society for Rock Mechanics (ISRM), Proceedings of the 13th International Congress of Rock Mechanics, ISRM Congress 2015 – Innovations in Applied and Theoretical Rock Mechanics.

Zhang, D., Wang, G., Yang, T. et al. (2013): Satellite remote sensing-based detection of the deformation of a reservoir bank slope in Laxiwa Hydropower Station, China. Landslides 10, 231–238, https://doi.org/10.1007/s10346-012-0378-9.

# Reading assignments in geography instruction: a (non-)functional part of a teacher's approach

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**ABSTRACT**
This article presents results of the research focused on reading assignments in geography teaching. The approaches of Czech geography teachers to reading assignments are explored by using the method of grounded theory. Altogether 22 teachers from secondary school participated in the research. The typology of teacher approaches and the identification of factors that influence the teacher's inclusion of reading assignments in the disciplines was developed. The teachers' attitudes show that their preferences in the general notion of (not only) geography are reflected, and that the constructs of their beliefs or personal theory play an important role. These factors can take on both supportive and limiting forms, depending on the context that is shown in the article with the aid of a paradigmatic model. The results are situated in relation to the teacher's professional learning.

**KEYWORDS**
reading assignments; geography; professional knowledge; vision and action; teacher's beliefs; grounded theory; secondary school; Czechia

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## 1. Reading in geography: a typology of teacher's approach

The topic of reading literacy of students is frequently discussed in the academic community. Our article focuses on reading in the disciplines or on the reading of students in subjects beyond the Czech language. We examine how teachers approach the inclusion of reading in the teaching of geography and which factors influence their approach.

Czech academic literature lacks a developed discussion of reading in the disciplines. Czech academic interest focuses primarily on pre-literacy and beginning literacy. Havlínová (2016) summarizes developments in these areas. Research examining the current state and development of literacy among students from the second level of elementary schools and secondary schools is less frequent. Radváková's (2015) article exploring secondary school student reading is one example.

In Anglo-Saxon countries (UK, USA, Australia, New Zealand) there are a number of papers that discuss the benefits of reading (and writing) in developing knowledge and skills in various school's subjects. This is due to the fact that the deliberate development of reading in the disciplines began to be supported as early as the 1920s (Shanahan, Shanahan 2012). Since about the early 1990s, there have been some changes in the concept and directions of research relating to reading in the disciplines (Shanahan 2013). The publication of Shanahan and Shanahan's (2008) article, in which they present a model of disciplinary literacy, can be viewed as a turning point. It is characterized by a shift from the simple using of general reading strategies (content area reading) towards the more content-specific readings that comprise disciplinary literacy. The authors argue that general reading strategies should be adapted to the various disciplines in such a way as to help students not only to read, but also to think, write, communicate and act in a way that reflects the specifics of the discipline. The aim of such teaching is not a state in which each student achieves the same level of reading, respectively disciplinary literacy in different subjects. Rather, the object is for students, regardless of their varied interests (some are more into geography, others history and others are musically inclined), to be able to read, write and think independently in various disciplinary situations.

The existence of this ongoing academic debate in Anglo-Saxon countries about why and how to utilize reading in subjects does not mean that there is not room for improvement in school practices. Many teachers use reading in the disciplines only on rare occasions, taking a skeptical stance to the method (e.g. Moje 2008). Nonetheless, the existence of various curricular documents (e.g. Common Core State Standards 2010; Next Generation Science Standards 2013; Common Core English Language Arts and Geography Connection 2013; The New Zealand Curriculum 2009) that systematically detail requirements for reading in the disciplines has a significant impact on the implementation of reading in subject areas. This is partly because teachers have standards with a obligatory or recommended nature. This emphasis is also reflected in changes in teacher education (Gilles et al. 2013). A consistent theme throughout the cited sources focused on how teachers could develop or are developing the literacy of their students, because reading – and writing as well – is a natural part of the discipline in question. The question "why" read in various subjects no longer receives the emphasis; it is more about "how" to read in the subjects.

If students are to meet and learn from a variety of texts in the school's subjects, then they need appropriate support or guidance from the teacher. We agree with Hattie (2012) that, while teaching students depends on many factors, the teacher – his or her beliefs and grasp of the responsibility for student learning along with corresponding actions – has the greatest instructional impact (Hattie 2012). We expect that students make the greatest progress as their teachers view themselves as those that adjust teaching by consistently observing their work through the results of teaching each of their students and seek improvement. Among other things, this requires knowledge of their own discipline and strategies or approaches for reaching desired outcomes with students. Directing research at teachers and exploring what they know or what they believe can be grounded in the conclusions of several authors (Korthagen 2011; Timperley 2011; Hattie 2012; Slavík et al. 2014 and others), who consider it fundamental to start professional development by uncovering what a teacher already knows, can do, thinks, and only then defining the focus of future professional learning.

We anchor a teacher's approach to reading in the disciplines with reference to the authors Minaříková and Janík (2012) in relation to three basic elements of teacher professionalism. Teacher's approach is primarily based on professional knowing. This includes a teacher's acquired knowledge, skills and beliefs concerning reading in the disciplines as well as other areas (knowledge of student, selection and fulfilment of selected goals, etc., see Griffith and Lacina (2017). Second, it is also influenced by the character of teacher's professional vision. We understand this as the ability to observe, carry out pedagogical reflection and interpret observations in their broader context. Third, a teacher's approach expresses itself in professional action, in the way that a teacher utilizes reading in geography instruction. We followed our research to at least partially explore teacher knowing and vision regarding reading in the disciplines. We consider a teacher's beliefs to be an important part of professional knowing, which may or may not be the engine of his action. To state it more precisely, we view a teacher's beliefs – in agreement with Hutner and Markman (2016) – as a so-called enabling mental structure that only impacts his or her actions if it is active in a given moment and context.

Teacher approaches to reading in the disciplines share similar characteristics with concepts such as subjective theories, personal theories, teacher's thoughts or instructional approaches. These concepts differ in several respects, but they all involve mental structures that the teacher formulates, they tend to be rather stable, and they significantly impact a teacher's ultimate actions. Grasping these concepts for the purposes of research is quite difficult, due to their nature as implicit, relatively unconscious and unbounded constructs (Janík 2005; Koubek 2015).

We did not find examples of academic research categorizing teacher approaches to geography Some methodological guidance were the studies Catling (2004) and Hanus, Havelková (2018). Catling's wor reflects the overall concept of geography. Catling expanded upon Walford's typology from 1996 adding to the initial question "What is geography?" a second question "Why teach geography?" Hanus and Havelková (2018) build upon the Catling's work by studying geography teachers' approaches for developing map skills in schools in Czechia. They identified three types of geography teachers (Navigators, Problem-oriented and Source-oriented), characterized by certain map skills. Discussing their results, they point out the mutual relationship between preferred map skills and geographic skills, in other words, a teacher's general view of geography instruction.

## 2. Research methodology

The initial state of knowledge on the issue of reading in the disciplines, as described above, influenced the focus of our research, which seeks a deeper understanding of geography teacher approaches regarding the inclusion of reading in geography instruction. We have narrowed the scope of this otherwise broad issue with a central research question:

How do teachers approach the inclusion of reading into geography lessons?

The unresearched nature of the topic helped determine our methodological approach: qualitative research. The grounded theory method was chosen as a research design. We employed the framework designed by Strauss and Corbin (1999). Following the principles of qualitative research (e.g. Hendl 2005), in

**Tab. 1** Basic characteristics of respondents.

| Teacher | Sex | Age | Type of school | Regions |
|---|---|---|---|---|
| A | Woman | 40–49 | Elementary school | South Bohemian Region |
| C | Man | 30–39 | Elementary school | South-Moravian region |
| D | Man | 40–49 | Extended length grammar school | Prague |
| E | Man | 30–39 | Extended length grammar school | Prague |
| F | Man | 30–39 | Extended length grammar school | Prague |
| G | Man | 20–29 | Extended length grammar school | Prague |
| H | Woman | 30–39 | Elementary school | Olomouc region |
| CH | Woman | 30–39 | Elementary school | Moravian-Silesian Region |
| I | Woman | 30–39 | Elementary school | Moravian-Silesian Region |
| J | Woman | 30–39 | Elementary school | Vysočina Region |
| K | Man | 30–39 | Extended length grammar school | Prague |
| L | Man | 30–39 | Extended length grammar school | Central Bohemian Region |
| M | Man | 30–39 | Extended length grammar school | South Bohemian Region |
| N | Woman | 30–39 | Elementary school | Vysočina Region |
| O | Man | 30–39 | Elementary school | Central Bohemian Region |
| P | Man | 30–39 | Extended length grammar school | Prague |
| R | Man | 30–39 | Extended length grammar school | Prague |
| S | Woman | 20–29 | Extended length grammar school | Prague |
| T | Man | 40–49 | Elementary school | Moravian-Silesian Region |
| V | Woman | 40–49 | Extended length grammar school | Prague |
| Y | Man | 20–29 | Elementary school | South Bohemian Region |
| Z | Woman | 30–39 | Elementary school | Moravian-Silesian Region |

Source: own research investigation

the process of carrying out the research, we further specified our objectives with two related questions:

1) What types of approaches to disciplinary reading are obvious to geography teachers?
2) What causes the apparent similarities and differences among teacher approaches?

The research included 22 geography teachers, which were known to have some experience with incorporating reading into their instruction. Half of the respondents (i.e. 11) were from extended length (6 or 8 years) grammar schools, while the other portion represented elementary schools (for more information see Table 1). All were fully qualified geography teachers. Primarily, these were teachers with connections to the Reading & Writing for Critical Thinking program or the project "We help schools succeed". We made no distinctions considering the types of experience teachers had with reading; for example, whether a teacher regularly included reading, the ways that students worked with texts, how their work was evaluated, etc. We employed this targeted selection because of the character of the central research question and in accordance with qualitative research methods (Švaříček and Šeďová 2007). We considered it necessary to collect data from teachers who perform reading in geography, in order to obtain the widest possible repertoire of responses from teachers who themselves state that they have experience with reading.

Data collection was carried out initially from 2013 to 2015 and then again in 2017. Teachers answered, in writing, nine open questions that were divided into two surveys. We chose to use written responses in order to allow respondents time to think over the answers to conceptual questions. Table 2 show all questions. In this paper, we present the results of an analysis of the three questions used (in Table 2 they are highlighted in bold). This questions focus primarily on the concept of reading in geography instruction. The remaining concerned the preferred objectives of geographical education and the evaluating the complexity of texts use in geography lessons. These were analyzed in a separate research.

Data analysis was broken into three phases.

The first phase, **open coding**, involved word-for-word exploration of teachers' answers followed by the classification of significant units (words, phrases, entire sentences) that were marked with terms. Over the course of the research, these terms were generalized into categories.

The second phase, **axial coding**, sought to define connections among the discovered categories, searching for correlations or possible causal relationships. For this phase, we used a paradigm model, which we tailored to our research and which can be seen in Figure 1. The paradigm model shows relationships a central phenomenon (i.e. the inclusion of reading in geography instruction) and other parts that we define, in accordance with Strauss and Corbin (1998), as detailed below. They are:

**a) causal conditions,** i.e. conditions or factors that led to the occurrence of a certain manifestation – e.g. inspiration from colleagues;
**b) intervening conditions**, i.e. conditions or factors tied to a teacher's strategies for acting – e.g. time for reading;
**c) context**, i.e. conditions or factors describing the circumstances in which a manifestation occurs – e.g. to what level does the entire school, or colleagues from the teaching staff, support literacy development;
**d) strategies for action**, i.e. a teacher's strategies for realizing reading in the disciplines leading toward a certain purpose for certain conditions and in a certain context – e.g. a teacher uses reading to awaken student interest about a research question or topic;
**e) consequences of action**, i.e. student activities related to reading in the disciplines that result from the actions of the teacher – e.g. students working with tables and graphs.

The categories were placed into the model such that their position would correspond as much as possible with their respective functions within the schema (e.g. inspiration from colleagues is a causal condition leading to a manifestation, i.e. the inclusion of reading into a geography class). The placement of viewpoints within the relationships was later confirmed with actual survey data and any necessary adjustments were made.

**Tab. 2** Set of questions for teachers.

| A set of questions focused primarily on reading in the discipline: | A set of questions focused primarily on the concept of the goals of geographical education: |
|---|---|
| **Why do you include reading a geographical text in the geography instruction?** | What are the goals in your geography instruction? |
| When including a reading<br>– you proceed rather from a specific text<br>– or are you looking for text for a given topic and skills used? | Do you perceive other goals in the geography instruction, which for various reasons can only be achieved with difficulty in schools? |
| What criteria do you consider as important for assessing the difficulty of a geographical text? | What do you see as the specificity of the geographical way of thinking when looking at specific phenomena, problems on Earth (please specific students activities)? |
| What influences your approach to choosing a text and evaluating its difficulty? | **Does reading have the learning potential to pursue geographical goals? If so, try to specify it.** |
| **Does the development of reading literacy at your school be supported?** | |

Source: own research investigation

The intent of the third phase, **selective coding**, was to focus the findings into a purposeful and explanatory whole that would enable us to answer the research questions. This phase involved the creation of a typology of teacher approaches to reading in the disciplines and identifying factors impacting the inclusion of reading into geography instruction.

## 3. Research results

We structure the research results into two parts, which correspond with the secondary research questions. They are interconnected because they arise out of the selective coding of respondent answers and are supported in the paradigm model (Figure 1).

What types of approaches to disciplinary reading are obvious to geography teachers?

Already during open coding, it gradually became clear that the individual statements of teachers have similar features and it would therefore be possible to distinguish several types. There was a fundamental step in the choice of such aspects that would allow the creation of a typology with a robust construction (Šeďová, Švaříček 2013). The typology we have

**Tab. 3** Typology of teacher approaches to reading in the disciplines.

| Type of reading in geography instruction | Student activity (scale of thinking skills + frequency of participation in the learning process) | |
|---|---|---|
| | Emphasis on simple thinking skills<br>Less active and occasional inclusion of students in the learning process | Use of more complex thinking skills<br>Active and frequent inclusion of students in the learning process |
| Reading to add variety to geography instruction | Type Emerging | Type Bridging |
| Reading as a natural and functional part of geography instruction | Type Partly developing | Type Fluent |

Source: authors

created utilizes two criteria identified during the axial and selective coding phases. The first point of classification is student activity – based on cognitive difficulty and/or the frequency of student participation in the learning process – as declared by teachers. The second axis of classification is the way a teacher

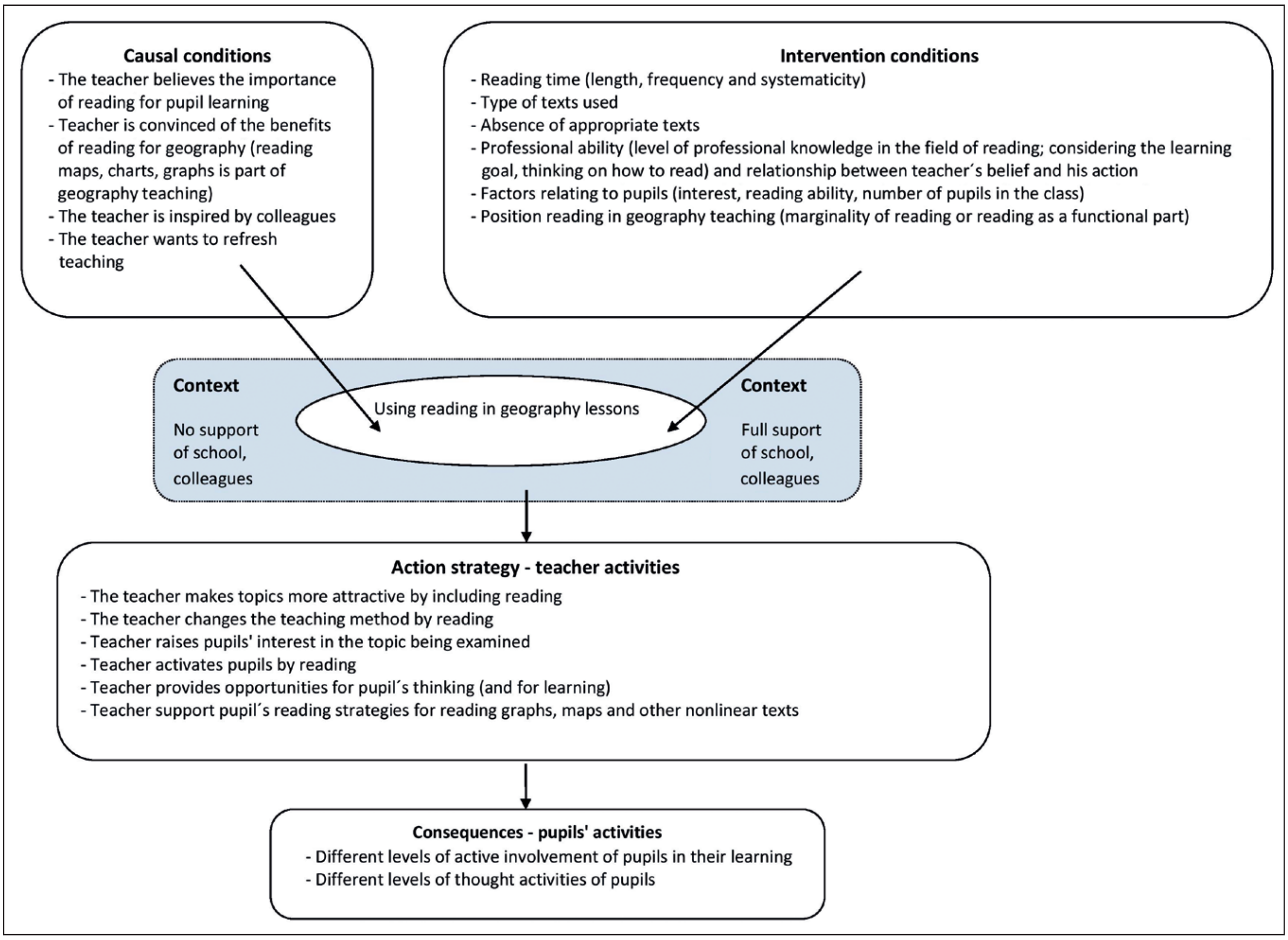


**Fig. 1** Paradigm model "The inclusion of reading in geography instruction".
Source: authors

connects reading with the attainment of geographic objectives. Whether reading is more of a coincidental element of instruction that a teacher includes to add variety, or reading is included more frequently and serves as a means of encouraging student thinking, or a teacher connects geographic and reading objectives.

The two classifying points mentioned divided respondents into four types (see Table 3).

### 3.1 Type Emerging

Emerging type teachers view reading as a means to liven up geography instruction, either by its content or by simply replacing a standard teacher lecture with a different source of information – geography textbook, travelogue or magazine article.

This is the case, for example, of Teacher V, who states:

> I use geographic magazines to enliven instruction. I select articles that will capture students' interest and increase their knowledge. Primarily, these are articles concerning the life of inhabitants of a given country or natural or cultural points of interest.

Reading represents a way to add variety to instruction or an occasional method that does not engage students in the learning process. The educational potential of texts is not fully realized. Students read them primarily in order to seek new information. Teachers of this type tend to be unsure of the benefits reading has for student learning or their beliefs are not in line with their actions.In this regard, they mention the limiting influence of a various external factors, for example, the number of students in a class, disinterest of students, lack of texts. Some teachers speak of the importance of supporting the development of student literacy, but in subsequent statements they either fail to support it more or rebut it altogether.

An example is Teacher P's opinion:

> I think that reading texts is a fundamental part of instruction in any discipline. … The reality of geography instruction and the utilization of opportunities to read texts from the discipline is rather marginal. Particularly, due to the wide variety of curriculum and the time available for this discipline. It could be used as a form of home preparation (homework – read the text and based on the items learned fill in a crossword puzzle or some sort of diagram (outline or blank map).

### 3.2 Type Bridging

It is characteristic Bridging type teachers that they include reading in instruction somewhat irregularly combined with a certain, specific objective. This could be an emphasis on reading non-linear texts, such as various tables, graphs or maps.

Teacher K, for example, states:

> I am not sure of anything that is 'specific' to reading in geography. With the exception of reading maps – in other disciplines this skill is rarely used; perhaps, graphs and tables – they are used in a minority of subjects. I consider reading maps, not only general geographic maps, but particularly themed maps, to be the most important addition to literacy.

Another purpose that these teachers pursue through reading is support for student thinking or certain communication skills.

An example is the approach of Teacher M, who uses reading of texts from the Internet to train students' systematic thinking:

> Hypertext by its very nature is not conceived linearly. It does not dictate a hierarchical structure. That structure is constructed by the reader. In other words, it is the same as if a reader opened a book to a random page, read it and then randomly continued to another, and so on and so on, and yet it would make sense from the reader's point of view. This brilliant thought does not work, of course, unless the reader is familiar with the principle of hierarchy; the result is a chaotic succession of pages with no rhyme or reason that is everything but not something meaningful. In short, new sources of information lack what books have, a sense of succession and order, provided by someone who is headed somewhere and who knows where he is headed.

Student activities working with texts are not often included, but they involve higher level thinking and students are, therefore, able to actively participate in the teaching process. Teachers of this type are the least represented in the research sample.

### 3.3 Type Partly developing

Teachers of this type generally believe in reading's importance in teaching students and view reading as a tool that enables students to think and participate in their own learning.

For example, according to Teacher L:

> Students are improving in working with text. While working with text, students are actively engaged in the learning process. In other words, 'Every thought spoken by the teacher is a shame.'

Partly developing type teachers include reading in instruction fairly frequently, though it is not clearly systematic and goal oriented.

Intellectually more challenging student activities are included rather intuitively. However, teacher responses show a level of uncertainty about how to implement reading in the disciplines. E.g. teachers use modal verbs: "Texts can be good to tune in to the topic, they can help to get students' attention, their interest", teacher N. This is likely influenced by the fact that, unlike their counterparts abroad, they are not equipped with know-how regarding possibilities for reading in the disciplines (how to read with students, how to select and assess texts, etc.). This type of teacher approach is the most common in the research sample.

### 3.4 Type Fluent

This type of teacher sees reading as an integral part of geography instruction. Their beliefs is founded both on the indispensability of reading for active student learning as well as reading's contribution to the achievement of a broader spectrum of geographic objectives[1]. In contrast to the preceding type, Type Fluent seeks to add a systematic and more comprehensive approach to the inclusion of reading. This is manifest, first, in teacher efforts to develop literacy skills that aid in the comprehension and in further work with texts.

Teacher A, for example, defends her approach:

> Students learn to think in broader contexts, to view issues critically, to not fear speaking up, or to change their opinions after gaining new information … to this point, I think, only 'working with texts,' as yet, I have not focused intentionally on the development of reading strategies. I am learning to work with that.

Second, it is manifest by teachers thinking about how to connect the objectives of geography instruction with the potential of a text and the needs of their students.

Teacher O, for example, states:

> I cannot imagine that anyone would not read in geography. I do not focus reading on textbooks, I use a variety of texts from magazines or from the web. I must find out how difficult the text is. Will students understand it? Does it contain many foreign words? How long are the sentences? Is it complicated? I try to read, at least a bit – at least a paragraph, in every class. Read in a variety of ways. Don't let it be a simple read through a textbook. I must know why I am inserting it, why a child should read in this class. What objectives am I following? Two objectives – literacy – I lead them to read also by the things that I present to them.

This teacher approach is reflected in student activities that require higher thinking skills and, therefore, their own active involvement in learning. Teachers also emphasize students learning one other.

E.g. Teacher J:

> On a simple level – searching for and sorting information. More difficult level – the ability to perceive that the text is always written from some point of view. It is the basis for further discussion and the ability to defend one's opinion.

Type D teachers tend to see themselves as readers and/or teachers that are responsible for the development of student reading.

No distinct boundaries separate the types of approaches. This is due to the complexity of research topic and the fact that teachers can shift among the various types of approaches as they develop professionally.

What causes the apparent similarities or differences among teacher approaches?

The typology of teacher approaches to reading in the disciplines described above is based on a combination of two points of classification or factors that influence teachers' approaches to reading in the disciplines. However, the reality is more complicated – the teacher's approach is shaped by a number of other factors. Moreover, even within one type, teachers do not show completely identical features. A deeper understanding is significantly aided by the paradigmatic model (Figure 1). It captures the factors identified by the research, which are part of the causal, intervening conditions and the wider context. These factors are interconnected and operate directly or indirectly in various phases of the implementation of reading in the disciplines. The specific form of the defining factors is dependent on the teacher's approach and his or her subsequent actions which impact student activities. As such it is important to also consider what led and leads teachers to include reading, what type of environment they work in and any other factors that may impact their work.

The research demonstrates the variety of reasons, i.e. causal conditions, that motivate teachers to include reading. Most frequently, teachers spoke of the importance of reading for teaching students at the general level. For example, Teacher CH observed, that:

> In my opinion students much more easily remember learning material that they have studied themselves and discussed among themselves.

Some teachers noted the importance of teaching with geographic objectives. Responses also frequently indicated that reading is a means for enlivening geography instruction. Responses of teachers indicates that the way to more thoroughly integrate reading can truly begin with the "mere" enlivening of instruction.

Specifically, Teacher A states:

1 We cannot claim that other types of teachers did not recognize a connection between reading and geography instruction, but this connection differs. It is either not consciously considered or it fits within a narrow spectrum of geographic objectives – for example, reading to attain some isolated information.

> The very first motivator was to make instruction more captivating, to make classes more entertaining – for students and certainly for me, as well. I tried to both topics that came up in the textbook – monsoons – along with topics that were only marginally related to the class's content and which may correspond with a current event.

Some teachers consider changes in topic to be enlivening to instruction (focus on interesting, or current-event topics or traditional topics viewed differently). Others see reading as another form of instruction, enabling students to engage in the learning process more thoroughly. For example, Teacher N thinks that: "a well selected text can surprise, frequently raising additional questions and at times even emotional responses." A fourth reason that expressed itself rather infrequently in teacher responses was inspiration from colleagues or schoolwide focus.

Teacher N mentions this reason:

> In part, I was influenced by cooperation with a colleague in paired instruction. This colleague frequently works with texts and she persuaded me in this direction upon my return from maternity leave.

In reality as teacher responses demonstrate (see teacher N), it is a combination of various causal factors that encourages teachers to include reading in instruction. The combination of an attempt to enliven instruction and to tap into the benefits of reading for student learning was common. Some teachers perceive benefits of reading in students' active participation in the learning process, as they ponder over texts. On the other hand, however, teacher responses make it clear that they include reading rather infrequently to add variety to instruction.

As soon as a teacher includes reading in a geography instruction, a number of factors arise and influence its implementation. One significant factor is the context, i.e. the specific situation at a given school that either does or does not support reading across all subjects. This lies in the presence (or absence) of literacy within a school's educational plan, in opportunities for cooperation and additional teacher training in reading in the disciplines, etc. No less important is the school's culture, which Hattie (2012) considers an integral part of any long-term improvement of learning teachers and students. Intervening conditions include factors that can either help or hinder the inclusion of reading in instruction. Table 4 presents all factors, including a description of these two sides, though we do find smooth transitions between them. Whether the character of a given factor proved to be supporting or limiting arises out of the research's theoretical framework with additional support from the data gathered. The ultimate character of a factor was often determined by recognizing clues in the teacher responses.

For example, Teacher P writes:

> It is difficult to retain students' attention during class and reading is often done automatically, without thinking. Sometimes they do not even know what they read about. For this reason, the texts should not be very long, enough to read in 10 or 15 minutes.

From this teacher's claim, we can deduce that student lack of attention is perceived as a threat that could limit the inclusion of reading in instruction. We can also determine that the teacher lacks understanding and know-how, concerning reading in the disciplines. Specifically, the teacher does not appear to bring any structure to reading assignments, he does not work with literacy objectives (this becomes clear from the statement "what they read about"), and reading is given relatively little time, limiting the opportunity for students think more deeply.

Based on the data, it was not possible to clearly determine whether the factor summarily labelled as "type of texts utilized" has a supporting or limiting nature. From teacher responses, we can only deduce that teachers supporting reading utilize texts that encourage student thinking (e.g. by containing various points of view regarding a given issue). The fact that many teachers mention a lack of appropriate texts or difficulty finding and obtaining such texts should not be overlooked.

## 4. Discussion and conclusions

The research revealed that between the approaches of geography teachers to the inclusion of reading, there are certain identical, resp. different features, which allowed the creation of a typology. The types were distinguished on the basis of two classification aspects and were called Emerging, Bridging, Partly developing and Fluent. The boundaries between the individual types are not sharp, teachers can switch between types during their professional learning and the approach of the included teachers is not completely identical within any type. This is due to the complexity of the phenomenon, which largely captures the Paradigmatic model developed by the authors (Figure 1). The paradigmatic model is also a tool that significantly helps to individualize each case. The typology of approaches will indicate what type of approach corresponds to a particular teacher, but examining the relationships and forms of individual conditions (context), strategies of action, and consequences will allow the teacher's approach to be better understood. In our proposed typology, the so-called zero type is missing. That is, a type of teacher who would not include reading in teaching at all. With regard to the situation in contemporary Czech education, however, we do not anticipate this situation, because textbooks and atlases are part of school's lessons and a certain reading of texts, including maps therefore takes place at least sometimes.

**Tab. 4** Factors influencing teachers in including reading in geography instruction.

| Factor | Supporting in nature | Limiting in nature |
|---|---|---|
| Position of school leadership and colleagues regarding student literacy development | Support from school leadership and colleagues. Teachers develop cooperation and take inspiration from one another. | Negative or neutral position from school leadership and colleagues. Teachers do not work together. |
| Teacher beliefs concerning the importance of reading | Teacher believes in the benefits of reading – for developing thinking and learning and for learning geography. | Teacher is skeptical of the benefits of reading, reading is more of a marginal activity, separated from other activities in geography instruction. |
| Teacher's professional preparedness | Teacher knows the scale of literacy skills, works with objectives, provides feedback, continually develops his or her professional knowledge and vision, utilizes assessments of student performance. | Teacher is not familiar with the possibilities of utilizing literacy skills, does not work with objectives, does not provide feedback, does not develop skills for including texts in instruction. |
| Role of reading in attaining geographic objectives | Reading is a tool of geography instruction and/or one of the objectives of geography education. | Reading is an accessory tool of geography instruction, operating simply as a means of enlivening instruction. |
| Relationship between beliefs and action | Teacher has a clear understanding of the benefits of reading and employs strategies to effectively include reading in instruction. | Teacher is unsure, grasps certain aspects of reading's importance, but the connection between beliefs and action is contradictory. |
| Student factors (interest /disinterest; attention; class size; level of literacy skills; etc.) | Viewed as circumstances that should be anticipated and around which instruction should be planned. | Viewed as limits or threats. |
| Lack of texts | Teacher actively searches for texts, thinks about what types of texts and why he/she is searching. | Teacher is skeptical, does not have clear objectives for working with texts and, as a result, does not know what texts to seek. |
| Time for reading | Reading is included regularly and often. Time is set apart for individual reading and reading assignments are broad enough to allow students to ponder. | Reading is including infrequently and at random. Reading and reading assignments are given a limited amount of time, which hardly allows students to think on the readings. |

* The order in which the factors are presented does not reflect their significance regarding reading in the disciplines.
Source: authors

Teachers do not seem to integrate reading with the primary goal of developing reading strategies (as mentioned content area reading). Similarly, it is not possible to document the approach of teachers that would correspond to the disciplinary literacy. Rather, the assembled data show that geography teachers incorporate reading more or less intuitively and that teacher's approach to reading in the disciplines seems to reflect preferences of their general concept of teaching, which have a variety of impacts on the teaching of students. If a teacher prefers instruction that is rather "encyclopedic" in nature, during which students are less active and tend to be mere passive receivers of prepared facts or interesting information, then reading will likely be less interesting to the teacher. Any potential student reading leads to the mere searching for facts. In an opposite case, when a teacher prefers student activities that require greater participation in the process of learning geography and by studying geography and additional cross-disciplinary skills (e.g. cooperation), this focus becomes evident in the manner of reading and utilizing texts. Of course, a number of variations exist between these two distinctive types. Research also suggests that reading could be a tool to allow teachers to change their teaching. This is indicated by the statements of teachers type Emerging, who state the reason for including reading as "activating students", and the statements of teachers type Partly developing, who already talk about active learning of students and distinguish them from another form, although not directly talking about it. A similar conclusion can be found in the research of Hanus and Havelková (2018) in connection with the preferred mapping skills. Furthermore, it would be possible to examine whether and under what condition the implementation of reading can contribute to the sharing of the teacher's concept of teaching. Considering the impacts of learning on students, Pearson et al. (2010) consider a teacher's approach that enables students to carry out real, practical activities ("hands on") and use reading and writing as necessary tools to unlock additional specifics of the discipline to be most beneficial. The cited authors base their opinions on a number of projects (e.g. Science IDEAS, Guided Inquiry supporting Multiple Literacies), which share a common emphasis on the connection of inquiry-based science and the inclusion of reading and writing. This does not mean that learning facts is not necessary, but it is not effective to continue to do only that. This approach most nearly approximates type Fluent as defined in our research.

A teacher's approach is not formed on its own but is influenced by mutually connected factors that impact the implementation of reading in the disciplines at differing degrees and in different times. In the paradigm model (Figure 1), these factors take the form of causal or intervening conditions or the context, in which a teacher works. Rather than present a list of supporting or limiting factors, the research proposes that the factors be viewed as being either supporting or limiting in nature (Table 4). Lazarová et al. (2012) view factors in a similar way, though in connection with organizational teaching. They point out that it depends on the specific situation. It is even possible that a factor could be considered an obstacle to teaching by one teacher and yet serve as a stimulus for positive change for another. For example, student disinterest can lead either to the reluctant inclusion of reading, with a noticeable lack of student participation, or to the searching out of texts and teaching methods that would increase student interest. The factors probably affect all teachers, but their specific form differs, and it is partly possible to say that teachers of, for example, type Emerging are united by a certain form of a specific factor. These teachers typically report that reading takes up little space in lesson. Type Fluent teachers often include reading and working with text is a key activity for students during the lesson. Research does not allow this statement to be transferred to the whole set of factors and all types of approaches. Further research could focus on examining the factors that influence the implementation of reading. This should contribute to the knowledge of the teacher's needs and thus more effectively support his professional learning.

Part of any teacher's professional knowing is a set of beliefs that significantly impact the teacher's approach. It appears that teachers corresponding with Type Fluent have formulated a specific and – for learning students – a beneficial understanding of the significance of reading and data show that they are fulfilling it. Responses from other teachers, particularly Type Emerging, in contrast, demonstrate uncertain beliefs regarding the significance of reading in geography instruction. This is manifest in their failure to provide more specific examples of generally formulated benefits of reading or, in some cases, by contradicting those stated benefits in other parts of their responses. This is not simply about gaining more knowledge of various strategies or techniques. Rather, it involves altering beliefs, which would then lead to change in existing personal theories.

The implemented research is accompanied by certain limits. One of them is the method of data collection – a written questionnaire with open-ended questions. There are several risks to this approach. It is possible that teachers may feel the need to respond as expected. If the teacher perceives the current emphasis on the development of reading in the Czechia, then he may think that it is "appropriate" to join in this direction, although the teacher himself does not share this opinion. Abroad, similar conclusions are reached by Milner et al. (2012), whose results suggest that teachers' own beliefs may be delayed (in the event of a change in the way disciplines are taught). Their final action are more influenced by the expected opinion than by their own. It is possible that some of the teachers involved in our research may have had this feeling as well. This would be indicated, for example, by uncertain wording about the benefits of reading. A way of talking in which teachers feel safe and feel that there are no "right" answers could help. The second pitfall is the inconsistent definition (understanding) of certain term. A typical example is the word "text". It is possible that teachers imagine only continuous texts, for example, as text. The choice of a written inquiry is also debatable. This is because two teachers from the sample we addressed answered so briefly and in general that it was not possible to responsibly interpret their answers and include them in the research. Nevertheless, this experience is also important, as it can indicate the uncertainty of teachers and their educational needs. The third limit concerns the choice of research tool, specifically the method of grounded theory. Although coding was done by two authors, it must be added that the resulting typology, including the compiled paradigmatic model, is probabilistic. It would be possible to explore the approach to reading in the discipline for a wider range of teachers – without our chosen deliberate choice (reading experience). This research could examine and complement the existing typology in order to contribute to further professional learning of teachers.

Greater knowledge of teacher approaches to reading in the disciplines, including factors that influence it, is important for teacher training in this area. Without including a teacher's earlier knowledge, skills and beliefs, the effectiveness of his or her professional training is threatened (Bransford et al. 2000; Timperley 2011; Korthagen 2017). Otherwise, teachers may reject or only acquire superficial understanding of new approaches and practices, resulting in a limiting effect on the progression of students through their teaching (Timperley et al. 2007). A deeper misunderstanding of a given method, that teachers are introducing, can lead to a situation that Timperley (2011) calls "over-assimilation". This means that a teacher implements the method (e.g. reading) without knowing what makes it important or what benefits it brings to learning students. The teacher thinks that what he or she is doing works well and is in line with the newly introduced method. However, the difference between what is being proposed and what is actually being taught can, in reality, be quite large. This can be seen in our findings (consider the discussed contradiction between a teacher's declared beliefs concerning the benefits of reading for active student learning and his/her approach or actions in instruction – the teacher P).

The effective implementation of reading in the disciplines in geography instruction requires us to know and understand additional realities. Additional research should focus on students and their teachers, the educational potential of various source materials for reading and the (non-)functional connection between reading in the disciplines and geography instruction, comparison of reading across subjects, etc.

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## References

Bransford, J., Brown, A., Cocking, R. (2000): How People learn: Brain, Mind, Experience and School. Washington: National Academy Press.

Buehl, D. (2011): Developing readers in the academic disciplines. Newark: International Reading Association.

Catling, S. (2004): An understanding of geography: The perspectives of English primary trainee teachers. GeoJournal 60(2), 149–158, https://doi.org/10.1023/B:GEJO.0000033575.54510.c6.

Common Core State Standards (2010): http://www.corestandards.org/wp-content/uploads/ELA_Standards1.pdf.

Common Core English Language Arts and Geography Connections (2013): http://www.nationalgeographic.org/media/common-core-ela-geography-connections.

Gilles, C., Wang, Y., Smith, J., Johnson, D. (2013): "I'm No Longer Just Teaching History" Professional Development for Teaching Common Core State Standards for Literacy in Social Studies. Middle School Journal 3(44), 34–43, https://doi.org/10.1080/00940771.2013.11461853.

Griffith, R., Lacina, J. (2017): Teacher as Decision Maker: A Framework to Guide Teaching Decision in Reading. The Reading Teacher 7(4), 501–507, https://doi.org/10.1002/trtr.1662.

Hanus, M., Havelková, L. (2018): Teacher's Concepts of Map-Skill Development. Journal of Geography 118(3), 1–16, https://doi.org/10.1080/00221341.2018.1528294.

Hattie, J. (2012): Visible Learning for Teacher. Maximalizing Impact on Learning. London and New York: Routledge, https://doi.org/10.4324/9780203181522.

Havlínová, H. (2016): Proměny pohledu na výuku čtení v české škole prizmatem výzkumů: od nácviku techniky čtení k rozvoji čtenářské gramotnosti. Orbis Scholae 10(2), 145–157, https://doi.org/10.14712/23303177.2017.7.

Hendl, J. (2005): Kvalitativní výzkum: základní metody a aplikace. Praha: Portál.

Hutner, T. L., Markman, A. B. (2016): Proposing an Operational Definition of Science Teacher Belief. Journal of Science Teacher Education 2(6), 675–691, https://doi.org/10.1007/s10972-016-9480-5.

Janík, T. (2005): Znalost a další pedeutologické kategorie. In: Janík, T.: Znalost jako klíčová kategorie učitelského vzdělávání. Brno: Paido, 32–33.

Korthagen, F. (2011): Jak spojit praxi s teorií: Didaktika realistického vzdělávání učitelů. Brno: Paido.

Korthagen, F. (2017): Inconvenient truth about teacher learning: toward professional development 3.0. Teachers and Teaching: Theory and Practice 23(4), 387–405, https://doi.org/10.1080/13540602.2016.1211523.

Koubek, P. (2015): Subjektivní teorie řídící jednání učitelů v kontextu jejich profesního rozvoje: teoretická a empirická východiska výzkumu. In: Švec, V. et al.: Znalostní báze učitelství. Brno: Masarykova univerzita, 13–32, https://doi.org/10.5817/CZ.MUNI.M210-7961-2015.

Lazarová, B., Pol, M., Hloušková, L., Novotný, P., Sedláček, M. (2012): Organizační učení v odborných diskursech. Pedagogická orientace 22(2), 145–161, https://dx.doi.org/10.5817/PedOr2012-2-145.

Minaříková, E., Janík, T. (2012): Profesní vidění učitelů: od hledání pojmu k možnostem jeho uchopení. Pedagogická orientace 22(2), 181–204, https://dx.doi.org/10.5817/PedOr2012-2-181.

Moje, E. B. (2008): Foregrounding the Disciplines in Secondary Literacy Teaching and Learning: A Call for Change. Journal of Adolescent and Adult Literacy 52(2), 96–107, https://doi.org/10.1598/jaal.52.2.1.

Next Generation Science Standards (2013): www.nextgenscience.org/search-standards.

Pearson, P. D., Moje, E., Greenleaf, C. (2010): Literacy and Science: Each in the Service of the Other. Science 23(328), 459–463, https://doi.org/10.1126/science.1182595.

Radváková, V. (2015): Práce s textem na střední škole. Orbis Scholae 9(3), 87–109, https://doi.org/10.14712/23363177.2013.6.

Shanahan, T., Shanahan, C. (2008): Teaching Disciplinary Literacy to Adolescent: Rethinking Content-area Literacy. Harvard Educational Review 7(1), 40–59, https://dx.doi.org/10.17763/haer.78.1.v62444321p602101.

Shanahan, T., Shanahan, C. (2012): What Is Disciplinary Literacy and Why Does It Matter? Top Lang Disorders 3(1), 7–18, https://doi.org/10.1097/TLD.0b013e318244557a.

Shanahan, C. (2013): What Does It Take? The Challenge of Disciplinary Literacy. Journal of Adolescent and Adult Literacy 57(2), 93–98, https://doi.org/10.1002/jaal.226.

Slavík, J., Janík, T., Jarníková, J., Tupý, J. (2014): Zkoumání a rozvíjení kvality výuky v oborových didaktikách: metodika 3A mezi teorií a praxí. Pedagogická orientace 24(5), 721–752, https://dx.doi.org/10.5817/PedOr2014-5-721.

Strauss, A., Corbinová, J. (1999): Základy kvalitativního výzkumu: postupy a techniky zakotvené teorie. Brno: Sdružení Podané ruce.

Šeďová, K., Švaříček, R. (2013): Jak psát kvalitativně orientované výzkumné studie. Kvalita v kvalitativním výzkumu. Pedagogická orientace 23(4), 478–510, https://doi.org/10.5817/PedOr2013-4-478.

Švaříček, R., Šeďová, K. et al. (2007): Kvalitativní výzkum v pedagogických vědách. Praha: Portál.

The New Zealand Curriculum (2009): http:// nzcurriculum.tki.org.nz/The-New_Zealand-Curriculum.

Timperley, H., Wilson, A., Barrar, H., Fung, I. (2007): Teacher professional learning and development. Best evidence synthesis iterativ. Ministry of Education, New Zealand, www.minedu.govt.nz.

Timperley, H. (2011): Realizing the Power of Professional Learning. McGraw-Hill Education, https://dx.doi.org/10.1111.

# Downstream fining trends of gravel bar sediments: a case study of Czech Carpathian rivers

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**ABSTRACT**

This study examines downstream grain-size trends in gravel bars, a typical feature of natural gravel-bed rivers, from two neighbouring heavily channelized rivers: the Lubina River and the Ondřejnice River draining the Czech part of the Outer Western Carpathians. It aims to examine the effects of the grade control structures, significant tributaries, and lateral sediment inputs on the downstream fining trends. Additionally, the relationship between the channel width and the grain sizes in bars was analysed, as well as the depositional trends in frontal, central and distal parts of the examined gravel bars.

The Ondřejnice River has, in most cases, higher D50 and median values of grain size of bar sediment and a higher downstream reduction coefficient (D50 = 0.033 mm $km^{-1}$; D84 = 0.036 mm $km^{-1}$) than the Lubina River (D50 = 0.026 mm $km^{-1}$; D84 = 0.032 mm $km^{-1}$). These intense reduction trends in the grain size are often observed in single and multiple-threaded rivers in the Western Carpathians. On both rivers, the predominant deposition of the highest D50 was detected in the central parts of the bars, and the wider channel widths often corresponded with finer sediment deposition in the Lubina River. The disruption of the downstream fining corresponded in some cases with the frequent grade control structures. However, in most cases, the downstream fining trends were not affected. A tributary and adjacent hillslope area could be possibly linked to the disruption of the downstream fining trend in the Ondřejnice River.

**KEYWORDS**

Carpathians; gravel bar; grain size; downstream fining; photo-granulometry

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## 1. Introduction

Gravel bars form frequently in streams and consist of granularly diverse sediments. The planar size of the bar usually corresponds to the channel width (Wohl 2014). There are many types of bars, such as alternate bars or point bars, and they are most often categorized by the origin or location in the channel (Wohl 2014; Gordon 2004). Generally, a source of sediments and the frequency of its delivery into the stream as well as decreases in flow velocity and transport capacity are preconditions for the formation of a river bar.

The sources of sediment may be colluvial material from adjacent hillslopes, incisions, lateral erosion, and tributaries (Wohl 2014). However, for sediment flux to enter the river channel is important the degree of connectivity in the river. Connectivity often refers to a certain level of connection in the river network or landscape where matter (including sediments), energy and biota is moved by fluxes. It exists in either longitudinal, lateral, or vertical dimension, and it is important in terms of the river responses to the human or natural disturbances. Therefore, maintaining or creating proper connectivity in rivers is crucial for the effectivity of river management. Specific interventions or disturbances which can be either natural (landslide, alluvial fan) or anthropogenic (dams, channelization, levees) often decrees connectivity in certain dimensions but can sometimes increase the connectivity in the other dimensions. For example, channelization decreases lateral connectivity but increases longitudinal connectivity (Wohl 2017). The barriers in the longitudinal river channel such as the grade control structures generally cause deposition of the finer sediment behind the structure (towards the upstream) while in the front are often observed coarser sediments due to the hungry water effect. This effect is when the river channel is lacking sediment supply because of the grade control structure block. It also causes channel incision (Škarpich 2010).

The rate of sediment transport is greatly affected not only by barriers but by channel morphology and its effect on flow resistance. Some studies dealing with estimating bedload transport in headwater streams presented that streams with lower sediment supply and transport have more developed bedforms and so the flow resistance. The streams with higher sediment supply showed less developed bedforms with lower flow resistance. (Galia and Hradecký 2014; Yager et al. 2007; Chiari and Rickenmann 2011).

The grain-size characteristics of gravel bars change throughout the longitudinal profile of the river depending on various factors. The main two factors include selective sorting during erosion, transport and depositional processes, and abrasion of individual sediment grains, so that the volume of individual particles starts to decrease downstream – also known as Sternberg's (1875) law (Gomez 2001). In contrast, sediment influxes can interrupt the process of downstream fining and lead to downstream coarsening, particularly in mountainous areas (Wohl 2014). These disruptions are often caused by alluvial sources such as tributaries, bank failures (Church and Kellerhals 1978; Dawson 1988; Knighton 1980; Rice 1998; Rice 1999) or terraces and alluvial fans (Rice 1998) or non-alluvial sources such as slope deformations – landslides, ravines (Rice and Church 1996; Surian 2002; Škarpich 2010; Škarpich 2019; Rice 1998). The sediment size in the river channel can also vary corresponding to channel width changes. Wider channels are considered to contain granularly finer sediments, whereas narrower channels contain coarser sediments (Rengers and Wohl 2007).

Differences in grain sizes within the planar area of individual bars are usually related to the type of bar or to the geomorphological regime of the stream. For example, in the case of braided rivers, there are very complex bars with many factors that influence the spatial distribution of grain-size fractions. However, the general assumption is that most bars tend to deposit coarser sediments in the upper (frontal) part of the bar with gradual refinement towards the lower (distal) part of the bar (Smith 1974; Bluck 1982; Ashworth and Ferguson 1986), as observed on alternating or point bars (Jackson 1976; Pyrce and Ashmore 2005). Lateral sediment refinement from the outer to the inner bank (Bridge and Jarvis 1976; Parker and Andrews 1985) is also considered a specific predominant type of deposition at point bars. Vertical fining from the bottom of the bed towards the bar surface has also been documented (Smith 1974; Bluck 1982; Ashworth and Ferguson 1986). However, some studies have demonstrated opposite trends, such as downstream coarsening in partially reinforced layers (Lunt and Bridge 2004) or coarsening in the upper and bottom parts of the bar due to previous anthropogenic channel modifications (Hradecký et al. 2019). In terms of different factors that cause changes in sedimentation across the bar surface, riparian vegetation is considered significant (Edwards et al. 1999). It usually increases the roughness in streams, which results in reduced flow and deposition of finer fractions (Wohl 2014). Different types of pioneer riparian vegetation (herbs, shrubs, and trees) also have different functions on river sediment forms; herbaceous plants provide a suitable area for other species by trapping diaspores and stabilizing of fine sediments, and shrubs and trees provide micro-climate, shadow and mechanical resistance (Corenblit et al. 2009). As soon as the sediment is deposited in the bar zone, the roots of plants provide a certain degree of stabilization which may result on the creation of mid-channel bars or islands (Ikeda and Izumi 1990). Riparian vegetation along the riverbanks is often a source for wood accumulation in the river channel. The wood can create barriers in terms of longitudinal connectivity and causes changes in morphology. Woody accumulations are defining according to its size to large woody debris (LWD) including tree trunks and branches and fine woody debris (FWD; <0.03 m in diameter) which typically include twigs or wood chips (Borák 2018). The definitions of categories and metrics vary, e.g. some authors may define small woody debris (SWD) instead of FWD. According to some authors, the LWD is stated as a woody material with dimensions of 10 × 100 cm (Borák 2018; Kaczka 1999; Faustini and Jones 2003) or >0.1 m in diameter (Hawson et al. 2012). When the LWD is oriented across the river channel, it has an effect of a barrier that decreases the energy and velocity of the river. This frequently causes sediments to deposit in front of the LWD (towards upstream) and immediately behind it downstream. Gravel bars with coarser sediments are found behind the woody accumulations, while the finer sediment tends to deposit in front of it (Borák 2018).

In this paper, we focused on downstream longitudinal changes in the grain sizes within gravel bars

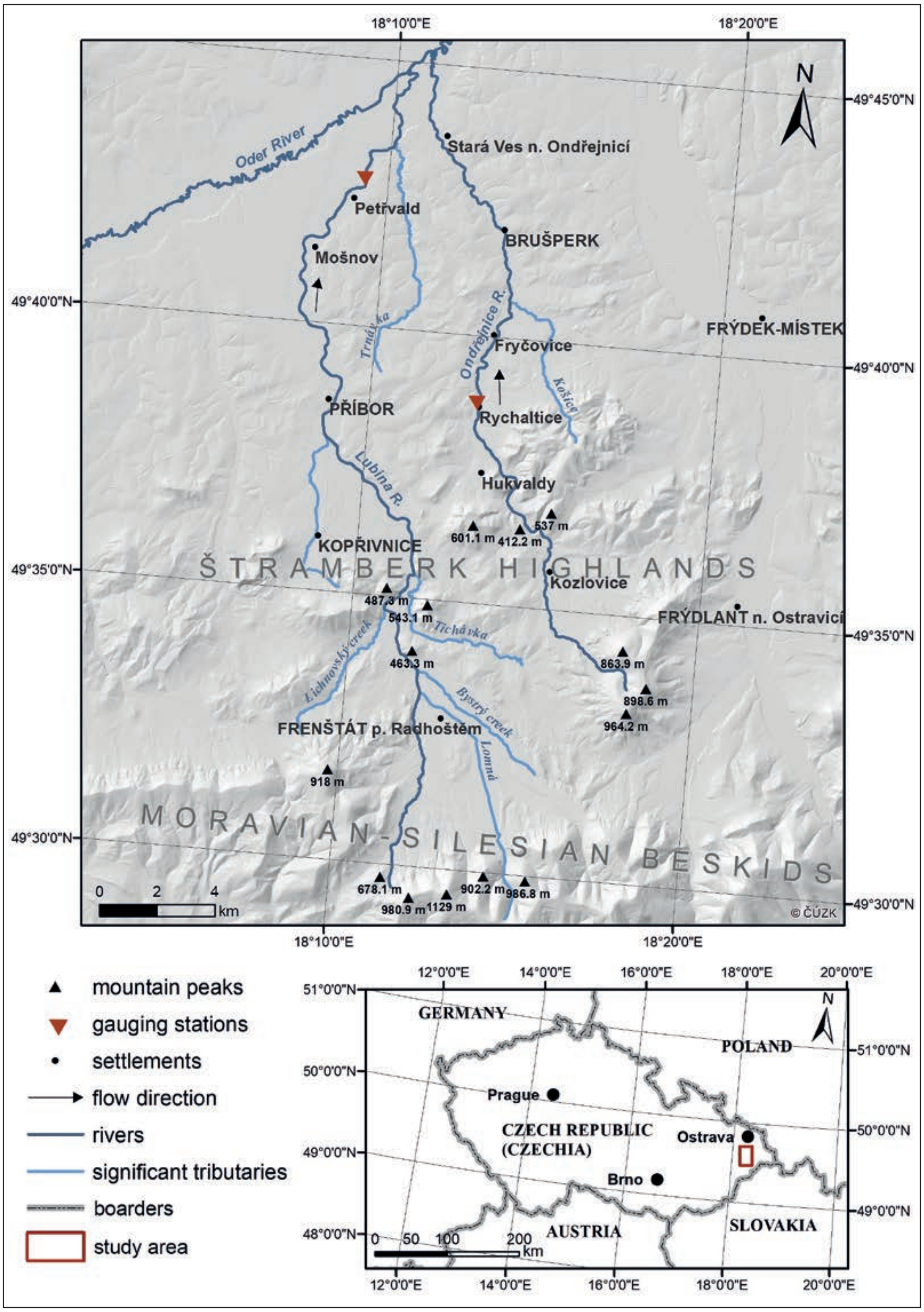


Fig. 1 Map of two studied rivers in the position of coordinates.

(downstream fining and downstream coarsening) and the sediment disruption linkage; to material fluxes from possible sources (significant tributaries, adjacent hillslopes); and to the effect of grade control structures and local vegetation cover. Secondarily, we examined the trends in the grain size of the frontal, distal and central sections of individual gravel bars, as well as the relationship between channel width and corresponding sediment grain-size changes. The efforts of the study are to bring new insights to the otherwise well-known process of downstream fining and its disruption in the area of Western Flysch Carpathians by assessing the possible sources of material, longitudinal connectivity issues due to high river management, and local factors of vegetation cover on the gravel bars.

## 2. Methods

### 2.1 Study area

The Lubina and Ondřejnice Rivers (Figure 1) are single-threaded, meandering rivers and right-side tributaries of the Oder River flowing in the foothills of the Moravian-Silesian Beskids in the Czech Republic. The Lubina River springs on the northwestern slope of Radhošť Mountain at 740 m a.s.l. The catchment area is 195.89 km$^2$ (CHI 2017), and the total length of the river reaches 36.3 km (Povodí Odry 2016). The mean annual discharge at the junction with the Oder River is 2.36 m$^3$ s$^{-1}$ (Štefáček 2008). The data of discharge and water level is from the gauging station situated at Petřvald (covers 165.18 km$^2$ of the total area of the basin) on the left bank side (Figure 1) (CHI 2020). The 1-year discharge corresponds to 41.3 m$^3$ s$^{-1}$, 5-year discharge to 99.3 m$^3$ s$^{-1}$, 10-year discharge to 131 m$^3$ s$^{-1}$, 50-year discharge to 223 m$^3$ s$^{-1}$and 100-year discharge to 269 m$^3$ s$^{-1}$. The mean annual water level is 25 cm. The highest recorded water level (1997) reached 260 cm (CHI 2020). There are five significant tributaries with catchment areas greater than 10 km$^2$: Bystrý creek, Lichnov creek, Tichávka creek, Kopřivnička creek and Trnávka creek.

The Ondřejnice River stems in the Moravian-Silesian foothills (Kříž 1995). The river springs near the village of Kozlovice on the western slope of the Ondřejník Mountain at an elevation of 760 m a.s.l. The catchment area is 99.38 km$^2$ (CHI 2017), and the length of the stream is 29.1 km (Povodí Odry 2016). The data of discharge and water level are from the gauging station (covers 41.09 km$^2$ of the total area of the basin) situated in the Rychaltice (Figure 1). The mean annual discharge is 0.575 m$^3$ s$^{-1}$. The 1-year discharge corresponds to 15.4 m$^3$ s$^{-1}$, 5-year discharge to 37.6 m$^3$ s$^{-1}$, 10-year discharge to 50.1 m$^3$ s$^{-1}$ and 100-year discharge to 104 m$^3$ s$^{-1}$. The mean annual water level is 78 cm, and the highest recorded water level from 1966 reached 385 cm (CHI 2020). The right tributary Košice creek is the only significant creek with a catchment area greater than 10 km$^2$ (Povodí Odry 2016).

The relief of the upper parts of both catchments is formed by rugged uplands, extending northwards from the territory of the Moravian-Silesian Beskids (with peaks exceeding 1200 m) and farther as flat highlands of Silesian-Moravian Foothills, e.g., the Štramberk Highlands with typical elevations of 450–500 m (Demek et al. 1965). The bedrock is formed by the Carpathian flysch rocks, and towards the mouths of the rivers, the bedrock is composed of much more complex lithological layers. The base is calcareous flysch from the Cretaceous period, especially claystone and marlstone. Significant subsoil includes limestone cliffs from the Jurassic period near the Štramberk Highlands and mountain ridges of Mesozoic igneous rocks such as teschenite and picrites (Chlupáč et al. 2002). Near the river mouth to the Oder River, the relief of the catchments consists of a wide Oder floodplain with low terraces. The subsoil consists mainly of Neogene sea clays in deeper layers and partially of Quaternary glaciofluvial sediments (GEOCR50 2015; Chlupáč et al. 2002) which are often covered with loess loam and slope material (Demek et al. 1965). A characteristic material of the studied bars is gravel derived from these flysch rocks (GEOCR50 2015).

In terms of river management, both rivers have been regulated roughly from the early 20th century. In the Lubina River, regulations included channel and bank stabilizations and an increase in channel capacity. Later, since the 1950s, more than 30 grade control structures have been implemented along almost the entire river course (except for the headwaters and most downstream parts near the confluence with the Oder) due to increasing infrastructure in the area (Figure 2). In the Ondřejnice River, most of the river regulations took place during the 1960s and 1980s, and in addition to channel capacity regulations, they included shifting of the channel. The river has more than 50 grade control structures and is regulated along more than 90% of its total length (Figure 2). Therefore, it is considered one of the rivers with the most interventions (Povodí Odry 2016).

### 2.2 Field work

Field measurements on both rivers took place in February 2019 during base flow conditions where the mean daily discharge during the days of field measurements varied from 1.88–2.28 m$^3$ s$^{-1}$ at the Lubina and from 0.54–0.78 m$^3$ s$^{-1}$ at the Ondřejnice (CHI 2020). Data were collected gradually from the river mouth of each river towards its headwaters. The representative grain sizes of the gravel bars were determined by the photo-granulometry method, which consisted of collecting grain-size data with digital photos and then processing by the appropriate software (Digital Gravelometer). For surface grain-size


**Fig. 2** Examples of previous river regulations; (A) large rocks (riprap) along the levee on right bank (the Lubina, channel width = 8 m, left-side bar, curved section); (B) check dam (the Lubina, channel width = 9 m, mid-channel bar, curved section); (C) bridge construction (the Ondřejnice, channel width = 11.5 m, left-side bar, straight section); (D) stone rockfill and grade control structure (the Ondřejnice, channel width = 11.5 m, right-side bar, straight section). Source: Author.

measurements, a wooden frame of 75 × 100 cm under which dots were placed in each corner was used to identify the four control points. After removal of the frame, the gravel bar surface was photographed above the centre so that the dots were clearly visible in the corners of the photo.

Photographs (13MP camera, 72 dpi 3120 × 4160 photos) were taken of the frontal, central and distal sections near the water level. A total of 15 gravel bars with 43 sites were measured on the Lubina River, where one site was measured in only one place due to the small planar area of the bar. Bars were measured at least every 1 kilometer of the river length with a few exceptions on the Lubina where the bar number was fewer and more clustered. Sixteen gravel bars with 48 sites were measured on the Ondřejnice River. The channel width was measured using a laser range-finder along the axis perpendicular to the bank and intersecting the centre of each gravel bar. Additional data were collected as GPS positioning, type and position of gravel bars and the vegetation cover according to Braun-Blanquet (1932) cover-abundance scale (Table 1). The vegetation mostly consisted of bunches of herbaceous vegetation remnants, since the field work took place in February. For a better understanding of the sediment grain-size disruptions and possible links with fluxes of sediment, the relative position of the bars between grade control structures, adjacent hillslopes areas and significant tributaries were mapped and observed in the field.

## 2.3 Data analysis

Photographs for photo-granulometry were further processed using the Digital Gravelometer software (version 1.0). This program is designed for processing digital photographs of fluvial sediments to analyse their grain size and distribution on the surface (Graham 2005). This method is less time-consuming than other methods of grain-size data collection, such as the Wolman pebble count method (Wolman 1954), which requires manual collection and measurement of sediments. In the Digital Gravelometer program, the "finer than" option was selected for the grain percentile calculation, followed by the "Grid-by-number" option for the distribution calculation. The grain-size unit was millimetres, and the lower truncation was set to 8 mm for all images. From the analytical report data, the statistical value of the geometric sorting and the percentiles D16, D50 and D84 were used. The average values of the grain-size percentiles of the frontal, central and distal parts of the bars were used for graphs of the downstream trends of the rivers.

Correlation analysis was calculated between the channel width data and respective percentiles from all measured parts of gravel bars. All data were tested for normality by the Shapiro-Wilk test, and afterwards, the Spearman correlation coefficient (with significance level of 0.05) for selected data series of both rivers was calculated.

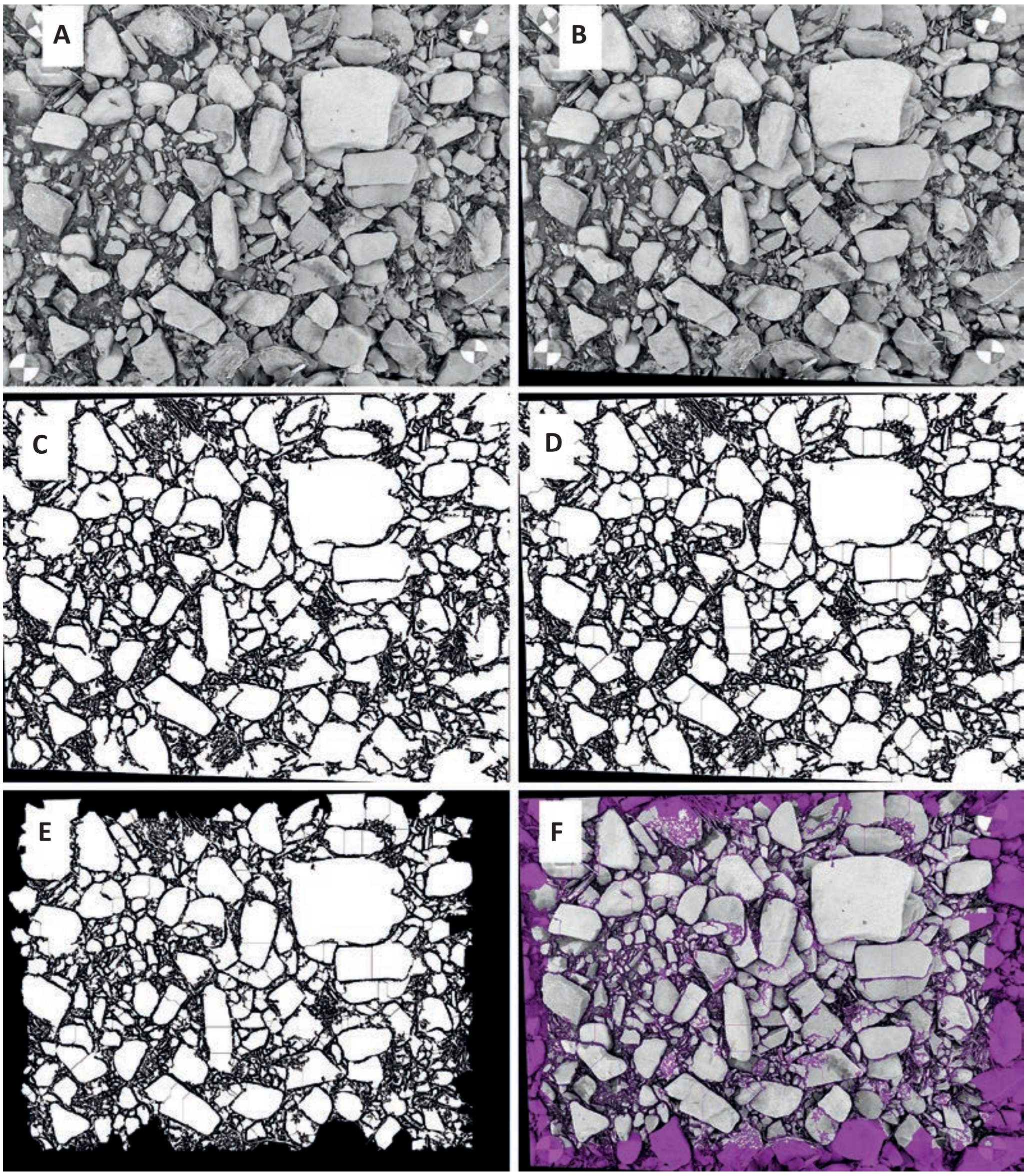


**Fig. 3** The process of photo analysis in Digital Gravelometer software; (A) Grayscale; (B) Transformed; (C) Grains; (D) Watershed segmented grains; (E) Grains selected; (F) Grayscale image overlaid on grains selected. Images source: Digital Gravelometer software; Data source: author.

**Tab. 1** Basic information and collected data for individual gravel bars.

| ID | River kilometer | Channel width (m) | Position in the channel | Flow section | Vegetation cover (Braun-Blanquet) | Relative position before-after the *GCS (m) |
|---|---|---|---|---|---|---|
| L1 | 0.8 | 25.0 | RB | CS | 2 | |
| L2 | 2.0 | 22.0 | RB | CS | 3 | |
| L3 | 5.7 | 16.0 | LB | CS | + | 330–700 |
| L4 | 11.6 | 17.5 | RB | CS | 1 | 200–40 |
| L5 | 12.7 | 16.0 | LB | CS | 1 | 300–100 |
| L6 | 13.5 | 15.5 | RB | CS | 2 | 420–410 |
| L7 | 18.0 | 24.5 | RB | CS | 1 | 50–900 |
| L8 | 18.1 | 22.0 | RB | CS | 3 | 510–14 |
| L9 | 19.9 | 27.0 | LB | CS | 2 | 700–500 |
| L10 | 25.0 | 16.5 | RB | SS | 4 | 750–400 |
| L11 | 30.0 | 6.5 | LB | SS | + | –400 |
| L12 | 30.5 | 8.0 | LB | CS | 4 | |
| L13 | 32.5 | 9.0 | LB | CS | + | |
| L14 | 33.7 | 8.0 | RB | CS | 1 | 15– |
| L15 | 33.8 | 9.0 | MB | CS | + | –3 |
| O1 | 0.5 | 15.0 | LB | CS | 1 | |
| O2 | 0.9 | 13.0 | LB | CS | 3 | |
| O3 | 1.3 | 11.0 | LB | SS | 2 | 820– |
| O4 | 3.5 | 10.5 | LB | CS | 2 | 1600–1500 |
| O5 | 5.6 | 9.0 | RB | SS | 4 | 680–660 |
| O6 | 7.2 | 8.5 | LB | SS | + | 960–600 |
| O7 | 9.0 | 8.5 | RB | SS | 1 | 60–800 |
| O8 | 11.3 | 11.0 | RB | SS | 1 | 35–370 |
| O9 | 12.5 | 13.0 | LB | CS | 1 | 1700–320 |
| O10 | 13.5 | 12.0 | RB | CS | 2 | 570–100 |
| O11 | 15.8 | 11.5 | LB | SS | + | 60–220 |
| O12 | 16.9 | 12.5 | RB | SS | 1 | 140–1400 |
| O13 | 18.7 | 10.5 | LB | CS | 1 | –1600 |
| O14 | 20.6 | 8.0 | RB | CS | 3 | |
| O15 | 22.2 | 9.5 | LB | SS | 2 | |
| O16 | 22.4 | 11.5 | RB | SS | 3 | |

O – The Ondřejnice River, L – The Lubina river, [MB] mid-channel bar, [RB] right-side bar, [LB] left-side bar, [CS] curve, [SS] straight, *GCS = grade control structures
Source: Author

## 3. Results

The comparison of grain-size of D50 between the studied rivers showed that the values were in most cases higher for the Ondřejnice River which is supported by median values for the frontal, central and distal parts of the bars (Table 2). Sorting values (Figure 4) ranged very similarly on both rivers: 0.65–1.32 Φ (Phi) on the Lubina River and 0.67–1.32 Φ on the Ondřejnice River, which according to Folk and Ward (1957) corresponds to moderately well sorted to poorly sorted sediment. The sorting of sediment on graph (Figure 4) showed a highly fluctuating trend in the Ondřejnice case while the Lubina showed a more gradual downward trend from poorly sorted to moderately well sorted sediment towards the river mouth.

The graphs (Figures 5 and 6) show the trends of average values for the frontal, central and distal parts of the bars and respective channel widths along with information about the location of adjacent hillslopes areas (Štramberk Highlands), significant tributaries and grade control structures. The downstream trend of grain size in both rivers showed rather complex patterns (particularly in the Lubina River case), but gradually decreasing exponential trends representing the downstream fining process were found for D50 and D84 in both rivers. The highest average values were detected at river km 32 in the Lubina River

**Tab. 2** The grain size of sediments (D50) and median values for studied parts of bars.

| Lubina | | | | Ondřejnice | | | |
|---|---|---|---|---|---|---|---|
| River km | D50 | | | River km | D50 | | |
| | Frontal | Central | Distal | | Frontal | Central | Distal |
| 33.8 | 24.7 | 31.3 | 31.2 | 22.4 | 29.4 | 50.5 | 43.4 |
| 33.7 | 40.9 | 48.8 | 62.5 | 22.2 | 33.9 | 39.2 | 42.4 |
| 32.5 | 43.9 | 52.9 | 62.7 | 20.6 | 45.9 | 52.0 | 40.4 |
| 30.5 | 19.1 | 40.3 | 30.6 | 18.7 | 42.8 | 44.2 | 42.0 |
| 30.0 | 44.2 | 41.4 | 37.9 | 16.9 | 35.2 | 48.8 | 39.8 |
| 25.0 | 47.2 | 39.0 | 35.4 | 15.8 | 28.9 | 24.7 | 31.6 |
| 19.9 | 27.6 | 26.2 | 33.6 | 13.5 | 30.8 | 35.8 | 27.4 |
| 18.1 | 28.0 | 31.3 | 25.4 | 12.5 | 26.3 | 29.7 | 26.4 |
| 18.0 | 29.2 | 17.2 | 17.6 | 11.3 | 34.7 | 34.4 | 26.1 |
| 13.5 | 21.3 | 22.4 | 19.4 | 9.0 | 26.2 | 27.1 | 23.1 |
| 12.7 | 21.0 | 18.7 | 21.8 | 7.2 | 37.6 | 34.7 | 33.2 |
| 11.6 | 23.8* | 23.8* | 23.8* | 5.6 | 30.7 | 36.1 | 27.9 |
| 5.7 | 18.0 | 19.2 | 18.6 | 3.5 | 18.6 | 16.7 | 17.6 |
| 2.0 | 20.8 | 23.2 | 15.9 | 1.3 | 25.8 | 25.4 | 26.0 |
| 0.8 | 22.4 | 20.7 | 19.4 | 0.9 | 27.4 | 26.9 | 23.4 |
| | | | | 0.5 | 25.1 | 18.8 | 19.3 |
| median | 26.2 | 28.8 | 28.0 | | 30.0 | 34.5 | 27.6 |

* The same value is due to the small planar area of the bar (only one sample photo).
Source: Author

(D84 = 100.36) and at river km 19 in the Ondřejnice River (D84 = 95.52).

According to the exponential trends in D50 and D84, decreasing grain size for both rivers is relatively high and regular. For the Lubina River (studied reach length is 33 km), the fining coefficient for D50 equals 0.026 mm $km^{-1}$ ($R^2$ = 0.70), and for D84, it equals 0.032 mm $km^{-1}$ ($R^2$ = 0.88). The results for the Ondřejnice River (studied reach length is 22 km) show even higher reduction as the fining coefficient for D50 equals 0.033 mm $km^{-1}$ ($R^2$ = 0.66) and for D84 is equal to 0.036 mm $km^{-1}$ ($R^2$ = 0.63).

The patterns of graph trends show some sudden changes in grain sizes (discontinuities), which indicate various interventions to the channel. In the Lubina River, despite the numbers of significant tributaries (Figure 5), there is no visible link between the discontinuities and these possible sources of sediment. In the Ondřejnice River, such discontinuities are more frequent, and they can be possibly caused by sediment supply from tributaries or slope-channel coupling (Figure 6). The observed vegetation cover of the bars (Table 1) showed increased coverage mainly in 18th, 25th and 30.5th river km in the Lubina and from 0.9th, 5.6th, 20.6th and 22.4th river km in the Ondřejnice which may cause increased tendency to deposit finer fractions. When combined with graphs, it can explain some discontinuities, for example, there is a decrease in grain size in the gravel bar of 30.5th river km, where the coverage according to Braun-Blanquet is class 4 (51–75%). However, in some cases, the grain-size on the respective gravel bars is higher which can be associate with sediment reinforcement by roots and higher flow rates. The final factor is the grade control structures which can cause decreased longitudinal connectivity. There is a very high number of check dam structures mainly in the Lubina case. Approximately from the 30th to 24th river km and from 21st to 5th river km are dense sequences of check dams where only a few discontinuities corresponded with increased grain-size of sediment (11.6th and 18th river km). The check dam sequences on the Ondřejnice (approx. 18th to

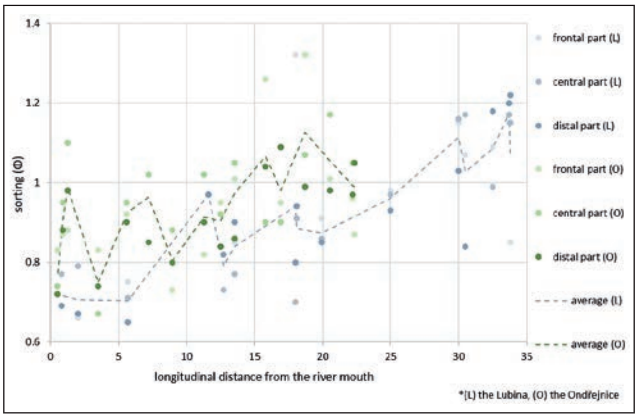


**Fig. 4** Trends of sediment sorting (Folk-Ward) for both rivers. Source: Author.

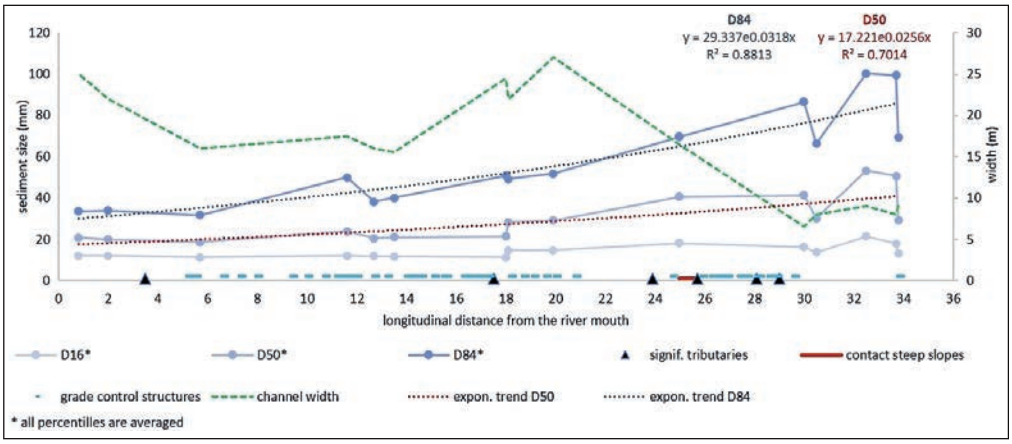


**Fig. 5** The trend of grain size on gravel bars at the Lubina River. Source: Author.

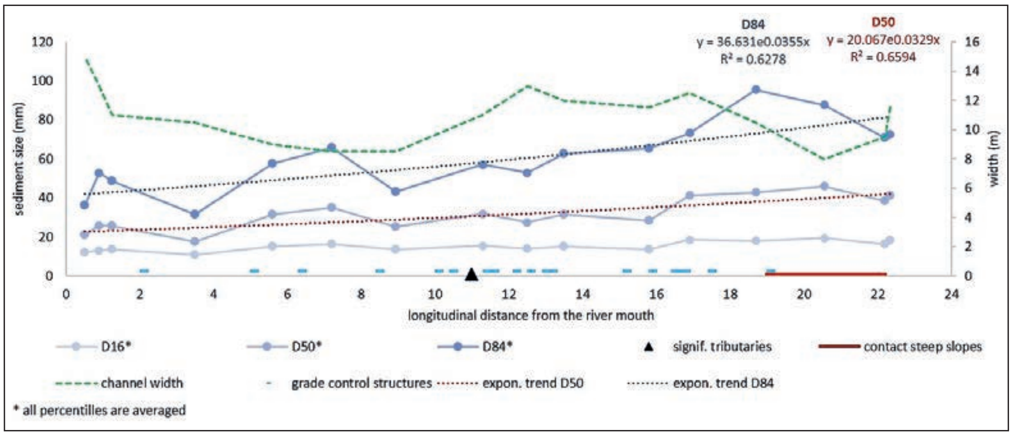


**Fig. 6** The trend of grain size on gravel bars at the Ondřejnice River. Source: Author.

15th river km and 14th to 10th river km) showed similarly only two cases of disruption of the downstream fining trend (11.3rd and 7.2nd river km) (Figure 6). In most cases, the area of sequenced check dams in the rivers did not affect the rapid downstream fining trends.

In the case of channel widths, similar tendencies can be observed on both rivers. Close the headwater areas, the widths are approximately 10 m. Thereafter, channel widths start to increase, moderately on the Ondřejnice (11–13 m) and rapidly on the Lubina (16.5–24.5 m). From approximately river km 14 on the Lubina River and river km 10 on the Ondřejnice River, channel widths start to moderately decrease downstream as the result of channel regulation works. Near the confluence with the Oder River, channel width values increase again (25 m for the Lubina; 15 m for the Ondřejnice). Overall, the channel widths range between 8 and 15 m on Ondřejnice and between 6.5 and 27 m on Lubina.

The distribution of the coarsest D50 within the three studied areas of the gravel bars (Table 3) shows relatively high spatial variation. On both rivers there exists a predominance for the coarsest sediments (D50) to deposit in the central parts of the gravel bars. The coarsest D50 on the Lubina is equally frequent on distal and frontal parts of the bars. Comparing the results on the Ondřejnice, the distribution of the coarsest D50 also shows the most frequent deposition in the central parts, with a notable increasing frequency towards the upstream direction (Figure 7).

In contrast, in downstream parts of the river, coarse deposits are more frequent in the frontal parts of bars. The least frequent deposition of the highest D50 is observed in the distal part of the bars.

The correlation was tested between the channel width data and the percentiles from all parts of the

**Tab. 3** Comparison of the rivers; distribution of the highest D50 on gravel bars from the source to the river mouth.

| **Lubina** river source → river mouth | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D50* | central | distal | distal | central | frontal | frontal | distal | central | frontal | central | distal | central | central | central | frontal | |
| **Ondřejnice** river source → river mouth | | | | | | | | | | | | | | | | |
| D50* | central | distal | central | central | central | distal | central | central | frontal | central | frontal | central | frontal | distal | frontal | frontal |
| | | | | | | | | | | | | | | | | |
| | frontal | frontal bar | | | central | central bar | | | distal | distal bar | | | | | | |

* The highest value.
Source: Author

**Tab. 4** Correlation between the channel width and grain-size percentiles.

| | Frontal Bar | | | Central Bar | | | Distal Bar | | |
|---|---|---|---|---|---|---|---|---|---|
| | D16 | D50 | D84 | D16 | D50 | D84 | D16 | D50 | D84 |
| Lubina $r_s$/p-value | 0.045 p = 0.874 | −0.118 p = 0.680 | −0.167 p = 0.553 | −0.543 p = 0.036 | −0.614 p = 0.015 | −0.670 p = 0.006 | −0.365 p = 0.180 | −0.541 p = 0.037 | −0.697 p = 0.004 |
| Ondřejnice $r_s$/p-value | −0.545 p = 0.029 | −0.397 p = 0.128 | −0.167 p = 0.536 | −0.210 p = 0.435 | −0.3203 p = 0.226 | −0.278 p = 0.298 | −0.24945 p = 0.352 | −0.26421 p = 0.323 | −0.24797 p = 0.354 |
| | | | | | | | | | |
| | | negative significant/non-significant | | | | | positive significant/non-significant | | |

Source: Author

gravel bars. These calculations were used to test the relationship between the channel width and the grain size of sediments (i.e., fining of sediments with increasing channel width). The negative trend is confirmed in most tested cases (Table 4). The correlation results for the Lubina show a significant negative correlation mostly in the central parts of the bars in all percentiles (D16 $r_s$ = −0.54; D50 $r_s$ = −0.61; D84 $r_s$ = −0.67) and partially in the distal parts in D50 ($r_s$ = −0.54) and D84 ($r_s$ = −0.70). The results for the Ondřejnice show only one significant correlation in frontal parts and D16 percentiles ($r_s$ = −0.56). Although there is a single significant correlation in this river, most data show a tendency for a negative relationship.

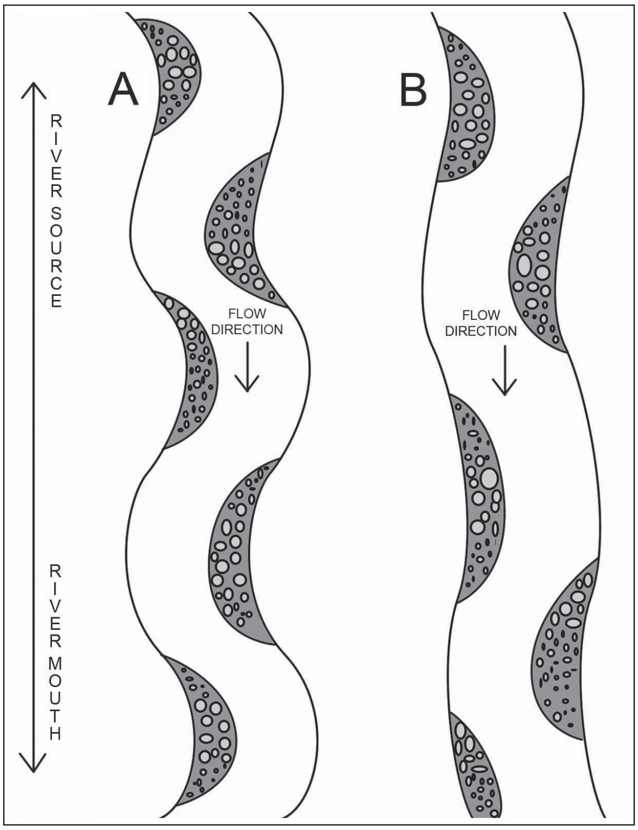


**Fig. 7** Diagram of the simplified deposition trends of the coarsest D50 sediments in the studied rivers; (A) The Lubina (main type = point bars), near the river source are the most frequent the central and distal parts of the bars, in the middle of the river the frontal parts start to show more frequently, near the river mouth the central parts are the most frequent; (B) The Ondřejnice (main type = alternate bars), the central parts of the bars are the most frequent in the upstream section while the frontal parts of the bars are more frequent downstream. Source: Author.

## 4. Discussion

### 4.1 Trends and variations of the downstream fining process

The downstream fining process was studied in terms of Sternberg's (1875) hypothesis of the exponential fining trend, and according to results from the studied heavily regulated rivers, there are regular downstream fining trends, particularly for the D84 percentiles: fining coefficient = 0.032 mm $km^{-1}$ for the Lubina and 0.036 mm $km^{-1}$ for the Ondřejnice. The percentiles of D50 show similar results with slightly lower coefficients of determination: fining coefficient = 0.026 mm $km^{-1}$ for the Lubina and 0.033 mm $km^{-1}$ for the Ondřejnice. The downstream fining coefficient, as well as the D50 percentile values and median of grain-size of sediment on the bars, is in most studied locations higher for the Ondřejnice River. These results are in accordance with those of other studies that observed more evident downstream reduction at the highest percentiles (Seal et al. 1997; Gomez et al. 2001). In general, the highest downstream reduction is often found in aggrading rivers, headwater streams or braided rivers (Galia et al. 2015; Bradley et al. 1972; Brierley and Hickin 1985; Dawson 1988; Paola and Seal 1995; Surian 2002), which is not the case for the rivers in this study. Our results also underline the rapid fining of bar sediments in the case of channelized rivers. Similar values of the fining coefficient have been observed in some Poland rivers of West Carpathians such as the Soła River (fining coefficient = 0.032 mm $km^{-1}$, study reach of 25 km) and Skawa River (fining coefficient = 0.036 mm $km^{-1}$, study reach of 21 km) both with multiple and single channel patterns (Malarz 2004).

In the case of the identified discontinuities and their associated causes on the studied rivers, there are surprisingly different results for each river. The longer Lubina River has a higher number of significant tributaries; nonetheless, the tributaries do not contribute to any significant change in the gran size of the gravel bars. Tributaries can also act as sources of both coarse and fine sediment, where finer sediment may be carried away by the river almost immediately if the river tends to have higher flow rates than the tributary (Škarpich et al. 2013), which may be the case. On the other hand, the Ondřejnice River has only one significant tributary, which correspond with an increase in grain size in this locality downstream from river km 11. Another source of coarse material most likely originated from the hillslopes in contact with riverbanks within the area of the Štramberk Highlands (river km 19–22) where the grain-size starts to increase. Compared to the Ondřejnice, there is no evident association with any tributary or adjacent hillslopes in the Lubina.

The vegetation cover can be the factor for minor shifts in grain-size trends such is the decreased grain-size on the bar in the 30.5th river km in the Lubina. However, the vegetation cover can cause either the deposition of finer sediment or the stabilization of coarser bar sediment (Wohl 2004; Corenblit et al. 2009). Therefore, it is difficult to link the trends of grain-size to the studied bars, moreover, when other factors (downstream fining process, longitudinal connectivity) must be considered (McMahon et al. 2020). In terms of the longitudinal connectivity, the grade control structures (check dams) are often located in sequences on both rivers (the Lubina: 30th to 24th river km, 21st to 5th river km; the Ondřejnice: 18th to 15th river km, 14th to 10th river km) and they corresponded surprisingly well to rapid downstream fining trends with a few exceptions. Increased grain-size trends below the check dam were detected at the 11th and 7th river km on the Ondřejnice and the 11.6th and 18th (only for the coarsest fraction) river km on the Lubina. These results correspond to the principle of disconnectivity caused by barriers in the river channel (Škarpich et al. 2010). The small number of detected disconnections are most likely due to the natural lack of bars towards the headwater area as well as the total number of studied bars. Nevertheless, the data showed that in most areas the downstream fining is not affected by grade control structures. Naturally, there may exist other possible causes that are not investigated in this study such as local downward and lateral erosion or channel slope.

### 4.2 Trends in the deposition of sediments on the surfaces of gravel bars

The size-dependent deposition of the coarsest D50 percentiles within the gravel bar surface shows great variability throughout the Lubina and a more gradual change in the case of the Ondřejnice. Both rivers show the most frequent depositional tendency of the coarsest D50 in the central parts of the bars. Additionally, the results for the Ondřejnice show a clear trend of the most frequent deposition in the central parts of the bars in the middle and upper river reaches and frequent deposition on the frontal parts in the downstream river reach. The deposition of the finest D50 on the distal parts is consistent with a common presumption that finer material tends to settle gradually behind the coarser sediment (Ashworth and Ferguson 1986; Bluck 1982; Smith 1974). The predominance of deposition of finer or coarser sediments in certain parts of the bars can be related to the different roughness conditions on the gravel bars, e.g., caused by growing vegetation (Li et al. 2014). However, there is no predominant type of deposition of D50 associated with the vegetation cover of the bars in the collected data. In the Lubina case, there are also the central parts of the bars the most frequent (mainly in the downstream area). The frontal and distal parts of the gravel bars were equally frequent. However, the deposition tendency of the frontal parts is higher within the middle area of the river.

### 4.3 Trends in the deposition of bar sediments by channel width

The range of values for channel widths on the Ondřejnice is much lower (8–15 m) than that on the Lubina, which shows very sudden changes from wide to narrow channels. This variability is probably the effect of artificial structures such as check dams or bridges located in the river or other human interventions. Compared to the Ondřejnice, the river is regulated particularly with respect to channel width since it flows through many built-up areas, and the river is often channelized to constant width. The correlations between channel widths and grain sizes of sediments show very different results for each river. In the Lubina, significant negative correlations are recorded for 5 of 9 cases. These correlations are observed mainly in the central parts (D16 $r_s = -0.54$; D50 $r_s = -0.61$; D84 $r_s = -0.67$) and in the distal parts of the bars (D50 $r_s = -0.54$; D84 $r_s = -0.70$). However, the Ondřejnice shows only one case of significant negative correlation in frontal parts (D16 $r_s = -0.5$). These results indicate the existence of a strong negative relationship between the channel width and sediment grain size in the Lubina River, while Ondřejnice shows a weak negative relationship. Again, these results can be assigned to frequent river regulations, particularly in the Ondřejnice, and to the fact that such rivers tend to show higher variability of sediment size, frequently due to their many different sources (Škarpich 2010; Rice 1998; Rengers and Wohl 2007).

## 5. Conclusion

In this paper, we focused mainly on the downstream fining process, secondarily on the trends in grain sizes deposition on the frontal, central and distal parts of the gravel bars and thirdly, on the relationship between the grain-size of the bars and channel width variations in the two channelized gravel-bed rivers. Trends of downstream fining showed a relatively high reduction in grain size in both studied rivers, where reduction coefficients were comparable to values observed along some of the single and multiple threaded rivers in the Western Carpathians. The results showed that a rapid reduction in sediment size is often observed even on highly regulated rivers such as the Ondřejnice. We also observed the trend of deposition of finer sediment in wider channels in the case of the less regulated river while there was almost no relationship in the heavily regulated river. The predominant deposition of the coarsest sediment D50 on the gravel bars occurred on the central parts of the bars, in contrast with the general tendency of coarse sediment to be deposited on the frontal parts, as observed in natural streams. The disruption of the downstream fining trend corresponded with the grade control structures only in a few cases, probably due to the total number of studied gravel bars. In most cases, the downstream fining was not affected by check dams. The significant tributaries and adjacent hillslopes were suggested as the possible sources of disruption, however, only in the case of the Ondřejnice River. Compared to the Ondřejnice River, the Lubina River showed that despite the high number of significant tributaries, disruption did not necessarily occur.

## References

Ashworth, P. J., Ferguson, R. I. (1989): Size-selective entrainment of bedload in gravel bed streams. Water Resources Research 25(4), 627–634, https://doi.org/10.1029/WR025i004p00627.

Ashworth, P. J., Ferguson, R. I. (1986): Inter-relationships of channel processes, changes and sediments in a proglacial braided river. Geografiska Annaler: Series A, Physical Geography 68(4), 361–371, https://doi.org/10.1080/04353676.1986.11880186.

Bluck, B. J. (1982): Texture of gravel bars in braided streams. In Hey, R. D., Bathurst, J. C. and Thorne, C. R., editors, Gravel-bed rivers: fluvial processes, engineering and management, Chichester: Wiley, 339–355, https://doi.org/10.1002/esp.3290080619.

Borák, L. (2018): The quantity and attributes of woody accumulations in the Moravskoslezské Beskydy Mountains Streams, AUC Geographica 53(1), 20–35, https://doi.org/10.14712/23361980.2018.3.

Bradley, W. C., Fabnstock, R. K., Rowekamp, E. T. (1972): Coarse sediment transport by flood flows on Knik River, Alaska. Geological Society of America Bulletin 83, 1261–1284, https://doi.org/10.1130/0016-7606(1972)83[1261:CSTBFF]2.0.CO;2.

Braun-Blanquet, J. (1932): Plant sociology (Transl. G. D. Fuller and H. S. Conrad). McGraw-Hill, New York, 539.

Bridge, J. S., Jarvis, J. (1976): Flow and sedimentary processes in the meandering river South Esk, Glen Cova, Scotland. Earth Surface Processes 1, 303–336, https://doi.org/10.1002/esp.3290010402.

Brierley, G. J., Hickin, E. J. (1985): The downstream gradation of particle sizes in the Squamish River, British Columbia. Earth Surfaces Processes and Landforms 10, 597–606, https://doi.org/10.1002/esp.3290100607.

Corenblit, D., Steiger, J., Gurnell, A. M., Tabacchi, E., Roques, L. (2009): Control of sediment dynamics by vegetation as a key function driving biogeomorphic succession within fluvial corridors. Earth Surface Processes and Landforms 34, 1790-1810, https://doi.org/10.1002/esp.1876.

Dawson, M. (1988): Sediment size variation in a braided reach of the Sunwapta River, Alberta, Canada. Earth Surfaces Processes and Landforms 13, 599–618, https://doi.org/10.1002/esp.3290130705.

Demek, J., Mackovčin, P. (2006): Zeměpisný lexikon ČR: Hory a nížiny (2nd ed.). Agentura ochrany přírody a krajiny ČR, Brno.

Edwards, P. J., Kollmann, J., Gurnell, A. M., Petts, G. E., Tockner, K., Ward, J. V. (1999): A conceptual model of vegetation dynamics on gravel bars of a large Alpine river. Wetlands Ecology and Management 7, 141–153, https://doi.org/10.1023/A:1008411311774.

Faustini, J. M., Jones, J. A. (2003): Influence of large woody debris on channel morphology and dynamics in steep, boulder-rich mountain streams, western Cascades, Oregon. Geomorphology 51, 187–205, https://doi.org/10.1016/S0169-555X(02)00336-7.5901.

Folk, R. L., Ward, W. C. (1957): Brazos River Bar: A study in the significance of grain size parameters. Journal of Sedimentary Petrology 27, 3–26, http://dx.doi.org/10.1306/74D70646-2B21-11D7-8648000102C1865D.

Galia, T., Hradecký, J. (2014): Estimation of bedload transport in headwater streams using a numerical model (Moravskoslezké Beskydy Mts, Czech Republic). AUC Geographica 49(1), 21–31, https://doi.org/10.14712/23361980.2014.3.

Galia, T., Škarpich, V., Hradecký, J. (2015): Connectivity of the coarsest fraction in headwater channels: imprints of fluvial processes and debris-flow activity. Geografiska Annaler: Series A, Physical Geography 97(3), 437–452, https://doi.org/10.1111/geoa.12086.

GEOCR50 (2015): Praha: Česká geologická služba [cartographer]. Geologická mapa České republiky [map] 1 : 50 000. Retrieved from: https://mapy.geology.cz/geocr50/.

Graham, D. J., Reid, I., Rice, S. P. (2005): Automated Sizing of Coarse-Grained Sediments: Image-Processing Procedures. Mathematical Geology 37, 1–28, https://doi.org/10.1007/s11004-005-8745-x.

Gomez, B., Rosser, B. J., Peacock, D. H., Hicks, D. M., Palmer, J. A. (2001): Downstream fining in a rapidly aggrading gravel bed river. Water Resources Research 37(6), 1813–1823, https://doi.org/10.1029/2001WR900007.

Gordon, D. N., Mcmahon, A. T., Finlayson, L. B., Gippel, J. Ch., Nathan, J. R. (2004): Stream Hydrology, An Introduction for Ecologist. Second Edition. John Wiley and Sons, Ltd., Chichester.

Heitmuller, F., Hudson, P. (2009): Downstream trends in sediment size and composition of channel-bed, bar, and bank deposits related to hydrologic and lithologic controls in the Llano River watershed, central Texas, USA. Geomorphology 112(3–4), 246–260, http://dx.doi.org/10.1016/j.geomorph.2009.06.010.

Howson, T. J., Robson, B. J., Matthews, T. G., Mitchell, B. D. (2012): Size and quantity of woody debris affects fish assemblages in a sediment-disturbed lowland river. Ecological Engineering 40, 144–152, https://doi.org/10.1016/j.ecoleng.2011.12.007.

Hradecký, J., Škarpich, V., Galia, T., Gurkovský, V., Vaverka, L. (2019): Štěrky, štěrky, štěrky… (ne)valící se kameny po Labi. Ochrana Přírody, 2.

CHI (2017): Czech Hydrometeorological Institute, Hydrological list of detailed catchment division of streams in the Czech Republic [PDF file]. Retrieved from: http://voda.chmi.cz/hr05/seznamy/hsp.pdf.

Chiari, M., Rickenmann, D. (2011): Back-calculation of bedload transport in steep channels with a numerical model. Earth Surface Processes and Landforms 36, 805–815, https://doi.org/10.1002/esp.2108.

Chlupáč, I., Brzobohatý, R., Kovanda, J., Stráník, Z. (2002): Geologická minulost České republiky. Academia, Praha.

Church, M., Kellerhals, R. (1978): On the statistics of grain size variation along a gravel river. Canadian Journal of Earth Sciences 15, 1151–1160, https://doi.org/10.1139/e78-121.

Ikeda S., Izumi N. (1990): Width and depth of self-formed straight gravel rivers with bank vegetation. Water Resources Research 26, 2353–2364, https://doi.org/10.1029/WR026i010p02353.

Jackson, R. G., (1976): Largescale ripples of the lower Wabash River. Sedimentology 23, 593–623, https://doi.org/10.1111/j.1365-3091.1976.tb00097.x.

Kaczka, R. (1999): Dynamics of production, movement and storage of coarse woody debris during the flood of the July 1997. Kamienice Lacka Valley, Beskidy Mts., Poland. 3rd Domodis workshop – Documentation of mountains disasters, Bucharest, 1–6.

Knighton, A. D. (1980): Longitudinal changes in size and sorting of stream-bed material in four English rivers. Geological Society of America bulletin 91, 55–62, https://doi.org/10.1130/0016-7606(1980)91<55:LCISAS>2.0.CO;2.

Kříž, V. (1995): Ochrana vod a vodní hospodářství Beskyd. Nadace Beskydy, Ostrava.

Li, Z., Wang, Z., Pan, B., Zhu, H., Li, W. (2014): The development mechanism of gravel bars in rivers. Quaternary International 336, 73–79, https://doi.org/10.1016/j.quaint.2013.12.039.

Lunt, I .A., Bridge, J. S., (2004): Evolution and deposits of a gravelly braid bar, Sagavanirktok River, Alaska. Sedimentology 51, 415–432, https://doi.org/10.1111/j.1365-3091.2004.00628.x.

McMahon, J. M., Olley, J. M., Brooks, A. P., Smart, J. C. R., Stewart-Koster, B., Venables, W. N., Curwen, G., Kemp, J., Stewart, M., Saxton, N., Haddadchi, A., Stout, J. C. (2020): Vegetation and longitudinal coarse sediment connectivity affect the ability of ecosystem restoration to reduce riverbank erosion and turbidity in drinking water. Science of the Total Environment 707, https://doi.org/10.1016/j.scitotenv.2019.135904.

Malarz, R. (2005). Effects of flood abrasion of the Carpathian alluvial gravels. Catena 64(1), 1–2, https://doi.org/10.1016/j.catena.2005.07.002.

Paola, C., Seal, R. (1995): Grain size patchiness as a cause of selective deposition and downstream fining, Water Resources Research 31(5), 1395–1407, https://doi.org/10.1029/94WR02975.

Parker, G., Andrews, E.D. (1985): Sorting of bedload sediments by flow in meander bends. Water Resources Research 21(9), 1361–1373, https://doi.org/10.1029/WR021i009p01361.

Povodí Odry (2016): Atlas hlavních vodních toků povodí Odry. Retrieved from: https://www.pod.cz/atlas_toku/.

Pyrce, R. S., Ashmore, P. E. (2005): Bedload path length and point bar development in gravel-bed river models. Sedimentology 52(4), 839–857, https://doi.org/10.1111/j.1365-3091.2005.00714.x.

Rengers, F., Wohl, E. (2007): Trends of grain sizes on gravel bars in the Rio Chagres, Panama. Geomorphology 83 (3–4), 282–293, https://doi.org/10.1016/j.geomorph.2006.02.019.

Rice, S. (1999): The nature and controls on downstream fining within sedimentary links. Journal of Sedimentary Research 69(1), 32–39, https://doi.org/10.2110/jsr.69.32.

Rice, S. (1998): Which tributaries disrupt downstream fining along gravel-bed rivers? Geomorphology 22, 39–56, https://doi.org/10.1016/S0169-555X(97)00052-4.

Rice, S., Church, M. (1996): Bed material texture on low order streams in the Queen Charlotte Islands, British Columbia. Earth Surface Processes and Landforms 21, 1–18, https://doi.org/10.1002/(SICI)1096-9837(199601)21:1<1::AID-ESP506>3.0.CO;2-F.

Seal, R., Paola, C., Parker, G., Southard, J. B., Wilcock, P. R. (1997): Experiments on downstream fining of gravel. 1. Narrow-channel runs. Journal of Hydraulic Engineering 123(10), 874–884, https://doi.org/10.1061/(ASCE)0733-9429(1997)123:10(874).

Smith, N. D. (1974): Sedimentology and Bar Formation in the Upper Kicking Horse River, a Braided Outwash Stream. Journal of Geology 82(2), 205–223, https://doi.org/10.1086/627959.

Sternberg, H. (1875): Untersuchungen über längen- und querprofil geschiebeführender Flüss. Z. Bauwesen 25, 483–506.

Surian, N. (2002): Downstream variation in grain size along an Alpine river: Analysis of controls and processes. Geomorphology 43(1–2), 137–149, https://doi.org/10.1016/S0169-555X(01)00127-1.

Škarpich, V., Galia, T., Ruman, S., Máčka, Z. (2019): Variations in bar material grain-size and hydraulic conditions of managed and re-naturalized reaches of the gravel-bed Bečva River (Czech Republic). Science of the Total Environment 649, 672–685, https://doi.org/10.1016/j.scitotenv.2018.08.329.

Škarpich, V., Galia, T., Hradecký, J. (2013): Podmínky transportu a akumulace sedimentů v člověkem ovlivněných korytech beskydských toků: příkladová studie soutoku řeky Morávky a Mohelnice. Geologické výzkumy na Moravě a ve Slezsku 19(1–2), 53–58, https://doi.org/10.5817/GVMS2012-1-2-053.

Škarpich, V., Galia, T., Hradecký, J., Peč, J. (2010): Identifikace (dis)konektivit vodních toků za využití makrogranulometrické analýzy korytových sedimentů (Moravskoslezské Beskydy). Geologické výzkumy na Moravě a ve Slezsku 17(1–2), 199–204.

Štefáček, S. (2008): Encyklopedie vodních toků Čech, Moravy a Slezska. Baset, Praha.

Wistuba, M., Sady, A., Poręba, G. (2018): The impact of Wallachian settlement on relief and alluvia composition

in small valleys of the Carpathian Mts. (Czech Republic). Catena 160, 10–23, https://doi.org/10.1016/j.catena.2017.08.017.
Wohl, E. (2014): Rivers in the landscape, Science and Management. John Wiley and Sons, Ltd., Chichester.
Wohl, E. (2017): Connectivity in rivers. Progress in Physical Geography: Earth and Environment 41(3), 345–362, https://doi.org/10.1177/0309133317714972.
Wolman, M. G. (1954): A method of sampling of coarse river-bed material. Transaction of the American Geophysical Union 35, 951–956, https://doi.org/10.1029/TR035i006p00951.
Yager, E. M., Kirchner, J. W., Dietrich, W. E. (2007): Calculating bedload transport in steep boulder bed channels. Water Resources Research 43: W07418, https://doi.org/10.1029/2006WR005432.

# Regional development trends in West Bohemia with a special focus on peripheral areas

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**ABSTRACT**

In this article, we study regional development trends in the Czech region of West Bohemia through the application of the core-periphery concept. In particular, we focus on the peripheral areas of West Bohemia, the development and differences between its core and periphery, and on the processes of peripheralization. We have used both 'scalar' and 'vector' indicators in the hierarchical cluster analysis. It revealed selective convergent and divergent trends of the core and periphery, in which the peripheralization takes place through the geographic expansion of existing peripheries rather than through the emergence of new isolated peripheries.

**KEYWORDS**

West Bohemia; periphery; core-periphery axis; regional development; cluster analysis

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## 1. Introduction

In recent years, we have witnessed the rapid development of national economies, but also crises and other social and political changes that also have a spatial dimension. These concerned, for example, market integration, the opening of borders and the (re-)construction of development policies. These factors have been the catalyst for changes in the territory, whether the strengthening of core areas, the development or decline of the periphery, or the emergence of new development poles. To monitor these changes, we chose the territory of West Bohemia.

The studied regions were selected as representatives of the territories that have been significantly and long-term, possibly permanently, influenced by a political decision. After 1945, over 2 million people had to leave the territory of border territory of Bohemia and Moravia inhabited by population of German nationality (Glassheim 2000), Jelinek (1993) and Frommer (2010) mentions an estimation of 2.5–2.6 million of relocated people. West Bohemia necessarily had a very significant share of Germans due to its geographical location; in a number of border areas, the displaced population of German nationality also constituted a significant ethnic majority. Many villages were completely abandoned and vanished (i.e. Böhmichdorf, Ulrichsgrün, Holzhäuser and many others).

The following period of socialism in this area had several typical aspects – central system, central planning or large-format agriculture; in terms of the settlement system also progressive urbanization and basically no suburbanization. After 1989 there were significant changes that contributed to the transformation of the society. First, the ideological anchoring of state power turned, and the main rules of society's functioning changed with the advent of capitalism. In addition to the society as such, space has also changed. After institutional and social change, territorial followed. The greatest changes in urban and suburban landscapes meant regeneration of urban centres and massive suburbanization (Sýkora, Bouzarovski 2012), which was often noncontrolled. On a wider scale, territorial differences began to widen when forced equalization ended (Hampl 2005). The core role of the largest cities strengthened greatly, and the peripheries had a greater chance to emerge or expand. The transformation period has also taken place in the spirit of strong economic decline and socio-economic disparity in some regions, particularly heavy industry and coal mining base regions.

Such variability occurs also in the territory targeted by this paper. The Plzeň Region is associated with the industrial character of the largest city of Plzeň and the transit function (Bavaria–Prague axis). The Karlovy Vary Region is often associated with problems of environmental or socio-economic nature since surface coal mining is widespread and the region is characterized by lower level of education and quality of labour (Hampl 2003).

The goal of this paper is to bring a typology of areas based on socio-economic attributes of the spatial units. The typology should follow the concept of the 'core-periphery' axis. Further, we aim to observe the changes among the types of areas and discuss possible ways of development of West Bohemian peripheral areas, on which this paper focuses the most.

## 2. Theoretical background

Periphery is a designation for specific areas that have a disadvantaged position in terms of social, economic and demographic qualities and are also affected by physical geographic obstacles and barriers in the region (Pociūtė-Sereikienė 2019; Havlíček et al. 2005). Core–periphery axis (see Wallerstein 1979; Friedmann 1966) indicates that peripheries are also, to some extent, determined by the distance from the core on which they depend. Social peripherality can be expressed, for example, in the educational structure and availability of education in general. The age structure of the population captures the demographic peripherality, assuming that the peripheral areas will have a higher proportion of post-productive population compared to the youngest generations (Kebza 2018; Bański 2005), the peripheral character is also captured by negative migration balances (Kubeš, Kraft 2011). Economic peripherality is based on lower economic potential. Industries with high added value are usually not concentrated in peripheries, not even important shopping centers, and jobs may also be unavailable. From the economic point of view, integration into the market system is important. In peripheral areas, however, it is insufficient and results from functional-spatial relationships disorder (Schmidt 1998). If the territory is completely removed from the integration, the term 'margin' is used to describe the non-productive territory affected by total isolation or out of the system (Pileček, Jančák 2011). The deepening of regional differences, or rather of peripheries, is exacerbated by the absence or lack of innovative activities and potential (Kühn 2015). On the other hand, active local entrepreneurs who form the economic base are not fundamentally limited by the peripheral character of the territory and can even benefit from it (Bečicová, Blažek 2015; Felzensztein, Gimmon, Aqueveque 2013).

Recent research also points to differences between the periphery as a static concept and the peripheralization as a dynamic process of changing the qualities of the territory (Kühn 2015; Lang 2012). An important element of the debate is also the knowledge about the possibilities of development of peripheral areas. While Humer (2018) discusses the possible impacts of the 'top-down' strategy of polycentric settlement system development on peripheries (in which the author sees some bugs), other authors consider options that require a 'bottom-up' approach of local actors. Human capital of municipal representatives and its effects is dealt by Pileček (2011), while Mayer, Habersetzer and Meili (2016) emphasize local entrepreneurs and their ability to create periphery-core ties in a way that a competitive environment is created in the periphery and the importance of dependence on cores is not that significant. Kebza (2018) put stress on innovation and the 'creative class' in the peripheral areas that could be essential for the future development.

However, peripheries might also be shaped by the perception of local people or the political representation (Willet, Lang 2018), but also by the external world. Such a negative perception is very difficult to overcome, despite considerable efforts.

Although remote positions at state (see Kubeš, Kraft 2011; Havlíček, Chromý 2001) or other administrative borders (Kebza 2018; Musil, Müller 2008) are often common for peripheral areas, these concepts cannot be perceived as identical. Boundaries can contribute to peripherality if they form a (political) barrier, but they cannot determine it. In Europe we find examples of border areas that we could not regard as peripheral (e.g. cities of Copenhagen-Malmö, Lille or Bratislava and their surroundings). In the case of Czechia peripheries often appear in mountainous borders and regional borders (Musil, Müller 2008), which are remote and far from important cores.

Similarly, it is necessary to approach the concepts of periphery and rural. Like some authors reject the understanding of one compact rural area and di-vide it into different groups according to various characteristics (Hedlund 2016), it is not easy to accept the claim of one periphery. Rural areas can be of peripheral nature, however, 'rural' also often includes suburbs of large cities and other rural areas with high development potential, which cannot be described as peripheral. This difference is clearly presented by Perlín, Kučerová and Kučera (2010), who distinguish the category of Moravian peripheries from seven other rural areas in their typology.

Like the rural, the peripheries can be also divided into several types. Kebza (2018), on the example of the West Pomeranian Voivodeship, divides the territory into several categories containing metropolitan (and semi-metropolitan) areas, semiperipheries and four types of peripheries:

- periphery located at the country borderline (in the case of bordering with more countries, it is possible to divide them further as frontiers with different countries can bring different effects),
- bordering periphery, that is situated at the boundary of self-governmening regions, but within the state,
- inner periphery, whose location is not related to any state border nor boundary of self-governing regions,
- pleasure periphery, which is a special category of a seaside or other area with highly developed tourism.

The possible typology of the peripheral areas can also be derived from other characteristics, whether in addition to the location there are attributes based on the dominant aspect of peripherality, peripheriality level (Pociūtė-Sereikienė 2019) or developmental tendencies of the territory.

Our research questions mainly concern the changes in spatial pattern and developmental tendencies affecting peripheries:

- Does the peripheralization process and thus 'production' of peripheries take place in West Bohemia?
- Are the differences between local core and peripheral regions widening?
- How do the dynamics of socio-economic development of peripheral, core and transitional (semi-peripheral) areas differ?

## 3. Studied area

The discussed territory of West Bohemia is composed of two administrative regions (see Fig. 1). Both Plzeň and Karlovy Vary Regions are on NUTS 3 level. Based on the East-West gradient concept, West Bohemia should have a very favourable location and should benefit from the proximity of progressive Bavaria. It turns out, however, that the long-term effects of the Iron Curtain, the displacement of inhabitants, and partly the relief or environmental problems in the Sokolov Basin, constitute barriers to fundamental development throughout the territory. The territory is typical of a large number of vanished municipalities (see Zaniklé obce 2019). According to the analysis of Novák and Netrdová (2011), problematic areas form a significant part of the region, mainly territories distant to larger towns (areas between Strakonice and Sušice, Stříbro and Horšovský Týn) and the north-eastern border of the studied region. On the contrary, larger cities and their surrounding areas, like Klatovy, Domažlice, Cheb, Karlovy Vary and especially Plzeň with its wider area and a significantly extended axis in the direction of Prague can be counted among the potential growth poles. Plzeň, as the second most populated city of Bohemia, is closely connected with Prague; the railway corridor and the motorway complement the system of medium-sized cities with a significant number of jobs in commercial premises (e.g. Rokycany, Žebrák or Beroun). Although very important transport routes pass through the area (see Fig. 1), the density of transport networks is described as weak (Drahošová 2011).

The development of the territory is also limited from several directions, especially in terms of human capital (Hampl 2003). Areas around Tachov and Cheb have below-average values of the educational

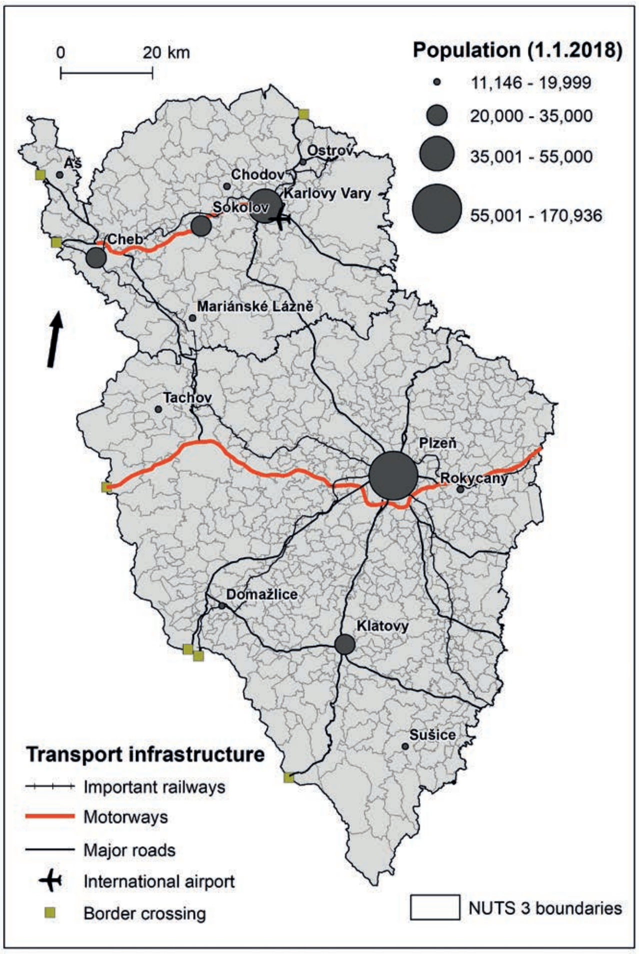


**Fig. 1.** Biggest cities and towns in Plzeň and Karlovy Vary Regions by population.
Source of data: ČSÚ (2019)

structure of population (Hübelová 2014). Novotná, Šlehoferová and Matušková (2016) introduce a number of other contrasts, where Plzeň and its surroundings are significantly different from the distant parts of the region.

## 4. Methods

If we want to study the peripheries in a particular area, spatial delimitation of them is necessary. However, the study of peripheries cannot be isolated (Havlíček, Chromý 2001). Thus, it is also naturally needed to demarcate the core and the transition zone formed by semiperipheries, which are socio-economically more advanced and more integrated than the peripheries (Wallerstein 1979).

The methods described below reflect the aim of the paper, especially to identify peripheral areas in West Bohemia on the basis of the above-discussed aspects of peripherality and to monitor the development trends of these areas in comparison mainly with the core areas.

For the purposes of this research, the years 2007 and 2017 were selected for comparison. In 2007, integration into European structures even at institutional level was already under way, while the initial wave of radical spatial changes, such as massive and uncontrolled suburbanization, that emerged under the third phase of transformation (Sýkora, Bouzarovski 2012) was ending. A decade later, these processes may appear in advanced form, probably closer to the natural trajectory. It would certainly be enriching to add this file to 1997, but this does not allow the limits of the data base.

The selection of suitable spatial units that enter the analysis is important. In general, relatively large number of empirical works are devoted to analyses at regional level (NUTS 2, NUTS 3 or similar). The evaluation of these units affects the regions as a complex territory based on functional relations, but the reduction of internal differences somewhat generalizes. Basic administrative units have been used for similar research (Kebza 2018; Novák, Netrdová 2011; Blažek, Netrdová 2009; Džupinová et al. 2008) as well as authors' non-standard units (Novotná, Šlehoferová, Matušková 2016; Musil, Müller 2008). These units are used for a more detailed insight into proposed geographical reality. A disadvantage, however, may be that the expression of extreme values is easier; the smallest municipal population in the area – Čilá – had only 16 inhabitants (ČSÚ 2019) in December 31, 2017 and belongs to the smallest municipalities in whole Czechia; in West Bohemia there are another 60 municipalities (out of 635) with less than 100 inhabitants, and only one of these is located in the Karlovy Vary Region (Přebuz, the smallest official Czech town). In this respect, partial distortions (outliers) can be expected, and must be taken into account in the interpretation.

For the statistical analysis, 4 scalar and 2 vector indicators were chosen. The selection should correspond to social, economic and demographic aspects of peripheriality mentioned in the theoretical part of the article. Scalar indicators are tied to the socio-economic characteristics of a given territory, while vector ones consider the distance to the municipality with certain central functions. Scalar indicators have a numerical superiority to avoid fogging or overlapping some of the potential phenomena that could occur near to major cities.

**Tab. 1** Scalar and vector indicators used in the analysis and their presupposed values in relation to the typology.

| | Net migration rate | Old-age dependency ratio | Unemployment rate | Newly built flats | 'Trade' | 'Education' |
|---|---|---|---|---|---|---|
| Core | high | low | low | high | high | high |
| Peripheries | low | high | high | low | low | low |

Source: authors' elaboration

Four scalar indicators are selected to respect the elements of peripherality mentioned above – population stability (net migration rate) and age structure of population (old-age dependency ratio). We monitor the economic potential by the unemployment rate, although it also has a social overlap (Nováček 2014). From the point of view of population stability we also express the attractiveness of the area by housing construction in municipalities (newly built flats per capita).

Net migration rate and newly built flats were measured for 2002–07 and 2012–17 since data for only one year could bring significant distortion. Both indicators mainly reflect the residential attractiveness of the area.Low or negative migration can positively correlate with high unemployment rate and create 'futureless localities'. The social aspect of peripherality is expressed by old-age dependency ratio, as the older population is typical for peripheral areas (Bański 2005).

Vector indicators, here called 'Trade' and 'Education' by nature take into account the distance (geometric peripherality), specifically retail and tertiary education centres. Quantities are calculated similarly to the contribution of Kebza (2018), a detailed methodology is described below. Retail centre is a city with a large-format, despecialized shopping mall with a relevant gross leasable area (GLA). Such cities or municipalities are usually important points of the settlement system, which have a large catchment area; in the case of more developed agglomeration, these shopping malls can also be located in the hinterlands of the centre as an element of commercial suburbanization. The centre of education is a city with a public university. These institutions have very wide catchment areas as public universities in the Czechia are concentrated in a relatively small number of large cities.

Due to the use of vector indicators, our own methodology approaches a variation on gravity models. This concept was used in the past (Wang, Guldmann 1996; Ogden 1978; Reilly 1931). This concept is also currently represented in academic work (Kraft, Blažek 2012). As Frantál et al. (2016) state in the title of their contribution, *distance matters*.

In addition to the above-mentioned indicators, other ones are used in similar empirical works. Data of those are often only available for larger territorial units. A good example of an economic indicator is the economic aggregate (described in Dostál, Hampl 2008; Hampl 2005), which includes the average monthly wage, that was used also as a single indicator, e.g. in works of Kubeš and Kebza (2018), Skaličková (2015), or Marada (2001). The other indicators among others include the share of university educated population, sectoral employment, share of commuters or development of technical infrastructure (see Kubeš, Kebza 2018; Novotná, Šlehoferová, Matušková 2016; Huggins, Thompson 2014; Czapiewski 2005; Quadrado et al. 2001 and others).

The vast majority of these indicators are 'scalar', statistical data primarily related to the internal characteristics of the territory without taking into account external relations. A specific feature of this paper is the use of vector indicators that emphasize the dependence of (peripheral) territory on core or central areas (see Pileček, Jančák 2011). The use of vector indicators was inspired mainly by the publication of Džupinová et al. (2008), but they were also used in other contributions for the delimitation of peripheries. Kubeš and Kraft (2011), in this sense, use the time accessibility of municipalities to important centres as the only indicator of the delimitation of peripheries.

Here, a modified method of Kebza (2018) is used: vector indicators were calculated using the coefficient of the centre's range ($k_1$), the coefficient of the centre's power ($k_2$) and the composite coefficient ($k_c$). The coefficient of the centre's range was defined differently for both indicators. While at retail centres the presence of shopping malls (to the detriment of size, see the formula below) is of primary importance, the importance of the educational institution corresponds to the number of students, in which the system of financing of universities is based in Czechia. It must be said that other Czech cities, which are not located in West Bohemia, but at least partly influence them, came into the analysis.

$$k1 = 1.5 + \ln(6)\ \frac{n}{10{,}000}\quad (n = \text{GLA in m}^2)$$

$$k1 = \frac{n}{200}\quad (n = \textit{number of students})$$

$$k2 = \frac{k1}{d}\quad (d = \textit{distance from the centre})$$

$$kc = \Sigma\ (\ln k1) \times m$$
$$(m = k_2 \text{ for each considered municipality})$$

In order to calculate the $k_2$ coefficients, the distance (by road) from each municipality to each centre of trade or education had to be measured. To optimize the distance measurement, a code powered by Google Maps was done using the Distance Matrix and Geocoding APIs. Developed as a IPython Notebook (also known as Jupyter Notebook), the code provided the distances considering the main routes between the places set by an input file, which contains only the names of the cities.

The values of scalar and vector indicators are analysed together in order to classify the territory and thus to delimitate the peripheral areas. For this purpose, the hierarchical cluster analysis (described e.g. by Kronthaler 2005) is applied for 2007 and 2017 (thus twice). Cluster analysis was performed using the SPSS software. The Ward method was chosen because it usually creates compact, even-sized clusters (Szmrecsanyi 2012) and was used together with the block intervals and standardization between values 0–1. We assume division into at least 4 categories – cores and their hinterlands (together as central areas), semiperipheries (as a transition zones between cores and peripheries) and peripheries. These results from 2007 and 2017 are compared, or more precisely the shift between categories is compared, in terms of shift up (periphery to semiperiphery; semiperiphery to central areas) or down (central areas to semiperiphery; semiperiphery to periphery) in this hierarchy. It is this comparison that can reveal peripheralization in the sense of the expansion or emergence of new peripheries. Furthermore, the values of individual indicators are compared in order to monitor the deepening or reduction of differences, especially between central areas and peripheries, and to monitor developmental tendencies in individual categories.

## 5. Results

After a pilot testing, a total of 5 clusters, which significantly differed in their properties, are distinguished: (i) the area with the most favourable values in all respects around Plzeň and Rokycany was evaluated as core, (ii) medium distant areas with various but average values (iii) rather remote municipalities with favourable unemployment rates and high migration rates, (iv) unattractive areas with high unemployment rates and a negative migration balance (v) remote municipalities with relatively higher unemployment, and almost zero migration increments.

Based on these clusters' properties, the municipalities were divided into three types which follow the concept of 'core-semiperiphery-periphery' axis – the Central area (cluster i), semi-peripheries (ii + iii) and peripheries (iv + v). The resulting typology (Fig. 2) also reflected the shift between the categories between 2007 and 2017 (see Tab. 2), and thus possible integration or disintegration within the given hierarchy.

According to the results of the analysis, the area of West Bohemia can be divided on the basis of the concept of 'core-semiperiphery-periphery' axis. Rather surprisingly, the whole territory adopts a monocentric image, although there are two administrative regional centres. Such result confirms the dominance of Plzeň and its surroundings, that are labelled as the Central area in the typology. Although Karlovy Vary Region has two relatively strong regional centres (Karlovy Vary and Cheb), it lacks the dominant growth pole, which also contributes to poor links with other progressive areas, institutional anchoring, e.g. in the form of a public college (so far, the only one is the Faculty of Economics at the University of West Bohemia with a marginal number of students) or stigma of distant and structurally affected areas.

On the other hand, Plzeň undoubtedly benefits from the position among important supra-regional centres, which gained in importance Czechia joined the Schengen area in 2007. Prague, Plzeň and Nuremberg create an important axis in Czechia recognized by the Ministry of Regional Development (2015) as a development axis. The stability of the Central area is also supported by the internal processes that take place in the urban agglomeration of Plzeň: ongoing suburbanization and intensifying commuting contribute to the strengthening of ties and thus stronger integration of the municipalities around Plzeň. The

**Tab. 2** Explanation of the typology based on shifts between the classifications.

| Category of area | Classification in 2007 | Classification in 2017 |
|---|---|---|
| Central areas | Central areas | Central areas |
| Disintegrated central areas | Central areas | Semiperipheries |
| Semiperipheries | Semiperipheries | Semiperipheries |
| Disintegrated semiperipheries | Semiperipheries | Peripheries |
| Successfully integrated peripheries | Peripheries | Central areas |
| Integrated peripheries | Peripheries | Semiperipheries |
| Peripheries | Peripheries | Peripheries |

Source: authors' suggestion

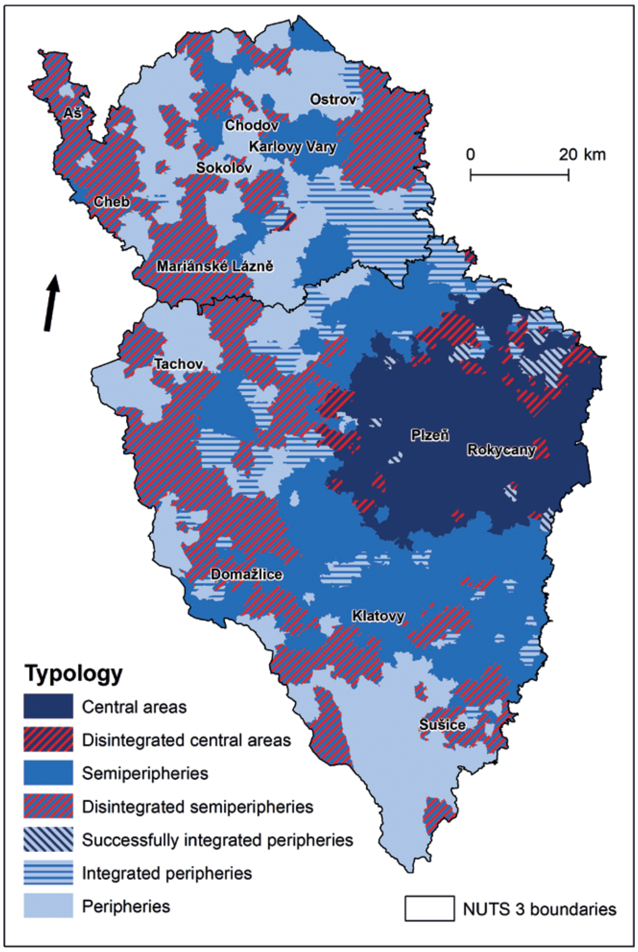


**Fig. 2.** Typology of areas according to the cluster analysis. Source: authors' elaboration

Tab. 3 Basic characteristics and average values of indicators according to the typology, year 2007.

| Category of area | Area (km²) | Population (thousands) | Unemployment rate (%) | Net migration rate (%) | Old-age dependency ratio (%) | Newly built flats per 100 inhabitants | 'Trade' ($k_s$) | 'Education' ($k_s$) |
|---|---|---|---|---|---|---|---|---|
| Central areas | 1,655.8 | 299.9 | 2.6 | 8.8 | 21.4 | 2.7 | 11.2 | 51.6 |
| Disintegrated central areas | 279.0 | 9.7 | 3.1 | 11.3 | 29.1 | 4.0 | 8.4 | 44.0 |
| Semiperipheries | 2,490.5 | 158.2 | 3.4 | 5.7 | 24.1 | 1.7 | 4.5 | 32.6 |
| Disintegrated semiperipheries | 3,013.2 | 209.1 | 4.2 | 6.3 | 18.1 | 2.1 | 1.2 | 23.7 |
| Successfully integrated peripheries | 96.1 | 2.1 | 7.9 | −3.1 | 22.9 | 1.3 | 9.4 | 47.3 |
| Integrated peripheries | 864.3 | 18.8 | 8.0 | −0.6 | 22.2 | 1.0 | 4.9 | 34.7 |
| Peripheries | 2,560.0 | 156.2 | 7.7 | 0.9 | 17.8 | 1.5 | 0.8 | 23.3 |

Source: ČSÚ (2019), authors' calculations

significant dynamics of Plzeň compared to the rest of the region also reflects the innovation potential (Dokoupil, Preis, Novotná 2016).

The compact Central area is followed by a group of municipalities that do not hold the growth rate and are labelled as 'disintegrated central areas', although strong ties with the city of Plzeň may persist. It is a small group of 27 municipalities, for which the unemployment rate has risen on average and the old-age dependency ratio has risen sharply (see Tables 3 and 4). 'Outer ring' of the Central area is complemented by 'successfully integrated peripheries'. Those areas were of peripheral nature in 2007, but in 2017 already belongs to the Central area. This interesting sample of only 12 municipalities apparently underwent successful integration into the most progressive part of the region, when they managed to reduce the unemployment rate by more than half during the period under review, the migration balance changed completely and housing construction also increased; at the same time, an increase of dependence on Pilsen can be expected.

The following group of municipalities are semiperipheries. These are increasingly typical of the Plzeň Region, where they form two larger compact territorial units to the south and north of the Central area. Very selectively, semiperipheral municipalities appear in the Karlovy Vary region, especially in its eastern (inland) part. Some larger cities such as Karlovy Vary or Klatovy belong among the semi-peripheral municipalities. More distant semiperipheral communes can be considered as places of amenity migration. However, there is also a large number of municipalities that were evaluated as semiperipheral in 2007 and their attractiveness in terms of migration and housing construction has changed negatively ('disintegrated semiperipheries'). Many of these municipalities are near the border and are more distant, but there are also

Tab. 4 Basic characteristics and average values of indicators according to the typology, year 2017.

| Category of area | Population (thousands) | Unemployment rate (%) | Net migration rate (%) | Old-age dependency ratio (%) | Newly built flats per 100 inhabitants | 'Trade' ($k_s$) | 'Education' ($k_s$) |
|---|---|---|---|---|---|---|---|
| Central areas | 318.0 | 2.2 | 5.3 | 28.4 | 2.5 | 13.0 | 48.7 |
| Disintegrated central areas | 9.9 | 4.3 | 3.4 | 42.6 | 2.9 | 10.2 | 41.7 |
| Semiperipheries | 159.9 | 2.6 | 6.0 | 32.0 | 1.6 | 6.8 | 30.9 |
| Disintegrated semiperipheries | 203.7 | 3.1 | −0.7 | 27.9 | 1.3 | 4.3 | 22.5 |
| Successfully integrated peripheries | 2.4 | 3.2 | 6.6 | 28.6 | 1.5 | 11.3 | 44.8 |
| Integrated peripheries | 18.7 | 4.9 | 5.1 | 33.0 | 1.3 | 7.4 | 32.9 |
| Peripheries | 149.5 | 4.6 | −2.7 | 26.3 | 1.2 | 4.7 | 22.3 |

Source: ČSÚ (2019), authors' calculations relatively large cities such as Cheb or smaller regional centres Aš, Domažlice, Mariánské Lázně and Sušice within this category.

Furthermore, a large group of rather smaller municipalities in the northern part of the Plzeň Region and the south-eastern part of the Karlovy Vary Region is demarcated, with an increase of net migration rate and the number of newly built flats, as well as a decrease in the unemployment rate. This group is called 'integrated peripheries', although it is not only about economic integration. However, the shift in socio-economic characteristics compared to the 'successfully integrated peripheries', which are much closer to Plzeň, is weaker.

Finally, a large number of municipalities form a peripheral area. West Bohemian peripheries are mainly composed of remote hilly and mountainous areas in the southern part of the Plzeň region, some of the border areas and various parts of the Karlovy Vary region. These peripheries maintain relatively high unemployment and migration decline, thus slightly moving away from other groups of municipalities. At the same time, the peripheralization in terms of the production of new peripheries, or rather their expansion, can be noticed. The newly peripheral areas ('disintegrated semiperipheries') are spatially connected to the existing peripheries and, with the exception of near Klatovy, no new compact peripherals are created.

Simultaneously, similarities with the terms of 'borderland' and 'rural' are shown – while peripheral areas to some extent correspond to the state (but rather not regional) border, rural areas form only a part of the peripheries. The verification calculation of the urbanization (share of population living in cities and towns over 3,000 inhabitants) showed that semiperipheries are significantly rural and the peripheries are, on the contrary, urbanized the most (64.4%) right after the central area (72.4%). Peripheral character of several large cities (Sokolov, Ostrov, Chodov, Tachov) contributes to the degree of urbanization.

According to the achieved results, even these peripheral areas cannot be compared with marginal areas, which are completely outside the integration processes, and thus 'outside the system'. In this case, it is possible to discuss the connection of peripheral areas by public transport to local centres, which operates throughout the territory (Podlešáková 2019), but locally there may be a danger of excessive dependence on one or a few roads (Šumava, Ore Mountains, Český les, Aš promontory).

As the results show, Karlovy Vary Region needs some special attention. Nowadays, Karlovy Vary Region is mostly covered by peripheral areas which are tightly characterized by high unemployment rates and low or even negative values of net migration rate. The depopulation, in addition to the previous analysis, can be related to regional economic development during the socialist era, when coal mines and heavy industries (especially in Sokolov district) expanded in the region to make Czechoslovakia a 'forge of the socialist camp' (Frantál, Nováková 2014). According to Dostál and Hampl (2002), low levels of qualification and flexibility of labour also worsen the context of Karlovy Vary Region. The vulnerability of Karlovy Vary Region is currently attested by the lowest employment rates in agriculture (Věžník, Bartošová 2012) and lower growth rates of gross fixed capital (Rusiński, Pietrusiak 2017). There is a multidimensional debate on convergent or divergent tendencies between defined types of territory. All of them are largely influenced by a broader context covering (inter)national trends and issues. Considering the indicators used, in some cases the semiperiphery approaches the Central area and the peripheries take on a completely different trajectory (net migration rate), in others the peripheries approach the other groups (unemployment, 'Trade') and in other cases there is neither convergence nor divergence (newly built flats, old-age dependency ratio, 'Education').

Looking in detail at the individual indicators, we find that the highest values of old-age dependency ratio are at the eastern border of the Plzeň Region. The peculiarity of this territory is the relatively 'younger' population in the borderlands, which has its historical-geographical causality. Dufek and Minařík (2009) believe that policies designed for migration flows can reduce the changes caused by the process of ageing of the population. Net migration rates for 2002–2007 and 2012–2017 periods were measured and then showed a complex scenario for demographic development, in which patterns and significant positive migration flows were predominantly found in urban agglomeration of Plzeň. Mountain and hilly areas that lack adequate infrastructure, education or job opportunities are most depopulated. However, some of these areas, which are aesthetically attractive (Šumava), are undergoing the construction of a relatively higher number of flats that are intended for second homes (recreation).

The unemployment rate followed the state of the national economy and decreased significantly in the period under review. Even so, it is possible to observe significant differences between Plzeň, its surroundings and the problematic area around the towns of Tachov, Sokolov or Sušice, or the entire northern border of the Plzeň Region. In general, the smallest changes are shown in the share of agricultural and forest land. It had decreasing tendency mainly in the suburban area of Plzeň, which we have expected (see Tab. 1).

Vector indicators represent dependence on cores. Several cities (Plzeň, Karlovy Vary, Prague, Cheb, Ústí nad Labem, České Budějovice, Most, Teplice, Chomutov, Příbram, Strakonice, Rakovník, Beroun and Králův Dvůr) were considered for testing the calculation of the $k_1$ and $k_2$ coefficients of the 'Trade' and 'Education'. From those cities, only Plzeň, Karlovy Vary, Cheb and Prague for 'Trade' and Plzeň, České Budějovice and Prague for 'Education' were relevant (measurable).

While the values of 'Trade' have increased in the direction from Prague, Plzeň and Karlovy Vary due to the construction of new shopping centres. 'Education' shows a generally declining trend due to the drop of students, although it is still the strongest in the only university city in the region, Plzeň, and on the axis connecting Plzeň with Prague.

## 6. Discussion

Each of the defined types of territory faces distinct challenges. For example, the Central areas are struggling with socio-spatial changes typical for urban agglomerations – mainly suburbanization that has an impact on the morphological, social and demographic structure of the hinterlands of large cities. Large cities themselves often face gentrification, social segregation, but also environmental challenges and other phenomena.

Development issues, whether of a regulatory or generative nature, are a particularly sensitive topic for transition groups of municipalities, especially for 'successfully integrated peripheries', where the demand for housing and housing has changed.

Quite differently, there are peripheries, which need a developmental impulse instead of regulations. These can be of two types, namely 'top-down', i.e. ideally institutional comprehensive solution, which, however, may not always fully meet the needs of a given territory, and 'bottom-up', when peripheral areas begin to prosper endogenously.

The 'top-down' approach in this regard is the polycentric development approach discussed by Humer (2018). Applied to West Bohemia, a similar development is taking place at a higher hierarchical level (Prague–Plzeň axis). The continuation of this axis towards Bavaria is also expected. Several large industrial zones (e.g. Nová Hospoda) have been opened thanks to the entry into the Schengen area and the completion of the motorway. Contribution of those industrial zones is not unequivocally positive; usually it is a simple production with lack of research and development. The influx of agency workers from abroad can also provoke local social conflicts. Other towns – Cheb, Domažlice or Mariánské Lázně – also have a chance to use the connections with cores through important railways. However, all three cities belong to the 'disintegrated semiperipheries' type, which does not indicate the suitability of this strategy. Such polycentric development strategy would also affect only a few selected areas, and especially more remote peripheries could be left out. The Cheb-Karlovy Vary basin axis has potential in this direction, although it is a short and isolated axis.

We consider the issue of human capital to be essential, both in the form of political and other public representation of municipalities (Pileček 2011) and individuals who are active, creative and willing to stay in their community and develop it. The properties of such a 'creative class' (see Florida 2005) are indispensable for the future development. In this regard, more significant settling of the University of West Bohemia in Cheb would be interesting and potentially beneficial. As a side effect, a deeper anchoring of the university could help to reduce the departure of young people from the peripheral region. A similar direction is represented by Eder (2019), who is exploring knowledge bases in conjunction with peripheries. Thus, the availability of (high-)quality tertiary education seems to be very important from the point of view of human capital development and demographic sustainability. This factor is all the more significant because the West Bohemian peripheries are structurally young (see Tab. 3 and 4) and potentially promising.

Active and creative individuals with the potential for soft development can influence the area through political and other public action, but also through their own business. Local entrepreneurs are dealt by Mayer, Habersetzer and Meili (2016) who look into their ability to create periphery-core ties, the goal should be a competitive environment in the periphery and thus reduced dependence on cores. Start-ups are gaining in economic importance, which also represent a possible way of doing business in the periphery, as demonstrated by Eriksson and Rataj (2019). Moreover, such start-ups can also have a very minimalist form of a municipal workshop with basic equipment.

Karlovy Vary and Plzeň Regions are also known by many square kilometres covered by untouched natural landscapes. While analysing Polish borderlands, Więckowski (2010) evaluates border regions as peripheral areas where there are often cultural, historical and natural attractions, although those features are not enough to develop the whole area itself. The mentioned description matches for Czechia's protected areas, such as Český les and Šumava National Park, and represent a considerable share of land on Bohemian-Bavarian border.

The possibilities of tourism for the purposes of local development are examined by Lang (2012) on the example of Upper Lusatian Hoyerswerda. Its development can have consequences in terms of negative prejudices about the territory and increasing its symbolic attractiveness (Lang 2012). In connection with the development of tourism, however, it must be said that there are places that should preserve the character of remote periphery in the region, those are especially protected natural areas, which are hit by touristification (e.g. Železná Ruda) which leads to decrease of the attractiveness of the locality for tourism, but also for local residents. A strong push for the development of tourism in the amiss perceived peripheries may lead to a 'boomerang effect', when, with institutional support, the perception of locality changes positively, but without subsequent regulation and after touristification, opinion about the place fades again.

In addition to tourism, peripheries can be a destination for amenity migration, which may also lead to revitalization of settlements (Bartoš et al. 2011). Attractive landscape can attract high-skilled amenity in-migrants which can start deperipheralization processes. This may also apply to the borderland, whose inhabitants were displaced after 1945, which locally becomes a destination for the descendants of former residents who invest financial resources, work and time here.

Finally, peripheral areas can ultimately also benefit from technological progress. A milestone may be the development of high-speed Internet and 5G networks, which can attract people who only work with computers and do not need social contact, and who do not prefer the urban environment.

## 7. Conclusions

This study presents a discussion on spatial socio-economic differentiation with focus on peripheral areas. The modified methodology of Kebza (2018) based on statistical analysis of basic self-governing units in West Bohemia. The modification of the above-mentioned procedure, which is a variation on gravity models, is based on the typology of territory emphasizing the development and movement of municipalities among the calculated clusters.

The analysis showed that the Central area around Plzeň maintains its position, which is relatively progressive in economic and social terms and also in terms of the availability of retail and tertiary education. The proximity of Plzeň is also important for the relatively wide surrounding area. However, the problem is in remote areas and areas with deeper problems and lack of some elements such as universities or employment. Answering the research questions, West Bohemian peripheries do expand, but new significant 'peripheral islets' do not arise. The widening of the gap between peripheries and the Central area is a selective matter, housing construction has remained at a similar level in all types of territory over the years, and unemployment rates even show a slightly convergent trend. The dynamics of socio-economic development in all monitored categories is largely determined by trends in a broader context; from a regional point of view, the consolidation of dominant positions of the core and higher variability in other areas is apparent. Compared to other areas, the periphery stands out from the potential of the younger generation due to the low values of the old-age dependency ratio, which is generally atypical for the periphery. The young(er) population is particularly important, especially in the areas affected by the displacement of population of German nationality. This is a challenge for local participants, who have a chance to take advantage of this state. To do this, it is necessary to strengthen the possibility of self-growth, which includes the availability and quality of education and available opportunities for self-realization.

## Acknowledgements

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## References

Bański, J. (2005): Suburban and peripheral rural areas in Poland: the balance of development in the transformation period. Geografický časopis 57(2), 117–130.

Bartoš, M., Kušová, D., Těšitel, J., Novotná, M., Kopp, J., Macháček, J., Moss, L. A. G., Gloriso, R. S. (2011): Amenitní migrace do venkovských oblastí České republiky. Kostelec nad Černými lesy, Nakladatelství Lesnická práce.

Bečicová, I., Blažek, J. (2015): Is there a Credit gap in a periphery? The perception of this problem by small entrepreneurs. Journal of Rural Studies 42, 11–20, https://doi.org/10.1016/j.jrurstud.2015.09.006.

Blažek, J., Csank, P. (2005): The West-East gradient and regional development: The case of the Czech Republic. AUC Geographica 35(1–2), 89–108.

Blažek, J., Netrdová, P. (2009): Can development axes be identified by socio-economic variables? The case of Czechia. Geografie – Sborník ČGS 114(4), 245–262, https://doi.org/10.37040/geografie2009114040245.

Czapiewski, K. Ł. (2005): Living conditions and functional structure of rural communes in Poland. Geografický časopis 57(1), 23–42.

ČSÚ (2019): Public database. Praha, ČSÚ – Český statistický úřad.

Dokoupil, J., Preis, J., Novotná, M. (2016): Management inovací v Plzeňském kraji a srovnání se sousedními bavorskými regiony. Trendy v podnikání 6(4), 62–69.

Dostál, P., Hampl, M. (2002): Metropolitan areas in transformation of regional organization in the Czech Republic. AUC Geographica 37(2), 133–155.

Dostál, P., Hampl, M. (2008): Development of national settlement systems in the industrial and post-industrial eras: a general discussion and the case of the Czech Republic. In Strubelt, W., Gorzelak, G. eds. City and Region. Papers in Honour of Jiří Musil. Opladen, BudrichUniPress, 43–54, https://doi.org/10.2307/j.ctvhktk69.6.

Dufek, J., Minařík, B. (2009): Age of population and the development of population ageing in the regions of the Czech Republic. Agricultural Economics – Czech 55(6), 259–270, https://doi.org/10.17221/35/2009-AGRICECON.

Drahošová, J. (2011): Evaluation of transport infrastructure in regions of the Czech Republic. Perner's Contacts 5(6), 58–73.

Džupinová, E., Halás, M., Horňák, M., Hurbánek, P., Káčerová, M., Michniak, D., Ondoš, S., Rochovská, A. (2008): Periférnosť a priestorová polarizácia na území Slovenska. Bratislava, Geografika.

Eder, J. (2019): Peripheralization and knowledge bases in Austria: towards a new regional typology, European Planning Studies 27(1), 42–67. http://dx.doi.org/10.1080/09654313.2018.1541966
Felzensztein, C., Gimmon, E., Aqueveque, C. (2013): Entrepreneurship at the Periphery: Exploring Framework Conditions in Core and Peripheral Locations. Entrepreneurship Theory and Practice 37(4), 815–835, https://doi.org/10.1111/j.1540-6520.2012.00515.x.
Florida, R. (2005): Cities and Creative Class. New York, Routledge, https://doi.org/10.4324/9780203997673.
Frantál, B., Nováková, E. (2014): A curse of coal? Exploring unintended regional consequences of coal energy in the Czech Republic. Moravian Geographical Reports 22(2), 55–65, http://dx.doi.org/10.2478/mgr-2014-0012.
Frantál, B., Malý, J., Ouředníček, M., Nemeškal, J. (2016): Distance matters. Assessing socioeconomic impacts of the Dukovany nuclear power plant in the Czech Republic: Local perceptions and statistical evidence. Moravian Geographical Reports 24(1), 2–13, http://dx.doi.org/10.1515/mgr-2016-0001.
Friedmann, J. (1966): Regional Development Policy: A Case Study of Venezuela. Cambridge, M.I.T. Press.
Frommer, B. (2010): Národní očista – Retribuce v poválečném Československu. Praha, Academia.
Glassheim, E. (2000): National Mythologies and Ethnic Cleansing: The Expulsion of Czechoslovak Germans in 1945. Central European History 33(4), 463–486, https://doi.org/10.1163/156916100746428.
Hampl, M. (2003): Diferenciace a zvraty regionálního vývoje Karlovarska: unikátní případ nebo obecný vzor? Geografie – Sborník ČGS 108(3), 173–190.
Hampl, M. (2005): Geografická organizace společnosti v České republice: transformační procesy a jejich obecný context. Praha, Univerzita Karlova v Praze.
Havlíček, T., Chromý, P. (2001): Příspěvek k teorii polarizovaného vývoje území se zaměřením na periferní oblasti. Geografie – Sborník ČGS 106(1), 1–10.
Havlíček, T., Chromý, P., Jančák, V., Marada, M. (2005): Vybrané teoreticko-metodologické aspekty a trendy geografického výzkumu periferních oblastí. In Novotná, M. ed. Problémy periferních oblastí. Praha, Faculty of Science, Charles University in Prague, 6–24.
Hedlund, M. (2016): Mapping the Socioeconomic Landscape of Rural Sweden: Towards a Typology of Rural Areas. Regional Studies 50(3), 460–474, https://doi.org/10.1080/00343404.2014.924618.
Hübelová, D. (2014): Regionální disparity kvality lidských zdrojů v České republice v kontextu demografického a ekonomického vývoje. Geographia Cassoviensis 8(1), 34–49.
Huggins, R., Thompson, P. (2015): Culture and Place-Based Development: A Socio-Economic Analysis. Regional Studies 49(1), 130–159, https://doi.org/10.1080/00343404.2014.889817.
Humer, A. (2018): Linking polycentricity concepts to periphery: implications for an integrative Austrian strategic spatial planning practice. European Planning Studies 26–(4), 635–652, https://doi.org/10.1080/09654313.2017.1403570.
Jelinek, Y. A. (1993). Violence and Arbitrariness during the Expulsion of Germans from Czechoslovakia: Pages from the Report of the US Liaison Officer. Bohemia 34(1), 123–132.
Kebza, M. (2018): The development of peripheral areas: The case of West Pomeranian Voivodeship, Poland. Moravian Geographical Reports 26(1), 69–81, http://dx.doi.org/10.2478/mgr-2018-0006.
Kraft, S., Blažek, J. (2012): Spatial interactions and regionalisation of the Vysočina Region using the gravity models. Acta Universitatis Palackianae Olomucensis 43 (2), 65–82.
Kronthaler, F. (2005): Economic capability of East German regions: Results of a cluster analysis. Regional Studies 39(6), 739–750, http://dx.doi.org/10.1080/00343400500213630.
Kubeš, J., Kebza, M. (2018): Geography of socio-economic differentiation of Poland according to subregions in 2002–2014, AUC Geographica 53(1), 36–48. https://doi.org/10.14712/23361980.2018.4.
Kubeš, J., Kraft, S. (2011): Periferní oblasti jižních Čech a jejich sociálně populační stabilita. Sociologický časopis 47(4), 805–829, https://doi.org/10.13060/00380288.2011.47.4.08.
Kühn, M. (2015): Peripheralization: Theoretical Concepts Explaining Socio-Spatial Inequalities. European Planning Studies 23(2), 367–378, https://doi.org/10.1080/09654313.2013.862518.
Lang, T. (2012): Shrinkage, Metropolization and Peripheralization in East Germany. European Planning Studies 20(10), 1747–1754, https://doi.org/10.1080/09654313.2012.713336.
Marada, M. (2001): Vymezení periferních oblastí a stadium jejich znaků pomocí statistické analýzy. Geografie – Sborník ČGS 106(1), 12–25.
Mayer, H., Habersetzer, A., Meili, R. (2016): Rural–Urban Linkages and Sustainable Regional Development: The Role of Entrepreneurs in Linking Peripheries and Centers. Sustainability 8(8), 745, https://doi.org 10.3390/su8080745.
Ministry of regional development of the Czech Republic (2015): Spatial development policy of the Czech Republic: updated version 1. Prague, Brno, Ministry of Regional Development of the Czech Republic, Institute for Spatial Development.
Musil, J., Müller, J. (2008): Vnitřní periferie v České republice jako mechanismus sociální exkluze. Sociologický časopis 44(2), 321–348, https://doi.org/10.13060/00380288.2008.44.2.05.
Nováček, A. (2014): Historical-geographical determinants of the west-east territorialf disparities in the Central European countries. Europa XXI 26, 5–23, https://doi.org/10.7163/Eu21.2014.26.1.
Novák, J., Netrdová, P. (2011): Prostorové vzorce sociálně-ekonomické diferenciace obcí v České republice. Sociologický časopis 47(4), 717–744, https://doi.org/10.13060/00380288.2011.47.4.05.
Novotná, M., Šlehoferová, M., Matušková, A. (2016): Evaluation of spatial differentiation in the Plzeň region from a socioeconomic perspective. Bulletin of Geography. Socio-economic Series 34, 73–90, http://dx.doi.org/10.1515/bog-2016-0036.
Ogden, K. W. (1978): The distribution of truck trips and commodity flow in urban areas: A gravity model analysis. Transportation Research 12(2), 131–137, https://doi.org/10.1016/0041-1647(78)90052-7.
Perlín, R., Kučerová, S., Kučera, Z. (2010): Typologie venkovského prostoru Česka. Geografie – Sborník ČGS

115(2), 161–187, https://doi.org/10.37040/geografie2010115020161.
Pileček, J. (2011): Potential for the Development of Borderland Peripheries in Czechia in Terms of the Significance of Human Capital: the case of Volarsko. AUC Geographica 46(2), 95–106, https://doi.org/10.14712/23361980.2015.34.
Pileček, J., Jančák, V. (2011): Theoretical and Methodological Aspects of the Identification and Delimitation o f Peripheral Areas. AUC Geographica 46(1), 43–52, https://doi.org/10.14712/23361980.2015.41.
Pociūtė-Sereikienė, G. (2019): Peripheral regions in Lithuania: the results of uneven development. Regional Studies, Regional Science 6(1), 70–77, http://dx.doi.org/10.1080/21681376.2019.1571437.
Podlešáková, N. (2019): Periferní oblasti Plzeňského kraje – vymezení, typy a stabilita. České Budějovice, University of South Bohemia.
Quadrado, L., Heijman, W., Folmer, H. (2001): Multidimensional Analysis of Regional Inequality: The case of Hungary. Social Indicators Research 56(1), 21–42, https://doi.org/10.1023/A:1011893713456.
Reilly, W. (1931): Methods for the Study of Detail Relationships. Bureau of Business Research. Austin, University of Texas.
Rusiński, E., Pietrusiak, D. eds. (2017): Proceedings of the 13th International Scientific Conference, Lecture Notes in Mechanical Engineering. Springer, https://doi.org/10.1007/978-3-319-50938-9.
Schmidt, M. H. (1998): An Integrated Systematic Approach to Marginal Regions: from definition to development policies. In Jussila, H., Leimgruber, W., Majoral, R. eds. Perception of Marginality: theoretical issues and regional perceptions of marginality in geographical space. Aldershot, Ashgate, 45–66, https://doi.org/10.4324/9780429447457-5.
Skaličková, J. (2015): Differentiation of regions in Czech Republic based on economic indicators. Actual Problems of Economics 8, 245–256.
Sýkora, L., Bouzarovski, S. (2012): Multiple Transformations: Conceptualising the Post-communist Urban Transition. Urban Studies 49(1), 43–60, http://dx.doi.org/10.1177/0042098010397402.
Szmrecsanyi, B. (2012): Grammatical Variation in British English Dialects: A Study in Corpus-Based Dialectometry. Cambridge University Press.
Věžník, A., Bartošová, L. (2012): Selected regional geographical differences of the Czech Republic agriculture, after the transformation processes. Agricultural Economics (Zemědělská ekonomika) 50, 207–216. https://doi.org/10.17221/5191-AGRICECON.
Willet, J., Lang, T. (2018): Peripheralisation: A Politics of Place, Affect, Perception and Representation. Sociologia Ruralis 58(2), 258–275, https://doi.org/10.1111/soru.12161.
Wallerstein, I. (1979): The Capitalist World-Economy. Cambridge, Cambridge University Press.
Wang, F., Guldmann, J. M. (1996): Simulating Urban Population Density with a Gravity-based Model. Socio-Economic Planning Sciences 30(4), 245–256, https://doi.org/10.1016/S0038-0121(96)00018-3.
Więckowski, M., (2010): Tourism development in the borderlands of Poland. Geographia Polonica 83(2), 67–81, https://doi.org/10.7163/GPol.2010.2.5.
Zaniklé obce (2019): Města, obce, osady, samoty a další objekty zaniklé či částečně zaniklé (dobové pohlednice, historie, vojenské mapy, místopis) [cit. 2019-01-24]. Retrieved from: http://zanikleobce.cz/index.php?menu=222?27,108.

# Geopolitics of geographical urbanonyms: evidence from Ukrainian cities

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## ABSTRACT

This article focuses on geographical urbanonyms in Ukraine – names of streets, squares, lanes, etc. that refer to the names of other geographical objects like cities, regions, countries, or continents. It shows the role of geographical urbanonyms as a powerful instrument used by political regimes to shape political identity by constructing and legitimizing borders between "us" and "them" at different spatial scales. The analysis revealed a significantly higher presence of geographical urbanonyms in Ukraine compared to former state socialist countries in Central Europe. The widespread presence of street names related to the former USSR proves the absence of post-Soviet decolonization in semiotic space, going beyond the pure decommunization, in the majority of Ukrainian cities since 1991. Regional differences in the dynamics, distribution and structure of geographical urbanonyms in Ukraine are explained by the historical, cultural and (geo)political divisions.

## KEYWORDS

urban toponyms; geographical urbanonyms; geopolitics; Ukraine

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## 1. Introduction

Recent literature in the field of critical toponymy focuses mostly on commemorative place names. Typically, commemorative toponyms include names honouring prominent personalities, events, organizations and institutions, abstract ideologies, while other toponyms are classified as descriptive, possessive, and euphemistic (Stewart 1954). While the role of commemorative place names as an instrument of memory and identity policy is not questioned, the symbolic (including political) significance of other categories of toponymy is often underestimated or overlooked. However, as Rose-Redwood (2017) has shown, any act of naming and renaming has a commemorative dimension.

In this paper, we want to draw attention to geographical group of urbanonyms – urban place names that derive from the names of geographical objects. On the example of Ukraine, a post-Soviet country with turbulent history, contingent and contradictory memory policy (Shevel 2011; Portnov 2013), ongoing processes of official legally-binding decommunization and unprompted voluntary decolonization, we want to show their roles both as cultural indicators and technology of power used by national and regional political regimes to assert their authority and symbolic power.

Hereinafter we use a term 'toponymy' to refer a set of toponyms (place names) within a specific territory, except for a phrase 'critical toponymy' signifying critical approach to the study of place names as belonging to structures of power and identity (Berg and Voulteenaho 2009).

## 2. Theoretical and methodological background

### 2.1 Urban toponymy as a mimicry of city-world relations

According to Lappo (2012), the city is a mirror of the region. The point is that cities reflect the specific characteristics, successes and problems of the surrounding regions. However, this role of the mirror is not limited to social, demographic, or economic relations. Any city is a symbolic (semiotic) representation of the surrounding space. A set of urban verbal and visual texts (signs, names of streets, restaurants, metro stations, advertising images, monuments, ethnic neighbourhoods, etc.) resembles a topographic model of the world (Nikolaeva 2014). The larger is the city, the more important role it plays in the national and world hierarchy, the wider and clearer resemblance relationships with its own region, country, and the whole globe are realized in its semiotic space.

Urban toponymy as the most common and most simple (to perceive and comprehend) form of urban semiotics plays a key role in this representation. Toponyms are not merely abstract names in the spatial structure of cities, but also represent the construct of social and power relations, through which the identity of the city and society is being formed (Berg and Voulteenaho 2009). E.g. as Smirnov (2013) points out, the toponymy of St. Petersburg in different historical epochs reflected and reflects the relations of the city and its inhabitants with foreign states, natives of these states, cities with which St. Petersburg is somehow connected, illustrating the changing assessment of certain epochs, other states and related statesmen and representatives of culture. Street names in Grozny reflect the city's socio-cultural relations with the Chechen Republic, the Caucasus region and the all-Russian geographical and cultural context (Thakahov 2019). Paraphrasing the apt statement about a streetscape as a political cosmos (Rose-Redwood, Alderman, and Azaryahu 2017b), the urban toponymy may be deemed to be a microcosm reflecting the macrocosm of the Universe through the cultural and political lenses.

### 2.2 Geographical urbanonyms and their role in the symbolic marking of space

The semantics of a large group of urbanonyms directly refers to the names of other geographical objects: cities, regions, countries, continents, etc. According to semiotic classification, used by Stiperski et al. (2011) and then by Bucher et al. (2013), these urban place-names are treated as geographical toponyms and include names derived from rivers, cities, regions, countries, mountains, islands, etc. Dala Costa (2020) follows the similar approach and defines such toponyms as referencing geographical places like cities, villages, countries, mountains or gorges. This group should not be confused with so-called location urbanonyms, deriving from important sites, places and objects within the city. In the literature these two groups of urbanonyms (geographical and location) together are treated as "geography urbanonyms" (Stiperski et al. 2011; Bucher et al. 2013) or "topographical urbanonyms" (Gnatiuk 2018). Geographical urbanonyms may be classified based on the location of the relevant geographical objects, e.g. into regional, national, foreign, etc. More detailed classification is also possible, e.g. street elsewhere with the name derived from Brno, Czech Republic, may be classified as Moravian, Czech, and European geographical urbanonym.

Urbanonyms have two key functions: orientation (utilitarian) and symbolic (commemorative) (Azaryahu 1990). Geographical urbanonyms are a good illustration of this thesis. Some of them are mainly utilitarian: e.g. a street leading to a certain town or village was given the respective name. Commemorative, in particular geopolitical considerations did not play a significant role in the creation of such street names. It can be assumed that such utilitarian geographical urbanonyms reflect the most important and stable relationships of the city with the outside world in certain historical epoch. Not surprisingly, utilitarian geographical urbanonyms are represented mostly by "regional" and, less frequently, "national" names. On the other hand, symbolic geographical urbanonyms are assigned in order to reflect a certain geographical object in the symbolic space of the city, while direct economic, social, or demographic connections of the city with this geographical object recede into the background.

The most common motivation for symbolic geographical place names is to emphasize belonging to a certain socio-cultural and/or political space: the power of naming is often the first step in taking possession (Todorov, quoted in Robinson 1989). The cities of a certain country naturally have some streets named after other cities of the same country: such toponymic policy cements the national cultural and political space. At the same time, the indigenous population of the colonized territories often perceives such toponyms as culturally alienated, imposed by the colonizers, as evidenced by the attempts to restore toponymic justice and return the right to name to the indigenous population (Rose-Redwood, Alderman, and Azaryahu 2017a). In this sense, developing the argument by Marin (2017), we should recognize that toponymic inscription involves not only chronotopic, but also direct chorotopic boundary-making, constructing and legitimizing borders between "Us" and "Them" in space – colonial/indigenous, national/foreign, East/West, etc. All cultures start out from the division of the world into an internal ("Our") space and an external ("Their") space (Lotman 2000 [1996]), and geographical toponyms are useful instrument to mark this division.

Thus, geographical place names, making political ideologies to appear as the "natural order of things" in the eyes of ordinary citizens (Azaryahu 2009), represent a powerful instrument for constructing political identity, in particular through colonization/occupation and decolonization/deoccupation, and have repeatedly constituted a subject of critical toponymy studies. In particular, in colonial Singapore, a lot of official street names were derived from British places (counties, urban centres, seaside resorts), as well as some cities elsewhere from the British Empire (Yeoh 1996, 2017). A major transport hub in Budapest was named as Moscow Square in 1951, and in 2016 original historical name was returned to that place (Palonen 2017). Some Arab geographical urbanonyms were replaced in Haifa after the creation of Israel (Azaryahu 2017). In the late-nineteenth century, many streets in Belgrade, Serbia, were renamed after geographical places important in Serbia's national history and major cities in the Slav world. Remarkably, if a virtual map were drawn connecting the places "remembered" in the new street names, the borders of medieval Serbia would come to the forefront; with this project, the nationally conscious intellectuals hoped to bring Belgrade's population to identify itself with the places remembered in the new street names so that they would accept them as "their own" (Stojanović 2007). Almost all street names in Zagreb referring to Serbian and Russian cities were changed in the early-1990s in order to erase the "negative others" from the streetscape of Croatian capital. Simultaneously, the role of Zagreb as the capital city of independent Croatia was symbolically manifested by an increased number of street names referring to Croatian territory. The renewed map of Zagreb inscribed also belonging to the common cultural sphere of Central Europe and common spiritual culture, as well as new geopolitical friendships (Šakaja and Stanić 2017). The new street names in the West Mostar (Bosnia and Herzegovina) after renaming in 1990s emphasize a shared history with the motherland of Croatia by recalling, among else, names of important Croat cities (Palmberger 2017). In Riga, Latvia, the names of several Hanseatic cities were concentrated in the living area of Mežaparks, but after the beginning of the World War I – particularly in 1915 – the names of these streets were all changed into names coming from Russian place-names. However, after the Soviet Union collapse, the names of Hanseatic cities were given once again to the new streets in Mežaparks (Balode 2012).The recent study on Minsk toponymic system (Basik and Rahautsou 2019) showed that the Russian (in particular, Siberian) street names, being irrelevant to the locals, were implanted into the urban semiosphere in Soviet period forming an artificial toponymic identity separate from the identity of the place; at the same time, place names related to the world outside the former USSR represent only 0.9% from the total of geographical urbanonyms. All these findings witness the role of geographical urbanonyms as an instrument to create and recreate symbolic spaces, in particular differentiating between geopolitically "our" and "their" space.

However, there are few studies focusing on geographical urbanonyms as a specific phenomenon. The exception is the above-mentioned paper by Balode (2012) that thoroughly examines a body of geographical urbanonyms in Riga. In addition to the above-mentioned observation, the paper tells the reader some other interesting facts, including the following: 1) quantitative prevalence of regional and national urbanonyms and low proportion of "foreign" ones, 2) the majority of the latter refer to the toponymy of the closest neighbour countries (Estonia, Lithuania, Poland, etc.), 3) toponymy of Russian (and Belarusian) origin is very rare nowadays due to the renaming of streets in the first years of Latvian independence after1990, but in Soviet times Russia-related street names were quite numerous, 4) some foreign place-names mentioned in urbanonymy were replaced by Latvian toponyms during the first independence of

Latvia. These facts conform to the concept of urban toponymy as a mimicry of city–world relationships and support the idea that such a mimicry is geopolitically shaped. However, although findings are valuable for current research, the author of the cited research follows rather descriptive than critical approach: geographical place names are simply listed without clear explanation of circumstances and factors, including political regime changes, influencing their occurrence and disappearance; the relevant conclusions are left up to the reader.

### 2.3 Ukrainian urban toponymy in the discourses of decommunization and decolonization

After the collapse of the socialist regimes, most countries of Central and Eastern Europe experienced transformations of urban toponymy aimed at the elimination of communist ideology and the formation of a new national identity (Light 2004; Gill 2005; Czepczyński 2008; Palonen 2008; Crljenko 2012; Light and Young 2014). Ukraine was not an exception from the general trend, but the toponymic process there had certain national specificity and consisted of two qualitatively heterogeneous stages. The first stage (1991–2014) resulted in a voluntary and weak decommunization of urban toponyms based on the initiatives of local governments with clear regional differences. In the Western Ukraine, especially in Galicia, almost all names related to the communist regime were erased at this early stage; in Central Ukraine the renaming was limited and related to the streets in the central parts of cities and streets that carried the names of the most odious communist regime representatives; in Southern and Eastern Ukraine, with some exceptions, the renaming of streets practically did not occur, and the communist toponymy was preserved almost entirely (Riznyk 2007). After the Revolution of Dignity, in 2015, the Ukrainian Parliament adopted so-called Decommunization Package of Laws, providing the criteria for communist toponymy that should be erased, as well as legal details of renaming procedure. This caused the second wave of communist street names liquidation that was much more massive and covered the entire territory of Ukraine due to its mandatory nature.

Critical comprehension of these waves of decommunization and accompanying toponymic processes in the literature takes place mainly in the context of the politics of memory in modern Ukraine. In particular, the following aspects are addressed: 1) differences between regional models of a new national identity building (Gnatiuk 2018), 2) spatio-temporal aspects of the urban toponymy transformation (Takhtaulova 2017; Gnatiuk and Melnychuk 2020; Pavlenko 2020), 3) key discourses / approaches to decommunization: “historical nostalgia”, “nationalistic” and “decolonization” (Males 2016; Males and Deineka 2020), 4) implementation of memory policy in a specific region or city (Hrytsak 2007; Vengryniuk 2012; Mahrytska 2013; Neher 2014; Fernos 2018; Savchenko and Takhtaulova 2019; Gnatiuk and Melnychuk 2020; Males 2016; Males and Deineka 2020; Kudriavtseva 2020; Pavlenko 2020), 5) influence of the axiological status of a place within a city on the politics of memory (Gnatiuk and Glybovets 2020), 6) legal and organizational features of the decommunization process, principles of choosing new names (Karoyeva 2017), 7) problematic aspects of state toponymic policy (Hyrych 2013). The toponymic space of the city is considered as one of the platforms for the ideology building in contemporary Ukraine, which is realized through social and state mechanisms of consensus and reconciliation (Takhtaulova 2015), as a symbolic capital (Males 2016) and as a spatial projection of the societal axiological system (Gnatiuk and Glybovets 2020).

However, geographical urbanonyms, despite their powerful significance for the formation of the symbolic urban space, remain on the periphery of decommunization discourse. The reason is the lack of their inalienable ideological connotations, although the name of “Moscow Street” may evoke associations with the communist regime, and the name of “German Street” – with the Nazis. Perception of such names as problematic, contradictory, undesirable, etc. is possible only within the discourse of decolonization, according to which current changes in the symbolic space in Ukraine should not end with the elimination of communist ideology, but should be continued in order to erase a memory of the “colonial” past of Ukraine as a part of the USSR, the Russian Empire, etc. (Males and Deineka 2020). Nevertheless, currently there is no official policy of “decolonization” in Ukraine: the available examples are spontaneous and voluntary initiative at the local level, just as decommunization until 2015. The voluntary nature of toponymic decolonization (mainly understood as de-Russification) makes it an attractive and objective tool for the study of changing self-identification of Ukrainians. After all, communist toponyms disappeared from the streetscapes in the East and South of the country not because the local population or local elites demanded it, but because the decommunization became mandatory. Cases of decolonization testify to the meaningful, mature (albeit debatable) nature of toponymic changes on the part of the local population and local political elites. This is shown both by the examples of Lviv, where de-Russification took place already in the 1990s (Hrytsak 2007), and Kyiv, where the relevant discourse unfolded after the Revolution of Dignity (Males 2016; Males and Deineka 2020).

## 3. Data and methods

In order to explore general representation and regional distribution of geographical urbanonyms in Ukraine, we used the data from the 40 largest cities of Ukraine, representing all administrative regions. The number and the share of geographical urbanonyms among all street names in 2020 were calculated for each city. Then, for each city, the structure of geographical urbanonyms was determined in terms of the location of their denotations (i.e. geographical objects from which names are derived). Depending on the geographical location of denotations, all geographical urbanonyms were divided into the following categories: "local" – within the same administrative region of Ukraine as the city itself; "Ukrainian" – within modern Ukraine; "Soviet" – within the former USSR; "Socialist Europe"– in the European countries of the former socialist camp; "Capitalist Europe"– in the other European countries; "other"– in the rest of the world. This classification is somewhat conditional and does not reflect the variety of circumstances of each place name origin, e.g. some names classified as "Soviet" may originated long before the Soviet Union or after its collapse. However, this approach is the most relevant for the modern historical context, when Ukraine is an arena of competition and interaction of (pro) European identity on the one hand and (post) Soviet and (pro) Russian identity on the other, so we decided to use it, addressing these problematic moments in the analysis. Also, we calculated the share of "Soviet" urbanonyms renamed during the years of independence (1991–2020) in order to identify individual and regional differences in post-Soviet decolonization of urban toponymy.

In order to trace and explain the regionally specific dynamics of the emergence and disappearance of geographical urbanonyms, we chose three cases – large cities, each representing a separate part of the country with a specific cultural and political background and different approaches to toponymic policy: Lviv (Western Ukraine), Kyiv (Central Ukraine) and Dnipro (Eastern Ukraine). Furthermore, denotations of geographical urbanonyms for each case city were mapped: point geographical objects (cities) were indicated as points in their actual locations, and linear and planar objects were replaced by points located in their geometric centres. In this way, we tried to visualize the mental map of the "intimate" world, which the inhabitants of each of these cities may shape under the influence of geographical street names.

Information on the naming, renaming and liquidation of city objects was obtained from the following sources: 1) official documents of local governments and local authorities, 2) directories and databases (e.g. Official Directory of the Streets of the City of Kyiv, electronic directory "Streets of Lviv" of the Centre for Urban History of Central and Eastern Europe), 3) maps and plans of cities for different years.

Thus, in the present research we applied the elements of quantitative interpretation, the comparative analysis, as well as the cartographic and archival methods. We tried to follow, at least partially, critical toponymy approach, i.e. not only to describe the spatial, structural and temporal idiosyncrasies of geographical urbanonyms in Ukraine, but to link them to key (geo)political actors, epochs and shifts, as well as to the geographic, socio-political and cultural factors and circumstances, demonstrating the role of such toponymy in the ideology building and memory policy of the ruling political regimes, totalitarian or democratic.

## 4. Results and discussion

### 4.1 Geographical urbanonyms at national and regional scale

"Soviet" urbanonyms are the most common category of geographical street names in the totality of the studied cities (40.3%). The second position is taken by "Ukrainian" urbanonyms (35.3%), the third – by "local" urbanonyms (18.6%). These three categories make up the vast majority of the total number of geographical urbanonyms and are present in all analyzed cities. The share of all other categories is slightly more than 5%, and the most numerous of them are those related to the former socialist Europe (3.3%) and other European countries (1.5%).

The share of geographical street names tends to increase with the size of the city: it varies from 10–15% in cities with a population of up to 500,000 to 25–30% in larger cities (on average). This can be explained by two reasons: 1) the toponymy of large cities reflects their more developed spatial relationships, while smaller cities are mostly attached to a purely local context; 2) geographical map was a useful source for street names in the period of a rapid growth of large cities. Also, these figures indicate that geographical urbanonyms are much more widespread in Ukraine compared with the other CEE countries: in study by Bucher et al. (2013) their share was 0–16%, and in study by Stiperski et al. (2011) – 2–9%. However, Ukrainian figures are similar to that of Minsk – 18.3% (Basik and Rahautsou 2019).

The share of geographical urbanonyms also shows a strong dependence on the region (Fig. 1). If in the west, in the centre and partly in the south it is equal to 0–10% in the cities with a population of up to 500,000 and 10–15% in the larger cities, in the east (especially in Donbas, Dnipro and Kharkiv regions) these figures are 15–25% and 20–30% respectively (on average).

The structure of geographical urbanonyms also shows regional differences (Fig. 1):

- In the western and central parts of the country, the share of "local" names is high: it does not fall below 20%, and in 7 cities out of 17 it exceeds 50%. In this respect, the cities of these regions resemble the case of Riga (Balode 2012). Also, high proportion of "local" street names is observed in the Crimea. In the rest of the southeast it does not exceed 20%, and in large cities like Dnipro, Zaporizhia and Kryvyi Rih it is less than 10%.

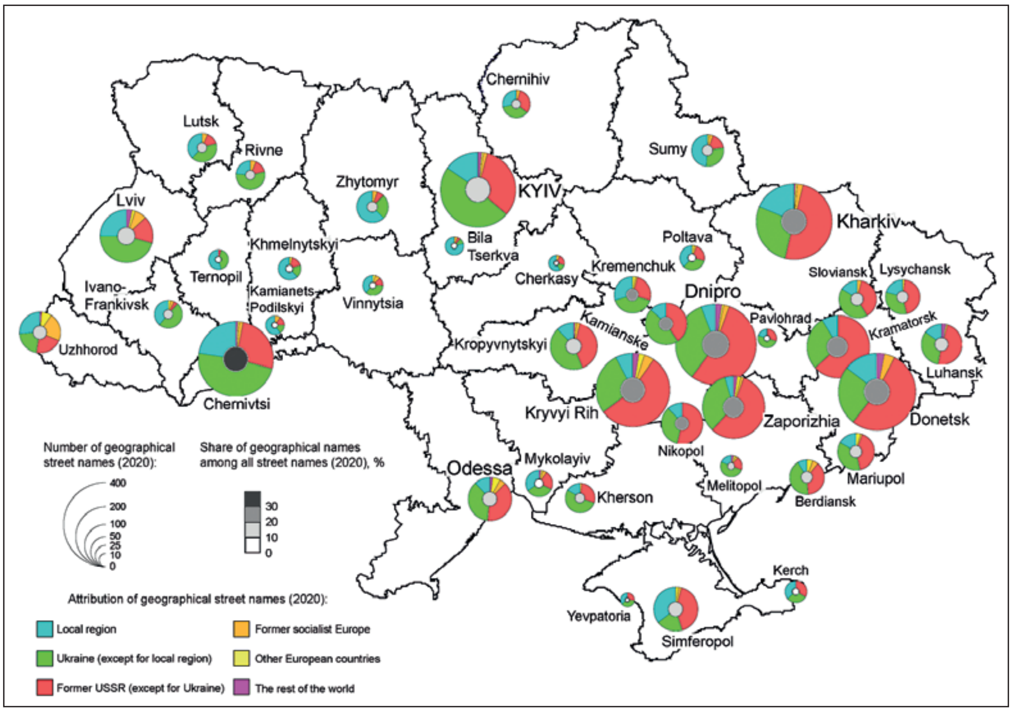


**Fig. 1** Number, share and structure of geographical street names.

- The share of "Ukrainian" names takes the largest values in the cities of the western and central parts of the country. In particular, in Galicia, Volhynia, Bukovina, as well as in Kyiv, it is close to 50% or slightly higher. A similar situation is observed in some cities of the southern part. At the same time, in other cities of the southeast, the share of these urbanonyms does not exceed 20%, and the lowest rates are typical for some cities in the central part (10–15%). Nevertheless, distribution of "Ukrainian" urbanonyms is characterized by the smallest interregional disparities.
- The share of "Soviet" urbanonyms shows the strongest interregional disparities and the clearest spatial pattern. The smallest values are observed in the west and centre of the country, where in the vast majority of cities they do not exceed 30%. In the south-east, the share of "Soviet" names does not fall below 30%, and in some cities of Donbas and Prydniprovia it is above 50% or close to this figure. The exceptions are Kerch and Yevpatoria in Crimea, as well as Melitopol (less than 30%).
- "Socialist Europe" urbanonyms are slightly more common in the cities of the west (with the absolute record in Uzhhorod – 22.1%) and centre compared to the south and east. "Capitalist Europe" street names are relatively evenly distributed, with the highest values in Uzhhorod (8.4%) and Odessa (5.6%). Urbanonyms associated with the rest of the world have no obvious regional patterns of distribution and are concentrated mainly in the largest cities with a population of over 500,000.

### 4.2 Geographical urbanonyms as markers of Sovietization and post-Soviet decolonization

Regional differences in the structure of geographical street names reflect the geopolitical past of different parts of the country – their belonging to the Austro-Hungarian and Russian empires, Poland, Czechoslovakia, Romania, and the Soviet Union. However, the influence of these geopolitical agents is asymmetric: "Soviet" names predominate over urban names associated with the European context almost throughout the country. Only in two cities of Western Ukraine, Uzhhorod and Ivano-Frankivsk, "European" toponymy prevails over "Soviet", and more or less balanced situation is observed also in other cities of the west and the centre of the country. In the rest of the territory, and especially in Donbas and Prydniprovia, "Soviet" toponymy is many times superior to "European" and, in some cases, to "Ukrainian" together with "local". Moreover, much of "European" names arose due to commemorating Soviet satellites, although it can be assumed that this aspect is not currently a key to the public perception of these urbanonyms. Thus, the everyday practices of the inhabitants in the majority of Ukrainian cities still take place in a continuous matrix of "Soviet" toponyms, and the former Soviet Union, including the Arctic, Kamchatka, Siberia and Central Asia, have every chance to be perceived as familiar, close, and intimate territories, while Europe and other regions of the world practically fall out of this mental map. In this respect, Soviet geographical place names proved to be a relatively stable category of toponymy, illustrating a kind of the toponymic continuity phenomenon considered by Light and Young (2017), Chloupek (2019) and Rusu (2020).

However, the reason for such a disproportionately wide presence of "Soviet" geographical street names is not only the special commitment of the Soviet regime to the use of toponymy as an ideological instrument, but also the fact of the most intensive demographic and spatial growth of Ukrainian cities in the Soviet era (Rowland 1983; Becker, Mendelsohn, and Benderskaya 2012). As will be seen from the analysis of cases, the practice of mass use of geographical urbanonyms in Ukraine became typical during the period of intensive spatial urban growth in the second half of XX century. Newly created streets and homonymic streets of former suburban settlements, merged with the city, required a lot of new names, and a map of the Soviet Union was a convenient source of them. The importance of such a naming practice as an instrument of identity may or may not be realized by officials, but eventually the city map became a reflection of the map of the "Great Soviet Motherland" and its geopolitical satellites. Accordingly, the larger is the city, the smaller, on average, is the share of "local" geographical urbanonyms that appeared spontaneously and performed a utilitarian function, and the larger is the share of geographical urbanonyms that have no direct relation to the city.

The widespread presence of "Soviet" geographical names on the maps of the majority of Ukrainian cities also indicates that the process of decommunization in Ukraine in most regions was not accompanied by the process of decolonization of public space. This fact becomes even more obvious when analyzing the number and the share of "Soviet" street names erased in 1991–2020 (Fig. 2). In fact, such decolonization (which largely meant de-Russification) took place only in the cities of Western Ukraine, where "Soviet" geographical place names were mostly eliminated along with communist names already in the 1990s, while in the rest of the country only some of the most odious names were eliminated. In many cities, in particular in the Crimea and Donbas, there were no "Soviet" urbanonyms that disappeared since proclamation of independence in 1991.

On the other hand, post-Soviet decolonization does not explain the sharp increase in the number and share of "Soviet" and other geographical urbanonyms in the southeast compared to the adjacent areas of the central part of the country. These differences were formed during the Soviet era. The assumption is that we are talking about the local specifics of the implementation of communist toponymic policy, when the naming decisions were made by local executive committees taking into account the predictable reaction of the local population. The transformation of the city map into a miniature map of the Soviet Union was quite acceptable for the urban communities of deeply Russified Kharkiv or Luhansk, but in Sumy or Poltava it was necessary to take more cautious steps, e.g. to rely more on the Ukrainian context and toponymy of neighbouring Soviet republics, avoiding the dominance of exotic place names from the Far East, Siberia or Central Asia. At least a partial coincidence of the outlined patterns with the basic electoral regions and fault-lines seems to be not accidentally (see Birch 2000; Katchanovski 2006; Clem and Craumer 2008; Osipian and Osipian 2012; Marples 2016; Diesen and Keane 2017).

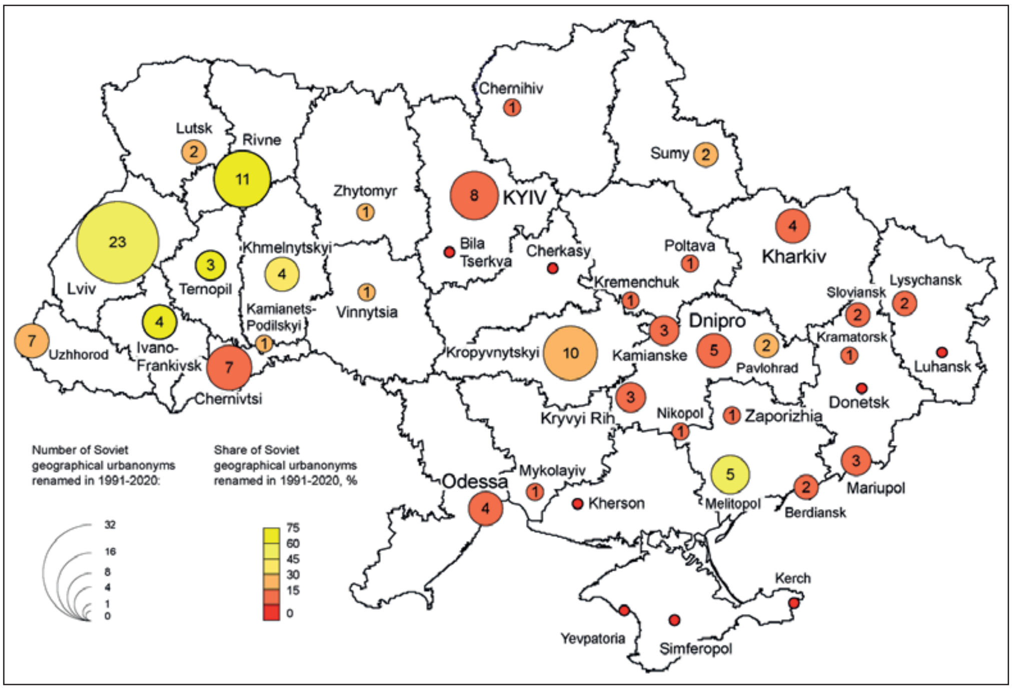


Fig. 2 Number and share of "Soviet" geographical street names renamed after 1991.

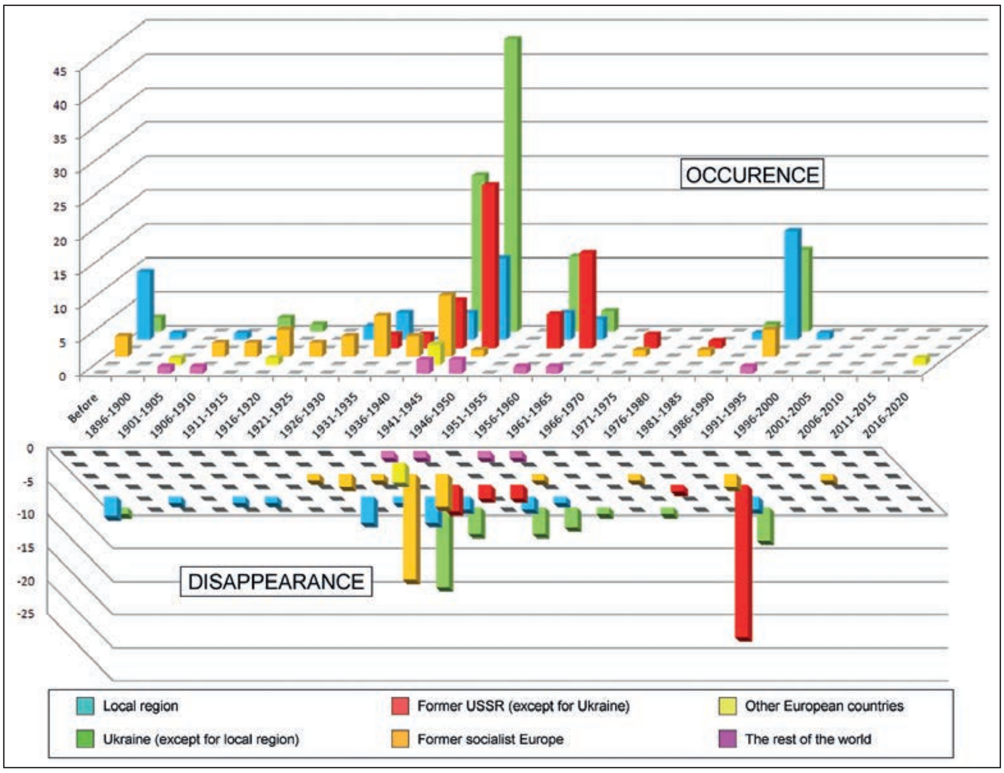


**Fig. 3** Occurrence and disappearance of geographical street names in Lviv.

## 4.3 Lviv: decolonization of public space as de-Russification

Until the first quarter of the twentieth century, geographical street names in Lviv referenced predominately to the geographical objects located in the immediate vicinity of the city or the surrounding region, including the contemporary Lviv region, other territories of Western Ukraine and adjacent territories of modern Poland (Fig. 3). All these territories were parts of the Austria-Hungary.

When Galicia became part of Poland in 1920, new place names associated with Polish cities and territories began to appear regularly, overlapping "local" names in quantity and share, and symbolically marking the city as a part of the Polish state and cultural space. When the Nazis came to Lviv in 1941, many streets were named after German and Polish (already occupied) cities and regions.

In 1945–1950, after the second establishment of Soviet power on the territory of Western Ukraine, more than half of all "Polish" and especially "German" urbanonyms were eliminated. Instead, a large number of new geographical urbanonyms appeared with domination of "Ukrainian", followed by "Soviet" and "local". The second, slightly smaller wave of mass appearance of geographical urbanonyms occurred in 1955–1965 and was marked by an even greater proportion of "Soviet" names. After that, new geographical urbanonyms became rare until the end of the Soviet Union. Throughout the Soviet period, there were also separate names associated with the countries of the socialist camp, as well as Soviet geopolitical allies in Asia. Geographical toponyms played important role in the formation of the "Soviet" image of Lviv as an international city, in the sense of the creation of the Soviet nation (Hrytsak 2007). However, geographical urbanonyms, introduced since 1945, started to abundantly disappear in a short while, both due to the renaming and the transformation of the street network – liquidation or merging of streets. In this way, only about 75% of geographical urbanonyms that emerged in the Soviet era survived by the time of Ukraine's independence.

The first years after Ukraine's independence were marked by a radical transformation of the structure of geographical urbanonyms in Lviv. During this period, more than half of all "Soviet" urbanonyms were eliminated; geographical urbanonyms from the other categories also disappeared extensively, but appeared in even greater numbers. As a result, the number and share of "Soviet" urbanonyms decreased significantly, and the number and share of "local", "Ukrainian", to a lesser extent, and "European" urbanonyms increased.

The following features are noticeable on the map of denotations of modern geographical urbanonyms of Lviv (Fig. 5):

1) Denotations of "Ukrainian" urbanonyms are concentrated on the territory of Western Ukraine, comprising an "own region" for Lviv, and slightly smaller centres of their concentration are confined to the historical region of Middle Dnieper (hypothesis

– emphasized importance of the region as a "heart of Ukraine"), and Black Sea region (hypothesis – symbolic marking of that peripheral and Russified territory as Ukrainian).

2) "Soviet" toponymy is quantitatively almost balanced with "European". Especially many street names still refer to the territory of Poland, of which Lviv was a part for a long time, in particular in 1920–1939.
3) Denotations of "Soviet" toponymy are represented in most of the former Soviet republics, except for Russia, which is a "white spot". Exceptions are national autonomies, mostly marginal, inhabited by ethnic groups different from the Russians: Kuban and Taman (inhabited by descendants of Ukrainian Cossacks), Dagestan, the Kuril Islands (object of Russian-Japanese territorial disputes), Koryak Autonomous District, Chuvashia. It should be noted that before the Soviet Union collapse, the set of "Soviet" urbanonyms in Lviv was much more diverse and included a number of names relating to the territory of Russia.

Thus, going beyond the decommunization discourse, local toponymic policy in Lviv after 1991 was aimed at 1) decolonization in the form of de-Russification (via selective erasing of "Russian" street names) and imaging Russia as a "negative Other" (Molchanov 2016), 2) formation/revival of local and regional identity (by increasing the number of "local" urbanonyms), 3) formation of a single cultural space with the rest of Ukraine as a nation state (by increasing the number of "Ukrainian" urbanonyms). It is also specific that new geographical urbanonyms almost did not appear in Lviv after 1995. The last observation well illustrates the specifics of the toponymic process in the Western Ukraine – the accentuated commemorative principle of naming in order to commemorate the prominent figures of Ukrainian national culture and liberation movement (Riznyk 2007; Hrytsak 2007).

### 4.4 Kyiv: de-Russified islands in the ocean of Soviet urbanonyms

In Kyiv, until the middle of the XX century, "local", "Ukrainian" and "Soviet" street names appeared regularly (until 1922, "Soviet" names should be interpreted as related to the territory of the Russian Empire). Before the Soviet Union formation, "local" and "Ukrainian" urbanonyms clearly prevailed, but after that, the number of "Soviet" names increased, and the proportions of these three categories of urbanonyms became virtually equal. However, although new geographical urbanonyms emerged regularly, this toponymic practice was not very popular (Fig. 4).

In 1944, immediately after the liberation of Kyiv from the Nazis, systematizing of Kyiv toponymy resulted in more than fifty new geographical urbanonyms, mostly "Ukrainian" and "local"; the share of "Soviet" names was very low. Shortly after, in 1953 and 1955, two acts of large-scale systematization of Kyiv's urbanonymy took place, the most striking feature of which was the mass introduction of geographical urbanonyms (up to 200 new names). In the following decades the intensity of their occurrence gradually decreased from almost a hundred to several dozen per 5-year period. Among them "Ukrainian"

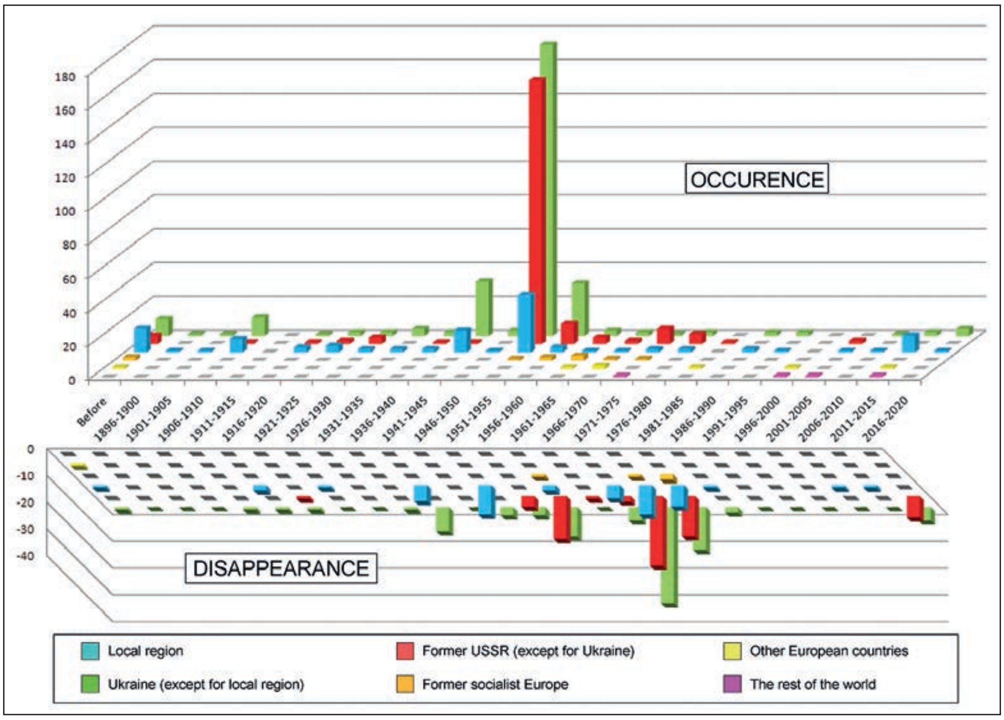


Fig. 4 Occurrence and disappearance of geographical street names in Kyiv.

names dominated, followed by "Soviet" and "local". Street names after the cities and countries of the socialist camp, as well as the twin cities of Kyiv from the "capitalist" Europe, constituted a minority among new geographical street names.

Just as in Lviv, geographical urbanonyms of all categories in Kyiv began to disappear in large numbers shortly after their introduction. Particularly large-scale waves of such disappearances took place in 1966–1970 and in 1975–1985. The main reason was liquidation of old low-rise housing in the process of building-up modernist housing estates.

In contrast to Lviv, radical changes in the number and structure of geographical urbanonyms after Ukraine's independence have not been observed in Kyiv. The trends of the 1900s were 1) break-up in the emergence of "Soviet" street names (the only exception was decommunization of Baku Commissars Street by renaming it after the Republic of Azerbaijan) and 2) almost complete cessation of the disappearance of existing geographical urbanonyms, including "Soviet": none of the latter disappeared from the map of Kyiv in 1991–2015. This phenomenon had two reasons, technical and ideological: the first was suspend in the construction of large residential estates, the second – the presence of Soviet place names on the city map was not perceived as a problem. At the same time, the liquidation of ideologically colored Soviet toponyms in Kyiv began in 1989 and lasted with variable intensity throughout Independence period (Gnatiuk and Melnychuk 2020).

The situation changed only after the annexation of Crimea and the armed conflict in the east of Ukraine, when Russia started to be perceived as an aggressor country. However, the changes were much more modest than in Lviv. Only up to a dozen of street names were changed, usually the most odious ones. In particular, Moscow Avenue, Moscow Square and Moscow Bridge were renamed; discourse analysis of the last two cases was performed by Males and Deineka (2020). Another illustrative example is Novorossiyska Street and Novorossiyskyi Lane: both were named after the city of Novorossiysk, but the term "Novorossiya" in Ukraine received a negative connotation due to its active use by pro-Russian separatists and some Russian officials and journalists with reference to the southeast of Ukraine (O'Loughlin, Toal, and Kolosov 2017). Thus, the process of toponymic decolonization is still eclectic in Kyiv, just as the decommunization before 2015 (Riznyk 2007).

On the other hand, after 2000, a little more than a dozen "local" and "Ukrainian" urbanonyms appeared in Kyiv. At first glance, it is possible to draw parallels between Kyiv and Lviv, but while in Lviv such names arose in the process of de-Russification and decommunization of urban toponymy, in Kyiv they appeared due to the naming of absolutely new streets. Another specificity of the Independence period, typical for Kyiv, but not for Lviv, was the regular appearance of street names related to Europe and the wider world context. In particular, historic names of European Square and German Street were restored; squares were named after Ankara and Santiago de Chile, and a street after the city of Bethlehem. This trend reflects the capital function of Kyiv, the space of which is designed to be not only a mimicry of home state, but also a matrix of international relations (Nikolaeva 2014). It is worth noting that structure of geographical street names in contemporary Kyiv is quite similar to that of another post-Soviet capital – Minsk (Basik and Rahautsou 2019).

The map of denotations of geographical urbanonyms of Kyiv has the following specific features (Fig. 5):

1) Denotations of "Ukrainian" urbanonyms are concentrated in the central part of the country ("own region" for Kyiv), while in the west, east and south their density is significantly lower. At the same time, in comparison with other cases, they are more or less evenly represented throughout Ukrainian territory.
2) "European" urbanonyms are significantly inferior to the "Soviet"; half of them are related to the countries of the former socialist camp (and, unlike in Lviv, Poland does not stand out against the general background), while the other half refer to the countries of the former capitalist Europe.
3) Denotations of "Soviet" urbanonyms are represented in almost all former Soviet republics, including, in contrast to Lviv, Russia. The distribution of denotations roughly reflects the population density map: most are concentrated in the European part of Russia, as well as Belarus, Transcaucasia and Ciscaucasia.

### 4.5 Dnipro: untouched Soviet geographical toponymy

The available data were too scarce to reproduce the integral continuous dynamics of the occurrence and disappearance of geographical street names in Dnipro just as for the other two cases. However, it may be stated that geographical urbanonyms were not numerous up to the XX century. Some streets were named after other cities of the Russian Empire, especially provincial centres, including those located on the territory of modern Ukraine. In the first Soviet decades, the practice of assigning geographical names was also not widespread; in addition, some geographical urbanonyms disappeared, leaving room for revolutionaries, Soviet statesmen and communist party figures. Just as in Kyiv, most of the geographical place names in Dnipro arose as a result of two decisions of the city executive committee in 1952 and 1956 respectively.

The Soviet Union collapse was not accompanied by the elimination of "Soviet" urbanonyms in Dnipro. Only after the official proclamation of decommunization in 2015, five "Soviet" street names disappeared from the city map. Four of them were formally subject

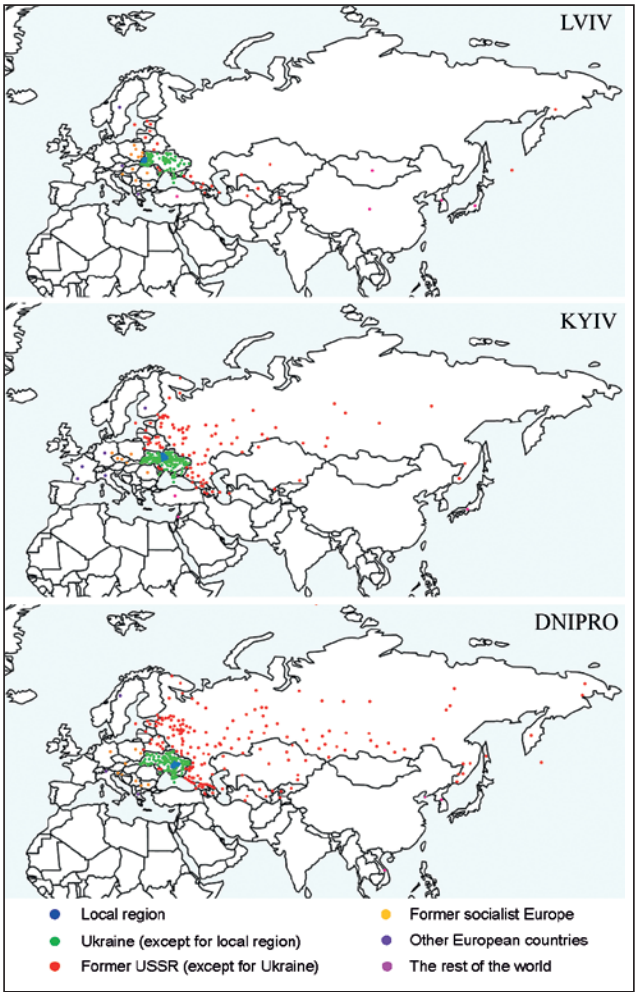


**Fig. 5** Geographical distribution of the denotations of geographical street names in Lviv, Kyiv, and Dnipro.

to decommunization laws, and only the renaming of Moscow Street may be considered a full-fledged act of decolonization. At the same time, after 1991, several "local" and "Ukrainian" urbanonyms appeared in the city, many of them as new names for decommunized objects. The last aspect qualitatively distinguishes Dnipro from Kyiv: in the latter preference was given to the commemoration of prominent figures of history and culture, while in Dnipro, as in other cities in the south-east, ideologically neutral toponyms were prioritized (Gnatiuk 2018; Kudriavtseva 2020; Golikov 2020). Several urbanonyms after the cities and countries of Europe appeared during that period in Dnipro as well.

The map of denotations of geographical urbanonyms of Dnipro has the following specific features (Fig. 5):

1) Although the clear boundary of the "own" region for Dnipro cannot be identified, denotation of "Ukrainian" urbanonyms are more dense in the eastern part of the country.
2) Most of "European" names are related to the former socialist camp countries in the Central Europe and the Balkan Peninsula.
3) Denotations of "Soviet" urbanonyms are present in all former Soviet republics, except Lithuania. Compared to Kyiv, the centre of distribution density is clearly shifted to the east, with better coverage of Siberia, the Far East, the Far North of Russia, and Central Asia.

The case of Dnipro demonstrates the vitality of (pro)Soviet identity in Russian-speaking cities in south-eastern Ukraine (Pirie 1996). Having removed visible signs of communist ideology, the streetscapes of these cities continue to bear the imprint of the past inside the Soviet empire.

## 5. Conclusions

Geographical urbanonyms represent important and currently understudied phenomenon. Reflecting the most important and long-lasting connections of the city with the outside world, they form a kind of mimicry of the external environment in which the city exists. This resemblance is geopolitically distorted, since geographical urbanonyms are used by political regimes to denote "their" and "alien" territories. Such urbanonyms are especially important in the context of colonization and decolonization study, including in the post-Soviet space.

Applying critical toponymy approach together with the elements of quantitative, cartographic and comparative analysis, we considered the spatial, structural and temporal idiosyncrasies of geographical urbanonyms in Ukraine. We tried to show their use by political elites of different epochs for either cementing national state or promoting internationalization (under the communist rule). The current dynamics of the geographical urban place names was linked to the discourses of decommunization and decolonization which predominate in the Ukrainian politics of memory during the recent years. Virtual maps of geographical places, remembered in the cityscape of the selected case study cities, were drawn to show the geopolitically distorted image of the world imprinted in the symbolic space of the cities representing culturally different regions of the country.

In Ukraine, geographical urbanonyms were used during the XX century by the ruling elites of key political regimes to mark their own cultural and political space. Regional differences in the distribution and structure of geographical urbanonyms within Ukraine are explained by the historical, cultural and (geo)political divisions. They reflect both the influences of other states and the national identity policies, as well as regional and local readings of the latter. In contemporary Ukraine, geographical urban place names are good marker of cultural decolonization process, i.e. wiping out any reminders of the Soviet rule from the symbolic space, not limiting exclusively to the communist ideology.

At the same time, the dynamics of geographical urbanonyms cannot be explained solely by the politics of memory or identity: demographic and spatial urban growth makes its contribution as well. However, the consequences of their introduction in large numbers on the public perception of the spatial cultural, civilizational and geopolitical structures should not be underestimated.

## References


Azaryahu, M. (1990): Renaming the past: changes in ‘city-text’ in Germany and Austria 1945–1947. History and Memory 2(2), 32–53.

Azaryahu, M. (2009): Naming the past: the significance of commemorative street names. [In:] L. D. Berg, J. Vuolteenaho (eds.) Critical Toponymies: The Contested Politics of Place-Naming. Farnham: Ashgate, 53–70.

Azaryahu, M. (2017): Revisiting East Berlin and Haifa. A comparative perspective on renaming the past. [In:] R. Rose-Redwood, D. Alderman, M. Azaryahu (eds.) The political life of urban streetscapes: naming, politics, and place. Abingdon, U.K.: Routledge, 56–73, https://doi.org/10.4324/9781315554464-4.

Balode, L. (2012): Place-names in the urbanonymy of Riga: mark of identity. Studii si Cercetari de Onomastica si Lexicologie 5(1–2), 17–28.

Basik, S., Rahautsou, Dz. (2019): Toponymic politics and the symbolic landscapes of Minsk, Belarus. Geographia Cassoviensis 13(2), 107–120, https://doi.org/10.33542/GC2019-2-02.

Becker, C., Mendelsohn, S. J., Benderskaya, K. (2012): Russian urbanization in the Soviet and post-Soviet eras. London: Human Settlements Group International Institute for Environment and Development.

Berg, L., Voulteenaho, J. (eds.) (2009): Critical Toponymies: The Contested Politics of Place Naming. Aldershot: Ashgate.

Birch, S. (2000): Interpreting the regional effect in Ukrainian politics. Europe-Asia Studies 52(6), 1017–1041, https://doi.org/10.1080/09668130050143815.

Bucher, S., Matlovič, R., Lukáčová, A., Harizal, B., Matlovičová, K., Kolesárová, J., Čermákov, L., Michalko, M. (2013): The perception of identity through urban toponyms in the regional cities of Slovakia. Anthropological Notebooks 19(3), 23–40.

Chloupek, B. R. (2019): Public memory and political street names in Košice: Slovakia’s multiethnic second city. Journal of Historical Geography 64, 25–35, https://doi.org/10.1016/j.jhg.2018.11.007.

Clem, R. S., Craumer, P. R. (2008): Orange, Blue and White, and Blonde: the electoral geography of Ukraine’s 2006 and 2007 Rada elections. Eurasian Geography and Economics 49(2), 127–151, https://doi.org/10.2747/1539-7216.49.2.127.

Crljenko, I. (2012): The renaming of streets and squares in post-Socialist Croatian towns. Language and Society 3, 230–241.

Czepczyński, M. (2008): Cultural Landscapes of Post-Socialist Cities. Aldershot: Ashgate, https://doi.org/10.4324/9781315575315.

Dala Costa, A. (2020): Toponymy and the issues of memory and identity on the post-Soviet Tbilisi cityscape. The Ideology and Politics Journal 1(15), 148–171.

Diesen, G., Keane, C. (2017): The two-tiered division of Ukraine: Historical narratives in nation-building and region-building. Journal of Balkan and Near Eastern Studies 19(3), 313–329, https://doi.org/10.1080/19448953.2017.1277087.

Fernos, Yu. (2018): Vplyv protsesu dekomunizatsiji na systemu urbanonimiv mista Umani [The influence of de-communization processes on the system of Uman urbanonyms]. Bulletin of Alfred Nobel University. Series “Philological Sciences” 2(16), 299–304, https://doi.org/10.32342/2523-4463-2018-2-16-28.

Gill, G. (2005): Changing symbols: the renovation of Moscow place names. The Russian Review, 64, 480–503, https://doi.org/10.1111/j.1467-9434.2005.00371.x.

Gnatiuk, O. (2018): The renaming of streets in post-revolutionary Ukraine: regional strategies to construct a new national identity. AUC Geographica 53(2), 119–136, https://doi.org/10.14712/23361980.2018.13.

Gnatiuk O., Glybovets V. (2020): Do street status and centrality matter for post-socialist memory policy? The experience of Ukrainian cities. Geographia Polonica 93(2), 139–161, https://doi.org/GPol.0167.

Gnatiuk, O., Melnychuk, L. (2020): Spatial-temporal aspects of toponymy decommunization in the city of Kyiv. The Ideology and Politics Journal 1(15), 83–114, https://doi.org/10.36169/2227-6068.2020.01.00005.

Golikov, A. (2020): (Pere)imenovanija i dekommuniozatsija po-ukrainski: makropolitiki, istoricheskaja pamiat i riski mediatizatsii (kejs Harkova) [(Re-)naming and decommunization in Ukrainian: macropolicies, historical memory and the risks of mediatization (Kharkiv case)]. The Ideology and Politics Journal 1(15), 33–62, https://doi.org/10.36169/2227-6068.2020.01.00003.

Hrytsak, Y. (2007): Konstrujuvannia natsionalnoho mista: vypadok Lvova [Construction of a national city: case of Lviv]. Dukh i Litera 17–18, 157–181.

Hyrych, I. (2013): Suchasna toponimika Kyjeva jak vyjav istorychnoji svodomosti [Modern Kyiv place names as an expression of historical consciousness]. Natcionalna ta istorychna pamyat’ 8, 133–141.

Karoyeva, T. (2017): Z dosvidu robochoji hrupy schodo dekomunizatsiji publichnoho prostoru Vinnytsi: pohliad istoryka [Abstract of practical activity of a workgroup on “decommunization” of public area of the town of Vinnytsia: historian’s view]. City: History, Culture, Society 2, 196–206, https://doi.org/10.15407/mics2017.02.196.

Katchanovski, I. (2006): Regional political divisions in Ukraine in 1991-2006. Nationalities Papers 34(5), 507–532, https://doi.org/10.1080/00905990600952939.

Kudriavtseva, N. (2020): Reconfiguring identities within the cityscape: ideologies of decommunization renaming in Ukraine. The Ideology and Politics Journal 1(15), 63–82, https://doi.org/10.36169/2227-6068.2020.01.00004.

Lappo, G. M. (2012): Goroda Rossii. Vzgliad geografa [Cities of Russia. A Geographer’s View]. Moscow: Novyi hronograf.

Light, D. (2004): Street names in Bucharest, 1990–1997: exploring the modern historical geographies of post-socialist change. Journal of Historical Geography 30(1), 154–172. https://doi.org/10.1016/s0305-7488(02)00102-0.

Light, D., Young, C. (2014): Habit, memory and the persistence of socialist-era street names in post-socialist Bucharest, Romania. Annals of the Association of American Geographers 104(3), 668–685, https://doi.org/10.1080/00045608.2014.892377.

Light, D., Young, C. (2017): The politics of toponymic continuity: the limits of change and the ongoing lives of street names. [In:] R. Rose-Redwood, D. Alderman, M. Azaryahu (eds.) The political life of urban streetscapes: naming, politics, and place. Abingdon, U.K.: Routledge, 185–201.

Lotman, Y. (2000 [1996]): Vnutri mysliashih mirov [Inside thinking worlds]. [In:] Y. Lotman, Semiosfera. Saint-Petersburg: Iskusstvo, 150–390.

Marin, A. (2017): Toponymic changes as temporal boundary-making. Street renaming in Leningrad /St. Petersburg. [In:] R. Rose-Redwood, D. Alderman, M. Azaryahu (eds.) The political life of urban streetscapes: naming, politics, and place. Abingdon, U.K.: Routledge: 132–149.

Males, L. (2016): Dyskurs dekomunizatsiji v Kyjevi [Decommunization Discourse in Kyiv]. Sociological Studios 2(9), 16–21, https://doi.org/10.29038/2306-3971-2016-02-16-21.

Males, L., Deineka A. (2020): Diskurs dekommunizatsii Kieva v opyte pereimenovanij [The discourse of Kyiv's decommunization in the frame of toponymic renaming]. The Ideology and Politics Journal 1(15), 115–147, https://doi.org/10.36169/2227-6068.2020.01.00006.

Marples, D. (2016): Ethnic and Social Composition of Ukraine's Regions and Voting Patterns. [In:] A. Pikulicka-Wilczewska, R. Sakwa (Eds.) Ukraine and RussiaPeople, Politics, Propaganda andPerspectives. Bristol: E-International Relations Publishing, 8–17.

Molchanov, M. A. (2016): Russia as Ukraine's 'Other': Identity and Geopolitics. [In]: A. Pikulicka-Wilczewska, R. Sakwa (eds.) Ukraine and Russia: People, Politics, Propaganda and Perspectives. Bristol: E-International Relations Publishing, 195–210.

Neher, O. (2014). Derzhavna ideolohija jak chynnyk vplyvu na rozvytok zakarpatoukrajinskoho urbanonimikonu v kintsi XX – na pochatku XXI st. [State ideology as factor of influence on development of urbanonymy of Zakarpattya at the end of XX – in the beginning of XXI centuries]. Suchasni problem movoznavstva ta literaturoznavstva 19, 66–69.

Nikolaeva, E. V. (2014): Fraktaly gorodskoy kultury [Fractals of the urban culture]. Saint Petersburg: Strata.

O'Loughlin, J., Toal, G., Kolosov, V. (2017): The rise and fall of "Novorossiya": examining support for a separatist geopolitical imaginary in southeast Ukraine. Post-Soviet Affairs 33(2), 124–144, https://doi.org/10.1080/1060586X.2016.1146452.

Osipian, A. L., Osipian, A. L. (2012): Regional diversity and divided memories in Ukraine: contested past as electoral resource, 2004–2010. East European Politics and Societies 26(3), 616–642. https://doi.org/10.1177/0888325412447642.

Pavlenko, I. (2020): Deradianizatsija ta dekomunizatsija ukrajinskoho urbanimikonu (na materiali nazv objektiv miskoho prostoru Zaporizhzhia) [Desovetization and decommunization of the Ukrainian urbanimicon (on the material of Zaporizhzhia place names)]. The Ideology and Politics Journal 1(15), 188–207, https://doi.org/10.36169/2227-6068.2020.01.00009.

Palmberger, M. (2017): Nationalizing the streetscape: the case of street renaming in Mostar, Bosnia and Herzegovina. [In:] R. Rose-Redwood, D. Alderman, M. Azaryahu (eds.) The political life of urban streetscapes: naming, politics, and place. Abingdon, U.K.: Routledge: 168–184, https://doi.org/10.4324/9781315554464-10.

Palonen, E. (2008): The city-text in post-communist Budapest: street names, memorials, and the politics of commemoration. GeoJournal 73(3), 219–230, https://doi.org/10.1007/s10708-008-9204-2.

Palonen, E. (2017): Building a new city through a new discourse Street naming revolutions in Budapest. [In:] R. Rose-Redwood, D. Alderman, M. Azaryahu (eds.) The political life of urban streetscapes: naming, politics, and place. Abingdon, U.K.: Routledge, 98–113, https://doi.org/10.4324/9781315554464-6.

Pirie, P. R. (1996): National Identity and Politics in Southern and Eastern Ukraine. Europe-Asia Studies 48(7), 1079–1104, https://doi.org/10.1080/09668139608412401.

Portnov, A. (2013). Memory Wars in Post-Soviet Ukraine (1991–2010). [In:] U. Blacker, A. Etkind, J. Fedor (eds.) Memory and Theory in Eastern Europe. New York: Palgrave Macmillan, 233–254, https://doi.org/10.1057/9781137322067_12.

Riznyk, O. (2007): Toponimichnyi landshaft Kyieva i problemy derzhavnoi toponimichnoi polityky [Toponymic landscape of Kyiv and problems of the state toponymic policy]. Retrieved from https://web.archive.org/web/20121023231457/http://www.culturalstudies.in.ua/statti_1_2007.php (accessed on 11 June 2020).

Robinson, D. (1989): The language and significance of place in Latin America. [In:] J. Agnew, J. Duncan (eds.) The Power of Place. Boston: Unwin Hyman, 157–184.

Rose-Redwood, R. (2017): From number to name. Symbolic capital, places of memory, and the politics of street renaming in New York City. [In:] R. Rose-Redwood, D. Alderman, M. Azaryahu (Eds.) The political life of urban streetscapes: naming, politics, and place. Abingdon, U.K.: Routledge, 274–289, https://doi.org/10.4324/9781315554464-16.

Rose-Redwood R., Alderman D., Azaryahu M. (2017a): Contemporary issues and future horizons of critical urban toponymy. [In:] R. Rose-Redwood, D. Alderman, M. Azaryahu (eds.) The political life of urban streetscapes: naming, politics, and place. Abingdon, U.K.: Routledge, 309–319, https://doi.org/10.4324/9781315554464-18.

Rose-Redwood R., Alderman D., Azaryahu M. (2017b): The urban streetscape as political cosmos. [In:] R. Rose-Redwood, D. Alderman, M. Azaryahu (eds.) The political life of urban streetscapes: naming, politics, and place. Abingdon, U.K.: Routledge, 1–24, https://doi.org/10.4324/9781315554464-1.

Rowland, R. H. (1983): The growth of large cities in the USSR: policies and trends, 1959–1979. Urban Geography 4(3), 258–279. https://doi.org/10.2747/0272-3638.4.3.258.

Rusu, M. S. (2020): Political patterning of urban name scapes and post-socialist toponymic change:

A quantitative analysis of three Romanian cities. Cities 103, https://doi.org/10.1016/j.cities.2020.102773.
Savchenko, L., Takhtaulova, M. (2019): Bazovi kharakterystyky kompleksnoho istorychnoho doslidzennia toponimiky ukrajinskoho mista (na prykladi Kharkova) [Base characteristics of the Ukrainian city toponymy historical research (the Kharkiv case)]. City: History, Culture, Society 6, 121–133, https://doi.org/10.15407/mics2019.06.121.
Shevel, O. (2011): The politics of memory in a divided society: a comparison of post-Franco Spain and post-Soviet Ukraine. Slavic Review 70(1), 137–164, https://doi.org/10.5612/slavicreview.70.1.0137.
Smirnov, S. B. (2013): Evropa i mir v toponimike Peterburga: metod analiza [Europe and the world in toponymy of St. Petersburg: a method of analysis]. Herald of Vyatka State University 4-1, 112–116.
Stewart, G. (1954): A Classification of Place Names. Names 2(1), 1–13.
Stojanović, D. (2007). Die Straßen Belgrads 1885–1914 [The streets of Belgrade 1885–1914]. [In:] U. Brunnbauer, A. Helmedach, and S. Troebst (eds.) Schnittstellen. Gesellschaft, Nation, Konflikt und Erinnerung in Südosteuropa. Munich: R. Oldenbourg, 65–79.
Stiperski, Z., Lorber, L., Heršak, E., Ptaček, P., Górka, Z., Kołoś, A., Lončar, J., Faričić, J, Miličević, M., Vujaković, A., Hruška, A. (2011): Identity through urban nomenclature: eight Central European cities. Geografisk Tidsskrift – Danish Journal of Geography 111(2), 181–194, https://doi.org/10.1080/00167223.2011.10669532.
Šakaja, L., Stanić, J. (2017): The spatial codification of values in Zagreb's city-text. [In:] R. Rose-Redwood, D. Alderman, M. Azaryahu (eds.) The political life of urban streetscapes: naming, politics, and place. Abingdon, U.K.: Routledge, 151–167, https://doi.org/10.4324/9781315554464-9.
Takhtaulova, M. (2015). Toponimika postradianskoho Kharkova: na shliakhu do dekomunizatsiji [The toponymy of the post-Soviet Kharkiv: on the way to the decommunization]. Science and Education a New Dimension. Humanities and Social Sciences 67(11), 36–39.
Takhtaulova, M. (2017): Kharkivska toponimika: etapy dekomunizatsiji [Kharkiv toponymy: stages of decommunization]. City: History, Culture, Society 1, 142–151, https://doi.org/10.15407/mics2017.02.142.
Thakahov, V. Kh. (2019): Identichnost i pamiat v toponimicheskoj politike Chechni [Identity and memory in toponymic policy in Chechnya]. Scientific Thought of Caucasus 2, 40–49, https://doi.org/10.18522/2072-0181-2019-98-2-40-49.
Vengryniuk, L. (2012): Realizatsija polityky pamiati: rehionalnyj vymir (na prykladi m. Ivano-Frankivska) [The implementation of the politics of memory: regional dimension (example of Ivano-Frankivsk)]. Precarpathian Bulletin of the Schevchenko Scietnific Society, Dumka Series 3(19), 243–252.
Yeoh, B. (1996): Street-naming and nation-building: toponymic inscriptions of nationhood in Singapore. Area 28(3), 298–307.
Yeoh, B. (2017): Colonial urban order, cultural politics, and the naming of streets in nineteenth- and early twentieth-century Singapore. [In:] R. Rose-Redwood, D. Alderman, M. Azaryahu (eds.) The political life of urban streetscapes: naming, politics, and place. Abingdon, U.K.: Routledge, 41–55, https://doi.org/10.4324/9781315554464-3.