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CONTENTS

THE ROLE OF SOCIAL CAPITAL IN ECONOMIC LIFE OF THE UKRAINIAN ENTREPRENEURS IN CZECHIA

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ABSTRACT

This article presents the concept of social capital and highlights its use in the economic performance of Ukrainian entrepreneurs in Czechia. The social capital stands as one of the important resources, which can be used by migrant entrepreneurs in creating their own businesses and ethnic economies. The concept of social capital with its different approaches, roles and impact on society is a frequent topic of current scientific debate, particularly in connection with mass immigration to the Western countries. In our analysis we use the individual approach of social capital that goes in line with personal ties, and thus it is closely connected to mutual trust, cooperation, contacts as well as mutual aid and solidarity. Our main research question is whether the Ukrainian entrepreneurs poses social capital and how they use it in their business activities. The article is founded on qualitative research based on 16 in-depth semi-structured interviews with Ukrainian entrepreneurs and key actors of the Ukrainian community in Czechia. We conclude that the Ukrainians do not use their social capital to the available extent. The networks of contacts exist among the Ukrainian entrepreneurs, but their use for economic cooperation is rather limited, which seems to be caused by their low level of trust. The mutual solidarity presented in private life and in economic activities does not play a significant role. Moreover, due to the absence of social capital, Ukrainian entrepreneurs have not yet developed their ethnic economy in Czechia.

Keywords: social capital, migrant entrepreneurship, Ukrainian migrants, Czechia

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1. Introduction

Entrepreneurs need resources for their business activities and migrant entrepreneurs are no exceptions (Light, Gold 2000). Social capital is considered as one of the essential resources, which, with some simplification, could be understood as 'social networks of social ties' (Light 1984). The Ukrainian entrepreneurs in Czechia and their social capital used in their business activities are in the centre of our interest. Presumably, the social capital of Ukrainian entrepreneurs may differ from other ethnic groups' business activities in Czechia as well as from that of other migrant communities in other Western countries. Our assumption arises from the fact that in post-socialist countries, different forms of social capital have been existing, which had been built on non-communitarian vertical exchange relations (Åberg 2000)[1]. Of great importance is the awareness that this non-communitarian social capital prevents the formation of mutual trust, which is the essential aspect of social capital in the studies of ethnic entrepreneurs (Åberg 2000; Light, Gold 2000).

Studying the topic of social capital in connection with immigration processes is also interesting because of the current scientific debate, which has escalated sharply around the topic of mass immigration to the Western countries and its impact on the decrease of social capital in the whole society (Putnam 2007; Portes 2014; Portes, Vickstorm 2015).

The research question in our article is whether social capital is one of the essential resources of the Ukrainian entrepreneurs in Czechia. We are mapping different features of social capital, how and to what extent it is being used by the Ukrainian entrepreneurs in their economic performance. We concentrate on the Ukrainian entrepreneurs, based on the fact that the whole group of Ukrainian immigrants of about 106,000 people in 2013 formed the biggest minority group and had presented the quarter of all immigrants in Czechia (Czech Statistical Office 2014/a). The intensive migration of Ukrainians could be explained not only by the economic inequality and intertwined history, but also by the geographic proximity, as well as the linguistic and cultural similarities (Drbohlav 2004; Drbohlav et al. 2013). There are different ways in which migrants react to new circumstances, opportunities and conditions in the country of destination (Waldinger et al. 1985). While some of them take the position of employees, others start their own businesses (Čermáková et al. 2011; Leontiyeva 2014). The average amount of self-employed Ukrainian immigrants makes about 30%. According to the Czech Statistical Office (b) in 2014, 10,515 Ukrainian-owned enterprises were registered in Czechia (7,557 of them in Prague). However, the databases of the self-employed and enterprises do not shed light on the actual number of business subjects operating today. The restrictions which came into force after

1 Conversely, communitarian social capital is being built on the horizontal network of exchange relations (Åberg 2000).

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the world financial crisis (2008) brought along the change that it is now much easier to obtain a work permit with a business license than with a job contract (see more in Čermáková, Kohlbacher 2012). This has led to quasi-economic activities when migrants legalize their staying as entrepreneurs (Drbohlav, Valenta 2014). Therefore, it is common that the Ukrainians launch their own business (to be self-employed), which is merely the formal measure, as in fact they work as employees for other entrepreneurs (Čermáková, Kohlbacher 2012). The most dynamic period of the Ukrainian entrepreneurship was the second half of the 1990s, when the Czech economy experienced great transformations, recognized by the immigrants entering the country and utilizing the economic opportunities of that time (Čermáková et al. 2011). The majority of the Ukrainian enterprises are concentrated in Prague and its surroundings (which may be in connection with the fact that this area has the greatest demand for new constructions as well as a better infrastructure for enterprise). In Czechia, the most active Ukrainian-owned enterprises can be found in the construction and manufacturing industry, also in the service sector, mainly in the form of small and medium-sized enterprises.

2. Migrant entrepreneurship and its resources

Three main approaches explain the existence of migrants' business in the countries of destination. The first and the most elaborated approach is called the cultural approach, which finds one explanation of ethnic entrepreneurship in group (ethnic) resources and another in the consequences of migrants' disadvantages in the country of destination (Light, Gold 2000). The cultural approach also brings about the concepts of ethnic economy, ethnic controlled economy, middlemen minority and ethnic enclave economy (Wilson, Portes 1980; Zhou 2004). The concept of ethnic economy is characterized by its marginal position to the general economy, rather large scale, usually concentrated in one economic sector with a controlling ownership stake, and strong economic ties on horizontal and vertical levels (Light, Karageorgis 1994).

The second approach is based on the idea of existence of structural opportunities for immigrant businesses, and it is also known as the interactive approach (Aldrich, Waldinger 1990). The existence of immigrants' businesses, sectoral specialization and economic outcomes is explained as an interaction of the environments of the host country (its structural opportunities), resources of ethnic group and individual skills of migrants. This approach has brought about new ethnic resources like transnational ties, and a new type of entrepreneur was introduced as 'transnational entrepreneur' (Portes et al. 2002).

The third and latest main approach to the research of migrants' businesses adopts the biographical perspective in order to emphasize the agency of individual actors in given opportunity structures (Hettlage 2008). This approach shifted the research from group perspective to the individual one, with emphasis on decision-making process and individual characteristics.

All three main approaches deal with class and ethnic resources, but in different views and importance. The cultural approach stresses the importance of ethnic (group) resources, the structural approach stresses both ethnic and class resources, and the individual approach considers the resources of individual migrant-entrepreneur as the most important factor.

Both ethnic and class resources are important for economic success of migrant entrepreneurs, but their proportion is different and varies in time and place (Razin 1989; Light, Gold 2000). The important fact about using ethnic and/or class resources is that any concentration of migrant entrepreneurs in occupational niches, localities, similar business strategies mean that ethnic resources are more present than class resources (Light, Gold 2000), and on the contrary, the incorporation of immigrant entrepreneurs into main economy means that class resources were more significant. Therefore, migrants with high level of class recourses very rarely create ethnic economies, ethnic enclave economies or any other economic niches (Zhou 2004). The social status of Ukrainian immigrants in Czechia is quite heterogeneous, and for this reason the class-based integration has a greater chance in a new country as class-based dissimilarities override similarities stemming from common ethnicity.

Ethnic resources present the resources which are inherent to all members of ethnic group, and thus the whole group can enjoy the economic benefits of them (Coleman 1988; Light, Gold 2000). They include identifiable skills, organizational techniques, reactive solidarity, sojourning orientation, and other characteristics based on traditions and experiences (Light, Gold 2000). On the contrary, class resources present financial, human, cultural and social capital, while the ownership of these kinds of capital differs within one ethnic group (Light, Gold 2000). Nevertheless, these capitals could be influenced by ethnic resources in the actual manifestation. For example, an ethnic group can provide the financial capital through personal loans and rotating savings; by sharing skills they provide the human capital, by vocation culture they provide the cultural capital and finally, by networks, solidarity, common membership they provide the social capital (see more in Light, Gold 2000; Gedajlovic et al. 2013).

3. Social capital and ethnic entrepreneurship

Although the concept of social capital has been presented in ethnic entrepreneurship research for several decades, it is still broadly used in current research, especially in use of social networks when starting and running business (Gedajlovic et al. 2013; Light, Dana 2013; Edwards et al. 2015; Shi et al. 2015). The first practical use of social capital was introduced by Pierre Bourdieu. He goes beyond the economic concept of capital and talks about cultural, social and symbolic capital. It shows that social capital is a set of resources which are tied with the affiliation to a certain group, and that some actors are utilizing them in order to develop social networks (Bourdieu 1983). According to Bourdieu, the amount held by the individual's social capital depends on the scope of net connections, which can be effectively mobilized. Later the concept of social capital became widely known through Coleman's work, who determined it as a resource which appears in the relations' structure between the actors and which facilitates the actions within this structure (Coleman 1988). Coleman found the role in facilitating the action particularly important; he linked the social capital with physical and human capital, namely the resources that are available for individuals to achieve their goals. Bourdieu and Coleman see social capital as the private asset. On the contrary, according to Putnam (1993, 2000), social capital is a public good, consisting of ties, trust, mutuality, solidarity and institutions, which can be transferred from one social environment into another. Fukuyama (1997) highlights two important components in the definition of social capital: collaboration and mobilization. According to him, we can only talk about usable and extensible resources (i.e. social capital) if we call social norms in given social relationship into life and mobilize them for the purpose of mutually beneficial cooperation. In Lin's definition (2001), social capital is the investment in social relationships, which pays for itself in the market, and the expected return on investment outweighs the costs.

As we can see, we can find different definitions of social capital, but according to Perreault (2007) and others, most of them share one point in common, namely the notion of trust. According to the first contributors in social capital literature, '*it involves relationships of trust and reciprocity that are inherent in social networks*' (Light, Dana 2013, p. 603). However, Light notes that social capital is more complex and puts it in the following way: '*the social capital is the assets that may be mobilized through networks, thanks to mutual trust and the norm of reciprocity*' (see also in Light, Dana 2013, p. 603). Portes and Sensenbrenner (1993, p. 284) generally define the concept of social capital as: '*those expectations for action within a collectivity that affect the economic goals and goal-seeking behaviour of its members, even if these expectations are not oriented toward the economic sphere*'. They distinguished four groups of resources of social capital: (1) *value introjection,* which motivates the members of the group to pay attention not only to their personal interest when acting, and thus their perception would be the standard to the other members of the group; (2) *reciprocity exchanges* is based on the kindness and exchange of social goods; (3) *bounded solidarity* is based on common difficulties and reactions to each of those groups; (4) *enforceable trust,* which arises when some members of the group put their own individual interests above the interests of the group, calculating on the future benefit. While the value introjection and reciprocity exchanges can be a generalized form for each social group, the bounded solidarity and enforceable trust are based on the strong sense of ethnic community (Portes, Sensenbrenner 1993). Due to these facts, we follow the links of solidarity and mutual trust further more in details. We focus more closely on community resources of social capital, which are activated by facing common difficulties, e.g. exclusion from the host society. Bounded solidarity is a reaction of the ethnic group to this situation and is rather based on moral standards than enforceability (Portes, Sensenbrenner 1993). The formation of bounded solidarity depends on the dissimilarity of particular groups. The higher the rejection against certain ethnic groups, the higher the degree of solidarity in the given group (Portes, Sensenbrenner 1993). The level of opportunity for the immigrant society to 'flee' from the exclusion is crucial for the development of bounded solidarity-based social capital. The lower the opportunity level, the likelier the development of solidarity (Portes, Sensenbrenner 1993).

The next resource of social capital, defined as enforceable trust, is created by the community's ability to control the given group (Portes, Sensenbrenner 1993). In this case, not the external factors, but rather the community's internal sanctioning ability plays a central role. The members of the group act under the fear of punishment or in the hope for a better reward. These sanctions and rewards in general are immaterial goods, but in the long run they can lead to material consequences too. The efficiency level of the sanctions depends on how members of the group can control each other. There exists also a positive influence of the social capital based on enforceable trust: it makes the various economic acts more flexible by reducing formal steps, thus the rate of economic offenses is lower due to the traceability of the group members. But a too close net of contacts in the immigrant community imposes serious limits on the group members, which may block their business careers. So we arrive to the assumption that social capital is not only a positive contribution to the socio-economic functioning of a community, but it also has a destructive influence on it. Although international literature mentions almost only the positive effects of social capital, more and more academic works start to reflect upon its negative influence (Waldinger 1995; Portes, Landolt 1996; Levine et al. 2014). Portes and Sensenbrenner (1993) also give negative examples of social capital: in closed societies, the relatives of successful entrepreneurs 'settle on' them and ask them for loans, job opportunities and claim for their profit. All these conditions hinder their business growth. As mentioned above, the trust and reciprocity is inherent in social networks, which, besides the advantages (for example job opportunities, easier management of permits and official documents), can bring some negative effects too, especially when ethnic groups with stronger social capital suppress smaller and weaker ones (Light, Dana 2013). Sometimes it happens that stronger ethnic groups use force against other, weaker groups, limit their decision-making capacity, and often enforce their own will. It is even more vigorous if the dominant group has a strong social capital, while the oppressed groups have a weak one.

If we examine the function of social capital among the ethnic groups in Czechia and other CEE countries, we get an unbalanced picture. In comparison with the Vietnamese (Grzymala-Kazlowska 2014), the third largest minority group in Czechia (Czech Statistical Office 2014/a), the Ukrainians dispose of a low level of solidarity. The reason for this could be mainly the linguistic proximity and the similar lifestyles of the Ukrainians and the host (Czech) nation (Bernard, Vašát 2015). The Ukrainians are less mutually interdependent within the ethnic group and their networks are rather less dense (Bernard, Vašát 2015). Nevertheless, the Ukrainians are not a homogeneous group, and it was revealed that manual workers have networks of higher density than highly qualified ones. On the contrary, the Vietnamese live much more separated, but the level of assistance and support to each other is higher than in the case of other examined groups like the Armenians and Ukrainians (Drbohlav, Dzúrová 2007).

A striking example of a system which is based on social networks has appeared in Czechia and it is called 'client[2] system'[3]. The system emerged in the 1990s and began to develop because of the Ukrainian labour migration, in order to organize illegal labour for (mostly) Ukrainian migrants. The cooperation was useful for both sides: the 'clients' got financial benefit from the employees' reduced wage, and the employees got a job, and administration was simple (see more in Čermáková, Nekorjak 2009). In this case the main source of social capital is institutional-based reciprocity norms. People essentially do not trust each other, but the exchange of favours and mutuality do work. Nevertheless, if we look at the aggregate, it is a rather negative example of social capital. In 1990s the 'client system' was built on the Ukrainian mafia system, when threatening, blackmailing and physical or verbal violence were common. Employees were in a subordinate relationship with the 'clients', and in some cases they could not change their working place, step out from a working circle or return home when they wanted to (Čermáková, Nekorjak 2009). After Czechia became an EU member state, great efforts have been made to suppress illegal labour and to comply with European labour regulations. Because of the strict conditions, the 'client system' gradually turned into an official institution and at the same time lost its exploiting, restrictive trait (Čermáková, Kohlbacher 2012).

4. Methodology

We are interested in the presence of social capital as a resource among Ukrainian immigrants in their business activities in Czechia. Due to the fact that the concept of social capital is not unanimously understood, in our interpretation we see social capital in its connection with ethnic communities (personal approach) and not with public good (see above). In the determination of social capital we rely on the definition formulated by Portes and Sensenbrenner (1993, p. 284): '*those expectations for action within a collectivity that affect the economic goals and goal-seeking behaviour of its members, even if these expectations are not oriented toward the economic sphere*', as described above. The aspects of social capital like mutual trust, cooperation, contacts, networks, mutual aid and solidarity were in the centre of our interest, and we were trying to detect those in interviews and, subsequently, analyze them.

The fieldwork for this study included sixteen in-depth interviews with Ukrainian migrant entrepreneurs, and also with key actors of the Ukrainian migrant community in Prague and in Karlovy Vary (*Table 1*). The interviews were held in the above mentioned two Czech settlements between October 2014 and March 2015 in Ukrainian (fourteen) or Russian (two) languages. The interviews lasted between one and one and a half hour long. Notwithstanding the sample is too small to allow a generalization about the Ukrainian entrepreneurship in Czechia, our general impression is – solidified by discussions with key actors of the Ukrainian community in Prague and in Karlovy Vary – that it offers a fairly typical picture of the Ukrainian entrepreneurship in Czechia.

Semi-structured in-depth interviews were conducted, with three main question groups: the first one contained questions about personal information; the second one contained questions relating to entrepreneurship; the third one focused on the economic and personal relationship among co-ethnics and non-co-ethnics. A semi-structured version of questions was intended to ensure collecting the basic data (type and age of business, number and ethnicity of employees, education and language skills of company-owners, and main features of the company) on the one hand, and on the other hand, storytelling encouraged participants to tell their 'own stories' (Bagwell 2006) about how they arrived to Czechia, how the business was started and how it developed. We intended to ascertain the main reasons and motivations in start-up business, the main characteristics in operating Ukrainian companies with special focus on the business relations among the Ukrainian migrant group. We concentrated on the first generation of migrants and tried to maintain sectoral as well as gender equality among the respondents.

2 The origin of the word 'client' is not clear, but according to Čermáková and Nekorjak it comes from the post-Soviet environment of organised crime and it is not primarily related to labour migration, rather more to a protection against underground persons by police and military forces (see more at Čermáková, Nekorjak 2009).

3 In academic literature it is known as the theory of middleman minorities (see more in Bonacich 1973).

Tab. 1 Basic characteristics of respondents.

Respondents	Name	Age	Family Status	Education	Number of employees	Length of stay in Czechia (years)	Foundation of the company (year)	Residence address	Sector/ occupation
R1	Taras	_	M	U	_	_	_	Prague	Member of the Ukrainian Business Club in Czech Republic
R2	Oleksandr	_	M	U	_	20	_	Prague	Member of the Ukrainian Business Club in Czech Republic
R3	Bohdan	37	S	U	_	37	_	Prague	Member of Ukrainian Initiative in Czech Republic
R4	Lyudmila	42	M	U	_	10	_	Prague	Former teacher of Ukrainian School in Prague
R5	Vladislav	44	M	U	_	9	_	Karlovy Vary	Member of Union of Ukrainians in Bohemia
R6	Mariya	33	M	U	0	6	2009	Prague	Entrepreneur in tourism business
R7	Oleksandr/a	44	M	P	4	10	2006	Karlovy Vary	Owner of company in property business
R8	Oleksandr/b	46	S	B	5	11	2010	Karlovy Vary	Entrepreneur in tourism business
R9	Tatjana	37	S	U	3	9	2009	Karlovy Vary	Entrepreneur in property business
R10	Oleg	40	M	P	2	16	2000	Prague	Entrepreneur in the service business
R11	Bohdan	36	S	U	21	20	1995	Prague	Entrepreneur in industrial business
R12	Ivan	53	D	U	20	22	1997	Prague	Owner of company in building business
R13	Roman	34	M	P	23	15	2011	Prague	Owner of the company in service business
R14	Nataliya	36	S	U	3	15	2009	Prague	Owner of the restaurant
R15	Anton	33	S	U	3	8	2012	Prague	Entrepreneur in the logistics business
R16	Pavlo	28	S	U	0	4	2013	Prague	Entrepreneur in the tourism business

Notes:
Education: B – basic, P – professional/high school, U – university;
Status: M – married, S – single, D – divorced;

During our fieldwork we faced two difficulties. The first challange was to find interviewees. Ukrainian migrants are often suspicious about getting involved into this type of research and also fear that the disclosure of their personal opinions or informal contacts may cause harm to them. We applied the snowball methodology to find informants. The second difficulty was that we often obtained superficial responses. The respondents' answers were hesitant and very often simple, even though we tried to push them to go into deeper explanations and concrete examples. They were often reluctant to openly speak about their personal and business strategies as well as about the strategies of the entire community. To tackle these difficulties we offered our participants anonymity.

Before the fieldwork, statistical data about the Ukrainian entrepreneurs and migrants had been analysed.

5. Results – The social capital of Ukrainian entrepreneurs

Social capital plays an increasingly important role especially when there is a lack of other types of ethnic and class recourses (like human, financial and cultural) among migrant businesses (Flap et al. 1998; Sik 2012). The resources of social capital, according to our research, is based on the mutual trust and its relation to cooperation, on contacts and networks as well as on mutual aid and solidarity. All these aspects of social capital could be very important in start-up business, successful economic activity and reduction of transaction costs[4] (Light, Gold 2000; Orbán, Szántó 2005). In accordance with other authors dealing with social capital (like Waldinger 1995; Portes, Landolt 1996; Levine et al. 2014), we also have to incorporate the negative aspect in the definition of social capital that could influence migrants' businesses as well as their personal lives.

We found that the level of mutual trust among the Ukrainian entrepreneurs is very low, and it is the crucial reason why they do not prefer to cooperate with other Ukrainian entrepreneurs or even with businessmen from other post-Soviet countries in Czechia. We, in agreement with other authors (Åberg 2000) see the reason for this low level of trust in the negative experience brought from the culture of the former USSR. Our respondents still have

4 Transaction cost includes the outlays of providing for some good or service through the market rather than having it provided from within the firm. In general, they are classified into three groups: search and information, bargaining and decision, policing and enforcement costs (Coase 1960).

in their minds the powerful activity of the prolific mafia system during the time of the Soviet Union and the years after the collapse of this regime, when they were strongly suppressed by it. Behind the low level of mutual trust and cooperation of Ukrainian entrepreneurs can also stand the current situation of high corruption and bureaucratic system in the country of origin. Their non-participation in business networks can be explained with the fear that involvement in business networks might connect them to the mafia or other illegal activities. Although such cooperation would be beneficial to some extent, but according to the respondents' expectations, it would pull them to failure. The aim of the migrants was a peaceful and economically successful staying in the Czechia, which for them does not correspond with being involved in the networks of Ukrainian entrepreneurs. However, none of respondents could describe the mafia activity and the entrepreneurs involved. Therefore, it is possible that their behavior is just based on the fear of the unknown and on their former experiences in country of origin.

'*I don't have economic ties in Ukraine. Honestly, I escaped from the corruption and from all that mess which is going on in that country (in Ukraine).*' (R8)

The interviewed entrepreneurs claimed that even if they were in an economic situation where they would have to start to cooperate with other post-Soviet entrepreneurs, they would be aware of the difficulties stemming from the soviet background.

'*I don't really like to do business with Ukrainians. I know their culture and I don't want to interfere with them.*' (R13)

The respondents see the problems of co-ethnic business cooperation in fraudulent acts and exploitation. By this behaviour they mean not following the formal contracts and verbal agreements, as well as the quality of work, time-keeping and bargaining about the already agreed amount of money (especially in the construction industry) (R11, R12, R16). Finally, co-ethnic cooperation could also mean being dragged into illegal Russian-speaking networks, which partially caused their migration from Ukraine (R10). If the Ukrainian entrepreneurs have the possibility to choose between doing business with the Czechs or the Ukrainians, they would select the formers, as well entrepreneurs from other EU countries. One reason for the high degree of willingness to cooperate with the non-ethnic groups is purely economic: Ukrainian entrepreneurs like to cooperate with those who are economically more advantageous[5]. Another reason is that Ukrainians desire to integrate into the mainstream society (Drbohlav, Dzúrová 2007); they consider their cooperation with Czech and EU entrepreneurs their 'entrance' to the European culture.

5 Cooperation with Ukrainian entrepreneurs is also acceptable if it entails economic benefits.

'*How do Ukrainians cooperate? Mostly in no way! They have business cooperation with those who financially are more beneficial!*' (R7)

'*They want to live like citizens of the European Union, according to EU standards. Maybe they think it is easier to integrate if they cooperate with Europeans.*' (R4)

'*If somebody asks me, I am a Czech entrepreneur. Why would I be a Ukrainian entrepreneur? I live in Czechia, I pay taxes here. The Czech economy is developing through my activity, too. So I am a Czech entrepreneur.*' (R5)

Mutual trust has another aspect as well: it is the way how local companies and governmental authorities deal with the Ukrainian entrepreneurs. The Ukrainian entrepreneurs went through some negative experiences in their business activities. In general, they find it non-problematic, but they do feel some negative attitude (primarily in distrust toward them from the Czechs). The Ukrainian migrant entrepreneurs stressed that they have to make greater efforts to reach a business deal than Czech entrepreneurs. They must demonstrate their aptitude, honesty, economic strength, better quality of work, and even lower prices. They are suffering from lower trust from institutions like banks or tax offices.

'*Czech banks have lower confidence in you than in the Czechs. They inspect your company and your economic background profoundly and more often than Czechs. For that reason you try to do everything right, even better than they (Czechs).*' (R15)

'*The motivation of migrants is always stronger than the motivation of indigenous societies. You know, once you left, there is no way back. You are much more conscious and cautious, too. Anyway, you have disadvantages compared to Czechs. You have to prove that you are honest and that you are worth something.*' (R6)

The negligible trust and cooperation correspond with little willingness of using the economic contacts and networks among the Ukrainian entrepreneurs in Czechia. Even though the exploitation of economic contacts and networks results in reduction of transaction costs, our respondents did not intend to create and improve them. They create institutionalized bodies very rarely. The exception is the *Ukrainian Business Club in Prague,* which was established at the end of 2014, in order to develop co-ethnic economic contacts and the competitiveness of Ukrainian enterprises in the Czech Republic and at the international business market, as well as to promote Ukrainian and Czech economic cooperation (R1, R2). Although this association is newly established and the founders demonstrate positive goals, we found that other Ukrainian entrepreneurs are rather suspicious about any co-ethnics' activities, which also show the distrust among them.

‘*I have never heard about this association. But I do not want to join them, because it is definitely involved in money laundering.*’ (R13)

The topic of mutual aid and solidarity among Ukrainian entrepreneurs was not significant for our respondents. None of the entrepreneurs mentioned making any steps to help other Ukrainian entrepreneurs to increase their profit. In their possible cooperation, distrust was stronger than the urge to help their co-ethnics. Solidarity also does not work among the entrepreneurs and their employees. Most of the entrepreneurs justified this with the reason that hiring Czechs is more beneficial than Ukrainians because of their language skills, local familiarity, and proficiency in the Czech labour market, even if their hourly wage is much higher. Thus, economic benefits are more important than co-ethnic relations.

‘*Ethnicity doesn’t matter. What matters is to do a good and quality work.*’ (R15).

Mutual solidarity has more relevance in private life; in friendship, family and church communities (Bernard and Vašát (2015) arrived to the same conclusion). These findings are not surprising as Ukrainians belong to very well-integrated communities, therefore there is no pressure to develop ethnic solidarity. This kind of solidarity is more typical for communities which are excluded from the host society (for example to Asians) (Bagwell 2006).

Conclusions

Social capital is one of the basic resources for entrepreneurship and has two main perspectives (public and the individual), and several definitions (Bourdieu 1983; Coleman 1988; Putnam 1993; Portes, Sensenbrenner 1993; Fukuyama 1997; Lin 2001; Perreault et al. 2007; Light, Dana 2013). What we were looking among the Ukrainian entrepreneurs in Czechia was the individual social capital with ethnic (community) features, which is based on value introjection, reciprocity exchanges, bounded solidarity and enforceable trust with its positive and negative aspects (Portes, Sensenbrenner 1993). The analytical features of social capital were mutual trust and consequent cooperation, contacts, mutual aid and solidarity. Our research was based on qualitative analysis resulting from 16 in-depth semi-structured interviews conducted with Ukrainian entrepreneurs and key actors of the Ukrainian community in Czechia. We faced two main challenges; first, it was difficult to find respondents willing to give interview, and second, some of the respondents’ answers were simple without deeper explanations and examples.

We came to the conclusion that among Ukrainian entrepreneurs there exist networks of contacts, but they are very rarely used for economic cooperation, and if they are, it is with caution. We found that the main reason for this situation is the low level of trust between them and the fear of being dragged into post-soviet social networks that will rather limit the positive features brought into their business activities. Although social capital is present among Ukrainian migrants, it has vertical embeddedness on an institutional basis, which does not allow creating mutual trust. The trust can be ‘transferred’ across the border, but institutions which legitimize some kind of corrupt informal status system and favour exchange system in Ukraine are not. In Ukraine there is no communitarian social capital which could create a transmitted trust (Åberg 2000). For this reason, Ukrainian entrepreneurs strongly prevent the interconnection of private contacts and life with the economic environment. It is primarily the fear of private life that defend their integration into economic ethnic networks. Another reason why entrepreneurs are not willing to get involved in Ukrainian ethnic networks is that they strongly desire to integrate into the Czech environment in a broader sense; they believe that through business relations with Czechs they could reach the integration into the Western business environment. Our main results about the existence and usage of social capital correspond to other research findings on social capital of Ukrainian migrants. These results declare that Ukrainian migrants have the lowest level of trust in each other in other European countries (Sereda 2013; Grzymala-Kazlowska 2014).

The existing social capital is used more significantly in private life than in the business sphere (the only exception is the system to organize jobs for Ukrainian migrants with the help of co-ethnic agents called ‘clients’). From the other aspects of social capital we found examples of mutual aid and solidarity, but again more among Ukrainians families than business activities. Not using the available social capital in business activities has its positive and negative aspects. The low level of social capital could bring economic disadvantages, e. g. slower information exchange (due to lack of trust) or longer bureaucratic procedures (with dealing and signing formal contracts), and can lead to significant financial and time expenses, which increases the transaction costs. On the other hand, the conscious decision to not cooperate economically with other co-ethnic entrepreneurs could open entirely new perspectives in the form of activities focusing on the main market rather than on the ethnic economy. We can conclude that the ethnic economy (immigrant economy) of Ukrainian migrants has not been created in the Czechia, and this is due to the fact that the functioning ethnic economy needs horizontal and vertical economic ties, which are also based on social capital (Light, Gold 2000). Unlike the Ukrainians the ethnic economy has developed among the Vietnamese, where the horizontal and vertical economic ties have established (Martínková 2011; Drbohlav, Čermáková forthcoming).

The next perception from our research is that among the heterogeneous group of Ukrainian immigrants in Czechia, the respondent entrepreneurs are (or claim to be) similar to Czechs in their aims, economic strategies and other behavioral features. Czech and Ukrainian linguistic and cultural proximity also encourage assimilation rather than creating enclaves (compared to Armenians or the Vietnamese).

Finally, we have to add one more aspect to the Ukrainian community's social capital in general. Although we concluded that social capital is on a low level among Ukrainian entrepreneurs, it has developed a specific system (called client system) for organizing jobs for Ukrainian migrants through co-ethnic agents (especially in the construction and manufacturing industry, cleaning services and agricultural sector). This system is based on social networks of immigrants, agents, and the Czech employers (Čermáková, Nekorjak 2009). It is another kind of social capital, but it is not based on mutual trust. Rather, it is an exchange system based mostly on compulsion, which in Ukraine is deeply embedded in the operation of official institutions too. The system has a rather negative aspects like corruption, and positions of power. However, due to the official Czech anti-corruption efforts, the institutionalization of this system has been eliminated, or it functions only partially. The institutional forms of client system, which were created with the mediation of ethnic groups on the basis of their experiences of negative social capital, did not become deeply rooted in the Czech economy and society in general.

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RESUMÉ

Role sociálního kapitálu v ekonomické aktivitě ukrajinských podnikatelů v Česku

Situace migrantů je v nové zemi velmi specifická – část svých ekonomických zdrojů nechávají v zemi původu, setkávají se s prostředím nové země, se znevýhodněním na trhu práce atd. Zdroje migranta, jejich složení a velikost, podmiňují jejich integraci v cílové zemi. Ekonomickou integraci stejně tak ovlivňují možnosti na trhu cílové země (Waldinger 1995). Zdroje migrantů se rozdělují na třídní a etnické (Light, Gold 2000). Třídní zdroje představují sociální, finanční, lidský a kulturní kapitál a je pro ně typické, že každý jednotlivec disponuje těmito zdroji v různém poměru. Na druhé straně etnické zdroje jsou vlastní celé etnické skupině a představují např. specifické znalosti, dovednosti, způsoby, přístupy, techniky, ale i mezietnickou solidaritu a vzájemnou pomoc. Nicméně platí, že i třídní kapitál může mít ve svých projevech etnické prvky. Také platí, že čím více mají migranti sociálního, kulturního, lidského a kulturního kapitálu, tím méně mají potřebu využívat etnické zdroje (Light, Gold 2000). Využívání etnických zdrojů migranty či celou etnickou skupinou se projevuje tím, že vytvářejí

odvětvové niky, koncentrují se v prostoru a mají podobné podnikatelské strategie.

Sociální kapitál je považován za jeden ze základních zdrojů migrantů, který při určitém zjednodušení souvisí se sítí sociálních kontaktů a vzájemnými vazbami (Light, Dana 2013). I přesto, že se primárně nejedná o etnický zdroj (není stejný v celé etnické skupině), může mít určité etnické prvky, např. vzájemná mezietnická solidarita, reciprocita, důvěra. Sociální kapitál má mezi výzkumníky různé pojetí chápání. Bourdieu (1983) prezentuje sociální kapitál jako množství vztahů, které jsou k vzájemnému prospěchu mobilizovány. Coleman (1988) vidí v sociálním kapitálu zdroj existující struktury vztahů, které usnadňují aktivity v rámci této struktury. Takto definovaný sociální kapitál je považován za osobní výhodu. Putnam (1993) vedle osobního pojetí sociálního kapitálu vidí sociální kapitál jako veřejný statek, který se skládá z institucí, které mohou být převedeny z jednoho sociálního prostředí do druhého. Putnam (2000) rozděluje sociální kapitál na svazující (omezený na blízké kontakty) a přemosťující (zahrnuje vzdálenější kontakty charakteristické slabými vazbami). Náš výzkum je zaměřen na osobní rovinu svazujícího versus přemosťujícího sociálního kapitálu, které se v souvislosti s výzkumem etnického podnikání nejvíce blížila definice Portese and Sensenbrennera (1993, s. 284): „aktivity v rámci kolektivu, které ovlivňují ekonomické cíle a chování svých členů a nejsou orientovány primárně k individuálnímu zisku“ V tomto pojetí je sociální kapitál založen na hodnotách, které motivují členy skupiny věnovat pozornost nejen svým osobním zájmům a dále na vzájemnosti, soudržnosti, ohraničené solidaritě (bounded solidarity) a vynucené důvěře (enforceable trust). Zatímco vzájemnost a soudržnost jsou součástí sociálního kapitálu každé sociální skupiny, tak ohraničená solidarita a vynucená důvěra mají v sobě silné etnické prvky a rozvíjí se jen za určitých podmínek většinou tam, kde musí etnická skupina čelit určitým znevýhodněním (Light, Dana 2013; Gedajlovic et al. 2013). Tyto etnické prvky sociálního kapitálu mají v sobě jak pozitivní aspekty (např. množství ekonomických možností, vztahy jsou pružnější bez řady formálních kroků), tak i negativní (např. strach odmítnout participovat, kontrola ostatních členů, omezené možnosti skupiny, silnější členové potlačí menší a slabší).

Cílem našeho článku bylo zjistit, zda sociální kapitál patří mezi zdroje ekonomických aktivit ukrajinských podnikatelů a jak je přítomna vzájemná důvěra a pomoc, spolupráce, kontakty, sítě a solidarita. Zaměřili jsme se na ukrajinské podnikatele, protože Ukrajinci představují v Česku největší skupinu migrantů, přibližně jedna třetina se věnuje podnikání a jsou registrovaní jako vlastníci v přibližně deseti tisících právních subjektech. Předpokládali jsme, že Ukrajinci stejně jako v jiných zemích střední a východní Evropy budou využívat sociální kapitál velmi málo a jestliže ano, tak bude mít podobu známou v postkomunistických zemích (Grzymala-Kazlowska 2014; Sik 2012; Åberg 2000). Sociální kapitál na Ukrajině není rozvinut na horizontální úrovni založené na vzájemné důvěře, ale na úrovni vertikální založené na mocensky nerovných vztazích. K našemu předpokladu nás také vedla existence tzv. klientského systému, na jehož základě je organizována práce převážně ukrajinských migrantů v Česku a tento systém právě využívá tohoto typu sociálního kapitálu (Čermáková, Nekorjak 2009).

Článek je založen na kvalitativní analýze 16 polostrukturovaných rozhovorů s ukrajinskými podnikateli a klíčovými aktéry komunity. Rozhovory obsahovaly několik témat včetně otázek zaměřených na ekonomické a osobní vztahy jak k jiným Ukrajincům a migrantům z postkomunistických zemí, tak k ostatním podnikatelům v Česku. Při sběru dat jsme se potýkali s velkou nedůvěrou potenciálních respondentů a realizované rozhovory byly jen na základě osobního doporoučení, a i přesto získané odpovědi byly zjednodušující a povrchní.

Závěrem našeho výzkumu je, že mezi ukrajinskými podnikateli v Česku existují sítě kontaktů v různých oblastech života, ale nejsou využívány v ekonomických vztazích, a pokud ano, tak s velkou opatrností a vědomím určitých rizik. Existující sociální kapitál využívaný v ekonomických vztazích ukrajinských podnikatelů se liší od běžně na Západě pozitivně vnímaného sociálního kapitálu (Light, Dana 2013). U Ukrajinců v Česku a stejně tak v jiných postkomunistických zemích je sociální kapitál charakteristický vertikální strukturou vztahů a chybí či je na nízké úrovni vzájemná důvěra, pomoc a solidarita. Toto jen potvrzuje, že sociální kapitál využívaný v tzv. klientském systému v Česku je také přítomný v podnikání Ukrajinců. Ukrajinští podnikatelé vědomi si tohoto faktu vyhledávají spolupráci s českými a dalšími podnikateli ze zemí EU a věří, že se jim podaří či již podařilo začlenit do západoevropského podnikatelského prostředí. Sociální kapitál s komunitními prvky založený na hodnotách, které motivují členy skupiny věnovat pozornost nejen svým osobním zájmům, ale i vzájemnosti, soudržnosti, ohraničené solidaritě a vynucené důvěře, se mezi ukrajinskými podnikateli nerozvinul. Přestože je sociální kapitál jako jeden zdroj ukrajinských podnikatelů využíván jen omezeně, neaktivovali ani další etnické zdroje. Z výše uvedeného poznání můžeme tvrdit, že etnická ekonomika Ukrajinců v Česku neexistuje na rozdíl například od Vietnamců, kde jsou horizontální a vertikální ekonomické vazby rozvinuty (Martínková 2011; Drbohlav, Čermáková v tisku).

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TEMPORAL ANALYSIS OF GLOFS IN HIGH-MOUNTAIN REGIONS OF ASIA AND ASSESSMENT OF THEIR CAUSES

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ABSTRACT

Glacial lake outburst flood (or shortly GLOF) has become a well-known phenomenon, one of natural hazards occurring in glaciated high mountain areas of the world. The aim of this study was to investigate temporal distribution of these events in Asia and to assess causes of lake outbursts. Therefore, a search of scientific literature and reports was carried out resulting in 219 flood cases found. In order to detect possible differences in temporal distribution a group of ice-dammed lakes was detached and compared with the rest. Concerning spatial distribution of GLOFs, it is influenced by availability of scientific literature which is determined by research teams' region interest. Temporal analysis revealed a certain pattern in ice-dammed lake outburst distribution and notable difference between the two lake groups in terms of outburst occurrence within a year. The moraine-dammed lake outbursts were recorded earlier in an ablation season (compared to ice-dammed lakes) which could be attributed to different mechanism of dam failure. Majority of lake outburst causes were included in the category of dynamic causes (e.g. ice avalanche), long-term causes (e.g. dead-ice melting) were less represented. Results of the study imply there can be notable variations of temporal distribution and causes of GLOFs among individual mountain regions even within one continent. Therefore, varying behavior of potentially dangerous lakes should be taken into consideration when, for instance, proposing mitigation measures.

Keywords: GLOF, glacial lake, mountain region, temporal distribution, outburst cause

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1. Introduction

Climate changes and its manifestations linked to mountain glaciation represent one of the most topical issues in the world of geosciences (Bates et al. 2008; Bliss et al. 2014; Li et al. 2007; Rowan et al. 2015; Zhao et al. 2015; Zhou et al. 2010). Faster rate of glacier melting leads to raised summer discharges in glacier-fed streams (Aizen et al. 2007; Wang et al. 2014), overfilling of glacial lake basins and destabilization of moraine dams. These processes may result in the phenomenon called GLOF (= glacial lake outburst flood), which has become a feared natural catastrophic process due to its difficult predictability, high velocity of spreading and often unexpectedly large affected area (Bajracharya and Mool 2009). The main goals of this paper are i) to analyze temporal distribution of recorded GLOFs, and ii) to assess causes of recorded glacial lakes outbursts.

The highest mountain range of the world, Himalayas, provide ideal conditions for the emergence of potential hazards of large proportions due to significant differences in elevations and very steep slopes, the term GLOF was developed for this area (Mool 1995). Climate change affects glaciers whose retreat or degradation results in the formation and development of potentially dangerous lakes (Chen et al. 2010; Komori 2008). These lakes can be of large dimensions and their outburst would cause a flood striking areas several tens to even hundreds of kilometers distant (Richardson and Reynolds 2000).

Other Asian mountain ranges where floods from glacial lake outbursts were recorded include Caucasus (Petrakov et al. 2007; Chernomorets et al. 2007), Pamir (Mergili et al. 2011), Hindu Kush-Karakoram (Gardelle et al. 2011) and Tien Shan (Narama et al. 2010; Janský et al. 2010).

2. Glacial lake outburst flood

Seasonal floods caused by snow melting or torrential rains have affected humans and their livelihood ever since. However, the GLOF, a natural hazard typical for post-LIA era, can be even more destructive – the highest recorded peak discharge was 30,000 $m^3 s^{-1}$ (Richardson and Reynolds 2000).

Recently, a rapid retreat of glaciers was recorded in Himalayas (Bolch et al. 2012; Chen et al. 2007) and other glaciated Asian mountain ranges (Sarikaya et al. 2012; Sorg et al. 2012; Shahgedanova et al. 2014) leading to a formation of new glacial lakes, enlarging of the existing ones and rising of a glacial lake outburst potential (Watanabe et al. 1994; Richardson and Reynolds 2000; Bajracharya and Mool 2009). These floods can reach extremely high flow rates and therefore are able to erode and transport huge amounts of material – up to millions m^3 (Hubbard et al. 2005). Consequently, debris flows reaching distances of as much as 200 km may evolve moving down a valley at higher speed than a flood wave due to double density

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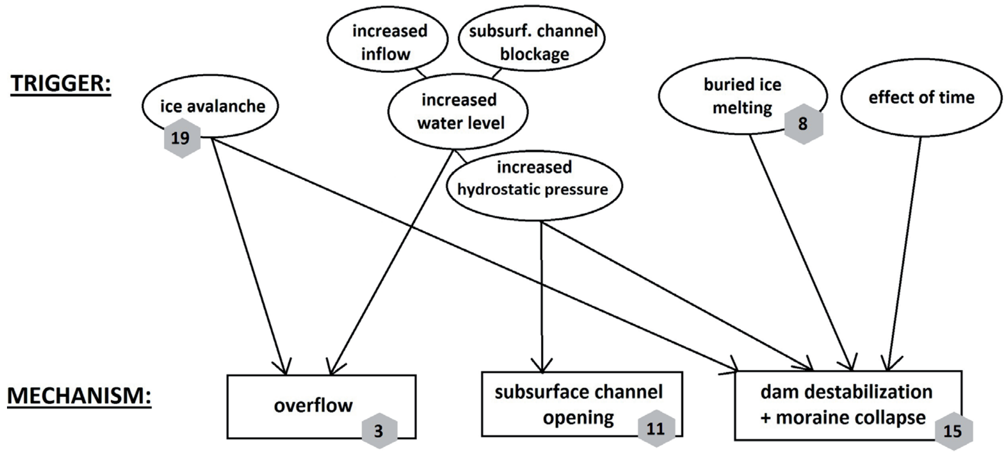

Fig. 1 Relationship of selected outburst triggers and mechanisms with number of cases.

compared to clear water (Richardson and Reynolds 2000). As GLOF is difficult to predict – outburst mechanism is very complex (Kershaw et al. 2005), longitudinal profile of mountain valleys is rather steep and there is often poor or non-existent warning system, material damage can be large and in some cases there could be even many casualties (Lliboutry et al. 1977).

It is important to understand the response of glaciers and glacial lakes to increase of air temperature, to identify potential risks and plan mitigation measures (Bajracharya and Mool 2009; Bennett and Glasser 2009). Remote sensing together with GIS models proved to be a vital tool in assessing risk and defining endangered areas (Bolch et al. 2011; Huggel et al. 2003; Komori 2008; Worni et al. 2012; Pitman et al. 2013).

Flood volume and course depends on many factors including the amount of water released from a lake, height, width and structure of its dam, outburst mechanism, valley shape and available quantity of sediment in the area affected by a flood (Costa and Schuster 1988). One example of an enormous lake outburst flood is an event from 1985, when part of a glacier terminus calved into Dig Tsho Lake, Nepal (Bajracharya and Mool 2009). A displacement wave ran over the dam which failed due to consequent erosion. Resulting flood wave had an initial flow rate of 2,000 $m^3 s^{-1}$ (Vuichard and Zimmermann 1987), Cenderelli and Wohl (2001) indicate even 2,350 $m^3 s^{-1}$. The consequences were noticeable even 90 km below the dam lake (Richardson and Reynolds 2000). Another catastrophic flood of 1994 from outburst of Luggye Tsho Lake was described by Richardson and Reynolds (2000), who claim that the flood wave (over 2 m high) was recorded on a hydrograph at distance greater than 200 kilometers from the source lake.

3. Methods

Total number of 219 cases of glacial lake outburst flood were compiled for this paper based on search of scientific publications and reports. The event parameters were searched as follows: lake's name, date of outburst (year, month, day), cause of outburst (probable trigger or mechanism), mountain range, and lake's coordinates. However, for some of the cases not all the desired information was available. In nine cases the exact year of event is not known, no information on cause of outburst was obtained in 17 cases, and the temporal analysis within a year was based on 128 cases only. The time span of compiled outburst floods begins in 1533 and ends with an event from 2012. Most recorded cases are from the 19th and 20th century, earlier ones are only sporadic.

When analyzing the GLOF cases a distinction is made between two groups – moraine-dammed lakes and ice-dammed lakes. Moraine-dammed lakes drain in most cases once, some do several times. Ice-dammed lakes, on the other hand, are dammed by a glacier blocking a valley; such lakes often form and drain repeatedly. The latter are set aside since the lake formation and consequent outburst are driven by different mechanism and glacier behavior (glacier retreat and degradation vs. glacier advance). And as the outburst is often repeated for decades, the statistics would be significantly influenced – 146 flood cases out of 219 were from ice-dammed lakes. Furthermore, the 146 cases were recorded within only a few localities: Inylchek glacier, Tien Shan (48), several valleys in upper Yarkant basin (24) and upper Indus basin (74), Hindu Kush-Karakoram. Spatial representation of the ice-dammed lake outburst floods is therefore rather unbalanced. The detachment of this group of cases allows to perform a comparative temporal distribution analysis between the two and to reveal differences in occurrence.

For 56 out of 73 cases of moraine-dammed lake outbursts there was information concerning GLOF cause. However, some sources stated an initial trigger of a lake outburst whereas the others mentioned an outburst mechanism. As there are more possible triggers leading to a certain outburst mechanism (Costa and Schuster

Tab. 1 Sources of information on GLOF cases.

		Number of cases with known					
Source	**No. of cases**	**Cause**	**Day**	**Month**	**Year**	**Time span**	**Mt range**
Gerasimov 1965	1	1	1	1	1	1963	Tien Shan
Gerassimow 1909	1	0	0	0	1	1909	Caucasus
Ives et al. 2010*	34	30	23	24	27	1935–2004	Himalayas
Liu et al. 2013	2	2	2	2	2	1998–2002	Himalayas
Liu et al. 2014	1	1	1	1	1	1988	Himalayas
Mergili et al. 2011	1	1	1	1	1	2002	Pamir
Narama et al. 2009	8	1	8	8	8	1970–1980	Tien Shan
Narama et al. 2010	7	5	6	6	7	1974–2008	Tien Shan
Petrakov et al. 2007	2	1	1	1	2	1993–2006	Caucasus
Petrakov et al. 2012	3	3	1	1	3	1988–2012	Tien Shan
Seinova and Zolotarev 2001	2	2	0	0	2	1958–1959	Caucasus
Wang et al. 2011	10	8	7	9	9	1955–2009	Himalayas
Yesenov and Degovets 1979	1	1	1	1	1	1977	Tien Shan
Glazirin 2010	48	48	37	48	48	1902–2005	Tien Shan
Hewitt and Liu 2010**	95	95	17	25	94	1533–2009	Karakoram
Iturrizaga 2005	3	3	0	0	3	1860–1909	Karakoram
Total	219	202	106	128	210		

* compiled from: Mool et al. 1995, 2001a, 2001b, Yamada 1998, Bajracharya et al. (2008); supplemented with information from: Wang et al. 2011

** supplemented with information from: Iturrizaga 2005

1988), some additional information would be necessary to assess the causes of all 56 events. In Figure 1 relationships of the identified triggers and mechanisms are specified.

Tha GLOF causes can be divided into long-term and dynamic causes according to Emmer and Cochachin (2013). The former include dam failures where an initial external dynamic trigger is absent, the latter are caused by a dynamic event (Yamada 1998).

4. Analysis of GLOFs

Following chapters assess the temporal distribution of outburst flood events and causes of lake outbursts within the high-mountain regions of Asia. Although the number of all outburst flood events is relatively high (219), not all enter the assessment as many lack some piece of information (Table 1).

Throughout the continent of Asia, information on a glacial lake outburst flood was found in following mountain ranges: Caucasus, Pamir, Tien Shan, Karakoram, and Himalayas. Altay and Central range of Kamchatka showed precondition for flood events as well, but no GLOF related publication from these regions was found in scientific literature.

Within Caucasus, information on only a few cases of outbursts were acquired (Petrakov et al. 2012), all of them situated in Elbrus region – surroundings of a glaciated massif of Mt. Elbrus (5,642 m asl). In Pamir, one case of lake outburst was recorded on the territory of Tajikistan (Mergili et al. 2011).

As many of Tien Shan ridges are glaciated, steep valleys and glacier retreat of last decades provide good conditions for lake outburst floods (Bolch 2007; Narama et al. 2010; Petrakov et al. 2012; Yerokhin 2003). However, probably only a minor number of cases were described in scientific literature as this region has long been rather neglected by foreign researchers. Repeatedly drained Lake Merzbacher, dammed by a glacier Inylchek, is an exception as it has been monitored closely for more than a century (Glazirin 2010).

Within the Hindu Kush-Karakoram range, only cases of ice-dammed lake outburst were found (Hewitt and Liu 2010; Iturrizaga 2005). These lakes are situated in upper parts of two basins: Indus and Yarkant, and floods caused by sudden drainage of these lakes have been regularly recorded by local population of downstream villages since 1830s.

A large number of glacial lake outburst floods were recorded in the Himalayas, partly because of the extensiveness of this mountain system and therefore vast glaciated area, but also due to the considerable interest of research teams from all around the world (Benn et al. 2012; Bolch and Kamp 2006; Rana et al. 2000; Richardson and Reynolds 2000; Quincey et al. 2007; Yamada and Sharma 1993). Number of potentially dangerous lakes and GLOFs has been rising in Himalayas since 1930 (Liu

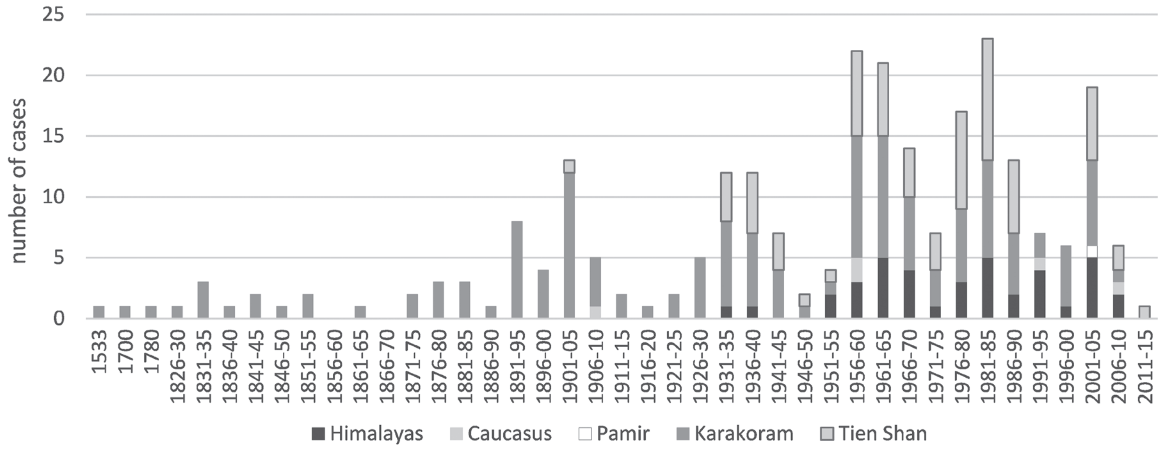

Fig. 2 Temporal distribution of GLOFs according to a mountain range.

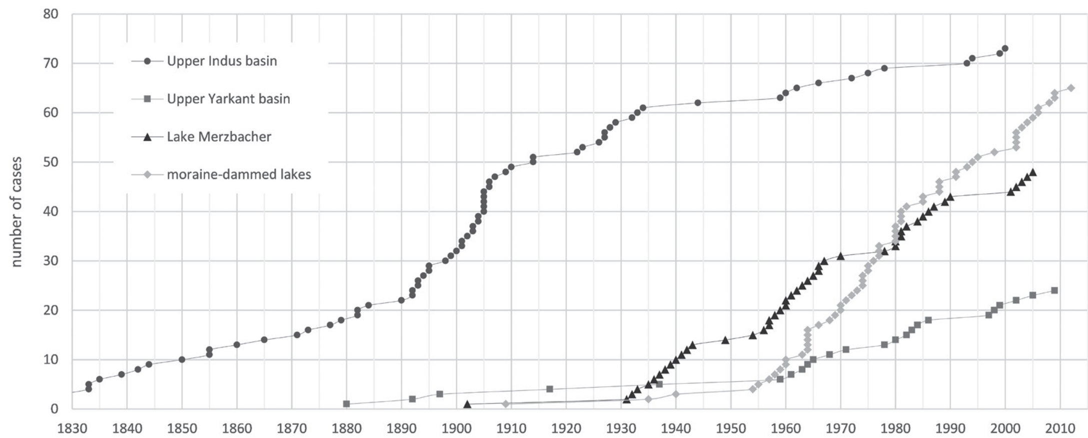

Fig. 3 Cumulative number of GLOFs in Asia divided into 4 categories.

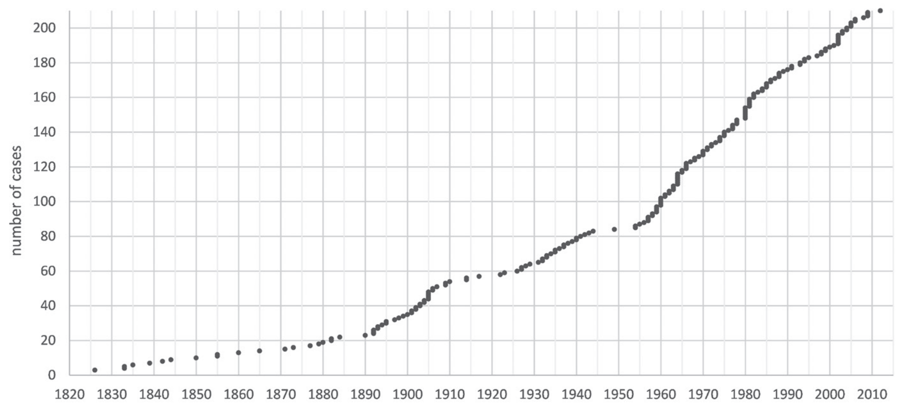

Fig. 4 Cumulative number of all GLOFs in high mountain Asia.

et al. 2013; Bolch et al. 2008), Richardson and Reynolds (2000) report that 33 outburst floods have taken place here until 2000.

4.1 GLOF temporal distribution

Outburst flood events with known year (210 cases) were compiled according to a mountain range where they occurred and classified into five-year segments (Figure 2). Number of recorded cases begins to rise at the end of the 19th century and peaks between 1901 and 1905 when 13 GLOFs occurred. This is followed by a noticeable drop in numbers around 1920. Similar pattern continues further on (peak in the 1930s and drop around the year 1950) with overall higher number of cases since late 1950s. Last significant drop in number of flood cases emerges in 1990s with the average of 1.3 cases per year in all Asian mountain ranges together, which is rather low compared to previous decade (1980s: 2.8 cases/year).

Comparison of the regions in terms of temporal distribution of cases is focused on three ranges with higher number of GLOFs – Himalayas, Karakoram, and Tien Shan. There is consistency among the ranges around the year 1950 when only very few cases occurred. However, the second drop in 1990s is not significant for either Himalayas or Karakoram whereas in Tien Shan not a single outburst flood was recorded. On the other hand, the periods with high numbers of cases are mostly coincident in all three mountain ranges.

An interesting pattern emerges when plotting the data into cumulative number of cases (Figure 3). The data were divided into groups of moraine-dammed lakes and ice-dammed lakes, the latter was further divided by watershed into three parts (Upper Indus basin, Upper Yarkant basin, Lake Merzbacher). All the localities where floods from ice-dammed lakes were recorded show perceptible grouping of cases, so that periods with high and very low number of cases alternate.

In the Indus basin (predominantly in valleys of Shyok, Shimshal, and Hunza) floods were recorded rather regularly during most of the 19th century. However, the first decade od the 20th century was characterized by significantly increased frequency of GLOFs; on average 1.7 cases per year occurred in the region. In contrast, the following period had only two outburst cases between the 1910 and 1922 events. Similar but less pronounced steps follow with rarely any cases recorded in periods 1935–1959 and 1978–1994.

GLOFs in the Yarkant basin also exhibit such pattern – rather short periods of higher and low number of cases alternate. Although the pattern emerged only since 1960s, it seems to be rather regular as well as pattern of outburst cases of Lake Merzbacher. The lake dammed by glacier Inylchek shows periods of almost annual drainage followed by shorter periods with one or no case.

The curve representing cumulative number of moraine-dammed lake events does not exhibit such obvious pattern, although certain periods of lower and higher outburst flood numbers can be found. However, it is not in accordance with the ice-dammed lake cases, except for the time around 1980 when many cases were recorded. That is also apparent in Figure 4 which shows development of cumulative number of all GLOFs in Asia. The blotting effect of moraine-dammed lake cases on the described pattern is confirmed as the alternating periods are visible only until the 1950s when the moraine-dammed GLOFs became frequent.

Distribution of GLOFs within a year was analyzed based on 128 cases with known month of occurrence. The floods are distributed mainly among months characteristic of ablation (June–September), however, there are even few cases which occurred in unusual time of a year (Figure 5). As expected, most outbursts were recorded in August, less in July and September. Slight difference arises due to separation of ice-dammed and moraine-dammed lakes: the former having most cases later in a year (1. August 2. September 3. October) compared to the latter (1. July 2. August 3. June).

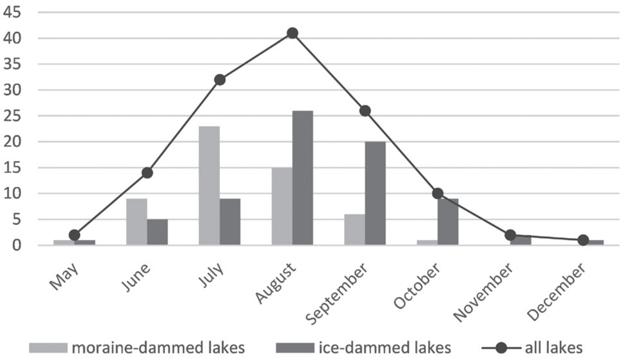

Fig. 5 Monthly distribution of GLOFs with distinction between moraine-dammed and ice-dammed lakes.

4.2 GLOF causes

The cause of GLOF may be difficult to determine as witness is rarely present and evidence may not always indicate to a particular cause with certainty. A total of 202 cases out of 219 were appointed with a cause of a flood, although not all were specific in terms of the outburst trigger.

All ice-dammed lake outbursts, i.e. 72.1% of all cases, were set aside into a category of increased hydrostatic pressure (Zhang 1992). Hewitt and Liu (2010) and Glazirin (2010) describe the mechanism of release of water detained behind the glacier tongue as a consequence of raised hydrostatic pressure which led to partial glacier uplift and opening of drainage channels.

Concerning causes of moraine-dammed lake outbursts, there are only 38 cases with known trigger, 18 with known outburst mechanism, and 17 cases without any information (Figure 6). The most often mentioned cause of lake outburst was ice avalanche falling into a lake (34%). Fall of mass into a lake generates a displacement wave which may either overflow the dam and commence its incision or destabilize the dam and lead to its collapse (Clague and Evans 2000).

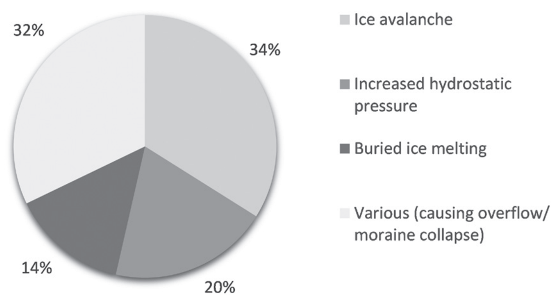

Fig. 6 A percentage share of triggers of floods from moraine-dammed lakes in Asia.

In case a lake does not have a surface outflow, it is sensitive to the amount of inflowing water. Significantly increased inflow (either from rapid snow melt or heavy

Tab. 2 Causes of lake outburst floods according to mountain ranges.

Cause / Mt range	Moraine dam				Ice dam	Total
	Ice avalanche	Increased hydrostatic pressure	Buried ice melting	Various (*resulting in overflow / moraine collapse*)	Increased hydrostatic pressure	
Himalayas	19	/	6	16	/	41
Tien Shan	/	8	1	2	48	59
Caucasus	/	2	1	/	/	3
Pamir	/	1	/	/	/	1
Karakoram	/	/	/	/	97	97
Total	19	11	8	18	145	201

rainfall) causes lake water level to rise together with hydrostatic pressure on a dam. This may lead to subsurface channel opening and lake drainage, which happened in 20% of the cases.

The third specifically mentioned outburst cause was melting of buried ice (14%), which is a part of a moraine damming a lake. The ice melting may disrupt the dam structure and destabilize it to such extent, that it cannot withstand the hydrostatic pressure of detained water and it collapses (Yamada 1998). A moraine dam degraded due to buried ice melting is also more prone to collapse even with a minor trigger (Clague and Evans 2000).

Remaining cases with known mechanism of outburst (32%) could not be classified to causes as both "overflow" and "moraine collapse" are too general and may be a consequence of various triggers.

Based on the knowledge of moraine-dammed lake outburst causes, these can be further divided into long-term and dynamic causes. Ice avalanche belongs among dynamic causes, increased hydrostatic pressure and cases with overflow as an outburst mechanism were also incorporated in this group. The long-term causes include buried ice melting. The ratio of dynamic and long-term causes then makes 33 : 8, with further 15 cases unclassified. The cause of ice-dammed lakes outburst (increased hydrostatic pressure) is considered also dynamic, which means that dynamic causes of lake outburst floods are generally more frequent in Asian high mountain areas.

Deployment of GLOF events in Asia together with the cause of lake outburst are summarized in Table 2. Although there are not enough cases for all the mountain ranges, some interesting differences in terms of outburst causes arise among them. Ice avalanche appears as a relatively common cause of outburst in Himalayas, however, avalanche or other mass movement into a lake was not recorded as a lake outburst cause anywhere else. In Tien Shan, Caucasus and Pamir the lakes drained often by opening of subsurface channels due to incresed hydrostatic pressure whereas in Himalayas this cause did not occur.

5. Discussion

Some of the major glacial lake outburst floods on the territory of Asia were studied in detail, e.g. Luggye Tsho in Bhutan Himalaya (Watanabe and Rothacher 1996), Tam Pokhari in Mt. Everest region (Osti and Egashira 2009) or Lake Zyndan in Tien Shan (Narama et al. 2010). Studies encompassing more lake outbursts include Bajracharya et al. (2008), Narama et al. (2009), Hewitt and Liu (2010), ICIMOD (2011), or Chen et al. (2010). This paper attempted to compile data on all recorded outburst floods in Asia, however, the main obstacle became unbalanced availability of GLOF reports among the mountain regions. Since most cases of GLOF included in this analysis were found in only a few articles dealing with specific locations or time periods, all statistics can be slightly biased due to the uneven spatial (and temporal) distribution of the obtained data. Special case is a group of ice-dammed lakes that are located within few sites and their outbursts are repeated. Although statistics from these data cannot be generalized, they provide interesting insight into the temporal distribution of the outburst floods and a comparison with outbursts from glacial lakes.

Concerning the temporal distribution, a significantly lower number of cases was recorded in 1950s and 1990s, on the contrary, 1960s were a period of very high number of cases. Chen et al. (2010) argue that lake outbursts are closely related to positive anomalous air temperature of a year. Precipitation, Chen et al. (2010) add, plays a role in flood peak discharge value. A certain correspondence was found for Tien Shan as both air temperature and precipitation in 1950s were at their low compared to previous and following decade, in the 1990s the air temperature raised rather slowly from its low at the end of previous decade (Černý et al. 2007). Liu et al. (2014) studied correlation between GLOF events and air temperature in Tibet and confirm that 1960s, 1980s and 2000s were very active periods for GLOFs due to higher temperatures during ablation season but also during accumulation.

Analysis of events distribution within a year found a noticeable difference between the ice- and moraine-dammed lakes with the latter draining earlier in a year. Ice-dammed lakes may react with greater delay as glacier dam uplift requires large amount of water causing sufficiently increased hydrostatic pressure (Glazirin 2010). However, Huss et al. (2007) and Glazirin (2010) both indicate a shift of ice-dammed lakes drainage to earlier time within a year mainly in the second half of the 20th century. It means the diference between the two lake types would not probably be that large if only the latest data were included. Liu et al. (2014) also note that the timing of outburst is influenced by lake's altitude – the higher altitude, the later burst within a season. However, in our case the lake's altitude is not of such importance to influence the outburst timing as the lakes are situated in similar altitude. The drained moraine-dammed lakes lay between 2,500 m and 5,500 m asl. and the ice-dammed ones in an altitude probably between 3,000–4,300 m asl. (the presize location within a valley – the damming glacier – is often unknown).

While frequency of ice-dammed lake outbursts has been significantly lowered since 1930 in Upper Indus basin (Hewitt and Liu 2010), it seems that floods from moraine-dammed lakes began to occur much more often since 1950s. As Hewitt (1982) mentions, it could be associated with general glacier recession which may have opposite effect on the observed lake groups. The overall higher numbers of moraine-dammed lake outbursts could be contributed to both accelerated glacier retreat as well as increased interest of researchers or better accessibility of the records by internet searching (Bajracharya et al. 2007).

Assessment of floods in terms of outburst causes is limited by the fact that some authors reported an outburst mechanism, not a trigger, and so the cause was specified for 38 cases of floods from a moraine-dammed lake. However, conclusions of this paper are relatively in accordance with other GLOF-related studies. Narama et al. (2009) reported buried ice melting and moraine collapse due to headwater erosion of the dam and increased inflow leading to subsurface channel opening as main causes of lake outbursts in northern Tien Shan. Most frequent causes of GLOFs in Tibet are, according to Liu et al. (2013), overflow due to fall of ice into a lake and moraine deformation and collapse due to piping, very similar results are also presented by Emmer and Cochachin (2013).

6. Conclusions

Cases of floods from glacial lake outburst, known by the acronym GLOF, were searched within the territory of Asia. Alpine glaciated areas around the world face this threat mainly due to retreat of glaciers and the subsequent formation of lakes or glacier dynamics generally. Within Asia, cases of flood from moraine-dammed lakes were found in following mountain regions: Caucasus, Pamir, Tien Shan and Himalaya. A large number of floods from lakes dammed by a glacier tongue were recorded in the Hindu Kush-Karakoram mountain range.

Spatial distribution of GLOF cases used in this paper is rather unbalanced. It is probably influenced by availability of reports and publications and the fact that some areas are more favorable for foreign researchers than others. Regarding temporal distribution of found outburst events, significant increase is apparent since 1950s, earlier cases include mostly ice-dammed lake outbursts. Generally, certain periods of higher (1960s, 1980s) and lower (1990s) number of events arise, this pattern is even more obvious for ice-dammed lake cases. Most outbursts occurred within ablation season with peak in August which is consistent with general assumptions. Slight difference was observed between moraine- and ice-dammed lakes as the former tend to drain earlier in a year.

Concerning causes of lake outburst, increased hydrostatic pressure leading to englacial channel opening was appointed to all ice-dammed lake cases (145). The most common cause of moraine-dammed lake outburst is an ice avalanche falling into a lake. Other observed causes include melting of buried ice and increased hydrostatic pressure on a dam due to water level rise. Although the proportion of outburst causes differ among the mountain ranges, dynamic causes constitute the majority of cases.

The main contribution of this paper is an assembly and following comparison of all available GLOFs in high mountain regions of Asia. Unlike other studies, it encompasses both moraine-dammed and glacier-dammed lakes and focuses on differences between the two groups uncovered by temporal analysis of outburst occurrence. Found patterns characterised by alternating periods of high and low number of events could be further analyzed in relation to climate in order to improve our knowledge on link between GLOFs and climatic elements. This is, however, beyond the scope of this paper.

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RESUMÉ

Časová analýza GLOF událostí ve vysokohorských oblastech Asie a zhodnocení jejich příčin

Práce se zabývá výskytem povodní způsobených vyprázdněním ledovcového jezera ve vysokohorských oblastech Asie a příčinami selhání hráze. V odborné literatuře byly vyhledány informace o tomto typu povodní v následujících horských masivech: Kavkaz, Pamír, Ťan Šan, Karákoram a Himálaj. Celkem bylo nalezeno 219 případů povodní z ledovcových jezer, z toho 145 případů u jezer hrazených ledovcem, ostatní hrazené morénou či nacházející se na morénovém valu. Co se časové distribuce týče, byla zjištěna období s nižším a vyšším výskytem průvalů ledovcových jezer, nejmarkantněji se to projevilo u jezer hrazených ledovcem. Drobné rozdíly mezi oběma skupinami jezer se vyskytly při analýze distribuce událostí v rámci roku. Většina povodní se vyskytla během ablační sezóny, ty způsobené vyprázdněním jezer hrazených ledovcem však byly zaznamenány spíše později (srpen–říjen) oproti povodním z morénových jezer (červen–srpen). Příčina vyprázdnění jezera byla zjištěna celkem pro 202 událostí, velká část z nich však nebyla dostatečně specifická. Mimo zvýšení úrovně hladiny a tím i zvýšení hydrostatického tlaku, jež vede k otevření podpovrchových odtokových kanálů, byla nejčastější příčinou ledová lavina zaznamenána pouze u případů z Himálaje. Další zjištěnou příčinou bylo tání pohřbeného ledu v hrázi.

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TICK-BORN ENCEPHALITIS RISK ASSESSMENT BASED ON SATELLITE DATA

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ABSTRACT

Tick-borne encephalitis (TBE) belongs among the dangerous vector-borne diseases. The number of TBE incidences has been permanently increasing in various geographical regions, including the Czech Republic. The presence of ticks and related diseases is driven by host-pathogen systems. The systems are rather complex and susceptible to environmental conditions represented in the first place by land cover/land use categories. The presented study looks for a possible relation between the types of forest vegetation specified in the Landsat 5 satellite data and relative TBE morbidity. First, supervised classification of forest areas into five vegetation classes predefined by a botanist was tested. Due to the spectral similarity of the classes, the resulting classification accuracy of Landsat scenes covering the entire area of the Czech Republic was quite low. Thus, an unsupervised approach was applied using nine spectral classes. Relative TBE morbidity data collected over 10 years for 206 administrative units covering the entire country presented field data that were correlated with the spectral classes. The TBE risk index (IRE) of a given spectral class was introduced at each satellite scene. To create a map of the TBE risk for the entire country, all IRE values were accumulated and divided into six risk categories. The disadvantages of the proposed method, especially regarding the accuracy of the final product with a nationwide cover age, are discussed. In addition, the correlation between the relative TBE morbidity and other environmental parameters, such as annual precipitation, average temperature, and number of hunted game were calculated, but they did not reveal any significant relationship.

Keywords: ticks, encephalitis, classification, Landsat

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1. Introduction

1.1 Concepts of using remote sensing for encephalitis risk assessment

The surveillance of vectors and vector-borne diseases is essential for their control. Vector surveillance can be defined as the monitoring of arthropod populations responsible for the transmission of pathogens. In addition to other things, vector surveillance can be used to detect the presence/absence of a vector population and, subsequently, be used for disease risk assessment.

The spread of many vectors and related diseases is driven by host-pathogen systems. The distribution of their locations is susceptible to environmental conditions, represented in the first place by land cover/land use categories (e.g. Cortinas et al. 2002; Eisen et al. 2006; Estrada-Peña 2001). Determination and mapping of the main land cover categories like vegetation, water, or urban areas can be done effectively by means of remote sensing (RS) from satellites or airplanes.

RS and geographic information systems (GIS) have been widely used in health applications for several decades. A substantial proportion of the research papers published in this field deals with application to spatially delineate vector habitats and disease patterns (e.g. Cortinas et al. 2002; Rogers and Randolph 2003; Tatem et al. 2004). The incidence of tick-borne encephalitis (TBE) and Lyme borreliosis currently continues to increase in many European countries while the reasons for this are not yet fully understood.

It has been recognized that efficient extracting the information from RS images and applying it in studies of disease control requires the inclusion of several professional fields such as geography, RS, biology, ecology, computer science, etc., which in turn demands interdisciplinary cooperation and research teams.

RS adds qualified information for the identification of vulnerable ecosystems at a relatively low cost, thus providing an important ancillary tool for studying certain endemics and supporting surveillance and control activities. In contrast to point feature of field observations, satellite data continuously cover the entire area of interest, allowing a more complete picture of the environmental conditions. Moreover, RS data can be processed in time series to gather information about changes and trends in environmental conditions.

Among the various sensors used, there was a predominance of AVHRR (NOAA satellite) and TM (Landsat satellite), possibly because they have long historical series and they are easily accessible. By contrast, there is only a negligible number of case studies using very high-resolution images. Data from Landsat and NOAA satellites were used in vector habitats studies mostly to classify land

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cover categories, namely vegetation categories using the Normalized Difference Vegetation Index (NDVI) (Herbreteau et al. 2007).

The NDVI calculated from NOAA-AVHRR data was used to monitor the seasonal activity of larvae and nymphs of *Ixodes ricinus* together with the TBE virus in seven European countries (Randolph et al. 2000). Several studies (Brown et al. 2008; Lourenço et al. 2011) demonstrated a relation between the spatio-temporal variability of NDVI and the occurrence of vector-borne diseases. Other RS parameters have been applied as well. Altobelli et al. (2008) developed a prediction model for the abundance of infected ticks (Ixodes ricinus) in north-east Italy using the values of Land Surface Temperature (LST), Land Surface Water Index (LSWI), Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI). A model for the distribution of another tick, *Hyalomma marginatum*, over some parts of Europe was prepared by Estrada-Peña et al. (2014).

The number of projects has been focused on the development of reliable methods for creating prediction maps of tick occurrence and related disease risk distribution using RS. An overview of the most important papers is given in several articles; for example, Estrada-Peña (2001). A review of a study on the use of GIS and RS for the *Ixodes scapularis* and the spread of Lyme disease in the central part of the United States has been published by Cortinas et al. (2002), while Cromley (2003) mentions another application of satellite imagery for monitoring tick-borne and other diseases in the United States.

The relationship between tick occurrence and vegetation types was confirmed during an experiment in the Siebengebirge nature reservation in western Germany, as described by Schwarz et al. (2009). For seven months, ticks were regularly collected in 5 areas together with measurements of air temperature and humidity 5 cm above the ground, the water content in the soil, climatological data, soil types, and namely, vegetation types. The highest average number of ticks was found in vegetation with humid dense herbaceous and shrub undergrowth and a layer of leaves. Tick occurrence decreased where the undergrowth was less developed and was the lowest in xerophilous vegetation and underdeveloped herbaceous and shrub floors. Furthermore, the number of ticks increased with a growing temperature (up to 24 °C) and decreased when the air humidity increased. A very strong positive correlation was then found between the number of ticks and the water content in the soil.

An example of the application of satellite data for the creation of a prediction map is shown by a study in the Mendocino district of California, where the density of nymphs of *Ixodes Pacificus* was studied (Eisen et al. 2006). Images from Landsat 5 TM acquired in different periods of the year (May, July, November, and February) were processed to get the NDVI and spectral features derived from the Tasseled Cap transformation. Three vegetation classes were selected and defined in accordance with the level of tick appearance: dense forest with a high incidence of nymphs, permanent grassland and woodlands with a grassy understory with adult ticks, and agricultural land and water areas without the occurrence of *Ixodes Pacificus*. Supervised classification of Landsat data gave the best results (82.64% overall accuracy of three risk categories) when carried out using NDVI and one spectral feature from February and July combined in one dataset. The classification results of seven forest types were assessed as insufficient. Processed satellite data together with additional climate and topographic parameters were compared with the density of *Ixodes Pacificus* nymphs collected during a field survey in 62 areas of the Mendocino district. The resulting model gives the nymph density prediction with 72% accuracy.

RS measurements and processing methods cannot identify the vectors themselves, but they can identify and characterize suitable vector habitats. However, they can be an important input in the development of disease risk maps and for monitoring changes over time. Maps showing seasonal risks of vector-borne diseases will be critical in monitoring the impacts of global climate changes on vectors. Satellites are unique tools for observation of the environmental influence on the spread of vectors and should be a part of any vector surveillance program (Martin et al. 2007).

Recently, environmental variables that are interpolated from meteorological stations or monthly estimates of remotely sensed features are included in correlation modelling. Estrada-Peña et al. (2014) produced a global dataset of variables derived from the monthly series of MODIS satellite data by Fourier transform. The dataset includes variables, such as day and night temperature or vegetation and water availability, which could potentially affect the physiological processes of the vectors.

1.2 Satellite data use for TBE risk determination in the Czech Republic

The most common type of tick in a wide geographical area of Europe, including the Czech Republic, is the *Ixodes Ricinus*. As everywhere, its specific occurrence depends on many different abiotic and biotic factors, such as temperature, humidity, vegetation density and potential host occurrence (Estrada-Peña 2001). The most serious diseases that this species of tick in Europe transfers are Lyme disease and tick-borne encephalitis.

Built on the heritage of traditional forms of tick research, testing of the possible use of satellite data started in the Czech Republic in 1990 with a pilot study demonstrating the use of RS data and methods to map the occurrence of *Ixodes ricinus* in the European context (Daniel, Kolar 1990). Image data from the Landsat 5 satellite of 1,600 km^2 test area was used for the localization of six land cover categories confirming the key influence of forests on tick occurrence.

The following research focused mainly on the selection and appropriate definition of vegetation types under consideration and on methods of correlation between TBE statistical data and classified satellite imagery.

Daniel, Kolar, Zeman (1995) evaluated using satellite data for predicting the risk of TBE morbidity caused by occurrence of *Ixodes Ricinus* on a 75 × 75 km^2 area south of Prague. Landsat 5 satellite scenes from the main part of the vegetation growth period (June–September) were classified under forest mask to get nine different categories of forests. An unsupervised classification method was used to get these nine classes. Botanical descriptions and definitions were given to the classes after a field trip to respective areas recognized in the classified images. Data obtained in the field created a training dataset for supervised classification of the whole area of interest. For the same test area a 0.5 km grid was created based on statistics of TBE morbidity in the region during the last twenty years expressing the expected incidence of the disease in eight levels. The grid was subsequently merged with classified satellite data for correlation analysis relating every forest class to a certain level of risk of the infection. Homogenous coniferous forest has shown the smallest risk, while very heterogeneous young deciduous trees have been indicated as a forest vegetation type with the highest risk to become infected by the TBE virus.

Geographical expansion of the processing procedure over the entire area of Bohemia was the objective of a follow-up project (Daniel, Kolar, Benes 1999). Its results demonstrate the advantage of RS for the prediction of sites with increased risk of tick-borne encephalitis infection over large areas. The study also includes a structural analysis of forest areas in addition to spectral classification in an effort to use the heterogeneity index as another indicator of tick presence in forests.

The GIS tools were used to select suitable sites for the field collection of ticks in southern Bohemia (Švec et al. 2009) followed by development of a disease risk prediction model, based on altitude, vegetation cover, population density, and recreational load. A significant correlation was demonstrated between the natural parameters and density of ticks as well as between the overall risk and the total number of diseases. Mixed and deciduous forests were reported as the places with an increased risk of TBE infection (Honig et al. 2011).

1.3 Concept of the research

The aim of the study described in this paper was to construct a map of a potential risk of TBE disease. In order to perform risk prediction of exposure to vector-borne diseases, both biotic data (e.g., tick and host abundance) and abiotic data (environmental constraints) are commonly employed.

The distribution of encephalitis is always indicated by tick presence. This correlation is rather fundamental, but the direct causal relationship linking habitat conditions to tick distribution or abundance still needs to be established. Additionally, tick presence numbers are general and the differentiation between infected ticks and non-infected ticks requires additional costly laboratory examination.

In our approach to develop a risk model for the geographical area of the entire country, we excluded a tick abundance input. Instead, long-term statistical data on encephalitis collected for smaller administrative units was used as an input about the disease distribution in the country.

The study was based on an assumption that the spatial distribution of vector-borne diseases follows certain habitat compositions providing suitable living conditions for vectors and pathogens. Our research position was that vegetation types in forests reflected inherently complex relations of both local micro-environmental variability and larger-scale climatic parameters.

Therefore, the suitable habitat for tick appearance was represented by forest vegetation categories obtained from processed Landsat satellite data depending on their spatial correlation with the morbidity data. As a novelty, vegetation categories have been defined by their spectral features only, not by botanical expression. On top of this, we included in our study the overlaying distributions of other variables, such as land-cover/land-use data, elevation, air temperature, and the occurrence of selected animals being potential tick hosts.

A suitable tick habitat is a necessary condition but still not a sufficient one to make another case of illness into statistics of TBE morbidity. For this, suitable tick habitats have to overlap with places in which human activities occur. Variables describing people's behavior are not easy to define, and they are less exact.

Our effort aimed at creating a statistical regression model estimating the relationship between one response variable (the TBE morbidity in our application) and a set of descriptive covariates. Rather large standard errors of estimated correlation just underline the complexity of the natural relations and objects under study. It provides uncertainty about the real significance of the examined variables for the risk prediction. In accordance with Dormann et al. (2013), a model may label some variables as not significant, even if they are truly influential for the disease incidence. Knowledge of the tick-habitat interactions needs to be further developed, particularly the scale of action of the environmental factors that are the most influential.

The application of the sample data for a modelling environment in different geographical or environmental landscapes can produce serious errors, because samples are likely to change. This is emphasized when satellite data from various dates and regions are to contribute to one resulting model. Bedia et al. (2013) give an example of statistical prediction models giving the impression of a well-fitted model which gives strongly insufficient results in new geographical regions or changed climatic conditions.

Research in this project aimed to derive the spatial distribution of disease from satellite imagery and other sets of ground parameters. The final result has been presented in the thematic map of risk levels with regard to TBE over the entire country.

The map creation for a geographically large area in this study required testing of a newly developed process when combining results from several models in different geographical areas into one result for the entire country.

2. Data sets used in the study

2.1 Tick-borne encephalitis morbidity data

Nationwide dense sampling of ticks and laboratory testing of these ticks would be the most reliable but, in practice, barely achievable way to gain data about the true occurrence and geographical distribution of TBE. In respect to this, the only suitable and available source of data about the rate of illness and its spatial distribution is the register of TBE cases administered by the National Institute of Public Health. The provided data were related to the area of the municipalities with extended power (MEP). Thus, 206 MEP covering the entire area of the Czech Republic became the basic area units of the investigation. Specifically, the data represents an annual average of TBE morbidity in the last decade related to 100,000 inhabitants in the unit. Only those TBE records were included in further analysis where an infected person was an MEP resident and the probable site of infection was located inside the MEP administration boundaries. This approach eliminated cases when the location where the infection happened was different from the home administration unit of the infected person. The entire scope of TBE values in all 206 MEP was divided into six risk categories in such a way that approximately the same number of MEP was inside each category (Table 1).

Tab. 1 Distribution of the relative tick-borne encephalitis (TBE) morbidity in municipalities with extended power (MEP).

Relative TBE morbidity category	Relative morbidity per 100,000 inhabitants	Number of MEP in the category	Average MEP area (km²)
A	<1.7	42	275
B	1.7–3.3	41	363
C	3.3–6.0	41	347
D	6.0–11.0	39	400
E	11.0–58.0	43	527

2.2 Satellite images and field data

Based on the assumption of an equal distribution of the infected individuals through the tick population, the risk of being infected is expressed by the morbidity. The spatial resolution of the morbidity is given by the respective MEP area, which is rather large and variable. Satellite imagery offers a meaningful alternative to obtain a nationwide thematic map of TBE risk with a substantially better level of detail.

After evaluating the spectral and spatial resolution, as well as the coverage and availability of imagery for the required time frames, data from the Landsat 5 satellite were chosen as the most suitable. It also allowed following the results of previous projects (Daniel, Kolar, Benes 1999; Daniel, Kolar, Zeman 1995) and improving the earlier applied methodology.

Only Landsat 5 scenes containing less than 10% cloud coverage were selected. The time period of the acquisition was restricted to between the years 2006 and 2010, and on dates in late summer (August, September).

The entire area of the Czech Republic was covered with nine Landsat scenes with about 30% and 10% overlap in the longitudinal and latitudinal directions, respectively. The selected satellite scenes (Table 2) were downloaded from the online USGS archive. The Standard Terrain Correction was applied to the data. The geometric quality of all the scenes was checked against the ZABAGED topographic database (ČÚZK 2015) using 12 check points evenly distributed in each scene. Moreover, the correspondence in geolocation was checked in the overlapping parts of the scenes. In both cases, RMSE smaller than one pixel were achieved. Atmospheric correction was not carried out because the classification results were primarily intended for evaluation inside one scene.

Seven three- to five-day field campaigns aiming at the collection of training and control polygons for the supervised classification were carried out from spring 2012 to autumn 2014 in selected forest areas distributed over the whole country. A botanist participating in the first field measurement described particularities of five defined forest classes (Section 3.1). Based on his input, a guideline for their discrimination in the field was created and used during the campaigns. In total, 676 training samples and 321 control points, including the photo documentation, were gathered in 128 different forest locations. All data were stored in a database.

2.3 Meteorological and environmental statistics and supporting data

Though the main focus of the study was on risk assessment of TBE based on forest vegetation categories, possible correlation between morbidity and other factors influencing the tick's life cycle were also studied. These factors comprised three groups of measures available for the entire area of the Czech Republic:

Tab. 2 Landsat scenes selected for the study and supervised classification accuracy (CA) for every scene.

Scene	Date	CA training dataset [%]	CA check points [%]
189-025	2007/06/11	92.48	78.18
	2010/09/23	79.98	60.81
	all	**79.09**	64.58
189-026	2007/08/14	41.22	35.85
	2007/06/11	58.75	41.98
	2009/09/20	53.07	31.58
	all	**80.91**	**53.09**
190-025	2007/05/01	80.80	54.88
	2007/08/01	87.01	73.13
	all	**93.29**	**73.42**
190-026	2007/05/01	50.36	31.92
	2007/08/01	62.32	55.39
	2009/09/27	74.85	57.69
	all	**79.37**	**59.52**
191-025	2009/08/01	63.45	45.80
	2010/09/21	67.19	37.90
	all	**71.50**	**46.28**
191-026	2009/06/14	62.19	38.64
	2009/08/01	52.32	28.00
	2010/09/21	63.70	41.82
	All	**79.37**	**37.50**
192-025	2007/04/29	60.90	38.69
	2009/08/24	63.70	58.94
	2010/10/30	60.33	48.29
	all	**75.87**	**57.36**
192-026	2006/06/13	86.23	63.49
	2010/07/10	85.20	76.81
	2009/09/09	88.75	69.57
	all	70.98	21.39
193-025	2006/07/22	74.8	37.4
	2006/09/24	68.1	41.0
	all	**77.2**	**37.4**

A) Climatic parameters in a 0.5 km grid format provided by the Czech Hydrometeorological Institute:
   - Annual average precipitation in the last decade;
   - Average number of days with temperatures over 10 °C in the last decade (the temperature over 10 °C is typical for tick activity);
   - Annual average temperatures in the last decade.

B) Numbers of hunted game (fallow, roe and red deer, mouflon, wild boar, duck, hare) in MPE areas provided by the Forestry and Game Management Research Institute.

In addition, two other data sets were collected in order to support our investigation and its results:

C) The European land cover database CORINE (EEA land cover 2006). Classes 311 (broad-leaved forest), 312 (coniferous forest), 313 (mixed forest), and 324 (transitional woodland-shrub) covering the majority of forest and shrub vegetation formed the mask of forestry areas utilized for the satellite data classification. The level of correlation between eight selected CORINE classes and values of TBE morbidity in every MEP unit was created to assess their possible mutual relationships (Table 8).

D) A vector layer with MEP borders was one of the most important inputs for the calculation of all statistics connected to the raster data (Landsat classification, CORINE, climate characteristics). It was also used for creating all final map products.

3. Satellite data processing

3.1 Supervised classification of satellite data

Based on the results of a previous project (Daniel, Kolar and Benes 1999), five forest vegetation categories were defined for the supervised maximum likelihood classification:

Class 1 – Coniferous forest
Class 2 – Mixed forest
Class 3 – Heterogeneous young deciduous forest and grassland
Class 4 – Homogeneous deciduous forest
Class 5 – Sparse deciduous forest

Single scenes as well as multitemporal datasets compiled from scenes acquired at different stages of the vegetation cycle were classified. The classification process consisted of the following steps:

1) creating a forest mask based on the CORINE database as mentioned in the Section 2.3,
2) detection of clouds and shadows and subtraction of respective pixels from the forest mask in each scene,
3) principal component transformation applied on single scenes and multitemporal composites; only components containing more than 0.5% information were used for the classification,
4) uploading training polygons and control points collected during the field campaigns,

5) maximum likelihood classification of pixels under the created forest mask; the classifier parameters were tuned for each scene in order to achieve the highest accuracy.

The statistical evaluation of the classification results is summarized in Table 2. The classification accuracy varies from one scene to another. While the total accuracy differs up to 20%, the producer/user accuracy of separate classes changes up to 55%. The coniferous forest class achieved the highest accuracy. Misclassification was typical for heterogeneous young deciduous forests and sparse deciduous forests. Sparse deciduous forest was classified with the lowest accuracy, 20% to 35%.

Classification results of such low accuracy did not provide a reliable input for searching for a relationship between the spatial distribution of classified forest classes and morbidity categories. The results of classification differed considerably in the overlapping areas of the scenes. Changes in atmospheric conditions between acquisition dates and geographical differences across the scenes were two of the reasons causing these discrepancies. Nevertheless, the main reason for the low classification accuracy comes from the spectral variability inside the vegetation categories. Although the class definitions were created by a professional botanist, their verbal descriptions could not always be objectively applied when assigning every forest type to one of the defined classes in the field. Moreover, even when the selected vegetation classes were recognizable and separable in the terrain, their spectral features in the datasets acquired by the Thematic Mapper sensor did not differ sufficiently between one to another to obtain better discrimination. In this case, even an increase of training samples would not lead to much better results. Thus, supervised classification did not bring expected and further applicable results and an unsupervised approach was applied.

3.2 Unsupervised classification

The objective of the research was to develop a process that would allow obtaining the spatial distribution of different levels of risk of TBE. Therefore, it has not been necessary to perform classification of the satellite data into predefined botanical vegetation classes; however, such a legend would certainly facilitate reading of the final map.

The unsupervised approach to the classification of satellite data was also supported by the finding of low portability of spectral features describing defined classes in one scene to another location. Classification into the classes defined previously could not sufficiently reflect the heterogeneity of the forests themselves and their differences between regions throughout the country. Moreover, natural conditions provided by a botanically defined vegetation class may change in space and time, resulting in different occurrences of ticks in a given class in different geographical areas.

To exploit fully the information assets of multispectral satellite data, the approach was to determine recognizable classes based on their spectral differences, only without an effort to give them a botanical name. The spectral features used for supervised classification were the measured relative values in the respective spectral bands (DN) and the normalized vegetation index NDVI, also computed from relative radiometric values:

$$NDVI = (DN_{NIR} - DN_R)/(DN_{NIR} + DN_R),$$

where DN_{NIR} and DN_R indicate the value in the near infrared and red bands, respectively.

The unsupervised classification procedure takes the same first three steps used for the supervised classification (Section 3.1). The unsupervised classification method by Isodata (Jensen 1998) was applied as the fourth step. The preselected number of requested classes was set to nine. The same number of classes was also used for the classification of forest cover in the previous work (Daniel, Kolar and Benes 1999). The decision about this number of different forest categories has also been considered to be large enough for the expression of a rather wide interval of morbidity values.

Classification took place for nine satellite scenes. Thus, altogether, 81 different spectral classes were identified. Each resulting class contains woodland objects with similar spectral properties inside the given scene. Although the number of spectral classes was the same for all the scenes, their botanical compositions are not necessarily the same. This is because the spectral features determining the given class (e.g. class 4) may be different from the spectral features determining the class labeled with the same number in another scene. This approach respects the diversity of the conditions under which the satellite scenes were taken and the natural diversity of the forest vegetation at various scenes.

The classification results are presented in Table 3. The total number of classified values in each scene is given together with its distribution into nine key spectral classes KL_i ($i = 1, \ldots, 9$). Similar statistics could be computed for every MEP.

4. Evaluation of the relationship between TBE morbidity and other parameters

4.1 Correlation analysis between relative TBE morbidity and environmental parameters

For the purpose of correlation analysis, climate parameters were averaged for each MPE area. The numbers of game hunted were normalized to the area of the forest and agricultural land within an MPE. The relation between relative TBE morbidity and climate and hunted game data was evaluated using Spearman's correlation coefficient r.

The climate parameters did not reveal an expected relation to TBE morbidity (e.g. $r = -0.19$ for annual

Tab. 3 The number of pixels assigned to classes KL1 through KL9 resulting from the unsupervised classification of the nine satellite scenes.

Scene	Total number of classified pixels	Number of pixels assigned to spectral classes								
		KL1	KL2	KL3	KL4	KL5	KL6	KL7	KL8	KL9
189-25	3 351 577	1 028 610	1 018 292	268 927	644 144	23 536	144 108	174 356	39 907	9 697
189-26	3 869 039	648 114	813 359	156 636	986 777	244 770	34 910	768 890	145 759	69 824
190-25	5 252 992	1 721 685	1 385 177	410 233	957 784	201 788	395 399	76 865	78 706	25 355
190-26	4 518 316	1 192 604	969 033	980 795	203 442	629 035	318 168	155 155	7 584	62 500
191-25	7 606 077	2 555 087	2 034 022	559 522	1 514 383	145 788	315 570	389 665	65 477	26 563
191-26	6 064 862	1 891 916	2 035 849	460 719	979 540	76 353	235 593	292 018	73 051	19 823
192-25	9 728 116	611 875	2 077 203	2 275 441	1 884 782	579 206	1 160 729	567 985	387 976	182 919
192-26	3 984 172	1 380 039	1 029 141	416 724	618 329	183 481	63 752	194 336	72 249	26 121
193-25	3 941 376	1 160 796	1 122 622	370 294	598 363	59 928	253 929	222 475	86 992	65 977

Tab. 4 The average number of hunted game per MPE and the relative morbidity risk categories.

Hunted game	Relative morbidity risk categories				
	A	B	C	D	E
Wild boar	19.9	27.8	34.7	41.1	33.1
Fallow deer	2.6	5.4	3.2	3.5	2.8
Red deer	5.1	2.7	2.3	2.8	2.1
Duck	33.0	56.6	50.6	37.2	121.8
Mouflon	1.4	2.2	1.6	2.7	1.5
Roe deer	29.1	36.7	34.0	27.6	28.3
Hare	101.9	225.8	133.6	84.92	57.7

Tab. 5 Average percentage of CORINE land cover classes in MPE and the morbidity risk categories. The sum of the areas of the selected classes corresponds at least to 94% of an MPE area.

CORINE land cover	Morbidity risk categories				
	A	B	C	D	E
Discontinuous urban fabric (112)	6.8%	5.5%	6.5%	5.3%	3.7%
Non-irrigated arable land (211)	27.1%	48.9%	40.9%	40.5%	36.7%
Pastures (231)	11.4%	5.9%	8.1%	7.3%	9.7%
Agriculture with natural vegetation (243)	12.0%	7.7%	9.0%	8.3%	10.1%
Broad-leaved forest (311)	6.1%	4.2%	4.4%	3.2%	1.8%
Coniferous forest (312)	18.7%	14.1%	15.3%	21.3%	27.2%
Mixed forest (313)	8.6%	6.9%	8.6%	9.6%	6.8%
Transitional woodland-shrub (324)	3.4%	1.9%	2.4%	1.2%	1.2%

precipitation, r = −0.15 for the number of days with a temperature above 10 °C). The main reason for such weak relationships is their high variance. Their usually strong heterogeneity within an MEP area was generalized into one value for the purpose of correlation. The distribution of these generalized parameters did not correspond to the normal distribution and their histograms differed from the histogram of the relative morbidity.

For hunted game, the highest correlation coefficient value (r = 0.39) was achieved in the case of wild boar. The absence of a relationship between the studied counts of hunted game normalized to the vegetated area within an MPE and the morbidity risk categories is evident in Table 4.

A correlation analysis between the CORINE land cover classes and the relative morbidity was also carried out. Table 5 summarizes the percentage of selected CORINE classes in an MPE area per morbidity risk category. Coniferous forest (312) is the only class showing a slight proportion of its area with a morbidity risk.

4.2 Relationship of the heterogeneity in a classified image to morbidity

The degree of heterogeneity was expressed for every pixel of the classified image. The number of different classes in the surrounding eight pixels was selected as a measure of heterogeneity. Depending on the number of adjacent pixels belonging to a different class, the central pixel was put into one of the categories of heterogeneity identified, H0 to H8, where H0 contains pixels with only the same class in their neighbourhood while category H8 includes pixels around which all eight surrounding pixels are from different classes.

Table 6 shows the number of pixels in six heterogeneity categories, H0 to H5 for different categories of relative morbidity. Categories H6 to H8 are no longer listed because they contain insignificantly small numbers of pixels. The highest number of pixels belongs to category H1, with a rapid decrease for other categories. The trend is almost identical for all different morbidity categories. Thus, heterogeneity as defined did not show a potential of being an indicator of relative morbidity.

4.3 Relationship of spectral classes to morbidity

To assess the possible correlation between certain spectral classes and morbidity in MEP areas, the results of the satellite data classification for every MEP were used. Then, a relationship between an area of spectral class occurrence and category of relative morbidity was created for each MEP.

Tab 6 Number of pixels in six heterogeneity categories, H0 to H5, for each category of relative morbidity. The correlation coefficient shows the strength of the relationship between local heterogeneity and relative morbidity.

Categories of relative morbidity	Number of pixels in heterogeneity categories					
	H0	H1	H2	H3	H4	H5
A	1 008 387	1 821 665	1 043 281	410 020	111 381	17 737
B	773 413	1 858 880	1 333 247	603 112	171 635	28 466
C	815 575	1 941 289	1 427 530	631 860	180 703	29 435
D	1 133 586	2 569 743	1 917 263	877 519	256 404	42 574
E	1 484 439	3 710 632	2 669 129	1 264 191	383 868	63 523
Correlation coefficient	0.22	0.33	0.33	0.34	0.34	0.32

Tab. 7 Distribution of spectral classes K1–K9 within the morbidity classes A–E, Landsat scene 189-26.

Scene 189-26									
Categories of relative morbidity	Number of pixels in spectral class								
	KL1	KL2	KL3	KL4	KL5	KL6	KL7	KL8	KL9
A	135105	144551	14752	238651	38738	6814	207544	27515	10786
B	293293	315161	83781	340694	84414	16023	246133	41197	23251
C	179004	279861	41521	284833	88184	8555	233133	55435	22078
D	23701	52194	12111	99596	26187	2675	72627	18763	11700
E	17011	21592	4471	23003	7247	843	9453	2849	2009

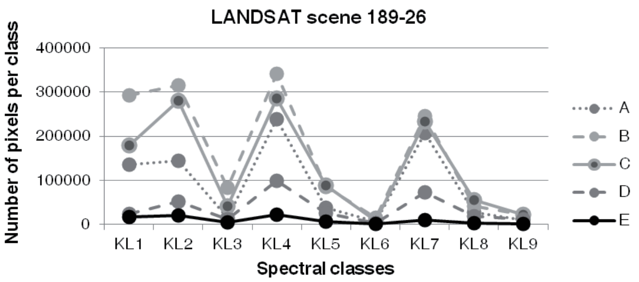

Fig. 1 Distribution of nine spectral classes within the morbidity classes A–E, Landsat scene 189-26.

Tab. 8 Risk associated with the relative morbidity categories expressed as weight coefficient W_j.

Categories of relative morbidity	W_j
A	1
B	2
C	4
D	8
E	16

The example of the relationship for Landsat scene 189-26 is presented in Table 7, giving a number of pixels P_{ij} in each spectral class i (i = 1, …, 9) belonging to certain categories of relative morbidity j (j = A, B, C, D, E). P_{ij} is a measure of the risk of potential disease associated with the given spectral class. The same relationship is presented in Figure 1.

To express the overall level of risk associated with a given class in the relevant scene more exactly, weights Wj were assigned to relative morbidity categories. The weights reflect the absolute values of relative morbidity in each category and are given in Table 8.

The index of the risk of the TBE – IRE was introduced for better expression of the relative risk connected with the specific spectral class inside the satellite scene in which the spectral class was classified. Using the parameters introduced above, the IRE for a given spectral class is defined by:

$IRE_i = (\Sigma P_{ij} W_j) / 10^{11}$, j = A, B, C, D, E

The IRE expresses the level of risk of disease associated with each of the nine classified classes for each satellite scene. For nine scenes there are 81 different values of relative risk indices (Table 9), which reflect the objective diversity of forests throughout the country and the difference between the external conditions under which the satellite data were taken. The IRE values determine which class indicates the areas of most risk; which one means less risky sites, and which class represents places where the risk of disease is almost zero. The relative order of risk is valid for the given single scene. Comparing the risk among scenes cannot be done without corrections for different air and ground conditions at the time of the data acquisition.

When the different conditions among satellite scenes are not taken into account, the IRE values can be presented over merged scene areas. The cost of this simplification is higher when differences in the scenes acquisition or in vegetation types within their territories are larger. Accepting this limitation, however, allows presenting unified incidence risk categories throughout the area of the entire country.

Using this concept, all 81 risk index values were categorized into six intervals of subjective selection (Table 10). Under this distribution there are two values in Category I of the highest risk, seven in Category II, four in

Tab. 9 Index of the TBE risk associated with the nine spectral classes KL1–KL9 in each scene.

Scene	Relative risk in spectral classes								
	KL1	KL2	KL3	KL4	KL5	KL6	KL7	KL8	KL9
189-25	101.8	117.3	4.6	37.9	0.0	2.0	3.9	0.2	0.0
189-26	0.5	1.4	0.1	2.9	0.2	0.0	0.9	0.1	0.0
190-25	13.6	10.6	0.8	5.5	0.3	1.2	0.1	0.1	0.0
190-26	237.5	85.9	31.0	4.4	10.5	7.1	2.0	0.0	0.4
191-25	229.0	150.4	14.7	67.2	1.0	4.8	5.7	0.2	0.0
191-26	192.3	257.4	12.5	70.9	0.4	3.8	6.4	0.4	0.0
192-25	33.9	355.1	442.5	232.1	31.8	70.1	16.2	6.6	1.7
192-26	384.0	248.0	53.7	99.6	8.8	1.0	10.2	1.3	0.2
193-25	10.1	34.8	1.7	4.9	0.0	0.2	0.2	0.0	0.0

Tab. 10 IRE values transformed into six risk categories.

Risk categories	IRE
I – the highest risk	>360
II – high risk	180–360
III – medium risk	90–180
IV – moderate risk	45–90
V – low risk	22–45
VI – no risk	0–22

Category III, five in Category IV, five in Category V, and the remaining 58 values in Category VI, meaning almost no risk.

Spatial distribution of the risk categories according to this model on the area of the Czech Republic is shown as a thematic map in Figure 2. An example of a more detailed view produced on the national topographical map background is presented in Figure 3.

5. Conclusion

Two processing approaches were tested in order to determine the different vegetation classes existing in Czech forests. Supervised classification was applied for five classes defined on a biological basis. The respective training and control datasets were obtained during field surveys in all main forest regions of the country. However, the final classification result did not achieve a useful degree of accuracy in practice. The reason was that even when significantly different from the biological standpoint, the spectral distinction of selected forest classes was too slight in the Landsat spectral bands. Other reasons include the variability inside each class in the field and the diversity of forest vegetation throughout the entire country, as well as the different conditions under which each satellite scene was taken.

As giving a botanical name and description to identified different forest types was not the final goal of the research work, the unsupervised classification approach was applied. In this approach, forest vegetation variations were discriminated only in respect to their spectral variety recorded in the given Landsat dataset. This processing concept respects both the diversity of forest and environment and climate conditions in different places and on different dates of the satellite data acquisition. Treated in this way, the satellite data can be used to assign spectrally various forest areas to degrees of relative risk of TBE. Through the classification of forest vegetation, the one known value of relative morbidity for the whole MEP territory has been decomposed into the hundreds or thousands of smaller areas across the surface of the MEP.

The practical outcome of the project was a thematic map of risk expressed in the relative six-level scale with the spatial resolution of the Landsat Tematic Mapper. The level of spatial detail allows producing maps of the risk distribution at the local or regional level in medium and large scales. No similar information is accessible from the currently provided statistical data. The credibility of the resulting relative levels of risk and their localization in the landscape is better when computed for a smaller area inside one satellite scene.

When one output for an area larger than one satellite scene is requested, a cost is paid for merging different conditions in several scenes and one generalized scale of risk categories. The local conditions can be determined only by direct comparison in the field. Ideally, the number of ticks picked up on the spot would be compared, which is not possible in practice. Therefore, the resulting map content provides a basic overview of the distribution of risk areas in forests over a larger area with reduced accuracy on local level. The index of disease risk (IRE) has been newly introduced for expressing this relationship.

Conclusions about the relationship between spectral classes classified in satellite data and the index of disease risk are also influenced by inaccuracies in morbidity assignment to the class. The statistical data of relative morbidity give a single value for an entire MEP territory of several hundred square kilometers. By contrast, the Landsat data give spectral features of area of dozens of square meters. Very high-resolution satellites even have pixel size of a few square meters.

Further progress in the use of remote sensing methods to determine risk areas for TBE can be expected in two fields. One involves deeper knowledge about specific vegetation types and other natural parameters influencing the tick occurrence. The other deals with the development of advanced remote sensing measurement equipment required to recognize the vegetation types of interest.

In addition to the printed format, the map of TBE morbidity risk has been published in electronic form on the web site www.access. Based on the Grifinor platform, the interactive map allows browsing the map at a selected level of detail, even on mobile devices.

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RESUMÉ

Stanovení míry rizika nákazy klíšťové encefalitidy pomocí metod DPZ

Klíšťová encefalitida (KE) je jedním z vážných virových onemocnění přenášených klíšťaty druhu *Ixodes ricinus*. V posledních letech je dokumentován nárůst tohoto onemocnění jak v České republice, tak v celé Evropě. Výskyt klíštěte je vázán na přírodní podmínky vhodné pro jeho existenci, které lze charakterizovat zejména typem vegetace, dále pak přítomností vhodného hostitele nebo nadmořskou výškou. Cílem prezentovaného výzkumu bylo najít vztah mezi prostorovým rozložením vegetačních tříd lesního porostu a relativní nemocností KE na úrovni obce s rozšířenou působností (ORP). Pro určení výskytu relevantních druhů lesního porostu byla použita data pořízená zobrazujícím radiometrem Thematic Mapper družice LANDSAT-5. Nejprve byla testována řízená klasifikace pro rozpoznání pěti botanikem popsaných tříd lesního porostu. Po porovnání výsledků s pozemními daty získanými během terénního šetření se tato metoda ukázala jako nevhodná vzhledem ke spektrální příbuznosti tříd, jejich odlišnosti na rozloze celého státu a také vzhledem k rozdílným podmínkám, za jakých byly pořízeny jednotlivé družicové scény. Proto byl sestaven metodický postup založený na neřízené klasifikaci, kdy bylo v každé scéně nalezeno devět tříd pouze na základě jejich spektrálního projevu v družicových datech. Výsledkem byl model respektující rozmanitost jak lesního porostu, tak i vnějších podmínek při pořizování družicových dat na různých místech v rozdílnou dobu. Na základě vztahu mezi četností výskytu spektrálních tříd a hodnotami relativní nemocnosti v ORP byl empiricky odvozen index míry rizika onemocnění (IRE), který je exaktním vyjádřením rizikovosti dané spektrální třídy na území příslušné družicové scény. Jako praktický výstup byla vytvořena tematická mapa zobrazující hodnoty IRE pro celé území České republiky s prostorovým rozlišením odpovídajícím datům Landsat, tj. 30 m. Pomocí platformy Grifinor byla mapa zpřístupněna v prostředí Internetu.

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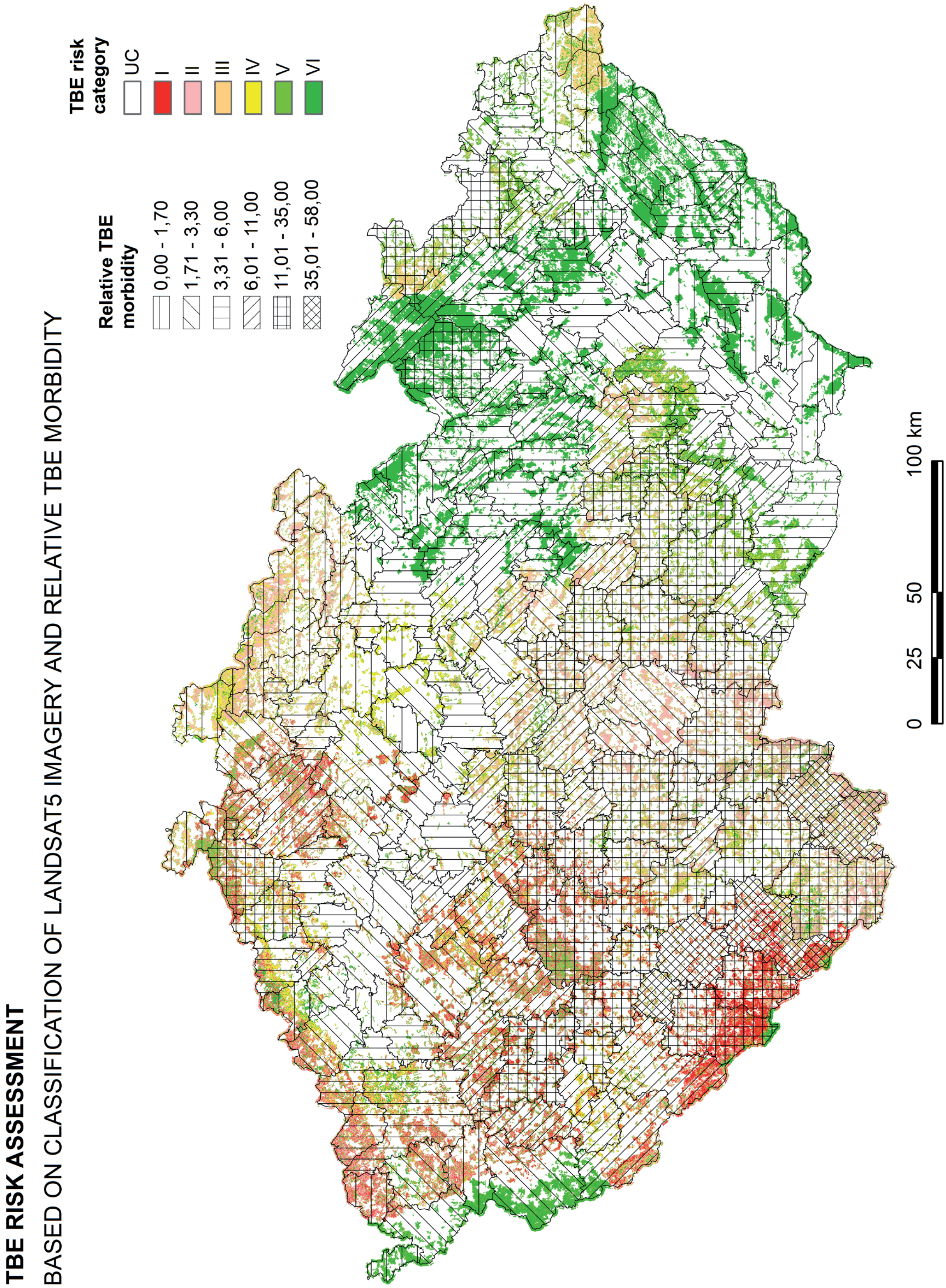

Fig. 2 Relative TBE morbidity and the TBE risk categories distribution in the Czech Republic.

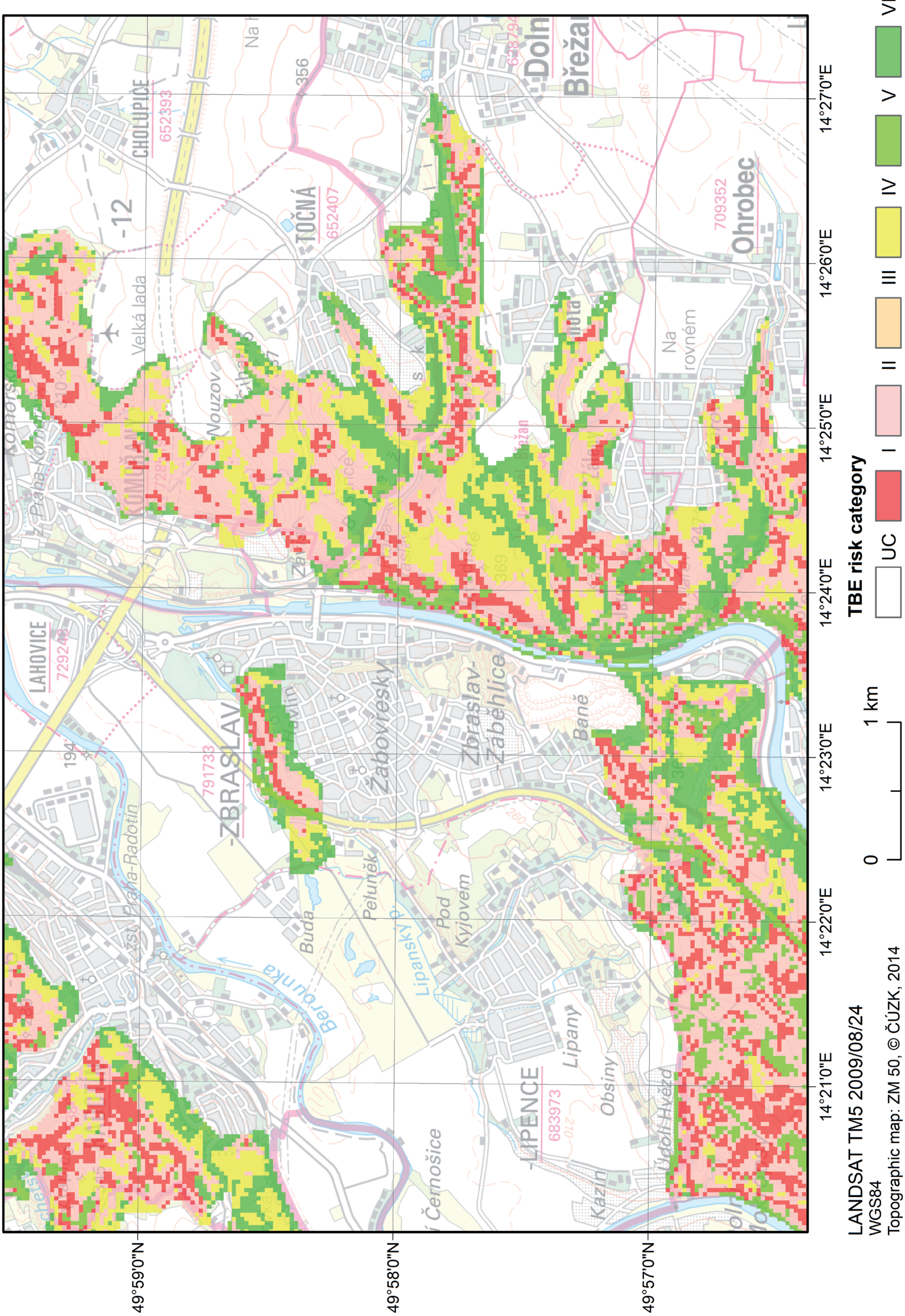

Fig. 3 TBE risk categories distribution in the model area Točná.

ACCESSIBILITY OF DIABETES CARE IN THE CZECH REPUBLIC

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ABSTRACT

Diabetes mellitus is a life-threatening disease, characterised by increased levels of sugar in the blood. In recent years, the incidence of diabetes has increased markedly and it is a lifestyle disease that is not only a problem in advanced parts of the world. The situation in the Czech Republic is much like that in other countries in the world and the prevalence of diabetes amongst Czechs is growing annually. Understandably, increasing attention will be focused on treatment options and prevention programmes that could halt the large increase in diabetes sufferers. Records held by the largest Czech health insurance company, Czech General Health Insurance (VZP) show that there are 510 diabetology clinics and 639 practising diabetologists. This article uses data collected by this health insurance company in the Czech Republic. Although the number of diabetologists has risen in recent years in the Czech Republic, one cannot simply say that there is adequate healthcare available for diabetes sufferers. There are many factors that are not sufficiently reflected in the statistics traditionally collected on the number of physicians per 100,000 inhabitants and which call for other, more comprehensive, approaches. One possible approach is the analysis provided in this article of the accessibility of diabetes care in the Czech Republic. ArcGIS software and Network Analyst extension is used to display the network of diabetes clinics in the Czech Republic and by creating a network of the access routes, the length of time required to access clinics is analysed.

Keywords: diabetes mellitus, accessibility, health, physicians, clinics, the Czech Republic

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1. Introduction

The human population is growing at an unsustainable rate. One of the signs of the improvements in the quality of human life is that hopes of living a longer life are also increasing. Innovations in healthcare and new medical approaches mean that we are living increasingly longer. Despite the major progress in medicine, diseases still exist today that result in high morbidity, invalidity and often end in the death of the patient. One such disease is diabetes mellitus, also known simply as diabetes. It is one of the most serious metabolic disorders and is also one of the most serious diseases generally, since the symptoms and complications affect all areas of medicine (Rybka 2007).

The growing number of diabetics and the ever increasing number of undiagnosed sufferers is naturally leading to increased interest in analyses of the state of the healthcare provided to diabetics. Attention should therefore be paid to diabetes in diagnosed patients and also to preventative programmes. Late diagnosis can lead to further complications, which are also significantly more costly. In this respect, the provision and accessibility of healthcare to those with diabetes is a deciding factor in issues relating to treatment. This article is concerned with the issue of diabetes healthcare and accessibility. In the sections that follow, we shall examine diabetes from an epidemiological perspective, emphasizing the increasing prevalence of this disease in the Czech Republic, and above all providing an analysis of the current network of diabetes clinics. This analysis does not consider the statistics traditionally used (the number of physicians per 100,000 inhabitants), but critically evaluates the network of diabetes clinics provided in the Czech Republic by calculating the absolute number of physicians in relation to contracted hours and by creating a network of access routes to the nearest diabetes clinic.

2. Data source and methodology

Public access to data on diabetics in the Czech Republic is largely limited by the absence of a complete register in which information on diabetes sufferers could be recorded. One of the main sources of data on the epidemiology of diabetes in the Czech Republic is the Czech Institute of Health Information and Statistics (ÚZIS). Alongside its Annual Reports on Healthcare Facilities, the Institute also publishes a yearly document entitled ‘Diabetes Care’. In this document, information can be found on the number of diabetes sufferers according to type and regional distribution, and there is also data on diabetes clinics and physicians specialising in diabetology. Information on the number of sufferers according to type of diabetes has been taken from this publication. ‘Diabetes Care’ also provides information on the number of diabetologists and the number of diabetes clinics.

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A downside of the document is that it does not provide data on the age distribution of diabetes. In the Czech Republic, data on the age distribution of diabetes is only held by the health insurance companies; however, this is not publically available. This paper uses non-public data of age structure of diabetics that were provided by the largest Czech health insurance provider, Czech General Health Insurance. For the analysis on the accessibility of diabetes care, data on diabetes clinics, physicians and their capacity was also taken from the Czech General Health Insurance. All the diabetes clinics were allocated geographical coordinates according to their address.

The aim of this article is to analyse access to outpatient diabetes care and consider the factors that shape the determinants directly impacting on of the overall accessibility of a particular kind of healthcare. The method chosen enabled us to assess accessibility using the travel time catchment areas for the various clinics, where the main outcome of the analysis was to identify areas in which access to healthcare is poor compared to the Czech average or, conversely, significantly above the Czech average. The advantage of this method is that it takes into account attributes such as physician age and gender distribution, contracted hours, patient age and gender breakdown and also commuting, thereby eliminating the consequences of using statically defined areas.

For the purposes of calculating and illustrating the travel time required to access diabetes outpatient care, we will only consider car travel. There are a number of reasons for only selecting this mode of transport. Given that we are attempting to analyse the Czech Republic as a whole, it would be extremely complicated to include public transport in the calculations and one could argue that doing so would not impact on the final results (in terms of reducing travel time), and as we have seen the Directive does not specify the mode of transport, and the quickest mode of transport appears to be the private car. Hudeček (2010) states that the private car is more flexible, saves time and represents the quickest means of travel when compared to other forms of transport. At this stage of transformation, there is significant growth in car ownership, while public transport services are seeing a decline (Marada, Hudeček 2006). We therefore propose only to consider the private car, bearing in mind the factors that may negatively impact on accessing diabetes care using this mode of transport. These factors may include, for instance, levels of car ownership and cost. Nonetheless we will consider the private car to be the ideal mode of transport for accessing outpatient diabetes clinics.

In order to analyse the travel time required to access care, we used ArcMap extension software, produced by ESRI. The data model used of the Czech road network was taken from the publically available sections of OpenStreetMap (Vaněk 2014). Network analysis is developed from Graph theory, and the road network is created out of individual restriction attributes and nodes, where the description of the various edges (type of road, number of lanes, location in relation to residential area, etc.) and their connections (nodes) is crucial to setting the average speed for that particular part of the network. The network dataset was created by allocating an average speed to each part of the road network. On the basis of the average speed setting, we calculated the average time, in minutes, taken to travel that particular section. The average time was calculated using the formula $t = s/v \times 60$, where s is the length of road in km, v is the average speed in km/h and t is the average time in minutes required to travel along that section of the road network.

Before calculating the average time, the average speed to be used must be set. According to Hudeček (2010) and Hudeček et al. (2012), average speed is affected by a range of factors including, for instance, the class and width of the road, curvature, longitudinal slope, traffic intensity, season, quality of vehicle, and so on. Given that the Directive does not specify the place and travel time accessibility (we are still concerned with average travel access time), in our road network model we shall consider only two crucial factors impacting on average speed. They are road class (motorway, trunk road, etc.) and built-up areas or urban and rural settlements (Vaněk 2014). The final calculations of average speed can be seen in Table 1.

Tab. 1 Average speed by road class and built-up area.

Road category	Average speed (km/h)	
	rural	urban
motorway	115	–
trunk road	105	65
primary road	70	35
secondary road	60	30
tertiary road	35	25
street	–	20
motorway_link	50	–
trunk_link	40	40
primary_link	40	30
secondary_link	30	20
tertiary_link	20	20

Note: The "link" road categories indicate sections linking roads with lower category roads. Source: Vaněk 2014

3. Diabetes mellitus

Diabetes mellitus is a heterogeneous group of diseases of which the main symptom is increased levels of blood glucose or hyperglycaemia (Česká diabetologická společnost 2012). This is a consequence of an absolute or relative lack of insulin. As already mentioned in the introduction, diabetes mellitus is one of the most serious diseases around today. It takes a long time for diabetes to cause pain or related complications (Svačina 2008), which is one of greatest dangers associated with this disease. Often the disease only comes to light when it is too late

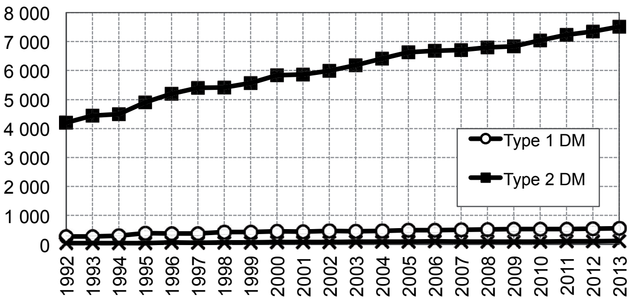

Fig. 1 Prevalence of diabetes (number of diabetics undergoing treatment per 100,000 inhabitants) in the Czech Republic, 1992–2013.
Source: ÚZIS ČR 2012, ÚZIS ČR 2013, ČSÚ 2013.

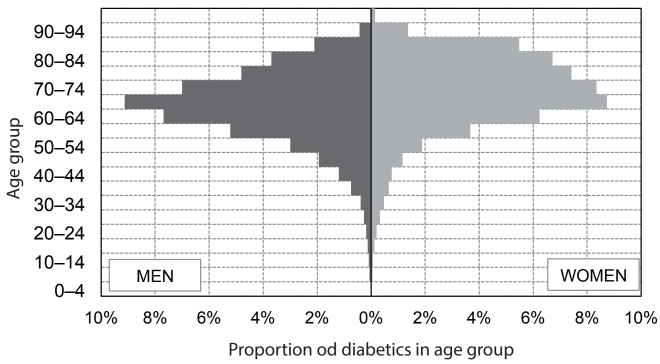

Fig. 2 Sex/age distribution of diabetics in 2013.
Source: VZP ČR 2014a.

and the sufferer already has serious health complications, which lead to a serious deterioration in the quality of life of the sufferer and which can be significantly more costly than the disease itself (Česká diabetologická společnost 2012).

Since etiologically, diabetes mellitus is a heterogeneous disease, it most often presents in two types – type 1 diabetes and type 2 diabetes (Škrha et al. 2009). Aside from these two groups, the Czech Institute of Health Information and Statistics also monitors secondary diabetes – identified in the new classification as 'other specific types of DM' (Škrha et al. 2009). The prevalence of the various types of diabetes in the Czech Republic is given in Figure 1.

Type 1 diabetes presents with the rapid destruction of beta cells in the sufferer (Rybka 2007). The destruction of beta cells leads to an absolute insulin deficiency and the sufferer thus becomes insulin-dependent. Various genetic and external factors contribute to the onset of type 1 diabetes (Škrha et al. 2009). In 2013 almost 59,000 people suffer from type 1 diabetes in the Czech Republic – which accounts for the prevalence of 560 diabetics per 100,000 inhabitants (ÚZIS ČR 2015).

The prevalence of type 2 diabetes is substantially higher than type 1 diabetes. The number of patients in the Czech Republic affected by this kind of diabetes is growing long-term and last year statistics showed that there were more than 789,000 sufferers (in 2013 the prevalence of type 2 diabetes in the Czech Republic was 7,515 per 100,000 inhabitants). Type 2 diabetes is caused by a combination of insulin resistance and insulin deficiency in the sufferer (Škrha et al. 2009). The risk factors for developing this kind of diabetes are old age and primarily obesity. Those who have type 2 diabetes typically have a higher body weight; 9 out of 10 sufferers are affected by this (Svačina, Bretšnajdrová, 2003).

In addition to these most common types of diabetes, the Institute also monitors secondary diabetes. This group of diabetics is now categorised in the new classification as 'other specific types of diabetes mellitus'. This category includes diabetes secondary to pancreatic disease or associated with endocrinopathies or Maturity Onset Diabetes of the Young (MODY) (Škrha et al. 2009). In the Czech Republic, the prevalence and numbers affected by some of these kinds of diabetes has remained minor for many years.

As already mentioned, appropriate treatment and patient responsibility are decisive issues in cases of diabetes. The incidence of diabetes is closely linked to obesity (Škrha et al. 2009). From onset, patients have to fundamentally alter their lifestyle, taking more exercise and changing their diet. Where necessary, patients are prescribed medication (peroral anti-diabetic drugs or insulin).

The increasing prevalence not only of diabetes but also of the associated complications (retinopathy, nephropathy or diabetic foot syndrome) represents a substantial financial burden for the state. The treatment of diabetes, and especially the diseases it causes, is financially onerous and one has to take account of the fact that sufferers may not be able to work full-time, which places further pressure on the state coffers. The Figure showing the sex and age distribution of diabetes in the Czech Republic in 2013 (Figure 2) shows that sufferers are concentrated in the older age groups. Bearing in mind that the number of elderly inhabitants will increase in coming years, one can assume that the number of diabetes patients will also grow. Therefore, issues relating to treatment are important and there is a need to establish how accessible treatment is to the whole population.

4. Geodemographic characteristics of the distribution of diabetes outpatient care

As the prevalence of diabetes increases, the number of diabetes clinics and the number of physicians working within them also increases. In the Czech Republic, there are currently more than 500 diabetes clinics, while the number of physicians working in them (according to capacity/contracted hours) is around 400, more than double the number in 1990 (Table 2). This data has primarily been taken from that gathered by the Czech Institute of Health Information and Statistics and published annually

Tab. 2 Number of outpatient providers of diabetes care in the Czech Republic.

Year	No. of diabetes clinics	Calculated no. of healthcare workers (PPP)
1975	238	81.8
1980	253	106.8
1985	284	145.4
1990	315	180.0
2000	409	212.7
2005	485	313.8
2010	482	346.6
2013	506	365.7

Source: ÚZIS ČR 2013, ÚZIS ČR 2000.

Tab. 3 Outpatient diabetic care providers in the Czech Republic in 2013.

District, region	Data provided by VZP ČR			
	No. of diabetes clinics	Physicians		
		No.	PPP	Average age
Prague	74	171	85.3	50.5
Středočeský	64	79	41.7	50.4
Jihočeský	26	32	19.8	52.9
Plzeňský	32	32	21.0	54.4
Karlovarský	11	11	7.2	59.4
Ústecký	39	43	23.7	55.6
Liberecký	18	18	10.4	49.0
Královéhradecký	28	25	17.0	54.8
Pardubický	29	27	13.9	52.8
Vysočina	25	23	15.3	52.9
Jihomoravský	50	62	39.9	50.0
Olomoucký	32	43	22.7	51.0
Zlínský	24	29	23.1	51.7
Moravskoslezský	58	63	44.6	50.4
CR total	510	639	385.4	51.7

Abbreviations: PPP = average calculated number of healthcare workers per contracted hours; average age of physician is calculated according to PPP, not the actual number of physicians.
Source: VZP ČR 2014b.

in its 'Diabetes Care'. However, only data from clinics that have submitted diabetes reports has been used. For a more detailed analysis, it is therefore better to use the data provided by General Czech Health Insurance, which gives greater insight into the number and distribution of diabetes clinics and physicians. In addition, General Czech Health Insurance is the largest insurance company and has contracts with almost all diabetes care providers, which is also important given the type of healthcare analysis undertaken in this article. In what follows we will disregard the fact that part of outpatient diabetes care is provided by GPs – the proportion of diabetes patients who are treated by their GP is around 20% and continually growing, according to data from the Czech Institute of Health Information and Statistics (Kocová, Šídlo 2014).

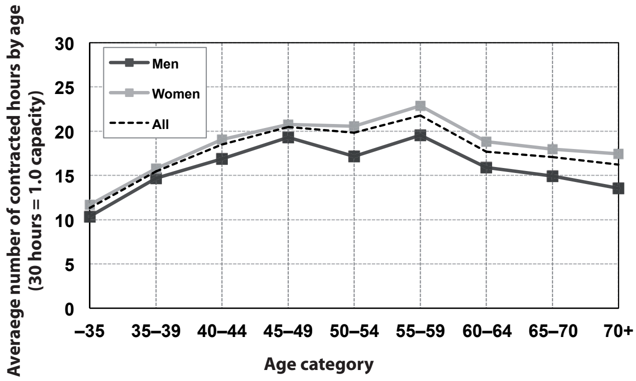

Fig. 3 Average number of contracted hours by physicians at diabetes clinics by age and sex, Czech Republic, as at 31 December 2013.
Note: For outpatient diabetologists is taken as 1.0 capacity 30 contracted hours per week.
Source: VZP ČR 2014b.

However, it is very difficult to reflect accurately this kind of healthcare since it is often recorded as part of primary care, which is paid on a capitation payment basis by the health insurance companies.

Data held by General Czech Health Insurance indicates that at the end of 2013, there were 510 outpatient diabetes clinics in the Czech Republic (Table 3) with 639 physicians. However, the number of those also working at other sites (particularly inpatient care) was almost 400 (Table 3). How should we interpret these figures – are they high or low? Is the provision of care equally available throughout the country or are there areas where access to care is worse?

In assessing area coverage, statistics on the number of physicians per 100,000 inhabitants are often used, which must then be considered in relation to the recommended number of doctors per 100,000 inhabitants, i.e. the guideline capacity number. However, we do not consider this method suitable for calculating local access to any kind of healthcare. There are a number of reasons for this, the most important being:

a) Number of physicians does not equal overall capacity of physicians – as already mentioned, particularly where outpatient clinics are concerned, physicians may work in more than one kind of place; it is therefore difficult to allocate the same weight to a physician working full-time in a diabetes clinic to one who works a fifth of the hours in the same clinic. Moreover, the average number of hours worked changes in relation to age (Figure 3), and so one can assume that changes in the age breakdown of physicians may also lead to changes in the average number of hours worked by physicians in diabetes clinics.

b) Differing populations affect the type of healthcare provided – the inhabitants may substantially affect the overall standing of the district, if they are considerably older, for instance, which in many cases means increased demand for potential care. The guideline capacity figures for that specialism should therefore more closely reflect the target population.

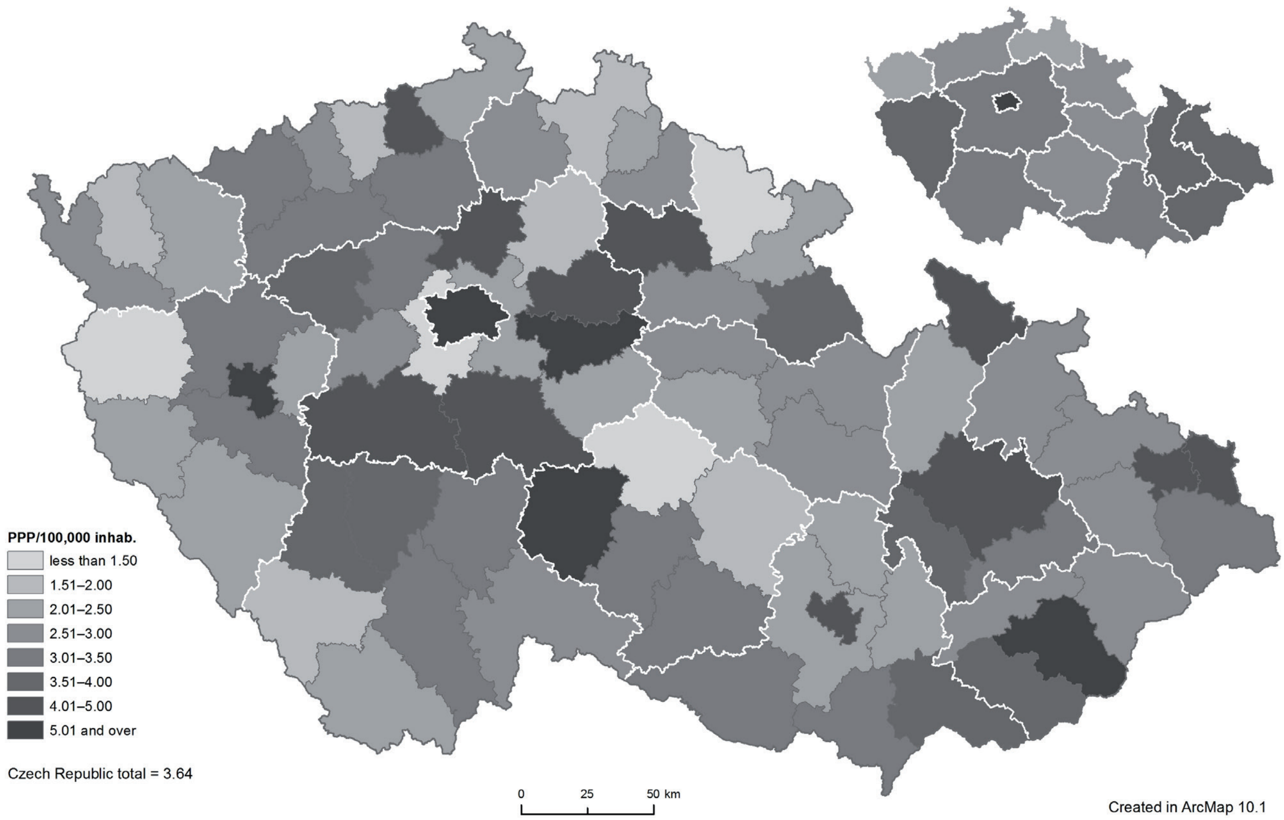

Fig. 4 Capacity of physicians providing outpatient diabetes care versus recommended number of physician posts in outpatient diabetology. Source: VZP ČR 2014b.

c) Guideline capacity figures are hard to define – there is no official table of guideline capacity figures in the Czech Republic and there is no legislation in place that would determine the required number of physicians per inhabitant in the districts and regions; however, it is possible to find documents where one can ascertain the recommended number of physicians posts required to ensure provision of outpatient care. This information is, however, often based on old data, for instance from the mid-1990s and does not fully reflect the current situation. In the digital parliamentary library, there are documents from the sessions of the Chamber of Deputies of the Czech Parliament from 1996 entitled 'Health Insurance Plan for 1997 for Czech General Health Insurance' (PS PČR 1996), part of which deals with the healthcare facility network and contains a table (table no. 15 in the document) with the recommended number of doctor's posts required for the provision of healthcare. Under diabetology (specialty 103) the figure given is 1.5 medical posts per 100 thousand inhabitants. If we use this figure in conjunction with the data provided by Czech General Health Insurance at the end of 2013 at district level, we find that the capacity of outpatient diabetologists is superseded; with the exception of four districts, all districts fulfil capacity requirements (Figure 4). It is also clear from the Figure that higher capacity levels are to be found primarily in districts in central Czech Republic, while border areas, mostly those on the German border and districts on the Czech-Moravia border have lower numbers.

d) Physician demographics – as we have already indicated in point one, physician demographics is one of the most fundamental factors that will continue to affect the availability of healthcare. It is not simply that as the age of physicians changes so does the average capacity of diabetes outpatient care, but that the gender and age of physicians changes as well. Three out of four outpatient diabetologists are women, which may be of importance given that women retire on average some years before their male counterparts and this may affect the potential future workforce. The age of physicians is more important than gender; however, in outpatient diabetology the differences are not as significant as in primary care for example (see for instance Šídlo 2010). The majority of physicians and posts are concentrated in the 40–49 year category (30% of workers and 32% of capacity). Nonetheless, it is interesting that 12% of workers (and 13% of capacity) are aged 65 and over (i.e. of pensionable age) and given the current age breakdown one can assume that this proportion will increase (Figure 5).

There are of course significant regional differences in age breakdown, apparent in the average age of a physician, which can be weighed against the contracted hours physicians work if the data is available. Such data is available from Czech General Health Insurance and so we can adopt this approach. We will therefore simplify this and identify this figure as indicating average age. There are already regions (in our case Czech districts) where this figure is high and it can be assumed – given the

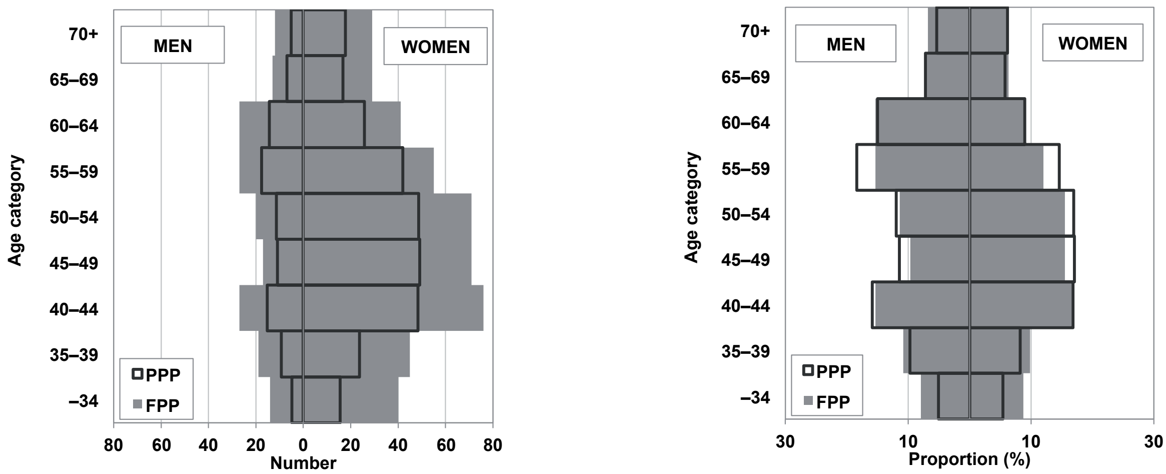

Fig. 5 Distribution of actual (FPP) and calculated number of healthcare workers (PPP) in the Czech Republic, outpatient diabetologists, as at 31 December 2013. Source: VZP ČR 2014b.

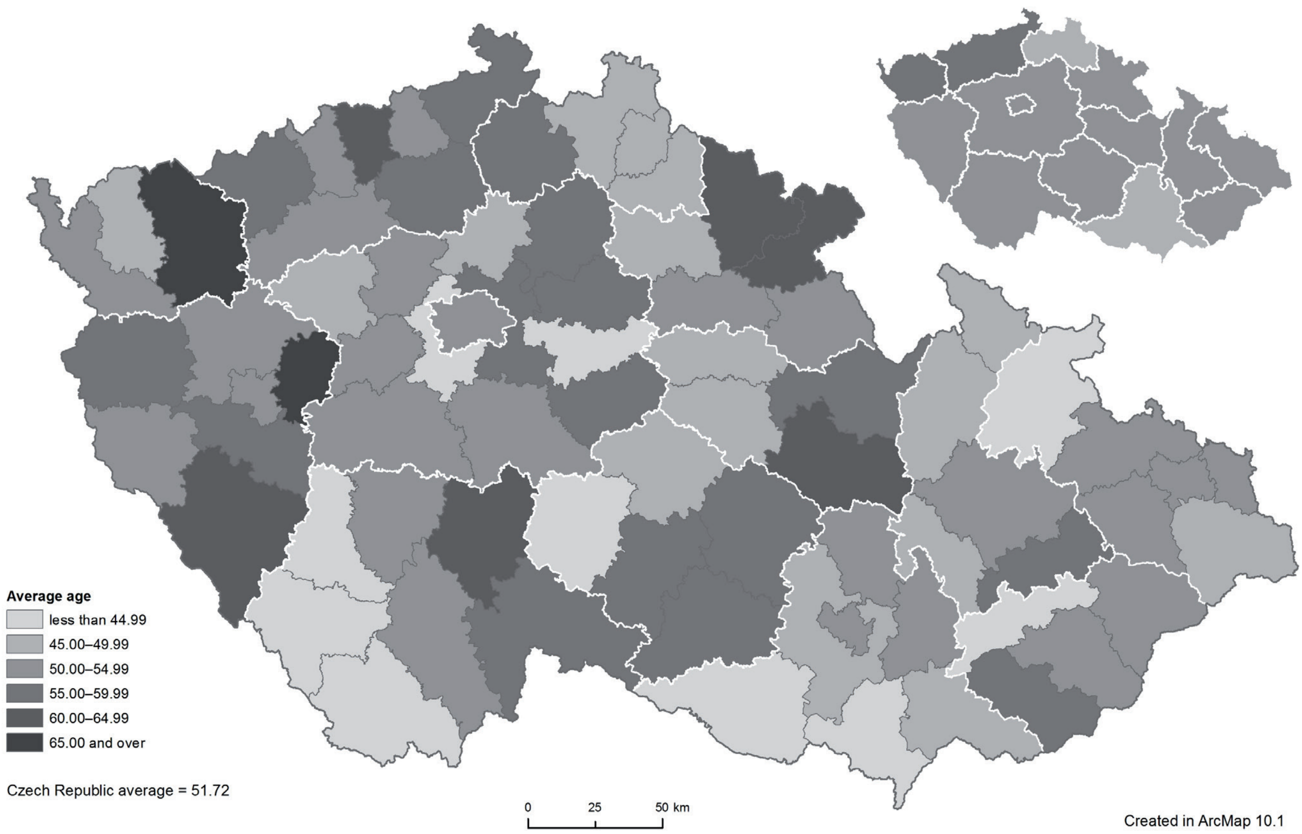

Fig. 6 Average age of outpatient diabetologists in Czech districts, as at 31 December 2013. Source: VZP ČR 2014b.

lower capacity in various districts – that in the near future access to diabetes outpatient care will worsen unless there is a deliberate generational exchange in physicians. This is particularly true in western and north western Bohemia (Figure 6).

e) Type of region – this is an equally important factor markedly impacting on the number of physicians per inhabitant, which tends to be substantially affected by administrative borders. These are frequently natural and so natural catchment areas are divided by these borders. In addition to the way in which districts are divided up, the character of the district also has a role to play. The accessibility of care will differ in urban districts, with demands differing in city regions where most people commute to work in the cities and also seek medical care there, and in peripheral areas with low population density which will have different demands for access. These factors must therefore also be taken into consideration when assessing the accessibility of healthcare.

The main factors which may varyingly affect assessments of the accessibility of medical care have been described above using statistics relating to the number of physicians per inhabitant. If we wish to seek out other methods of assessing the accessibility of medical care, which are also to be found in the legislation, then the place to look would be in the assessment of local accessibility as provided for by the Government Directive on Local and Travel Time Accessibility of Healthcare Services (307/2012 Coll.) from 29 August 2012 (Česká republika 2013). In the section on local accessibility, travel times are set out in terms of the maximum amount of time within which a patient using transport can access the required healthcare. The various kinds of healthcare are divided into inpatient and outpatient care and are then divided up into subcategories. The time limit for outpatient diabetes care is set at 45 minutes. The thinking behind this notion of local accessibility is good; however, the way it is set out in the Directive is far from complete. The Directive only stipulates that the care must be accessible within the specified travel time period but does not resolve other issues, which largely relate to the factors described above. The main inadequacy lies in the fact that the Directive does not concern itself with whether the healthcare provider works full-time or only four hours a week, but with whether a clinic exists in that area. For outpatient clinics, where people often require assistance quickly and within ordinary clinic hours, the question of capacity is important. In what follows, we shall attempt to assess the above both in relation to the Directive and also in relation to other important factors which may affect the issue of local accessibility.

5. Travel time required to access outpatient diabetes care

The Directive places diabetes care in the category of other outpatient care specialties and sets the travel time within which the diabetes clinic should be accessed at 45 minutes. However, the Directive does not specify the means of travel and so travel time is understood as the time limit during which a patient must be able to access the required care under average conditions. Average conditions can be taken to mean conditions which are not affected by unexpected events, such as accidents, heavy traffic, unfavourable weather conditions, and so forth.

To calculate the travel access time, a Network Analyst extension was used, specifically, Service Area. As the facilities, we selected diabetes clinics localised at their address. Limiting values (15, 30 and 45 mins) were used to create a total of four polygons indicating travel time to the outpatient diabetes clinics. Spatial location was used to incorporate the basic unit of settlement (ZSJ) points layer into the polygon, and then from there the number of inhabitants by distance from the diabetes clinics was calculated.

The results of the network analysis confirm that, as far as outpatient diabetes care is concerned, the regulatory conditions were met for accessing this kind of healthcare within the maximum time period (Figures 7 and 8).

Tab. 4 Number of districts and inhabitants by travel time from diabetes clinic.

Travel access time	ZSJ units		Inhabitants	
	abs.	%	abs.	%
within 15 mins	13,268	59.2	8,536,944	81.8
within 30 mins	8,314	37.1	1,770,326	17.0
within 45 mins	803,000	3.6	125,294	1.2
45 mins and more	42,000	0.2	3,996	0.0
Total	22,427	100.0	10,436,560	100.0

Source: Novák 2015.

Table 4 clearly shows that 0.04% (3,996) of inhabitants living in a total of 42 ZSJ units are unable to access diabetes care within the 45 minutes set by the Directive. A total of 81.80% of inhabitants in the Czech Republic can access their nearest diabetes clinic within 15 minutes. In cumulative terms, 98.76% of inhabitants can reach diabetes care within 30 minutes. It is therefore possible to state that in terms of travel time, outpatient diabetes care is accessible to all inhabitants in the Czech Republic. Table 4 also supports this as it clearly shows that only in some border areas is the nearest clinic further away than 45 minutes. These areas are also sparsely populated with minimal numbers of inhabitants.

Nonetheless, there is still a need to take account of factors that may significantly affect access to care but have not yet been considered in the analysis. As mentioned above, the number of physicians can play a fundamental role, as can their age and contracted hours along with the gender and age of the population and patients.

The specialist literature does not cover this kind of global approach to analysing healthcare access. Therefore, the method chosen is one which, on the basis of the catchment area and the calculation of the hypothetical number of patients per PPP (outpatient diabetologist), indicates the regions that have above or below the Czech average number of patients per full-time physician. It is therefore possible to identify the areas where access is at risk and areas where the care on offer exceeds demand.

The catchment areas were created by allocating the nearest clinic (in terms of travel time) to each district in the Czech Republic (centroid of the district). The database created was aggregated to the district in which the diabetes clinic was located. A total of 225 catchment areas were identified, or, one could say there are 225 Czech districts each with a diabetes clinic. To this database the following were then added: overall number of posts and the age and gender distribution of the inhabitants of that catchment area. The calculation of the hypothetical number of patients was then derived from an assumed calculation of the age distribution of Czech General Health Insurance patients treated in relation to the age distribution of the total number of inhabitants in the Czech Republic (Figure 8). We also obtained the percentage of diabetics by gender and age of the population of the Czech Republic. We then applied this to the age and gender distribution

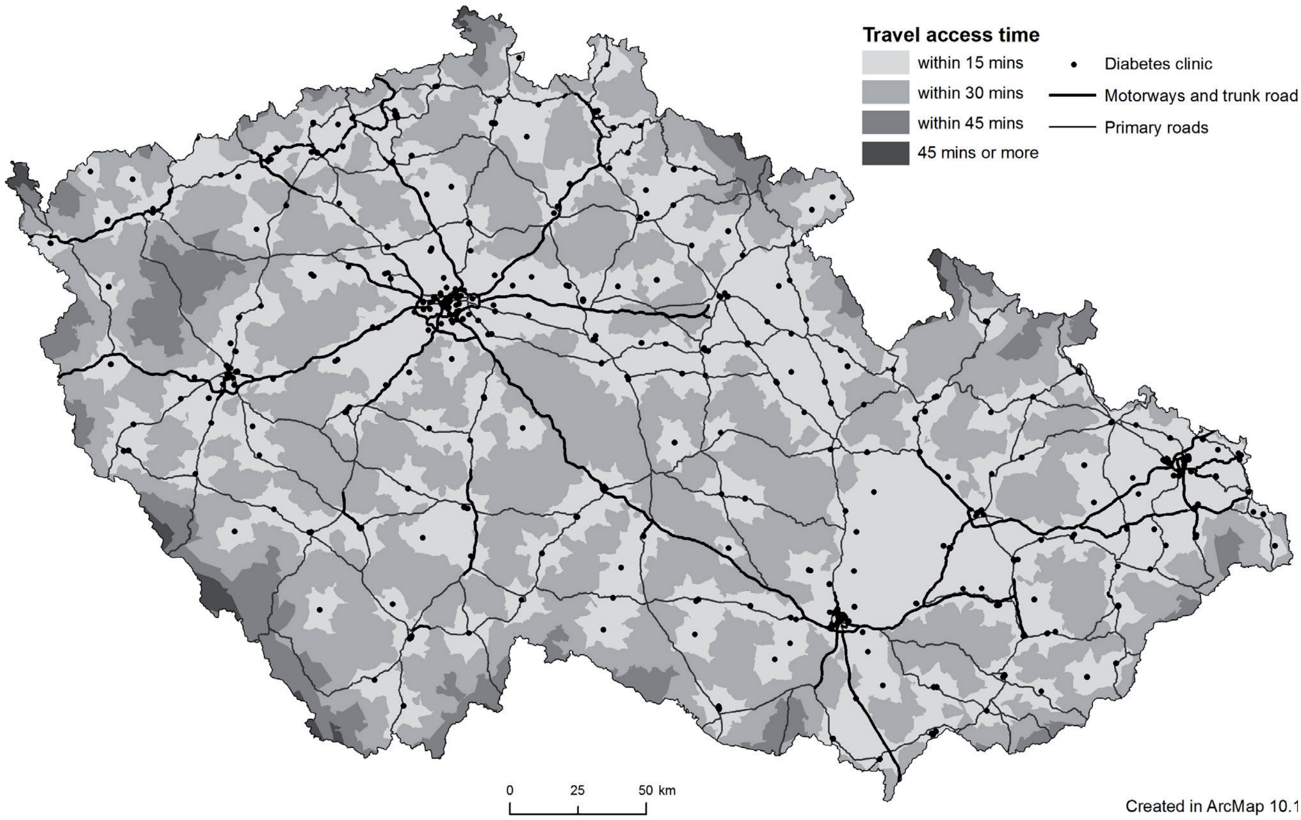

Fig. 7 Travel access time to diabetes outpatient clinics. Source: VZP ČR 2014b.

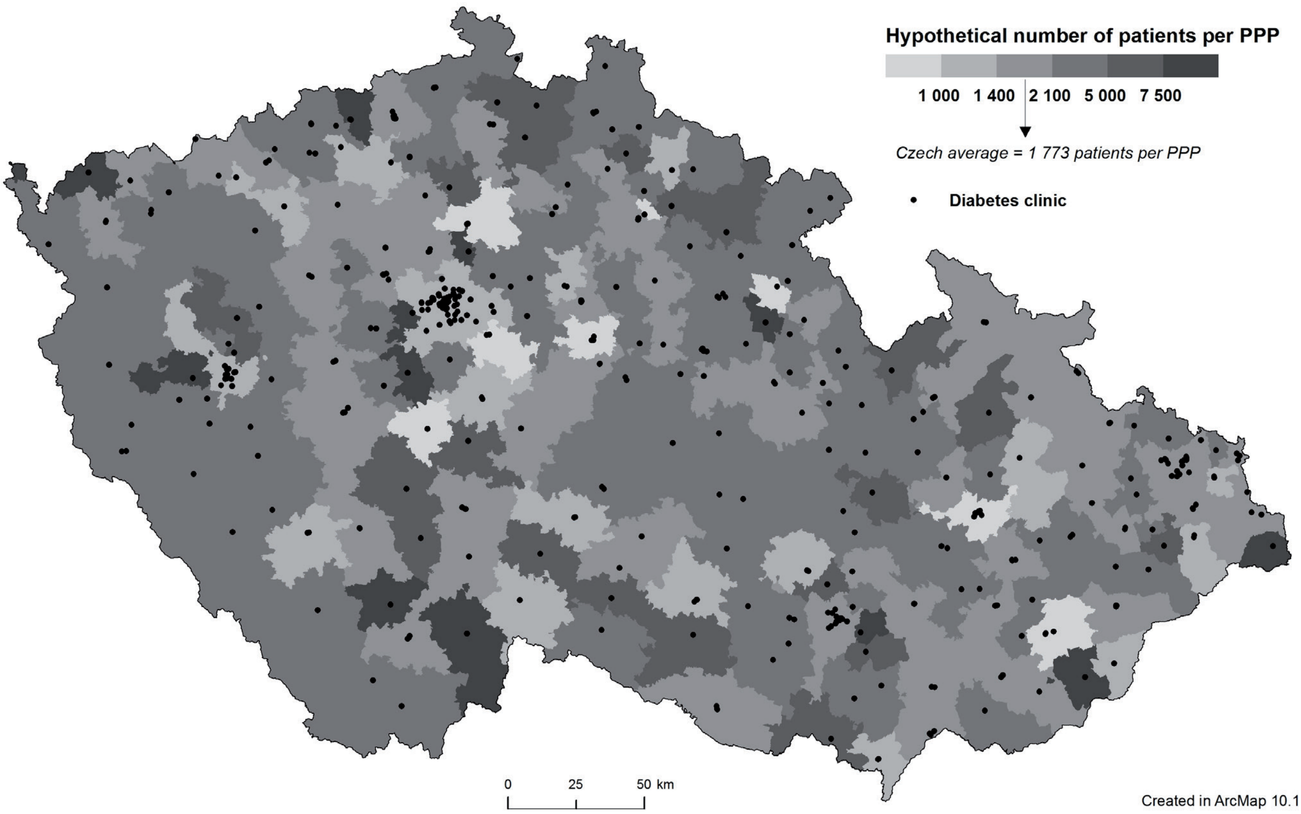

Fig. 8 Hypothetical number of patients per full-time physician per district, Czech Republic, 2013. Source: VZP ČR 2014b.

of the inhabitants of the catchment area and the resulting figure is the hypothetical number of patients in relation to the number of diabetologist posts. The results were then incorporated into the map (dasymetric method) and the accessibility of diabetes outpatient care can be displayed including the attributes that most affect access to care.

In using this method, the fact that the catchment areas were created in relation to the nearest diabetes clinic must be taken into account. The access route may not be the most natural one since the catchment area is based on the most quickly accessed roads. It could be the case that patients will seek healthcare in their local area or on the way to work. Some clinics (especially in Prague and Plzeň or areas where the patient per PPP is below average) may supplement care in areas where it is insufficient. It is therefore important to note areas that occupy larger parts of the Czech Republic and have worse access or have a higher hypothetical number of patients per PPP.

In this respect, there are three larger areas in southern, south-west and north-east Czech Republic where, compared to the Czech average (1,773 patients per 1 PPP), there is a higher hypothetical number of patients per full-time physician post. It is clear from Figure 8 that diabetes care providers are often partly concentrated in the larger cities (Prague, Brno, Ostrava and Plzeň). This, and the age distribution of physicians may, particularly in areas where there are more patients per PPP, have a great impact on future access to care. If we take into account the fact that the highest average age of physicians is to be found in western districts and we look at current accessibility, it seems likely that future access in these regions may be at risk.

6. Conclusion

Healthcare access is now becoming an increasingly relevant topic. Thus far, analysis and academic research on the location of healthcare providers and issues of access has been limited and looks only partially at the individual aspects of this issue. Existing analyses have, for example, calculated the number of physicians or posts per inhabitant or the age breakdown of physicians including differences in administrative districts. This limited kind of approach is not, however, appropriate for a comprehensive analysis and there are a number of reasons for this (see points a–e in the main text).

This example of access to outpatient diabetes care clearly shows that although travel access time corresponds to the legal requirements, that in terms of healthcare providers, it is possible to determine areas where access to outpatient diabetes care is already limited. The patient per PPP ratio is markedly disproportionate. If we look at the age and gender breakdown of outpatient diabetologists, we can see potential risks in the fact that a greater number of physicians will leave the profession, yet are unlikely to be replaced by in sufficient numbers by new, younger doctors. This risk is most marked in the west and south-west of the Czech Republic, where the average age of physicians is highest. The analysis demonstrated the weaknesses of the current legislative measures of accessibility of outpatient health care in Czech Republic.

Abbreviations

FPP – Actual number of healthcare workers (headcount)
PPP – Calculated number of healthcare workers (posts)
ÚZIS – Czech Institute of Health Information and Statistics
VZP – Czech General Health Insurance

Acknowledgements

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RESUMÉ

Dostupnost diabetologické péče v České republice

Diabetes mellitus neboli cukrovka je nebezpečné onemocnění charakteristické zvýšenou hladinou cukru v krvi. Četnost výskytu diabetu v posledních letech výrazně narůstá a diabetes, jakožto jedna z civilizačních chorob, již není problémem pouze vyspělé části světa. Situace v Česku je obdobná jako v jiných zemích světa a prevalence diabetu mezi českou populací každoročně narůstá. Stále větší pozornost se tak bude pochopitelně upírat k možnostem léčby a k programům prevence, které by tak masivní nárůst nemocných mohly zmírnit. Největší česká zdravotní pojišťovna, Všeobecná zdravotní pojišťovna ČR, eviduje v Česku 510 diabetologických pracovišť a 639 lékařů-diabetologů. A právě data od této největší české zdravotní pojišťovny byla v tomto článku využita. Přestože počet diabetologů v Česku za poslední roky narostl, nelze jednoduše říci, zda je zdravotní péče o nemocné cukrovkou dostatečně zajištěna. Je zde mnoho faktorů, které tradiční ukazatel počet lékařů na 1000 obyvatel činí nedostatečným a ospravedlňují spíše jiné, komplexnější postupy. Jedním z možných postupů je i předkládaná analýza dostupnosti diabetologické péče v Česku. Pomocí softwaru ArcGIS a jeho nadstavbové extenze Network Analyst je v článku zobrazena vizualizace sítě diabetologických zdravotních zařízení v Česku a pomocí vytvoření dojezdových areálů je analyzována časová dostupnost jednotlivých ambulancí.

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REGION IN ITS COMPLEXITY: A DISCUSSION ON CONSTRUCTIVIST APPROACHES

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ABSTRACT

The contemporary regional geography paradigm is characterized by emphasizing the socially constructed nature of regions. However, the discussion on the conceptualization of region is very rich, it does not reach universal conclusion. Such a universal conceptualization is probably neither possible nor desirable. This paper aims to contribute to the ongoing discussion. It examines the various approaches towards region with special focus on the conceptualization of the institutionalization of the region based on the heuristic literature review and it attempts to propose more complex (but not ultimate) theoretical conceptualization of region that should enable to bridge the duality of region; addressed as an "animate", constantly changing, phenomenon which also makes it a resource for regional actors to meet their particular goals, one that people may perceive and feel attached to while further mediating their images thereof. The paper builds upon the Lefebvre's theory of the societal production of space and the Paasi's theory of the institutionalization of region and presents the idea of the societal production of region. It argues that any complex approach to region must incorporate three levels of region: "given" (practice of region), "made" (representation of region) and "perceived" (idea of region). Better understanding of the concept of region is still more necessary and relevant especially due to the increasing pressure on the applicability of regional research. Thus, the paper suggests the closer insight into the interrelation of three mentioned levels of region is crucial from the view of the contemporary state of art. This text is also published in Czech as the official on-line supplement of the article. The Czech version can be downloaded here: http://www.aucgeographica.cz/index.php/AUC_Geographica/article/view/159.

Keywords: new regionalism, region, regional identity, institutionalization of region, societal production of region

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1. Introduction

The contemporary regional geography paradigm (e.g. Claval 2007) is characterized by emphasizing the socially constructed nature of regions (e.g. MacLeod, Jones 2007; Paasi 2010; Jonas 2012; Jones, Woods 2013; Chromý et al. 2014; Harrison, Grove 2014; Vainikka 2015). The "constructivist" approaches can be traced back to the 1980s. Their main stream of the 1990s was primarily focused on the economic perspective of the region. Despite criticism, the economic and political focus of most studies perpetuates itself even in the contemporary discourse. Although, the main focus is centered on regional actors and their networks that are responsible for the (re)production of regions (Amin 2004; Allen, Cochrane 2007). Region and its delimitation are thus understood as constructed by those regional actor networks that make decisions about the purpose, the territory, symbols, etc. of either an emerging or a reconstituted region. Therefore, region is a (political) process (e.g. Pred 1984; Paasi 1986).

However, the discussion on the conceptualization of region is very rich, it does not reach universal conclusion. Such a universal conceptualization is probably neither possible nor desirable. This paper aims to contribute to the ongoing discussion. It examines the various approaches toward region and its delimitation with special focus on the conceptualization of the institutionalization of region based on the heuristic literature review and it attempts to propose more complex (but not ultimate) theoretical conceptualization of region that should enable to bridge the duality of region; addressed as an "animate", constantly changing, phenomenon which also makes it a resource for regional actors to meet their particular goals, one that people may perceive and feel attached to while further mediating their images thereof. The text is structured on the heuristic discussion of world literature and the reflection thereof in the Czech academic environment. The discussion leads to the proposal of complex conceptualization based on societal production of region.

2. New regionalism in the world literature

The regional geography paradigm is strongly influenced by the orthodoxy of the resurgence of regions (Keating 1998; Johansson 1999; Harrison, Grove 2014) in the last few decades. As stated by Fawn (2009: 5): "region, regionalism and regionalization matter". However, none of these is new to geography. Region has always been a fundamental phenomenon examined in geographical research (e.g. Vidal de la Blache 1994;

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Semian, M. (2016):
Region in its complexity: A discussion on constructivist approaches
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Hartshorne 1939; Gilbert 1960; Grigg 1965; Haggett 1965; Hägerstrand 1970; Urry 1981; Claval 1987). The origin of (modern) regionalism is usually connected with the rise of the state system after WWI, however, its patterns can be studied even further back in history (Fawcett 1996; Semian 2015). From a certain perspective, "the regionalized world has always featured in human history" (Fawn 2009: 6–7).

The revitalized interest in regions can be dated back to the 1970s. Being strongly intertwined with the reaction to strictly nomothetic approaches in geography, it strives to replace them with more humanistic ones, stressing the importance of human actions in the reproduction of geographical space and its organization. Place is produced and space is structured through human perception (Tuan 1990). Thus, every place has an individual character. Actually, this idea is based on Heidegger's conception (cf. place as lived and experienced space; Heidegger 1971: 152). A special stream of regional conceptualization can be identified within humanistic approaches. It deals with vernacular regions and define region as a product of the spatial perception of average people (Jordan 1978: 293). This stream was popular especially in North American literature of the 1970s and 1980s (e.g. Meining 1972; Jordan 1978; Zelinsky 1980), but it perpetuates until today (e.g. Reginster, Edwards 2001; Liesch et al. 2015; Vukosav, Fuerst-Bjeliš 2016). Nevertheless, humanistic geographers are more concerned with personal experience and an individual's position within a community, and less with the examination of communities as a complex. Thus, place has a highly personal character and any particular part of space may have different meanings for different people. In distinction therefrom, the concept of region has a collective character (Paasi 1986). Therefore, rethinking the region must equally be seen through the prism of the "cultural turn" and "spatial turn" in social science (Claval 1998; Thrift 2006) and, later, also through the "institutional turn" in economic geography (Jones, Woods 2013; Tomaney 2014) as an attempt to adapt the fundamental concepts to the changes of the forms of the society's geographical organization (Hampl 2002) caused by general development processes in society, namely globalization and transition to postindustrial society. Over time, region came to be understood more or less as a static category that was used by a majority of scholars to sort data and information (Klemenčič 2005). Without any deeper discussion region was often taken as given. The static and given category has nonetheless been brought into question and region has become a subject of geographical research.

The attempts to adapt the conceptualization of region to the dynamic societal changes of the last three decades have resulted into pluralistic approaches toward the concept itself and are regularly criticized for exaggerated constructivism and over-theorizing (Martin 2001; Barnett 2004) on the one hand, and for a vague theoretical embeddedness on the other (Schmitt-Egner 2002), namely in terms of conceptual definition of the concept of the region itself (Harrison, Grove 2014). For many authors region has become a concept hard to grasp and is often labelled as elusive (Keating 1998), chaotic (Lovering 1999) or enigmatic (MacLeod, Jones 2007). Nevertheless, rethinking the region as a social construct (Thrift 1983; Pred 1984; Paasi 1986) can be seen as the central point of the emergence of these discussions. This conceptualization became dominant in the new regionalist discourse of the 1990s (Keating 1998) wherein the region is often canonized as a development and governance tool in the hands of economists and policy-makers (Fawn 2009; Jones, Woods 2013; Semian, Chromý 2014). This was most noticeably the case of the vision of "Europe of Regions" promoted by the European Union (Johansson 1999). Regions were taken for basic economic units with a potential to erode the integrity of national states as an essential factor for further economic and political integration (Harrison, Grove 2014). The same (economic) understanding of the new regionalism can be identified in the United States (Jonas, Pincetl 2006; Hamin, Marcucci 2008), even though with greater emphasis on city or metropolitan regions, and is well documented in other literature (Thompson 2000; Frost 2008; Paül, Haslam McKenzie 2015).

The economy-based understanding of region tended to be unsatisfactory and somewhat narrowing the complexity of the fundamental geographical concept. It is in particular contradictory to the very idea of rethinking the concept of region. Such a narrow conceptualization is often criticized for being strictly pragmatic (Hampl 2002) and ideologically reproduced (Lovering 1999), lacking any critical reflection of the social construct model which is regularly taken as given without any further theorization (Paasi 2010). The economical conceptualization generally lacks any political and power-related perspective: who constructs and reproduces the region and why (Frisvoll, Rye 2009; Paasi 2010; Jonas 2012; Harrison, Grove 2014), but also any cultural perspective: how the inhabitants perceive various regions, how they orient themselves among them and whether they can feel some attachment to them (Semian 2012; Antonsich, Holland 2014).

Since the late 1990s, rethinking the region as relational may have been considered a parallel stream of reflection but in many ways it has been a complementary paradigm for the aforementioned constructivist conceptualization of region (Johnson et al. 2011). Central to these discussion are, among others, works by Massey (1994), Allen et al. (1998) and Amin (2004). Nevertheless, the idea of relational perspective on region is not new at all. As Jonas (2012: 264) puts it: "in fact, several distinctive strands of relational thinking about regions have emerged from the work of radical human geographers and social theorists in the 1970s and early 1980s (Jonas 1988; Pudup 1988; Sayer 1989)". The idea of spatial organization according to relations and social or actor networks is crucial to these approaches. However, the relations and networks do not necessarily have to be bounded neither territorially nor in scale. They are increasingly dynamic and spatially diverse. Yet truly unbounded, territorially independent regions are still somewhat theoretical imagination (Allen et al. 1998) and their discovery is not absolutely necessary for further progress in theorization of the regional concept (Jonas 2013). Relational approaches emphasizing the idea of the space of flows and actor networks may be identified as crucial in contemporary discussions about regional development of fuzzy-bounded soft spaces (e.g. Deas 2006; Allmendinger, Haughton 2010) and city-regions (e.g. Harding et al. 2006; Lloyd, Peel 2006).

One can witness further theorization of the conceptualization of region in the new millennium which responds to the above-mentioned criticism. While political power relationships have acquired a dominant position, the regional economic framework usually continues to serve as a context for the regional development issue (Amin 2004). The rethinking of region is connected with multi-level governance and metagovernance (Jessop 2004). Owing to the different quality of research interest in regions, some authors refer to such paradigm as "new new regionalism" (Ballinger 2007) or "new regionalism vol. 2" (Harrison, Grove 2014). Such approaches see region as a somewhat contested unit that does not necessarily have to be bounded in space. However, this does not mean that regions cannot be territorially recognizable. Usually, general localization is widely accepted but the specific delimitation may differ according to the purpose of each particular region and its individual perception. Allen, Cochrane (2007) designate regional plurality as regional assemblage, addressing region as an assemblage of actor-networks with an influence on decision-making processes within a particular region. Regional actors do not necessarily have to be embedded in that region and their relational impact may reach beyond any territorial fixity. That is where the authors think beyond simple overlapping and intersecting of various regional initiatives. Thus, region possesses the intermediary character in all three scale modalities (size, level and function; cf. Howitt 1998) that integrates a region into the system and therefore it cannot be approached as a single piece of "the Russian doll" (Allen et al. 1998).

3. Constructed nature of region

As mentioned above, the contemporary paradigm is strongly influenced by the orthodoxy of the resurgence of region and the so-called new regionalism, or rather by one of its more recent variation. Nevertheless, this does not mean that the other conceptual approaches are not present. Contemporary geographical research basically distinguishes three modalities of understanding regions:

(1) Probably the most common approach to region in the contemporary science is taking region as given. However, such regions, too, are constructed and researchers tend to use them merely as a category for sorting data and information (Klemenčič 2005). Within this approach to region, various scopes of regions can be identified, ranging from natural (delimited and based on natural features) to ad hoc ones (established for a particular purpose). Unfortunately, instead of further scrutinizing the concept of region, most authors use it as a statistical or institutional unit, i.e. as an analytical tool. As stated by Paasi (2010: 2297), this approach goes on gaining strength, as it is well linked to applied research wherein region is not the primary subject of the study.

(2) (a) The traditional geographical approach sees region as a construct of geographical research, searching for "a relatively autonomous complex of mutually intertwined and qualitatively hybrid components of environment" (Hampl 2002: 334). Regions are thus bounded, contiguous subdivisions of broader units (Paasi 2010). Traditional vernacular regions can be counted among them (e.g. Jordan 1978; Zelinsky 1980). (b) Additionally, the synthesizing scholar quest for geographical organization can also be ranked into this category. The core of these approaches is, generally speaking, geographical organization modeling according to spatial patterns of various social processes. In this sense, they are still attached to the former ones, since they look for functional regions through the integrity of socio-economic relations (Hampl, Marada 2015).

(3) The most recent understanding of region puts the concept of region in relation to social discourse (Paasi 2010). Region is not only influenced by, but also influences the reproduction of socio-economic, cultural, political and power relations in space. Such relational understanding conceptualizes the region as a product of networks, interactions and articulations of live "everyday" connections (Allen et al. 1998) and thus can emerge across the imposed constructed boundaries, and even across scales.

This division allows to conclude that region is a social construction. It can be constructed by scholars in an attempt to identify and comprehend the spatial organization on Earth's surface. It is a result of external frameworks and internal conditionality. In view thereof, a region may be constructed by various actors in an attempt to enforce their interests or demonstrate their power. This particular part varies a lot. By these terms one can understand: (a) a simple statistical regionalization whose main purpose is to compare diverse parts of the world and measure the differences; (b) administrative regionalization aimed at decentralizing the existing political power in search for better governance; but also (c) activities of regional actors advancing (by way of founding ad hoc regions) their vision of development trajectories (Semian et al. 2016). A region may also be constructed by citizens through their "everyday" activities, relations and perception of the enveloping information of "regional" character (Sørensen 2008).

Region as a social construction is reproduced as a historically contingent process (Pred 1984; Wilson 2007), no matter whether it is endowed with a long historical narrative path or the result of a recent ad hoc initiative. Thus, region is a process. It is changeable in space and time. Region is constructed (formed), constantly reproduced through the process of institutionalization and may disappear some day through deinstutionalization (Paasi 1986; Raagmaa 2002; Zimmerbauer, Paasi 2013). It means that every region is perpetually in a state of being formed and reproduced through both material and symbolic processes (Granier 2007). Once a region acquires a place in the regional system, it becomes part of the reproductive and transformative process of society. Regions thus influence and are simultaneously influenced by political, economic, social and cultural processes, i.e. the basic mechanisms of all societal changes. Paasi (1986) provides a guideline suggesting to comprehend the process of "becoming" as that of regional institutionalization. Despite having been contested by many scholars, including Paasi himself (cf. e.g. Frisvoll, Rye 2009; Paasi 2010; Riukulehto 2015; Vainikka 2015), this framework remains to be a very useful tool to deconstruct a region, both theoretically and methodologically, when conducting research. Paasi (1986) distinguishes four phases of the process of institutionalization of regions: (1) the assumption of territorial shape of a region; (2) the development of symbolic shape of a region; (3) the development of regional institutions (institutional shape); (4) the establishment of region as part of a regional system.

The order of these phases is purely theoretical. In practice, these phases can take place simultaneously or in a different order varying according to different purposes (types) of region (cf. e.g. Kašková, Chromý 2014). However, each phase and its reproduction mutually influence the reproduction of all other phases (e.g. Messely et al. 2014). Apart from that, some scholars try to establish some chronological order among the four phases; e.g. Zimmerbauer (2011) sees as pivotal the necessity for the emergence of territorial and symbolic shapes. These should provide a basis for further development of regional institutions, and, potentially, clear the way for regions to get embedded in a regional system.

Nevertheless, there are other modalities showing how to approach the process of institutionalization of region both theoretically and methodologically. The understanding of region as an institution can be dated back to Paul Vidal de la Blache (1994: 26), who argues that region is substantially shaped by human action. In his paper on "American West", Donald Meining (1972: 161) suggests that regional research should focus on four regional features: (1) population; (2) circulation; (3) political areas; and (4) culture. According to Meining, region must be studied in all its complexity, including not only its socio-cultural features, but also all the relations within and between regions. However, under the term "political areas" he understood merely the basic administrative territories that can be replaced, in a more recent perspective, with a region defined as a contested arena of political decisions.

Other authors, too, have listed criteria crucial for the emergence of region. Some of them approach the region from a strictly socio-cultural position. Bill Lancaster (2007: 24) regards common space, language, culture, economy, political movements, traditions, and relationship to the nation-state as key unifiers of a region. His list represents a typical example of scrutinizing region as a community which has revived the humanistic tradition in geography (Tuan 1990). In the same publication, Charles Phythian-Adams elaborates the crucial regional features in more depth (Phythian-Adams 2007: 8–9), listing seven key features for defining a regional community: (1) concentration of population; (2) hierarchical structure of settlement; (3) intra-dependence of region; (4) self-identifying, but interlocking neighborhoods; (5) regional economic or political interest counterweight against national power structures; (6) a demographic continuity (of indigenous families); and (7) a regional sense of belonging together.

Likewise, scientists based in different (non-Anglophone) scholarly traditions deconstruct region in very similar ways (Riukulehto 2015). Borders, landscape, language, group solidarity, and administrative autonomy are the main criteria defining region mentioned by Desiderio Fernández Manjón (2010: 68–69) based on José Ortega y Gasset's assertion that any human being is defined by her or his circumstances (as cited in Riukulehto 2015: 10). Even though the criteria listed above differ from one study to another, a closer look reveals many significant intersections among the aforementioned concepts.

4. Reflection of constructivist approaches in the Czech literature

Similarly to the world literature, region is often reduced to a mere category or context for the study of various phenomena in Czech geographical literature (e.g. Kůsová 2013; Novotná et al. 2013; Ženka, Pavlínek 2013). In such researches, region is scrutinized as a given, unchangeable and static entity and its nature is not further theorized.

Moreover, the strong and persistent influence of nomothetic approaches to a region can be witnessed in Czech geographical literature. The nomothetic delimitation and evaluation of regions represents one of the most important branches of contemporary regional research in Czechia (e.g. Halás, Klapka 2010; Kraft et al. 2014; Hampl, Marada 2015). It is based on the construction of regions according to various relations in space (e.g. commuting, transport, etc.). This kind of regional studies has a long tradition in Czech science and its roots can be traced back to the doyen of Czech human geography Jaromír Korčák, who broadly discussed the possibility of delimitation of functional regions. Approaching them from the cultural-geographical perspective, he called them *přirozené krajiny* [organic landscapes] (Korčák 1934: 421). Korčák's work triggered a diversion to the nomothetic exploration of the concept of region in Czech geographic literature although Korčák (1934: 433) himself admitted that the regions he defined were very similar to those delimited by Václav Dědina. Dědina, who was influenced by Paul Vidal de la Blache, defined regions with the use of the "basin and valley concentration" method (Dědina 1921 as cited in Korčák 1934: 433).

Despite the aforementioned, approaches of new regionalism gained strength in Czech regional research in the last decades. Their central point is the conceptualization of region as a historically contingent process. However, this concept has been introduced already 30 years ago, the publication of Pavel Chromý's the paper titled *Formování regionální identity: nezbytná součást geografických výzkumů* [Formation of regional identity: A necessary part of geographical research] (2003) can be considered a milestone in the application of this concept in the Czech academic environment. The author de facto introduces the Anssi Paasi's concept of the institutionalization of region (Paasi 1986) into the Czech literature and milieu. Many other papers, books and theses using this conceptual background or methodological framework have been published ever since. Most Czech (and Slovak) authors focus on the analysis of the inhabitants-territory relationship and its measuring (Nikischer 2013; Bucher, Ištoková 2015) or on the study thereof in a specific context such as second housing (Fialová et al. 2010) and peripheral regions (Chromý, Janů 2003; Chromý, Skála 2010). Special attention is also paid to its differentiation based on the continuity of socio-cultural development, especially in the context of areas affected by the expulsion of Czech Germans after WWII (Osoba 2008; Chromý et al. 2009; Šerý 2014). In connection with this recently introduced conceptual framework, many researches deal with individual partial shapes of region and their imprints in people's consciousness. These comprise in particular names, symbols and logos (Šifta, Chromý 2014; Semian 2016a; Semian et al. 2016), mediated regional images (Kučerová et al. 2016), regional institutions (Kašková, Chromý 2014; Chromý et al. 2014), or people's perception of historical borders (Siwek, Bogdová 2007; Šerý, Šimáček 2012). It must be said that many of these works incorporate Paasi's concept uncritically. They fail to further elaborate or critically discuss it in view of more recent regional conceptualizations. I can claim with a bit of a hyperbole that numerous works keep scrutinizing regions as a mere category which serves as a context for the study of various phenomena, namely "regional identity", i.e. an articulated emotional relationship to a region. The region is either poorly defined or reduced to a specific unit in these researches (e.g. Nikischer 2013; Štefánková, Drbohlav 2014; Bucher, Ištoková 2015; Ryšavý 2015).

5. Societal production of region

It is clear, the further theorization of the concept of region is necessary. From above mentioned, one can conclude many approaches to the concept of region have very similar bases building on the understanding of the region as a process, as a construct in flux. The region thus defined is usually addressed within three mutually interdependent dimensions: (1) *given*: the way "regional assets" are present and organized; (2) *made*: the way "regional assets" are produced and mediated by various regional actors having different goals; and (3) *perceived*: the way inhabitants perceive "regional assets" and establish bonds to a region. Here, the term "regional assets" is used to encompass all tangible and intangible, environmental, natural, cultural, political, economic and historic features and components of any particular region. It is also clear that an institutionalized region is something more than a mere sum of regional features (Nay 1997). Regional identity is thus one of the key phenomena in the study of regions. "Obviously, regions can be identified and characterized by the use of regional identities" (Riukulehto 2013: 45). This implies that not only regional actors, but also regional community are crucial for the research of regions.

One can find the link to Lefebvre's constructivist framework of the societal production of space (Lefebvre 1976; 1991; cf. Brenner, Elden 2009) which can be adapted to the societal production of region. Thus, region can be approached as a product of the interaction between three distinct layers:

(1) Practice of region – the way people interact with their surrounding environment in their everyday life. This interaction reproduces the region as a relation and lived space. The everyday practices are influenced by the existing regional representations and they also produce information which affects human perception.

(2) (Re)presentation of region – the way a region is mediated by various groups of actors with various goals and through various media. This means that information is produced and mediated the way someone would like others to perceive the region. This layer involves generating mediated images, but also various constrains that can be imposed on everyday life depending on the level of institutionalization.

(3) Idea of region – the way people perceive a region as a spatial entity. Their perception is influenced by many aspects, both outer and inner, wherein the quality and quantity of information are very important. Such perception also has an influence on and is influenced by everyday activity of each person.

This interaction is reproducible in time and space as all the three layers undergo perpetual changes. All the three

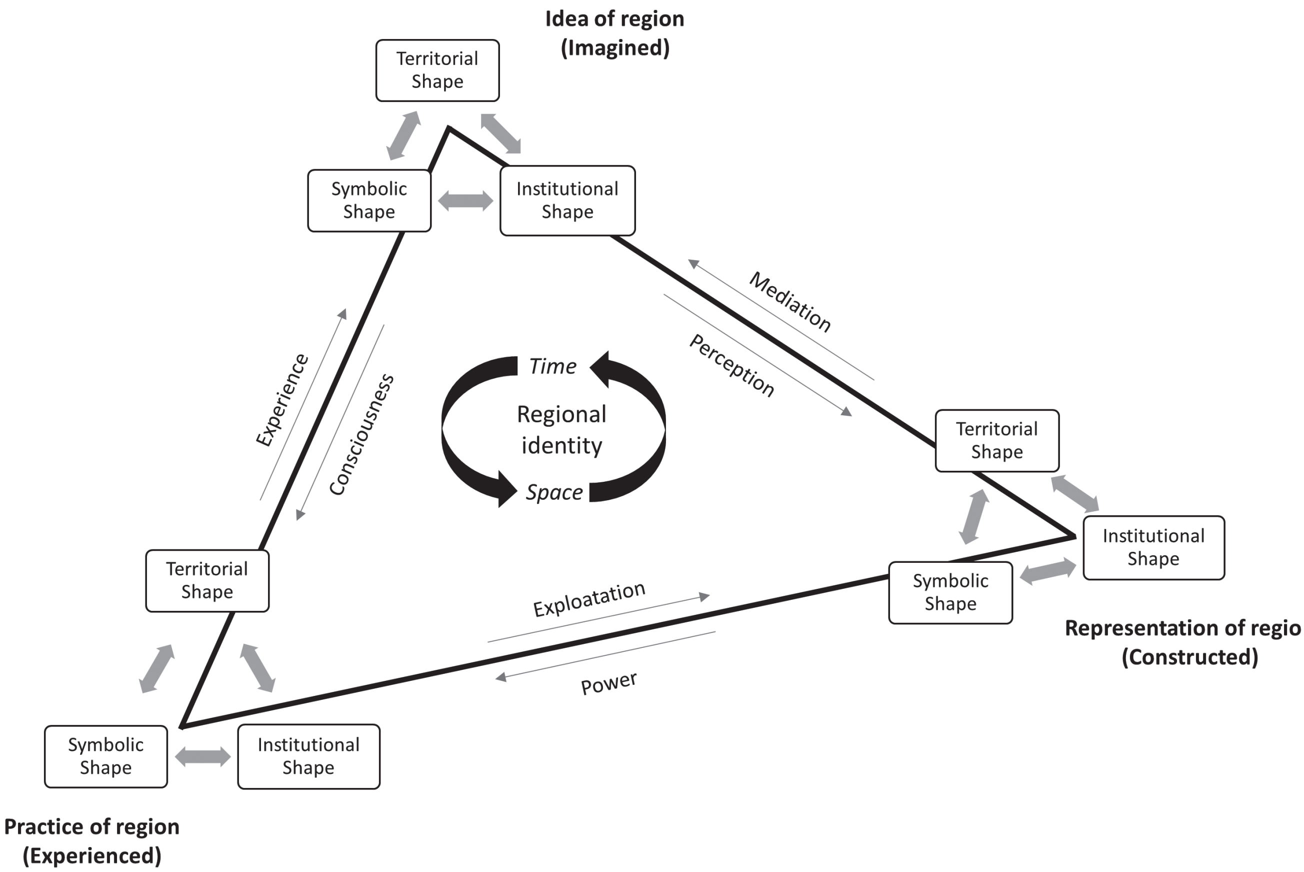

Fig. 1 Societal production of region. Source: author's own framework based on Lefebvre 1976; 1991; Paasi 1986.

components are in a constant interaction and mutually influence one another during the process of reproduction. And so, region is a social construct that is reproduced through, de facto, constant teetering at the interface of these layers. Although it can exist lacking one or even two of these layers, it becomes fully developed (institutionalized) only through the blending of all three of them. A fully developed region is more resistant to disappearance. Furthermore, for analytical purposes it is possible to interlace this framework with the three Paasi's shapes of region: territorial, symbolic and institutional. The fourth shape, termed as "regional embeddedness", is de facto substituted by the interaction of those three layers which gives the identity to the region (Fig. 1).

The proposed concept integrates functional, normative and perceived regionalization in a complementary way. The partial components have been widely discussed, yet their mutual relation has been at the margin of regional scholars' interest. The study of this relation is necessary in order to understand the process of the formation and reproduction of region as well as to explore the general idea of any particular region in question.

6. Conclusion

There is a plentiful complex of regional conceptualization in contemporary geographical literature. Nevertheless, many of these concepts explain the process of regional formation and reproduction only to a limited extent. Any complex approach to region must incorporate three levels of region: "given" (practice of region), "made" (representation of region) and "perceived" (idea of region). It is possible to explore the general idea of region by way of studying these levels. The change of the society's value orientation comes along with the general changes of society. Thus, the meaning, the importance and the gist of the need of "moorage" are also changing and this change brings into question human relation to place and region (the sense of belonging). Therefore, the third, perceived dimension has been gaining both strength and importance.

With the use of the inhabitants' regional consciousness and their sense of belonging it becomes possible to introduce some order and clarity into the plurality of regional manifestations. Thus, the complementarity of images of regions gets synthesized through people's perception in the collective consciousness. It is important to point out that such synthesized region will not be universal but shared, representing the most common image of a produced, mediated and perceived region. Moreover, regions delimited according to the general idea appear to be widely accepted by the public, and thus, they have a potential to become a unifier that builds the community, ties it together and stimulate the inhabitants' willingness to collaborate in regional development and social life. Or, at least it represents a good trademark suitable for the regional promotion often addressed by regional actors.

Region is truly an intricate concept. Thus, this paper should be seen as a contribution to the never-ending discussion on the conceptualization of region and not as an attempt to come up with a universal answer. Such a universal conceptualization is neither desirable nor possible. Nevertheless, a better understanding of the concept of region is still more necessary and relevant especially due to the increasing pressure on the applicability of regional research (regional development, tourism management, etc.). Therefore, the discussion on region should focus more on the understanding of the process of formation and reproduction of region instead of a mere delimitation and evaluation of regions. Further, closer insight into the interrelation of above mentioned three levels of region seems to be crucial from the view of the contemporary state of art.

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RESUMÉ

Region ve své komplexitě: Diskuse konstruktivistického přístupu

Tento článek vychází z paradigmatu nové regionální geografie, které se v geografickém myšlení prosazuje od 80. let 20. stol. Podstatou tohoto přístupu je pojetí regionu jako sociálního konstruktu, který je historicky kontingentním procesem. Region je tedy v čase vytvářen, reprodukován a posléze zaniká. Diskuse konceptualizace fenoménu regionu spojené s tímto myšlenkovým proudem je velmi bohatá, přesto nepřináší univerzální odpověď na teoretické uchopení regionu v celé jeho různorodosti. Zdá se však, že univerzální konceptualizace není nezbytně nutná a snad ani možná. Představovaný text tak přispívá do této nikdy nekončící diskuse. Na základě heuristické rešerše světové odborné literatury tento článek diskutuje různé přístupy ke konceptualizaci regionu, zvláště se pak zaměřuje na proces jeho institucionalizace. Dále se text zabývá reflexí světových přístupů nové regionální geografie v českém akademickém prostředí a snaží se představit komplexní (nikoli univerzální) teoretickou konceptualizaci regionu, která by umožnila překonat jednu ze základních dualit regionu. Jeho pojetí jako „živého" neustále proměnlivého fenoménu, který je na jedné straně vytvářen regionálními aktéry za určitým účelem a na straně druhé je vnímán a dále reprodukován obyvateli ve snaze porozumět okolnímu světu a potřebě najít si ve světě své vlastní místo. Navrhovaný koncept staví na Lefebvrově teorii societální tvorby prostoru a Paasiho teorii institucionalizace regionu a představuje myšlenku societální produkce regionu. Tento koncept integruje funkční, normativní a percepční regionalizaci komplementárním způsobem a tvrdí, že každý komplexní přístup k regionu musí zahrnovat tři dimenze regionu: „danou" (praktikování regionu), „vytvářenou" (reprezentace regionu) a „vnímanou" (představa regionu). Region je tedy skutečně spletitým konceptem. Nicméně, zvláště s rostoucím tlakem na aplikovatelnost poznatků regionálního výzkumu, je lepší porozumění konceptu regionu relevantní a stále více nezbytné. Proto tento článek navrhuje, aby se další vědecké úsilí zaměřilo na hlubší poznání fungování vzájemných vztahů jednotlivých zmíněných dimenzí regionu a zvláštní pozornost by se pak měla věnovat dimenzi vnímané. Tento text vychází také v češtině jako oficiální on-line dodatek tohoto článku. Českou verzi lze nalézt zde: http://www.aucgeographica.cz/index.php/AUC_Geographica/article/view/159.

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EVALUATION OF THE HYDROCLIMATIC EXTREMES IN THE UPPER HRON RIVER BASIN, SLOVAKIA

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ABSTRACT

This paper deals with the occurrence of hydroclimatic extremes in the upper Hron River basin in Slovakia in 1951/61–2010. Select trends in hydroclimatic parameters in 1931/61–2010 are also studied. Emphasis is placed on the occurrence, frequency, and seasonality of dry episodes and flood events. The de Martonne index, the relative precipitation index, base flow index, low flow index, linear regression, the Mann-Kendall test and IHA software were used in the analyses.

Mann-Kendall test pointed to significant changes in runoff of the upper Hron River basin. The annual runoff has decreased. Changes in minimums and maximums have had a fundamental influence on this decrease, particularly in the cold half year. Major changes occurred in Q_1, Q_{Max}, Q_{75pct} and 1-day, 3-day and 7-day maximum values. Approximately since the 1980s there has been a decrease in discharge events equal to or greater than one-year flood Q_1. Events where discharges were equal or greater than Q_5 occurred only in the first period 1951–1980 (in 1954 and 1974). The de Martonne index, the relative precipitation index and the low flow index show similar results, the longest above-average period of annual values reached from 2007 to 2010 and the longest below-average period from 1990 to 1993.

Keywords: drought, flood, de Martonne index, Mann-Kendall test, Hron River basin

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1. Introduction

The threat of hydroclimatic extremes, a topic of frequent discussion among experts mainly in relation to climate change, is a serious problem. Slovakia will not be able to avoid extreme droughts and floods in the future. The extremely dry year of 2003 and the very wet year of 2010 are examples. Last year, 2015, was also extremely dry. It was one of the warmest and driest years since measurements have been taken. The year 2013 also saw hydrological extremes. Most of Central Europe was hit with extensive flooding. Therefore, it is appropriate to focus attention on this problem with the realization of the lasting risks associated with these extremes.

There are few studies which would devote more complex these extremes. The presented study is an attempt to more fully evaluate hydroclimatic extremes in headwater area of the river. The aim of this study is to evaluate the incidence of hydroclimatic extremes (droughts and floods) in the upper Hron River basin in the period 1951/61–2010. The following are evaluated trends of selected hydrological parameters in the period 1931/61–2010. The knowledge gained from this study may have basic importance for risk assessment of both floods and droughts in the territory of Slovakia.

Define drought is quite difficult and therefore there are many definitions of drought. Put simply, we can say that the drought is the lack (deficit) of water. Tallaksen and van Lanen ed. (2004) define drought as a sustained and regionally extensive occurrence of below-average natural water availability, and can thus be characterized as a deviation from normal conditions of variables such as precipitation (meteorological drought), soil moisture, groundwater and streamflow (hydrological drought).

A distinction between droughts and low flows: drought is a natural event resulting from a less than normal precipitation for an extended period of time; low flows, on the other hand, is a seasonal phenomenon, and an integral component of a flow regime of any river. Various low-flow indices may be estimated from 'lowflow section' of a flow duration curve. The flows within the range of 70–99% time exceedance are usually most widely used as design low flows (Smakhtin 2001). Brázdil and Trnka et al. (2015) give a comprehensive overview of methods for determining drought and dry episodes and discuss their causes, their impact on select sectors of the national economy, their temporal and spatial variability, and finally future scenarios. Ledvinka (2015) has dealt with the development of low discharges using and comparing statistical tests.

The biggest drought events in Europe from 1950 to 2012 were examined by Spinoni et al. (2015). According to the results, Northern and Eastern Europe show the highest drought frequency and severity from the early 1950s to the mid-1970s, in Central European regions in the period 1971–1990, and in Southern Europe in the period 1991–2010. In general, it was found a small but continuous increase of the European areas prone to

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drought from the early 1980s to the early 2010s. Hisdal et al. (2001) also examined the incidence of droughts in Europe. The Mann-Kendall test and a resampling test for trend detection showed that it is not possible to conclude that drought conditions in general have become more severe or frequent. However, distinct regional differences were found. The increasing drought deficit volumes were found in Spain, the eastern part of Eastern Europe and in large parts of the UK, whereas decreasing drought deficit volumes occurred in large parts of Central Europe and in the western part of Eastern Europe. Briffa, Schrier and Jones (2009) analyzed wet and dry summers in Europe since 1750 and they observed that a major cause for the large areal extent of summer drought in the last two decades was high air temperatures. Significant decreasing trends of summer low flows and increasing winter low flows were investigated by Mann-Kendall test, using data from 144 Czech catchments for the period 1961–2005. Increasing drought duration as well as deficit volumes were observed (Fiala et al. 2010; Fiala 2011). Brázdil et al. (2009) have dealt with drought variability in the Czech Republic in 1881–2006. This study clearly confirms growth in dry episodes in the studied period as a result of growing air temperatures and decreasing precipitation.

The index for indicating hydrological drought in snow-influenced catchments was created by Staudinger et al. (2014). The study with Swiss catchments suggests a closer description of hydrological droughts by *SMRI* (the Standardized Snow Melt and Rain Index) than by *SPI* (the Standardized Precipitation Index). A decrease of snow in the cold season has a negative effect on soil and groundwater storages during spring and might cause low streamflow values in the subsequent warm season. Jeníček et al. (2016) quantified how long snowmelt affects runoff after melt-out and to estimate the sensitivity of Swiss catchments with different elevation ranges to changes in snowpack. For higher- and middle-elevation catchments and years with below-average SWE maximum, the minimum discharge in July decreased to 70–90% of its normal level. Additionally, a reduction in SWE resulted in earlier low-flow occurrence in some cases.

On the territory of Slovakia a decreasing trend of annual runoff was observed in 1961– 2000 (reference period 1931–1980 and 1961–2000), which was higher in cold half year (November–April) and smaller in warm half year (May–October), Majerčáková et al. (2004). A significant decrease in winter runoff (December–February) was observed in the upper Hron River basin in 1931–2010 (Blahušiaková and Matoušková 2015). This basin is categorized as a basin with a decreasing long-term discharge trend (Poórová et al. 2013a). Minimum discharge trends in different parts of Slovakia vary. The most favorable conditions are in the upper catchments of the Váh, Hron, and Slaná Rivers as well as in the basins of the Hornád, Poprad, Bodrog, and Danube Rivers. In contrast, southern Slovakia, that is, the basins of the lower Váh, Hron, and Slaná, and the basins of the Ipeľ, Nitra, Malý Dunaj, Bodva, and partially the Morava indicate a significant decreasing minimum discharge trend (for the period 1961–2012; Poórová et al. 2013b). Demeterová and Škoda (2009) have observed dry periods on many Slovak rivers. They also analyzed long-term dry periods (lasting more than 30 days) in the upper Hron River basin. They report one of the greatest frequencies of winter long-term dry periods in all of Slovakia (more than three times in ten years).

Floods can be characterized according to various aspects. A review of applied methods for flood-frequency analysis in a changing environment it offers by Madsen et al. (2013). A contribution includes a comparison of trend analysis results and climate change projections for 21 countries in Europe (including the Czech Republic and Slovakia). The review indicates a gap between the need for considering climate change impacts in design and actual published guidelines that incorporate climate change in extreme precipitation and flood frequency. The examination of flood frequency in central Europe (Germany, Switzerland, Czech Republic and Slovakia) using annual and seasonal maximum discharge time series was made by Villarini et al. (2011). The results show that there is a marked seasonality in the flood peak record, with a large fraction of annual maximum flood peaks occurring during the winter in the western part of the study domain, and during the summer in the southern portion of this region. A study by Svensson et al. (2005) discusses the detection of trends in flood and low-flow index series at 21 daily mean river flow stations across the world. There is no general pattern of increasing or decreasing numbers or magnitudes of floods, but there are significant increases in half of the low-flow series. For the annual maximum daily mean river flow series, the negative trends are in Northern Europe and the northwest of the Balkan Peninsula; positive trends are in central Europe and the British Isles. In the study areas of Europe (including central Europe) there are positive trends in the annual minimum 7-day mean river flow series. Yiou et al. (2006) have investigated the possible relationships between flood magnitude, climate variables (temperatures, precipitation) and atmospheric circulation patterns for the Vltava and Elbe rivers in Bohemia. The results showed that occurrence and intensity of floods have generally decreased over the 20th century. The decrease in winter is slightly correlated with the mean air temperature increase. A similar tendency is detectable in the eastern part of the Czech Republic for the Morava and Oder rivers (Brázdil et al. 2005).

Runoff extremes in Slovakia, specifically peak runoff, have been dealt with by Blaškovičová et al. (2014). Peak discharge trends were studied on the Danube River in 1877–2012; a slight increasing trend was observed. The most significant increasing trends are in December and April. In contrast, based on Mann-Kendall test results, a statistically significant decreasing trend in annual peak discharge in the basins of east and central Slovakia was detected (Jeneiová et al. 2014).

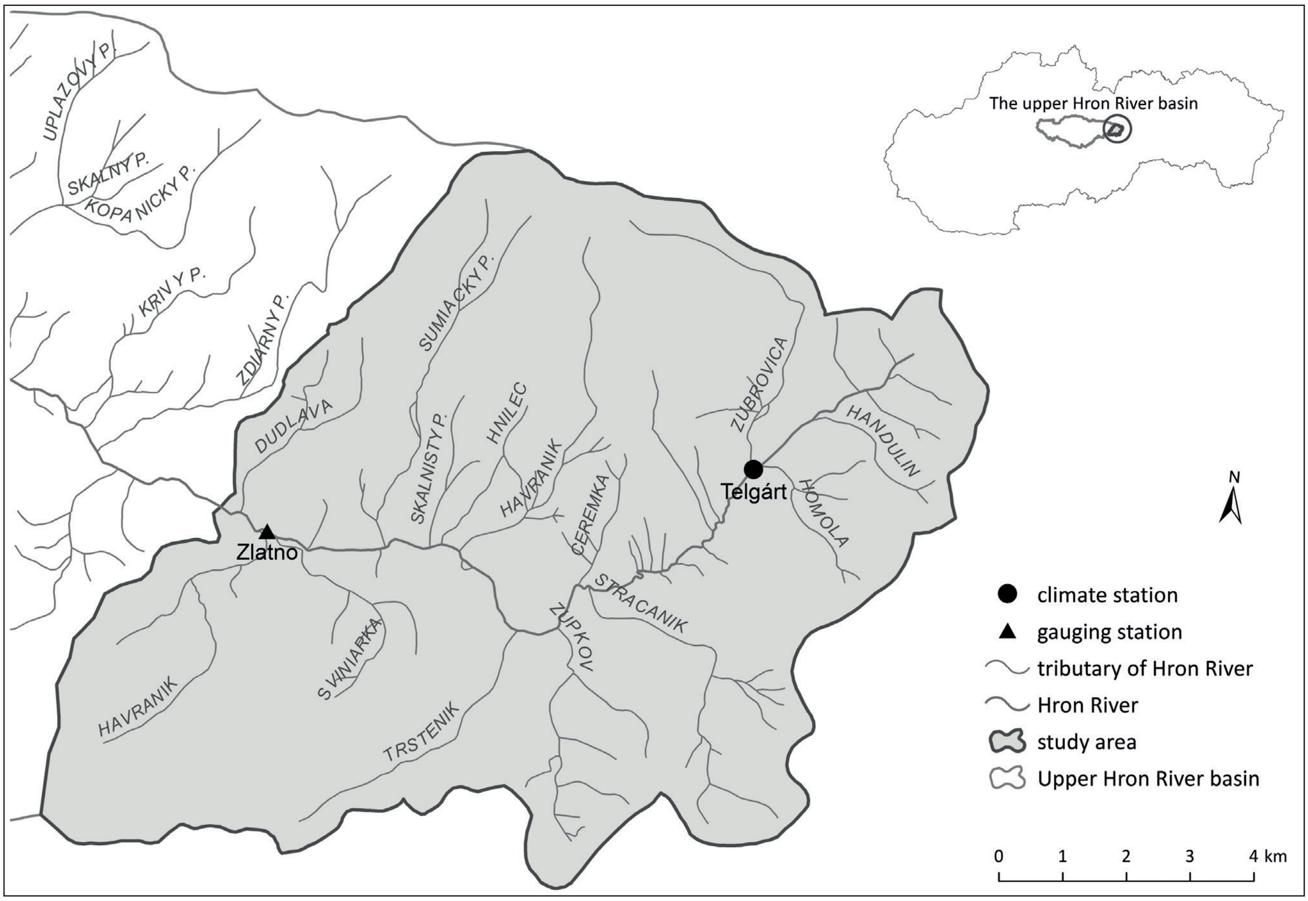

Fig. 1 Study area – the upper Hron River basin, Slovakia. Data source: SHMI, B. Bystrica

Tab. 1 The individual characteristics of the study basin.

Study area characteristics	Data from station	Time	Value	Note
Area	Zlatno	–	83.7 km^2	from the source to Zlatno station
Altitude	Telgárt	–	901 m a.s.l.	–
Altitude	Zlatno	–	733 m a.s.l.	–
Long-term annual precipitation (P_a)	Telgárt	1961–2010	853 mm	–
Maximum annual precipitation total	Telgárt	2010	1282 mm	150% of long-term precipitation normal (1961–2010)
Minimum annual precipitation total	Telgárt	2003	528 mm	62% of long-term precipitation normal (1961–2010)
Long-term mean air temperature (T_a)	Telgárt	1961–2010	5 °C	–
Maximum mean annual air temperature	Telgárt	2007	6.4 °C	for the period 1961–2010
Minimum mean annual air temperature	Telgárt	1965, 1980	3.6 °C	for the period 1961–2010
The warmest month of the year	Telgárt	July	from 12.2 °C to 17.6 °C	for the period 1961–2010
The coldest month of the year	Telgárt	January	from –10.7 °C to –0.1 °C	for the period 1961–2010
Mean annual snow cover depth (SCD_r)	Telgárt	1961–2010	24 cm	from November to April
Maximum mean annual snow cover depth	Telgárt	1963	67 cm	from November to April (1961–2010)
Minimum mean annual snow cover depth	Telgárt	1989	5 cm	from November to April (1961–2010)
Long-term mean annual discharge (Q_a)	Zlatno	1961–2010	1.4 m^3 s^{-1}	–
Specific runoff (q)	Zlatno	1961–2000	16.41 s^{-1} km^{-2}	average value of Slovakia is 8.61 s^{-1} km^{-2}
Annual runoff coefficient (φ)	Zlatno	1961–2000	0.55%	–
Maximum mean annual discharge (Q_{rMax})	Zlatno	1965	2.4 m^3 s^{-1}	for the period 1961–2010
Minimum mean annual discharge (Q_{rMin})	Zlatno	1993	0.8 m^3 s^{-1}	for the period 1961–2010
The most water month	Zlatno	October 1974	6.5 m^3 s^{-1}	37% of annual runoff
The least water month	Zlatno	February 1984	0.3 m^3 s^{-1}	1.5% of annual runoff
Maximum mean monthly discharge	Zlatno	April	2.8 m^3 s^{-1}	for the period 1961–2010
Minimum mean monthly discharge	Zlatno	January, February	0.7 m^3 s^{-1}	for the period 1961–2010

Source: SHMI, B. Bystrica; Pekárová and Szolgay 2005

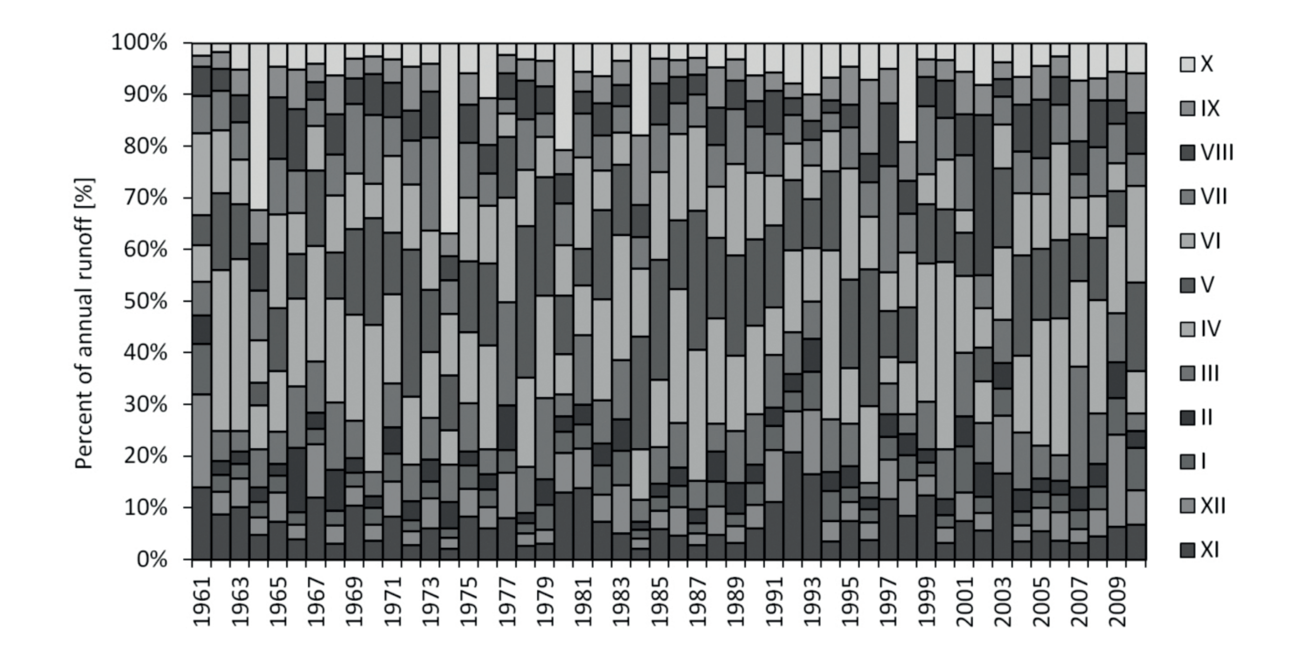

Fig. 2 Seasonal changes in runoff in Zlatno (1961–2010). Data source: SHMI, B. Bystrica

2. Study area characteristics

The Hron River (basin area of 5465 km^2) springs under the Kráľova hoľa Mountain in the Low Tatras at 934 m a.s.l. and flows into the Danube near Štúrovo at 103 m a.s.l. The source section of the upper Hron River basin up to Zlatno gauging station (altitude 733 m a.s.l.) has an area of 83.7 km^2 and was selected as the study basin (Figure 1).

The basin is located in a cold and humid to very humid climatic region. The area shows a relatively well-preserved natural runoff regime. Runoff regime of the upper Hron River is nivo-pluvial. Forest covers 59% of basin area (Holko and Kostka 2008). It exceeds the mean value of forestation for Slovakia, which is 41% (NFC 2011). Figure 2 shows seasonal changes in runoff in Zlatno during 1961–2010. The individual characteristics of the river basin are listed in Table 1.

3. Data and Methods

3.1 Used data

Climate extremes are evaluated on climate station Telgárt for the period 1961–2010. The analyzed dataset included daily (P_d), monthly (P_m), annual (P_r) precipitation amounts and the long-term annual precipitation (P_a) in millimeters (mm); mean daily (T_d), monthly (T_m), annual air temperature (T_r) and the long-term mean air temperature (T_a) in Celsius degrees (°C). Snow cover conditions were evaluated for days with permanent snow cover, i.e. period in which the snow cover was not interrupted for more than three consecutive days and a minimum height of snow cover was 1 cm. We processed data on daily snow cover depth (SCD_d), mean monthly and annual snow cover depth (SCD_m, SCD_r) in centimeters (cm), and number of days with snow cover in the month/year (SCN_m, SCN_r). The SCD_r was calculated for a winter season (November–April).

Hydrological extremes were evaluated on Zlatno gauging stations in the period 1951/61–2010. Values of Q_d (mean daily discharge), Q_m (mean monthly discharge), Q_r (mean annual discharge) and Q_a (the long-term mean annual discharge) in cubic meters per second (m^3 s^{-1}) were used. Analyzed are the maximum (Q_{Max}) – the highest mean daily discharge and the minimum (Q_{Min}) – the lowest mean daily discharge. In the evaluation were added mean daily discharges Q_{330}, Q_{355} and Q_{364}. The Q_{330} refers to mean daily discharge that was reached or exceeded 330 days in the year, the Q_{355} was reached or exceeded 355 days in the year and the Q_{364} was reached or exceeded 364 days in the year.

All data provided by the Slovak Hydrometeorological Institute (SHMI) in Banská Bystrica were homogenized.

3.2 Methods for investigating climate indicators

The occurrence of drought was evaluated based on the two selected indexes and seasonality achieved on the basis of the total precipitation and the number of days without precipitation respectively, with only a small amount of precipitation.

The de Martonne Aridity Index (Sobíšek 1993) indicates the degree of dryness, or humidity, of the climate in relation to various climatic elements and factors. In this study we used the de Martonne Aridity Index as modified by Reichel (eMS 2015), which is calculated based on a formula

$$i = \frac{R}{T+10} \cdot \frac{N}{180} \qquad (1)$$

where i is the aridity index; R is annual precipitation in mm; N is the number of days with precipitation at the given location; T is the mean annual air temperature in °C; and the figure 180 represents the average number of days with precipitation in Central Europe. Each year is categorized based on this index (Table 2). Although calculating this index requires two or three meteorological variables, it can still be considered simple, and it takes into account not just precipitation but also air temperature. The number of days with precipitation emphasizes the significance of the distribution of daily precipitation.

Tab. 2 Annual de Martonne Aridity Index (dMi).

dMi	Climate classification
|<10	Dry or arid
15≤|≤24	Semiarid
24<|≤30	Moderately arid
30<|≤35	Slightly humid
35<|≤40	Moderately humid
40<|≤50	Humid
50<|≤60	Very humid
60<|≤187	Excessively humid

Source: HOA 2016

The Relative precipitation index is also used; it is calculated as the percentage of current precipitation in a given period divided by the long-term mean. It is calculated using a formula

$$I = \frac{P}{Pa} \cdot 100 \qquad (2)$$

where I is the relative precipitation index, P is current precipitation and P_a is the long-term annual precipitation for the given period (1961–2010). Values lower than 100 (%) indicate below-average precipitation. When the index value decreases, the probability of drought increases (Novický et al. 2008).

The seasonality of dry episode occurrences (in cold half year: November–April and warm half year: May–October) is analyzed on the basis of the number of days without precipitation, or rather, the number of days with precipitation, with a predetermined threshold value (the minimum duration of the dry period 15 days and maximum precipitation 8.5 mm). On the basis of these data, dry episodes are defined and classified into four groups A–D (Table 3). The advantage of defining episodes in this way is that it allows researchers to determine the beginning and end of dry periods, their frequency during the studied period and their seasonality.

Tab. 3 Definition of dry episodes in Telgárt (1961–2010).

Group	Duration (days)	Maximum precipitation (mm)
A	15 and more	to 1.0
B	20 and more	to 2.5
C	30 and more	to 5.0
D	40 and more	to 8.5

3.3 Methods for investigating hydrological indicators

For identifying changes in hydrological time series were used values of mean daily discharges (Q_d). Of these values were calculated median values, monthly discharges (Q_m), annual discharges (Q_r); maximums (Q_{Max}) and minimums (Q_{Min}) of discharges were determined, coefficient of dispersion, base flow index and daily discharges Q_{330}, Q_{355} and Q_{364}, which are frequently used as a threshold value for determining drought. N-year flood events and values of Q_{Max} and high flows were used for determining floods. Detection of trends in hydrological parameters was determined using non-parametric statistical Mann-Kendall test and linear regression.

An easy-to-use tool for calculating the characteristics of natural and altered hydrologic regimes is the Indicators of Hydrological Alteration (IHA) software (Richter et al. 1998) and IHA 7.1 statistics software (TNC 2009). The power of the IHA is that it can be used to summarize long periods of daily hydrologic data into a much more manageable series of relevant hydrologic parameters. Using this software, we evaluated the values of Q_d during the period 1951–2010, which we divided into two time periods (1951–1980 and 1981–2010), and those we compared. Selection period 1951–2010 was influenced by the availability of climate data (order to allow a comparison of climate and hydro results), and also the fact that we wanted to compare the same long period. As a turning point, the year 1980 was chosen. The IHA software calculates 67 statistical parameters. The following parameters were used in our study: median values (the 50th percentile of daily flows), Q_{75pct} (the 75th percentile of daily flows), coefficient of dispersion (COD) → (75th pct-25th pct)/50th pct (pct → percentile), minimums and maximums (Q_{Min} and Q_{Max}), the 1-, 3-, 7-, 30-, and 90-day minimums and maximums, base flow index (7-day minimum flow/mean flow for year), frequency, timing and duration of high and low pulses. The initial separation between high and low flows is done using a single fixed threshold, which was 1.6 $m^3 s^{-1}$ (this is Q_{75pct}). All flows greater than this value are classified as high flows, and all flows less than or equal to this threshold are classified as low flows. For comparison with the results of climatic indexes was added low flow index (Poff and Ward 1989). It is calculated using a formula:

$$\text{LOWFLOW} = Q_{Min} / Q_a \qquad (3)$$

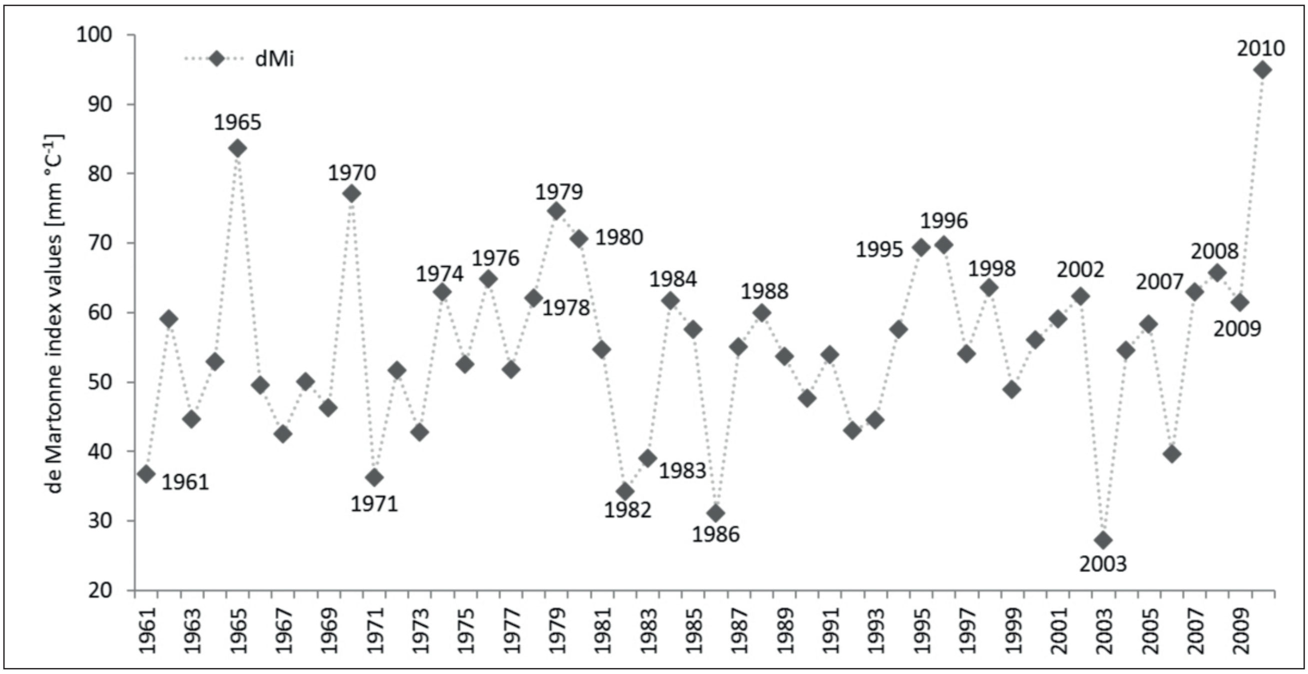

Fig. 3 The distribution of years based on the de Martonne index in Telgárt (1961–2010). Data source: SHMI, B. Bystrica

where LOWFLOW is low flow index, Q_{Min} is the lowest mean annual daily discharge and Q_a is the long-term mean annual discharge (1951–2010).

Detection of trends of selected hydrological parameters was detected using the Mann-Kendall test and linear regression. A seasonal non-parametric Mann-Kendall test (Bawden et al. 2014; Helsel and Frans 2006; Kendall 1975; Libiseller 2004; Mann 1945; Yue et al. 2002, 2012) has two parameters important for the trend detection: a significance level (p), which represents the power of the test, and a slope magnitude estimate (Mann-Kendall statistics *MKS*), which represents the direction and volume of the trend. The trend significance level of 0.05 has been set for all statistical analysis. The duration of observations plays an important role in the assessment of trends in hydroclimatic factors. If the goal of research is to identify the changes of the hydrological regime, then it is justifiable to use a time series that is as long as possible. In the upper Hron River basin, there are hydrological data available since 1931, so the MK test was run for the two periods 1931–2010 and 1961–2010.

N-year flood events (Table 4) were used as the basic selection criterion, while a flood was defined as a hydrological situation where the Q_d achieved or exceeded the value Q_1 (one-year flood). Evaluated flood events ≥ Q_5, Q_{20}, Q_{50}, Q_{100} were included in the assessment. In order to analyze the frequency and seasonality of floods, peak discharge values (Q_{Max}) were used as source data. Seasonality was assessed using data on Q_d that exceeded the value of Q_1. Ten days preceding the day with Q_1 occurrence determined the boundaries between individual flood events. If a flood began in one month and subsided in the next, the month in which the peak flow occurred was recorded.

Tab. 4 N-year maximum and minimum discharges ($m^3 s^{-1}$) in Zlatno.

Zlatno (N-year)	1	5	20	50	100
Max (1931-1987)	10	23	38	49	58
Min (1931-2004)	0.26	–	0.23	0.20	0.18

Source: Pekárová and Szolgay 2005

4. Results

4.1 Analysis of extremes based on annual and monthly climate data

By calculating the selected indices it was possible to determine the character of each year in the studied period 1961–2010. The results of the de Martonne index (Figure 3, Table 2) indicate that longer wet periods occurred at the end of the studied period (from 2007 to 2010, all years with a value over 60 mm °C^{-1}), with 2010 being the highpoint (95 mm °C^{-1}). A three-year period from 1978 to 1980 follows, and then 1995 and 1996 (all with a value above 60 or 70 mm °C^{-1}). In contrast, 2003 was one of the driest years (27 mm °C^{-1}), followed by 1986, 1982, 1971, 1961, and 1983 (all below 40 mm °C^{-1}).

Similar results were obtained from calculating the relative precipitation index, which classifies each year as above-average, average, and below-average, where average equals 100%. Years with values below this threshold are below-average and those above it are above-average. The longest above-average period was from 2007 to 2010, when, for example, the exceptionally wet 2010 was 150% of the long-term mean. The longest below-average period was from 1990 to 1993, when, for example, 1993 was 78%

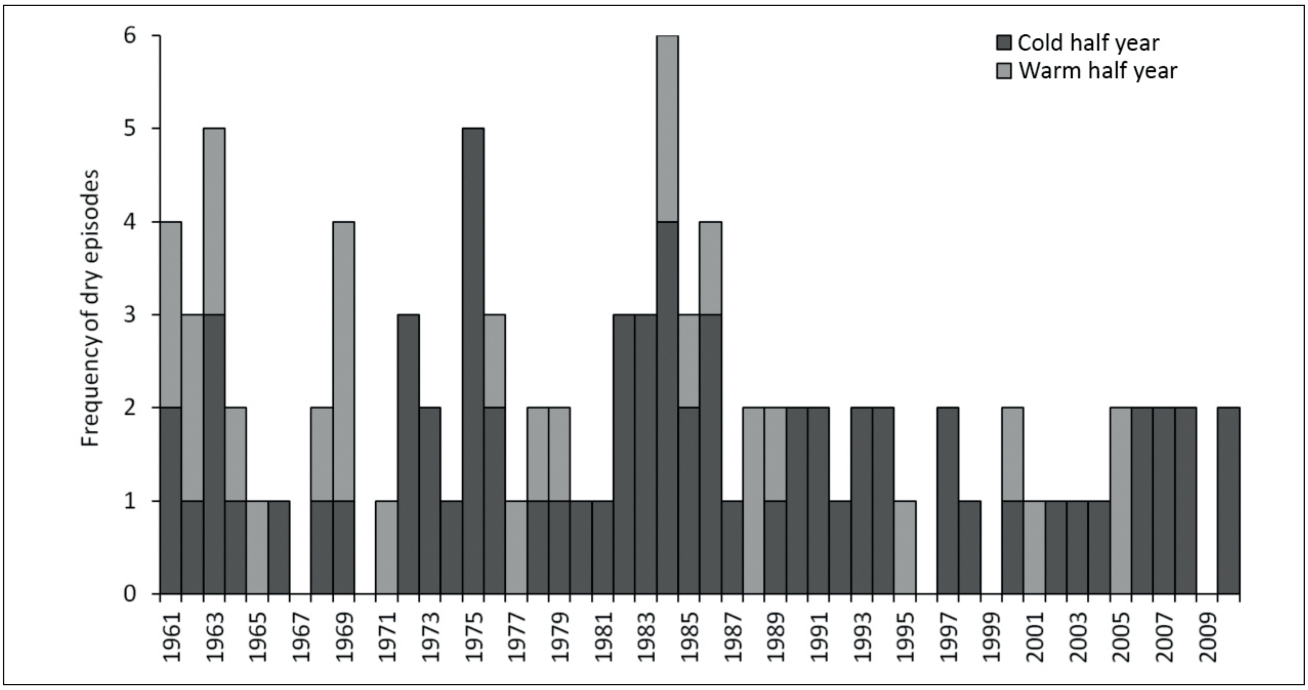

Fig. 4 Frequency of dry episodes lasting 15 days and more with a maximum precipitation to 8.5 mm in cold and warm half years in Telgárt (1961–2010). Data source: SHMI, B. Bystrica

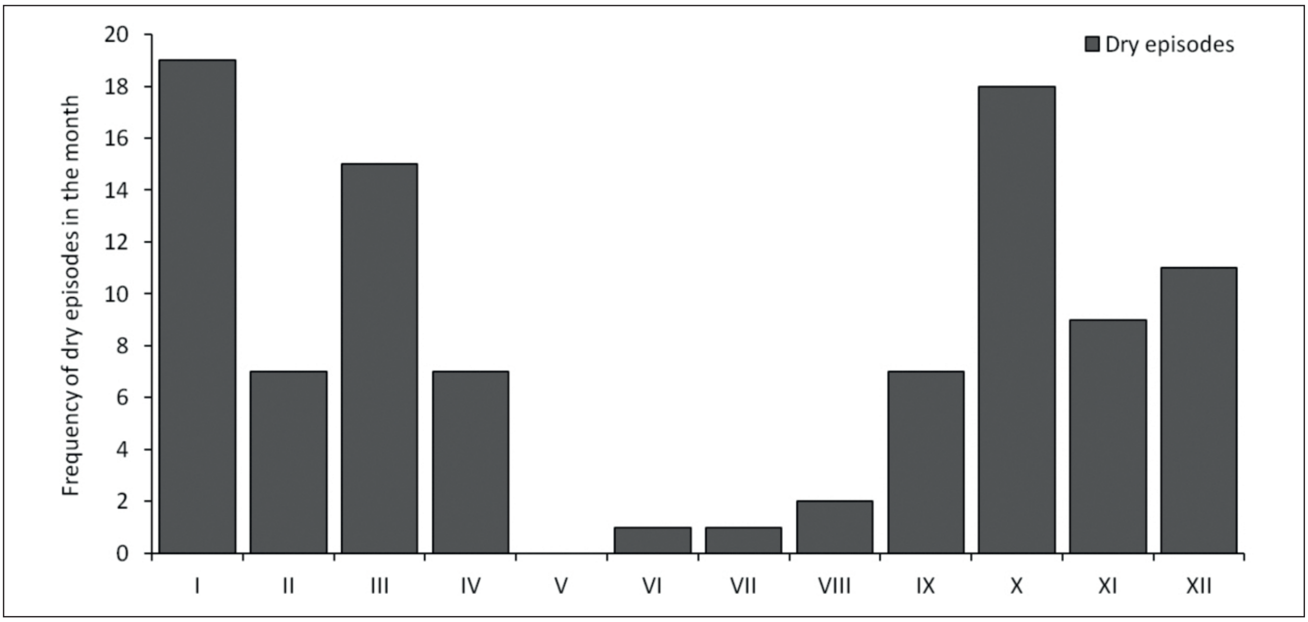

Fig. 5 The frequency of dry episodes lasting 15 days and more with a maximum precipitation to 8.5 mm in Telgárt in each month during the period 1961–2010. Data source: SHMI, B. Bystrica

of the long-term mean. The driest year, 2003, was only 62% and 1986 68% of the long-term mean.

Figure 4 indicates that dry episodes (episodes lasting 15 days or more with a maximum precipitation 8.5 mm) were more frequent in the cold half year (November–April), and they were most frequent in 1975 and 1984. Dry episodes in this period were prevalent primarily in the 1970s, 1980s, and early 1990s. In contrast, in the warm half year (May–October), dry episodes occurred mainly in the 1960s, with the most occurring in 1969. Nineteen dry episodes occurred in January, followed by October (18) and March (15). In the period from May to August they were much fewer in number. Their overall frequency is depicted in Figure 5. The longest dry episode occurred from 16 February to 23 April 1974, with 8.5 mm of precipitation. A drought occurred at the similar time of year 2003, lasting from 6 February until 2 April with 6.4 mm of precipitation. Droughts also frequently occur in autumn. The third-longest-lasting dry episode occurred from 5 October to 26 November 1978

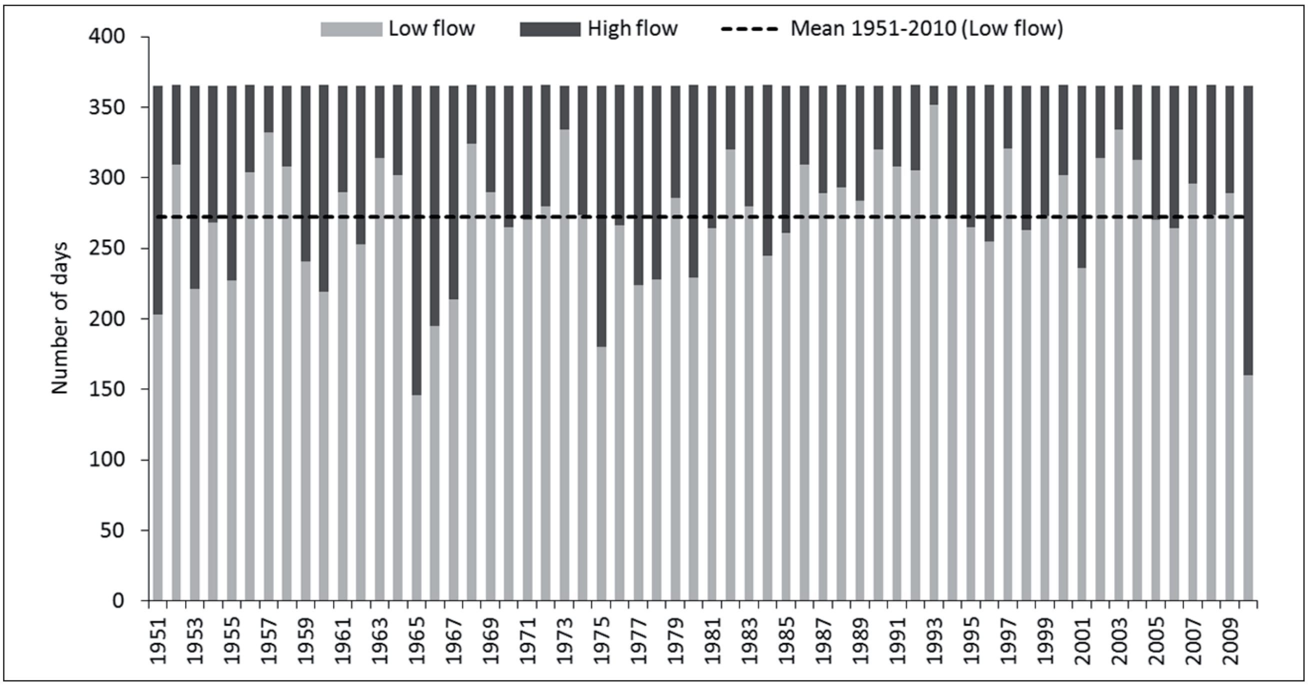

Fig. 6 The frequency of days with low and high flow in Zlatno (1951–2010); a threshold between low and high flow is 1.6 m³ s⁻¹; an average number of days with a low flow was 272 and with a high flow was 93 (1951–2010). Data source: SHMI, B. Bystrica

with 5.5 mm of precipitation. The fourth longest episodes occurred from 7 September to 29 October 1985 with 7.6 mm of precipitation. All dry episodes categorized in group D are displayed in Table 5.

Tab. 5 The duration of the dry episodes (Group D; maximum precipitation 8.5 mm) in 1961–2010.

Start	End	Precipitation (mm)	Days
19.09.1962	29.10.1962	1.6	41
18.12.1963	31.01.1964	3.4	45
04.12.1972	15.01.1973	4.4	43
16.02.1974	23.04.1974	8.5	67
01.02.1982	12.03.1982	6.7	40
05.10.1978	26.11.1978	5.5	54
07.09.1985	29.10.1985	7.6	53
07.01.1989	19.02.1989	3.9	44
13.12.1992	21.01.1993	7.2	40
06.02.2003	02.04.2003	6.4	56
02.10.2005	15.11.2005	2.5	45
24.03.2007	03.05.2007	6.2	41

Data source: SHMI, B. Bystrica

4.2 Analysis of extremes based on annual and monthly hydrological data

Detecting high and low flows using IHA is one of the preconditions for evaluating hydrological extremes. In Figure 6 it can be seen that the second half of the studied period, 1981–2010, was in total less wet at Zlatno station. The least wet period was the second half of the 1980s and the early 1990s (from 1986 to 1993) as well as from 2002 to 2004 (mainly 2003). In contrast, the wettest periods were in the mid-1960s (from 1965 to 1967), the second half of the 1970s (1974 to 1981), and the 1990s (1994 to 1996 and 1998, and 1999) in addition to 2001, 2005, 2006, and 2010. Exceptionally dry years in 1951–2010 were, in order from driest, 2003, 1993, and 1973, and exceptionally wet years were, in order from wettest, 1965, 2010, and 1975. Low flow index also indicates that the driest period was the second half of the 1980s and the early 1990s (Figure 7). Other dry years were 1967, 1974, 2000, 2003, 2004 and 2007. Among the wettest years belonged 1953, 1959, 1967 and 2010. These results are similar with the results of climate indices.

The decrease in wetness in the second half of the studied period is connected with a decrease in frequency and extremity of flooding as depicted in Figure 8. The figure shows that approximately until the 1980s the frequency and extremity of events where discharge was $\geq Q_1$ and Q_5 was greater. The greatest peak discharge (27.3 m^3 s^{-1}) occurred during a flood in 1954 with a value equal to Q_5. The flood in 1974 reached the same N-year value, with a peak discharge 26.5 m^3 s^{-1}. In the 1958 hydrological year, Q_1 was exceeded, moreover, for a total of seven days. In 1964 it was six days and in 1967 and 2002 it was five days. In 1951–1980 there were 18 such events, in 1981–2010 there were only seven, which the linear trend line also demonstrates. The seasonal distribution of events where discharge was $\geq Q_1$ in 1951–1980 and 1981–2010 is displayed in Figure 9. The month of April is of great importance for spring runoff on the upper Hron. Its

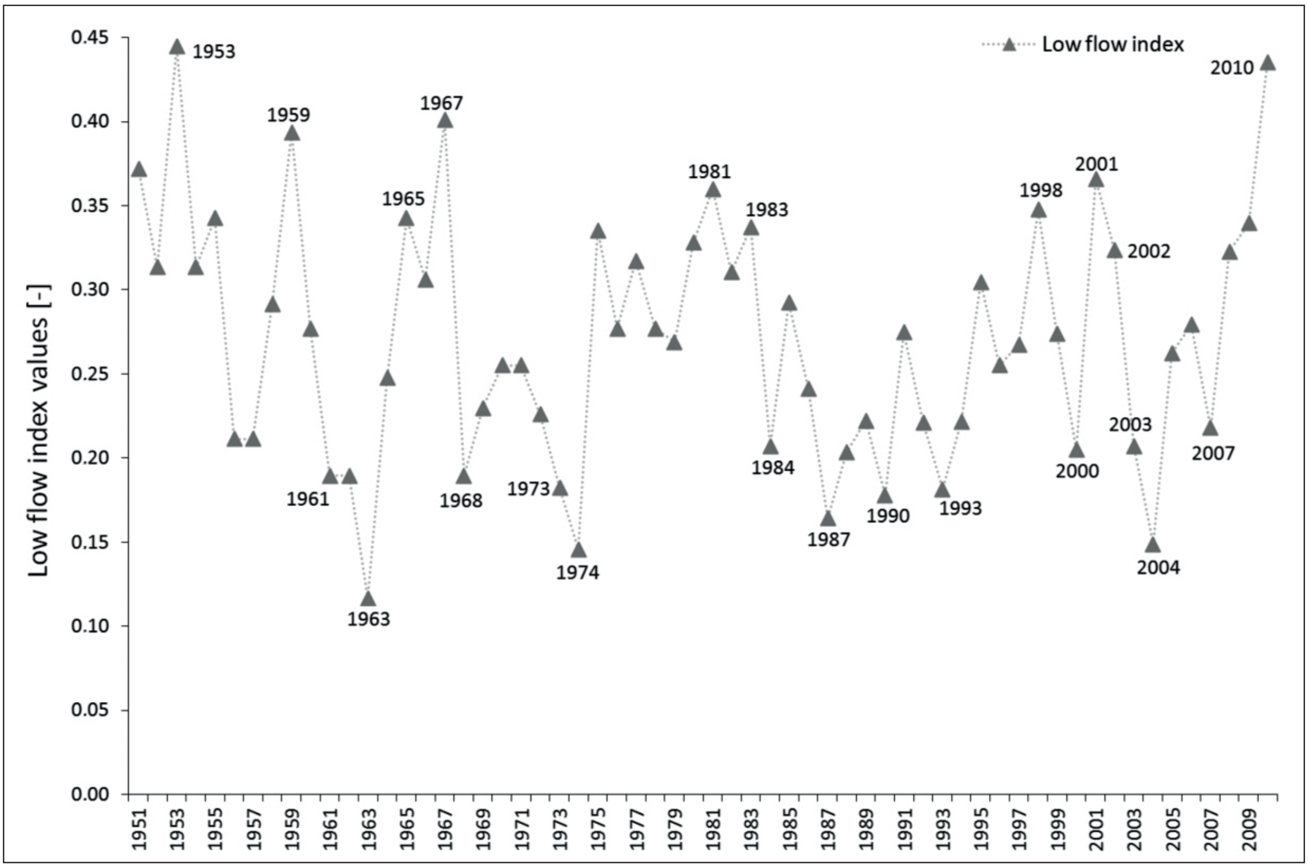

Fig. 7 The distribution of years based on the low flow index in Zlatno (1951–2010). Data source: SHMI, B. Bystrica

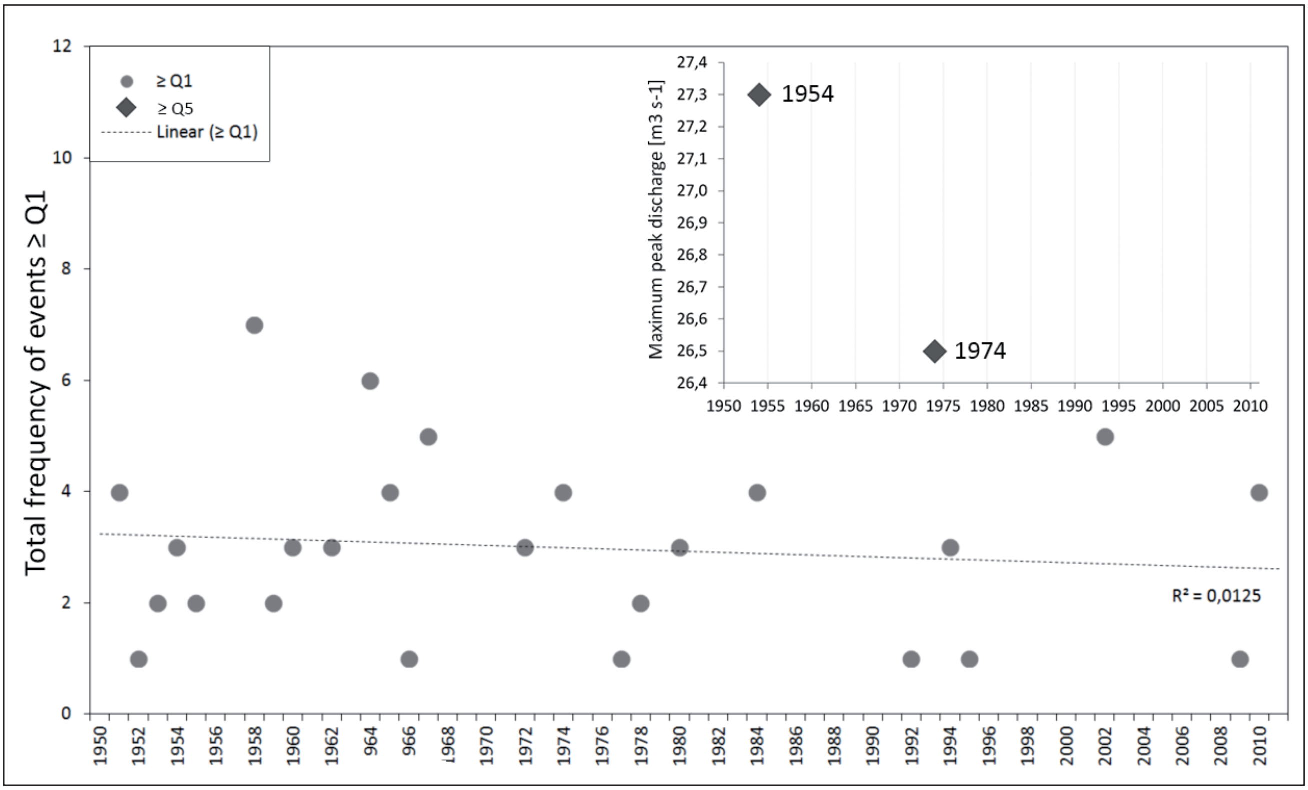

Fig. 8 The frequency of events ≥Q1 and Q5 in Zlatno (1951–2010). Data source: SHMI, B. Bystrica

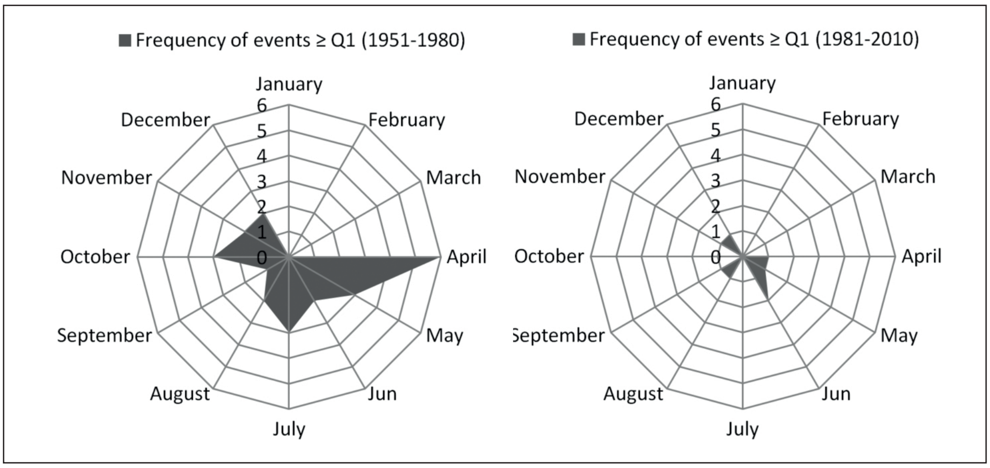

Fig. 9 A seasonal distribution and frequency of events ≥Q1 in Zlatno, a comparison of periods 1951–1980 and 1981–2010. Data source: SHMI, B. Bystrica

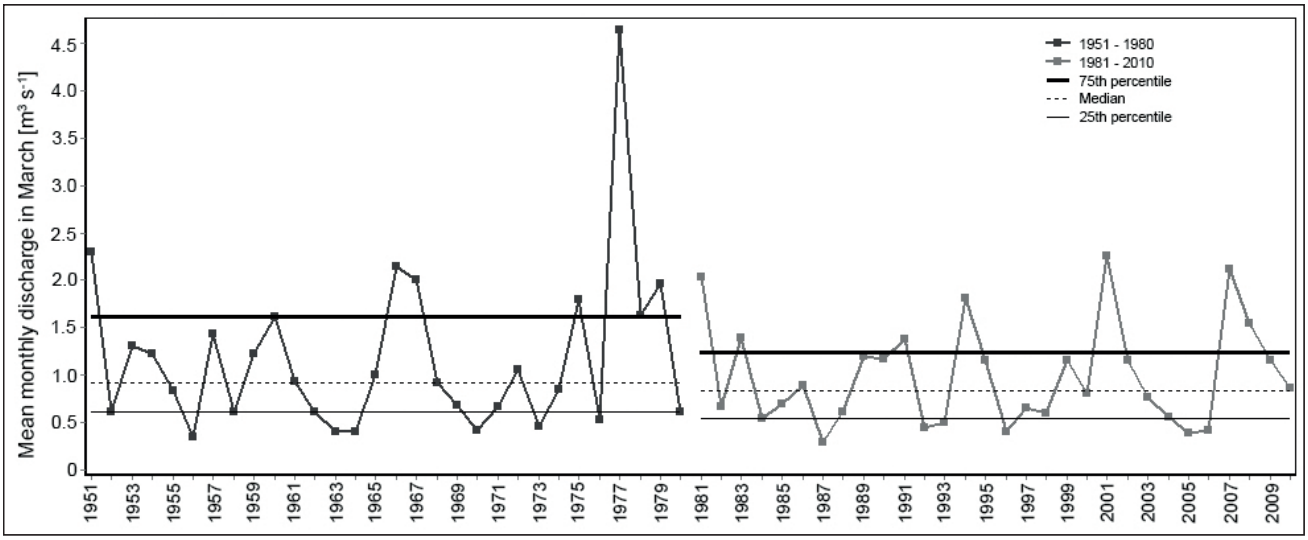

Fig. 10 The mean monthly discharge for March in Zlatno in periods 1951–1980 and 1980–2010. Data source: SHMI, B. Bystrica

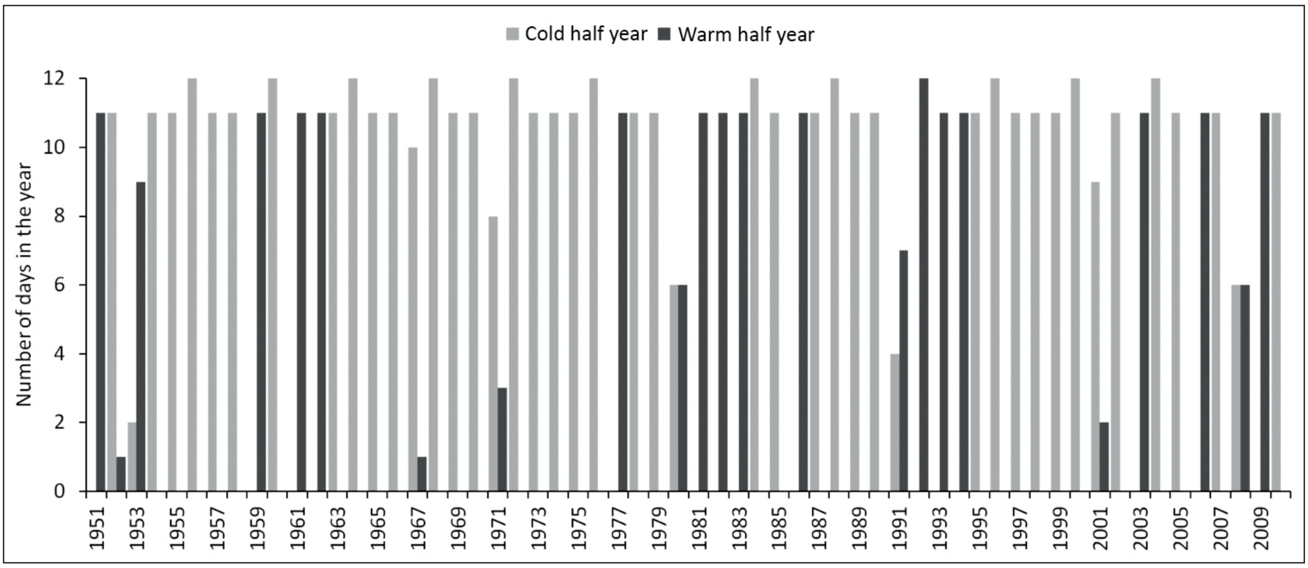

Fig. 11 Seasonality of daily discharge Q355 in Zlatno (1951–2010). Data source: SHMI, B. Bystrica

great contribution to runoff in 1951–1980 decreased in the following period of 1981–2010. The number of events decreased from six to one. A more significant decrease happened in May, July, and October.

From the results using IHA software is obvious a decrease in Q_{Max} values in March and October. In contrast, increases occurred in January and September (Table 6). In comparison with Q_{Min} and median values, more specifically values of Q_{75pct}, a more significant decrease occurred, moreover in the already-mentioned months of March (Figure 10) and October. In comparison with Q_{Min}, median values, and Q_{75pct} values, Q_{Max} values experienced the most significant decrease. The decrease in February is also significant. In contrast, the largest increase occurred in January. It is therefore possible to state that decreasing Q_{Max} values contribute to the upper Hron's decreased runoff. Using of IHA and the MK test confirmed these changes (section 4.4).

Tab. 6 Comparative analysis of monthly and daily flow parameters between 1951–1980 and 1981–2010 periods.

Month	Medians	Coefficient of Dispersion	Minimum	Maximum
November	0.03	−0.22	−0.06	−0.82
December	0.00	−0.44	−0.06	−0.63
January	−0.07	−0.41	−0.04	0.48
February	−0.12	0.03	−0.07	−1.25
March	−0.09	−0.25	−0.05	−2.38
April	−0.53	−0.16	−0.33	−0.45
May	−0.24	−0.27	0.13	−0.75
June	−0.30	0.14	−0.22	−0.19
July	−0.51	−0.16	−0.20	−0.91
August	−0.12	0.05	−0.27	−0.53
September	−0.10	0.18	−0.01	0.35
October	0.04	−0.20	0.03	−2.30
1-day minimum	−0.02	0.01	0.04	−0.01
3-day minimum	−0.01	−0.02	0.03	−0.08
7-day minimum	−0.03	−0.02	0.04	−0.03
30-day minimum	−0.05	0.00	−0.05	0.12
90-day minimum	−0.06	−0.21	−0.08	0.27
1-day maximum	−3.96	−0.02	−1.43	−10.74
3-day maximum	−3.20	0.05	−1.36	−5.91
7-day maximum	−2.60	−0.04	−1.01	−1.99
30-day maximum	−1.27	−0.02	−0.17	−0.09
90-day maximum	−0.46	0.04	−0.22	−0.09
Base flow index	0.03	0.10	0.00	0.06

Notes: decrease (–) / unchanged / increase (+); input data of discharges ($m^3 s^{-1}$) dark grey – increase, light grey – decrease. Data source: SHMI, B. Bystrica

4.3 Analysis of climatological and hydrological extremes based on daily time series data

Based on precipitation data and the number of days without precipitation, or with just a small amount of precipitation (Table 3), dry episodes in the upper Hron River basin were determined in 1961–2010. The longest drought lasted from February to April of 1974 (67 days, Table 5) with 8.5 mm of daily precipitation and a mean daily discharge of 1.25 $m^3 s^{-1}$ (Figure 12 B). This year was rich in extremes as a flood occurred in October. On the graph it can be seen that at the start of the year precipitation was below-average and air temperature was above-average. Snow accumulation from November and December of 1973 melted rapidly due to higher January air temperatures, which then negatively affected the situation in the following months. More intensive precipitation began in May and continued until the end of October, when air temperatures remained below-average. These factors were behind the creation of a flood wave with a peak discharge of Q_5 (26.5 $m^3 s^{-1}$). In total, 1974 was an excessively humid year according to the de Martonne index (HOA 2016). Another excessively humid year was 1962 (Figure 12 A). In this year, the situation was reversed, with flooding in spring and drought in autumn. Significant snow accumulations in February and March and below-average air temperatures contributed significantly to spring flooding in April 1962 (peak discharge 11.8 $m^3 s^{-1}$). Groundwater supplies and more regular precipitation contributed to runoff values in summer being higher than in 1974. In mid-August, however, precipitation receded and during 41 days (from 19 September to 29 October) only 1.6 mm of precipitation fell at Telgárt. October discharges fell below the values of Q_{330} to Q_{364} (0.4 to 0.26 $m^3 s^{-1}$).

The years 2010 and 2003 saw the most extreme flooding and drought. In the studied 1961–2010 period, 2010 was the wettest and 2003 the driest. The hydrographs in Figures 12 C and D clearly demonstrate this fact. Throughout all of 2010, in May and June in particular, intensive precipitation (150% of the long-term mean) caused multiple floods. The largest peak came in early June with a discharge of 15.4 $m^3 s^{-1}$. Thus, in hydrological year 2010, daily discharge on 55 days was below 1 $m^3 s^{-1}$; in 2003 it was 244 days. It is also interesting to note that 2003 was preceded by a very wet period lasting from the late 1990s until 2002. The longest dry episode in 2003 occurred in winter and early spring (6 February to 2 April) and lasted 56 days. In this period, 6.4 mm of precipitation fell at Telgárt. Snow accumulation mainly in February only very slightly increased spring discharge values and overall snow cover depth was only 1/3 of the maximum depth of 1963. The largest decreases in discharge occurred in July, August, and September, when air temperatures were above-average and precipitation occurred only sporadically.

The findings that Q_{Max} have primarily impact on the decrease in runoff confirms when assessing the daily

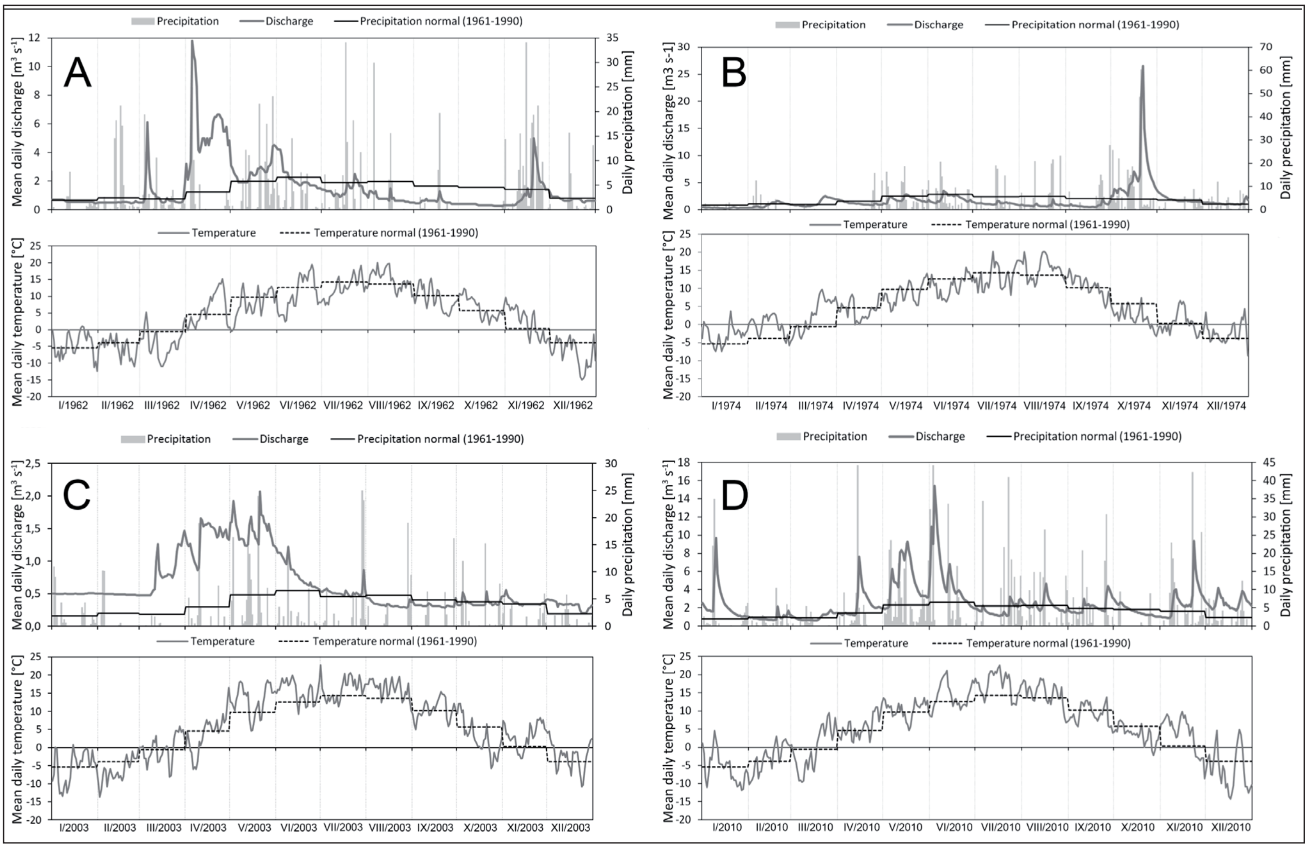

Fig. 12 Development of mean daily air temperature, daily precipitation amounts and mean daily discharge in Zlatno and Telgárt stations in 1962 (A), 1974 (B), 2003 (C) and 2010 (D). Data source: SHMI, B. Bystrica

hydrological data. The largest decrease occurred in value of 1-day maximum, but also in values of 3-day and 7-day maximum (Table 6). A slight increase occurred in 1-day, 3-day and 7-day minimum. From the values of 7-day minimum flow and mean annual flow was calculated base flow index. In medians, COD and maximum values there was only a slight increase in this index.

4.4 Statistical evaluation of extremes using Mann-Kendall test

The results of Mann-Kendall test (Table 7) revealed significant changes in the value of Q_m, Q_r, Q_{Max}, Q_{Min} and daily discharges Q_{330}, Q_{355} and Q_{364} in Zlatno station in the period 1961–2010. Prolonged period in the past, significant changes occur.

Assessing the entire year, we can state that the greatest decreases occur in Q_r and daily discharge Q_{330}. There were slightly weaker decreases in Q_{Max} and Q_{Min} and daily discharges Q_{355} and Q_{364}.

Examining monthly time series, decreases dominated in the cold half year, in the period from November to February. We recorded the largest decrease in Q_m, and slightly weaker decreases in Q_{Max} and Q_{Min}. The decrease in Q_m is most evident in December, followed by November, February, and January. The most significant decrease in Q_{Min} occurs in December and January. In contrast a significant decrease in Q_{Max} occurs mainly in November and then in February. No significant changes occurred in the summer. Thus, long-term changes in Q_{Max} and Q_{Min} in the cold half year have an influence on the decrease in Q_r.

5. Discussion

This paper evaluates hydroclimatic extremes (droughts and floods) in the upper Hron River basin, which is classified as a basin with a decreasing long-term discharge trend (Poórová et al. 2013a). The European areas are susceptible to drought from the early 1980s to early 2010s, confirms the results Spinoni et al. (2015). On the growth of dry episodes since 1881 in the Czech Republic inform Brázdil et al. (2009). As the main cause include growth air temperature and decrease of precipitation. Conversely, a study by Hisdal et al. (2001) argues that it is not possible to conclude that drought conditions in general have become more severe or frequent. But they found distinct regional differences, for example with decreasing drought deficit volumes in large parts of Central Europe. Trends in drought deficit volumes or durations are explained through changes in precipitation or artificial influences in the catchment. Analyses from Zlatno station confirmed finding by Poórová et al. (2013a), Spinoni et al. (2015) and Brázdil et al. (2009). Overall, the second half of the studied period, that is, 1981–2010, was less wet.

Tab. 7 Results of Mann-Kendall test (*MK-S* values) for mean monthly and annual discharge, maximum and minimum in the month/year, daily discharges Q_{330}, Q_{355}, Q_{364} in Zlatno in two periods (1931–2010 and 1961–2010).

Discharge	Period	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	Year
Mean	1931–2010	−2.67	−2.70	−2.57	−2.64	−1.82	−0.47	−0.42	−1.74	−0.91	−0.60	−1.64	−1.36	−2.65
	1961–2010	−0.69	0.09	0.57	0.13	−0.37	−0.96	−0.79	−1.87	−1.22	0.09	0.23	0.77	−1.28
Maximum	1931–2010	−2.46	−2.27	−1.82	−2.44	−1.50	−0.75	−0.39	−1.31	−1.19	−1.32	−1.67	−1.28	−1.86
	1961–2010	−1.16	0.30	0.52	−0.26	−0.69	−0.91	−0.76	−1.56	−0.90	−0.09	−0.56	0.20	−0.75
Minimum	1931–2010	−2.09	−2.47	−2.28	−2.01	−1.80	0.97	−0.29	−0.52	−0.87	−0.13	−1.75	−1.63	−2.34
	1961–2010	0.66	0.14	0.36	1.17	0.73	−0.28	−0.19	−1.29	−1.13	0.67	0.64	0.72	1.16
Q_{330}	1931–2010													−3.02
	1961–2010													0.65
Q_{355}	1931–2010													−2.44
	1961–2010													1.05
Q_{364}	1931–2010													−2.08
	1961–2010													1.62

Notes: significant values are highlighted in colour, a significant decreasing trend (dark grey), a slight decreasing trend (light grey).
Data source: SHMI, B. Bystrica

A longer-lasting less wet period from 1986 to 1993, the period 2002 to 2004 with the exceptionally dry 2003, and 1982 and 1983 contributed to decreased wetness. Despite this, one of the wettest years (2010) occurred at the end of the entire study period (Šipikalová et al. 2011). We may conclude that the de Martonne and the relative precipitation index, chosen for this analysis, have brought comparable results.

Statistically decrease in wetness in the upper Hron River basin confirmed Mann-Kendall test. The most significant is the decrease in values of Q_r and daily discharge Q_{330}. There were slightly weaker decreases in Q_{Max} and Q_{Min} and daily discharges Q_{355} and Q_{364}. A clear decrease in runoff occurs at Zlatno station in the cold half year (mainly from November to February), which corresponds with the findings of Majerčáková et al. (2004) and Demeterová and Škoda (2009). According to Mann-Kendall test results, the largest decrease in Q_m was in December, which corresponds with a shift in minimum values from late November to mid-December and a significant decrease in Q_{Min} values (Blahušiaková and Matoušková 2015).

Poórová et al. (2013b) found that the most favorable conditions for the development of Q_{Min} are in the upper catchments of the Slovak rivers. But in the upper Hron tributaries (from Low Tatras and Slovak Ore Mountains) there is a decreasing trend of Q_{Min}, which changed the character development Q_{Min} on the lower flow of the river. Results using IHA demonstrate a decrease in Q_{Min} of 0.1 $m^3 s^{-1}$ at Zlatno station between 1951–1980 and 1981–2010, in both the cold (a decrease of about 24%) and warm half years (a decrease of about 19%). Interesting would be found out what numerical impact has this decrease on the lower flow of the Hron River.

One of the greatest frequencies of winter long-term dry periods (more than three times in ten years) in Slovakia was observed in the upper Hron River basin by Demeterová and Škoda (2009). Based on our results, the dry episodes were more frequent on the upper Hron in the cold half year. The driest episodes occurred in January; the longest however occurred from February to April of 1974 and 2003. It is given to the fact that in our analyses were included autumn and spring months to the cold half year, which affected the development of drought in the winter. Great influence on the development of drought on the upper Hron has snow cover. An example were years 1974 and 2003. A decrease of snow in the cold season affects the value of runoff in the warm season (Staudinger et al. 2014). A reduction in SWE resulted in earlier low-flow occurrence (Jeníček et al. 2016). In the warm half year the dry episodes were more frequent mainly in the 1960s. But, the longest dry episodes occurred from October to November of 1978 and from September to October of 1985.

Based on the Mann-Kendall test there is a statistically significant decreasing trend in annual peak discharge in the basins of east and central Slovakia (Jeneiová et al. 2014). The same results were obtained in our analysis. Different results are in south-west region of Slovakia, where a slight increasing trend was observed (Blaškovičová et al. 2014). In a more detailed analysis, we find that the largest decrease occurred in value of 1-day maximum, but was also significant in values of 3-day and 7-day maximum. Decrease wetness was confirmed also by an analysis of the frequency of occurrences of events where discharge is $\geq Q_1$. Eighteen such events were determined in 1951–1980, compared to seven such events in 1981–2010. Moreover, the Q_1 threshold was exceeded on seven days in 1958. Events where discharge was $\geq Q_5$ occurred only in 1951–1980 (in 1954 and 1974). We observed this decrease not only at Zlatno station, but in the entire upper Hron River basin (Blahušiaková and Matoušková 2015). The results by Yiou et al. (2006) also point that occurrence and intensity of floods in Bohemia have generally decreased over the 20th century.

Seasonality of annual maximum flood peaks in Central Europe (Germany, Switzerland, Czech Republic and Slovakia) was examined by Villarini et al. (2011). The results showed that in the southern portion of this region there is a large fraction of annual maximum flood peaks occurring during the summer. For the upper Hron River basin is typical occurrence of floods at the end of winter and during spring. From our results it is significant that changes in maximum peak values have a significant impact on the decrease in runoff in the cold half year. Between the periods 1951–1980 and 1981–2010, Q_{Max} decreased in the cold half year on average by 0.8 $m^3 s^{-1}$ (a decrease of about 25%) and in the warm half year by 0.7 $m^3 s^{-1}$ (a decrease of about 18%). Significant decreases occur in November and February. There was a significant decrease in events where discharge is $\geq Q_1$ in April. Q_{Max} values and events where discharge is $\geq Q_1$ decrease mainly in October, May, and July. In contrast, they increase in January and September.

Studying the occurrence of past extremes can help interpret their occurrence in the present. They indicate that in the past it was not unusual for both a long-lasting drought and devastating flood to occur in the same year. A good example is 1974 when drought occurred from February to April and a flood in October. Another example is 1962 with a flood in April and drought lasting from September to October. Equally interesting is the last decade of the studied period, when two of the most extreme years occurred: the exceptionally dry 2003 and the exceptionally wet 2010.

6. Conclusion

The main conclusions of this study are:

(1) In the upper Hron basin there is a decreasing trend in runoff, which was significant in 1931–2010. The largest decrease can be observed in Q_r, Q_{75pct} and daily discharge Q_{330}. Decrease is particularly significant in the cold half year (from November to February).

(2) Q_{Min} values in both the cold and the warm half years decreased on average by 24% and 19%. The longest dry episodes lasted from February to April (in 1974 and 2003). A shift in minimum values from November to mid-December was observed. The values of base flow index do not show changes.

(3) Q_{Max} values decreased, in the cold half year on average by 25%, and in the warm half year by 18%. The largest decrease occurred in values of 1-day maximum, 3-day and 7-day maximum. In March and October was recorded the largest decrease. A decrease in events where discharge was $\geq Q_1$ was recorded from approximately the mid-1980s. There was a significant decrease mainly in April. At the same time a decrease in the extremity of flood events was observed.

(4) The de Martonne, the relative precipitation index and the low flow index show similar results in determining the character of the each year in studied periods. The longest above-average period of annual values reached from 2007 to 2010 and the longest below-average period from 1990 to 1993. In 1961–2010 exceptionally dry years were 1973, 1993, and 2003. In contrast, 1965, 1975, and 2010 were exceptionally wet years.

(5) Decreases in the occurrence of Q_{Max}, Q_{75pct}, and events where discharge is $\geq Q_1$ as well as more frequent occurrence of Q_{Min} in the cold half year contribute greatly to the decrease in runoff on the upper Hron.

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RESUMÉ

Hodnocení výskytu hydroklimatických extrémů v povodí horního Hronu, Slovensko

Článek se zabývá výskytem hydroklimatických extrémů v povodí horního Hronu na Slovensku v období 1951/61–2010. Sledované jsou trendy vývoje vybraných hydroklimatických parametrů v období 1931/61–2010. Důraz je kladen na výskyt, frekvenci a sezonalitu suchých epizod a povodňových událostí. V analýzách je použitý de Martonneho index, index relativního množství srážek, index základního odtoku, index nízkého průtoku, lineární regrese, Mann-Kendallův test a IHA software.

Mann-Kendallův test poukázal na významné změny v odtoku v povodí horního Hronu, hlavně na pokles ročního odtoku. Na tento pokles mají zásadní vliv změny v minimálních a maximálních průtocích, a to především v chladné polovině roku. K největším změnám došlo v hodnotách Q_1, Q_{Max}, Q_{75pct} a v hodnotách 1-denních, 3-denních a 7-denních maxim. Hodnoty základního odtoku nevykazují žádné změny.

Přibližně od 80. let 20. století došlo k poklesu událostí s průtokem rovnajícím se nebo větším než je jednoletý průtok Q_1. Události s průtokem =>Q_5 se objevily jenom v období 1951–1980 (v roce 1954 a 1974). De Martonneho index, index relativního množství srážek a index nízkého průtoku ukazují podobné výsledky při určování charakteru jednotlivých období. Mezi výrazně suchá období patřila perioda 1990–1993, naopak nadprůměrně vodným obdobím byla perioda 2007–2010. Mezi mimořádně suché roky ve sledovaném období patřily: 1973, 1993 a 2003; mezi mimořádně vodné roky: 1965, 1975 a 2010.

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FACTORS OF FORMATION AND DEVELOPMENT OF SUPRAGLACIAL LAKES AND THEIR QUANTIFICATION: A REVIEW

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ABSTRACT

Supraglacial lakes greatly affect the rate of glacier ablation and a potentially dangerous (GLOF – Glacier lake outburst flood) proglacial lake often forms through their development. The main part of the paper recapitulates the factors of the formation and drainage of supraglacial lakes, as well as the mechanisms of their development through a review of the scientific literature. In total there are five factors of the formation of supraglacial lakes and four factors (three of them alternative to one another) of the drainage. Three factors delimit the maximum extent of the emergence of supraglacial lakes, two of them determine the detailed distribution of localities suitable for hosting supraglacial lakes. The circumstances leading to the drainage mainly reflect the decisive role played by englacial voids. According to the current degree of scientific knowledge there are no factors controlling the development of supraglacial lakes. The complete process of the expansion of a supraglacial lake may be viewed as a positive feedback loop consisting of three major mechanisms. In the final part all of the factors are provided with quantitative intervals responding to the respective probability scales, which enable a relatively objective assessment of the probabilities of formation/drainage of supraglacial lakes. The most frequent application is the case of the assessment of the probability of the formation of a large supraglacial lake, due to its likely development into a proglacial lake.

Keywords: supraglacial lakes, glaciers, high mountain areas, GLOF

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1. Introduction

Supraglacial lakes are usually a small but very important phenomenon on a glacier, as shown in the following two paragraphs. In spite of their significance, only a few authors have discussed the evolution of supraglacial lakes in a global way and only Reynolds (2000) and Quincey et al. (2007) considered criteria for the assessment of supraglacial lakes. This study firstly aims to summarize, in the form of a review of scientific literature, the factors influencing the evolution of supraglacial lakes and the mechanisms and processes through which a supraglacial lake forms, expands and becomes extinct. In accordance with the theoretical background, the factors are given quantitative limit values that enable objective assessment of particular glacier reaches in respect of the emergence and development of supraglacial lakes.

Hutchinson (1957) regarded supraglacial lakes as transient, ephemeral phenomena that are interesting to a scientist only as limnological curiosities. He also quotes even older authors (e.g. Delebecque 1898; Collet 1925) who carried out a research of particular Swiss glaciers describing lake basins with a diameter reaching 130 m. Progressing climate change and the retreat of glacier termini showed the importance of supraglacial lakes and of the research carried out on them.

The formation and subsequent expansion of supraglacial lakes is regarded as a reaction of a glacier to the climate change (Benn et al. 2012; Xin et al. 2012). Supraglacial lakes and their outbursts substantially affect the net ablation rate of a glacier (Benn et al. 2000) having a great impact on its mass and water balance (Liu et al. 2013). The melting of ice cliffs exposed around supraglacial lakes accounts for large portions of the whole-glacier ablation rate, even though the ice cliffs cover only a small part of the surface of a glacier (Sakai et al. 1998, 2000). The evolution and expansion of a supraglacial lake finally results in its transition to a moraine- or bedrock-dammed proglacial lake (Komori 2008; Benn et al. 2012), which presents a significant threat to downstream situated areas with respect to many worldwide GLOF events (e.g. Lliboutry et al. 1977; Vuichard and Zimmerman 1987; Clague and Evans 2000). For this reason, Reynolds (2000) suggests identifying areas appropriate for the formation of large supraglacial lakes on glaciers with a negative mass balance, in order to start early remedial works that should prevent the storage of large volumes of meltwater.

1.1 Typology of glacial lakes

Glacial lakes may be classified with respect to many points of view. The simplest typology distinguishes scoured and dammed lakes. More detailed classification discriminates glacial lakes with respect to the material forming their dams: bedrock-, moraine-, and ice-dammed lakes (e. g. Emmer et al. 2014). For the purposes

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Baťka, J. (2016):
Factors of formation and development of supraglacial lakes and their quantification: a review
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of this review the most appropriate approach is to classify glacial lakes according to their position relative to the glacier, i.e. proglacial lakes, located downstream of the glacier snout, and supraglacial lakes, that develop directly on the glacier (Gardelle et al. 2011). Logically, the second group should contain not only supraglacial lakes but also englacial and subglacial lakes emerging inside and under the glacier, respectively. In some cases, the lake may seem to be proglacial, but is still underlain by dead ice and should be classified as being supraglacial, such as Tsho Rolpa (Khumbu Himal, Nepal) (Chikita et al. 1999).

1.2 Typology of supraglacial lakes

There are two possible ways of classifying supraglacial lakes. Benn et al. (2012) distinguish two types of supraglacial lakes according to their relative elevation to the hydrological base of the glacier (the level at which meltwater leaves the glacier, usually the lowest point of the crest of the moraine dam) as perched and base-level lakes. Perched lakes are situated above the level of the hydrological base and persist only if their basin is formed by impermeable ice, otherwise their drainage takes place (Section 4.3). Their diameter seldom exceeds 100–200 m. The surface of base-level lakes, on the contrary, lies at the same level as the hydrological base. The existence of this type of supraglacial lakes depends on the stability of the dam and their length along the valley line may reach several kilometres (e. g. 3 km long Tsho Rolpa, Rolwaling Himal, Nepal) (Chikita et al. 1999).

A typology of Nakawo et al. (1997) or Takeuchi et al. (2012) is based on the existing/missing connection of supraglacial lakes to the glacier drainage system. Logically, base-level lakes can only be connected to the drainage system. In the case of perched lakes, both combinations are possible (Figure 1).

2. Methods

Information from various papers on high-mountain supraglacial lakes or on processes relating to them was gathered as a basis for this study. The absolute majority of the results of the field-work research published in the source articles was from on glaciers of high Asian mountain ranges (mainly the Himalayas, but also the Karakorum and the Tien-Shan), other destinations include the Southern Alps of New Zealand, the European Alps, and the mountain ranges of Alaska. The results of several laboratory and theoretical modelling studies were taken into account and a few review articles were also studied. The findings of the research of supraglacial lakes on the Greenland and Antarctic Ice Sheets were almost wholly omitted because substantial differences exist between lakes emerging on high-mountain glaciers and those forming on ice sheets. All of the information was analysed, critically assessed and categorized according to the main subject of the review.

Afterwards, each factor relevant for the formation/drainage was assigned a list of limit values. Published graphs and tables (ice density, surface gradient and debris cover thickness) were utilized when possible. The factors of surface depressions and surface outflow enable only a yes–no approach, which means they are either present or absent. Quantitative limit values of a particular factor generate a sequence of intervals with a corresponding succession of approximate probabilities. Particular probability scale bounds and also some of the limit values (e. g. the distance to the englacial void) were determined at least partly subjectively because of the lack of a background of empirical relations.

3. Factors of formation and distribution of supraglacial lakes on glaciers

There are three essential conditions for a supraglacial lake to form. First, the surface of a glacier must be impermeable for meltwater. During the process of firn compaction, the critical value of firn density is usually 0.80–0.83 g/cm^3 (Barnola et al. 1991). However, the firn-snow transition occurs at lower or higher densities in some cases, with the minimum and maximum density being 0.78 and 0.855 g/cm^3, respectively (Gregory et al. 2014). A lake also needs sufficient inflow of meltwater. Many supraglacial lakes emerge during the melt season and then freeze again in middle and high latitudes, whereas in the tropics the absence of thermal seasonality favours lake formation throughout the year. Finally, appropriate topography of the glacier surface enables the collection of meltwater. Shallow depressions serve as lake basins, so can the confluence of two or more glacier streams (Reynolds 2000), and if present debris cover can also trap water (Raymond and Nolan 2000). Occasionally, blocked englacial conduits may be exploited as a lake basin and sometimes a formerly drained lake basin can be re-filled by meltwater (Benn et al. 2000).

The maximum extent of the emergence of supraglacial lakes along the longitudinal profile of a glacier is constrained mainly by thermal conditions and debris cover. The highest position of the zero isotherm during the melt season defines the upper maximum level, and the glacier terminus the lower boundary of the possible formation of supraglacial lakes (Benn et al. 2012; Sakai 2012). Thick debris cover prevents melting on the lowermost part of glacier tongues. Thus, the lower end on debris-covered glaciers is shifted somewhat further from the terminus into the area, where the thickness of the debris layer gets thinner (Benn et al. 2012). For example, the initial development of Imja Tsho (Khumbu Himal, Nepal) in the 1960s followed this notion (Watanabe et al. 2009).

Liu et al. (2013) examined eight debris-covered glaciers in the Khan Tengri-Tomur Mountains (Tien-Shan,

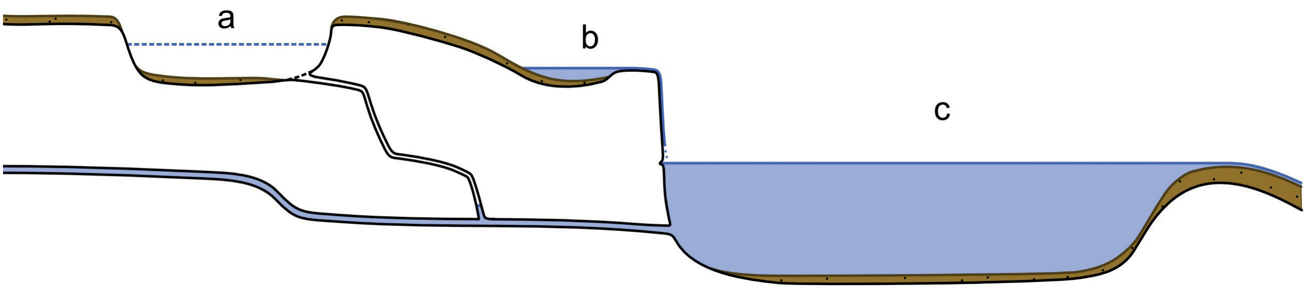

Fig. 1 Typology of supraglacial lakes. Drained perched lake formerly unconnected to the glacier drainage system (a). Perched lake connected to the drainage system (b). Base-level lake (c).

Central Asia) and their findings illustrate the impact of debris cover and mean air temperature on the distribution of supraglacial lakes quite well. In altitudinal distribution, supraglacial lakes appear 100 or 200 m above the glacier-snout level. The area of supraglacial lakes increases with altitude and thinning of the debris cover thickness, peaks near the altitude where small areas of clean ice emerge, and then gradually decreases with air temperature.

The distribution of supraglacial lakes on the glacier tongue is also influenced by the surface gradient. Based on the research carried out on several Bhutanese glaciers, Reynolds (2000) presents a simple relationship. A steeper gradient generally means a higher flow velocity, which then raises the probability of the opening of surface crevasses, and meltwater is more likely diverted off the glacier surface. Only a small number of supraglacial lakes form under such circumstances. When the values of the surface gradient exceed a particular limit no supraglacial lakes emerge since all of the meltwater is effectively drained downglacier. Reynolds (2000) also quantifies this relationship (Table 1).

More recent papers, however, question these intervals, especially the limit for the formation of supraglacial lakes. Salerno et al. (2012) applied the techniques of remote sensing to compile the database of all of the glacial lakes in the Sagarmatha National Park. An analysis of the obtained data suggests that supraglacial lakes may emerge on reaches sloping more than 10° but are usually short-lived. On the other hand, Salerno et al. (2012) confirm the value of 2° of the surface gradient as the upper threshold for the development of large supraglacial lakes. Liu et al. (2013) present similar results having used analogous methods in the Khan-Tengri Mountains. A small portion (14.3%) of supraglacial lakes was located on the glacier reaches, which sloped more than 10°. The majority (42.8%) of lakes lay in the zones with a surface gradient spanning from 2° to 6°. Baťka (2015) shows that the upper limit for the emergence of supraglacial lakes lies at 25°.

To summarize, there are relatively gentle reaches along the longitudinal profile of the glacier with the potential for the formation of supraglacial lakes alternating with icefalls where no lakes emerge regardless of other factors (temperature/debris cover).

Tab. 1 Relationship between the glacier surface gradient and supraglacial lake formation Reynolds (2000).

Surface gradient	Interpretation
0–2°	formation of large supraglacial lake over stagnant or very slow moving ice body forms from the merging of many smaller discrete ponds
2–6°	supraglacial ponds form, may also be transient locally, but sufficiently large areas affected by presence of ponds
6–10°	isolated small ponds may form, transient due to local drainage conduits opening and closing due to ice flow
>10°	all meltwater is able to drain away, no evidence of ponding

4. Mechanisms of growth of supraglacial lakes

4.1 Albedo change and ablation near the lake

The formation of a supraglacial lake means a change of surface material (from ice, snow, or debris to water surface, Table 2) and thus a drop in the value of albedo inside the polygon of this new lake (Reynolds 2000). The amount of absorbed heat rises through the higher input of the shortwave solar radiation, the main source of heat (Sakai et al. 2000). Due to this, the lake water temperature is kept a few degrees above the point of freezing for most of the year, and the lake actively ablates the ice that forms its basin and expands through the retreat of the sides of the basin (Reynolds 2000). Snowflakes melt in the lake water during snow storms, yet the nearby glacier surface becomes covered with a white blanket and the albedo difference peaks as the albedo of snow is the highest one. Supraglacial lakes also freeze later than their surroundings before or during winter and at the start of the ablation season the ice lid melts sooner than the adjacent surface (Reynolds 1981, 2000).

The change in albedo is important mainly in the case of debris-free glaciers, where supraglacial lakes present the principal means of glacier ablation (Komori 2008). On debris-covered glaciers, however, the difference in albedo of the water surface and debris is not as high as that of the former glacier type. Here, the thickness of the surface debris layer plays a substantial role as it lowers the albedo and isolates the underlying ice (Figure 2). The

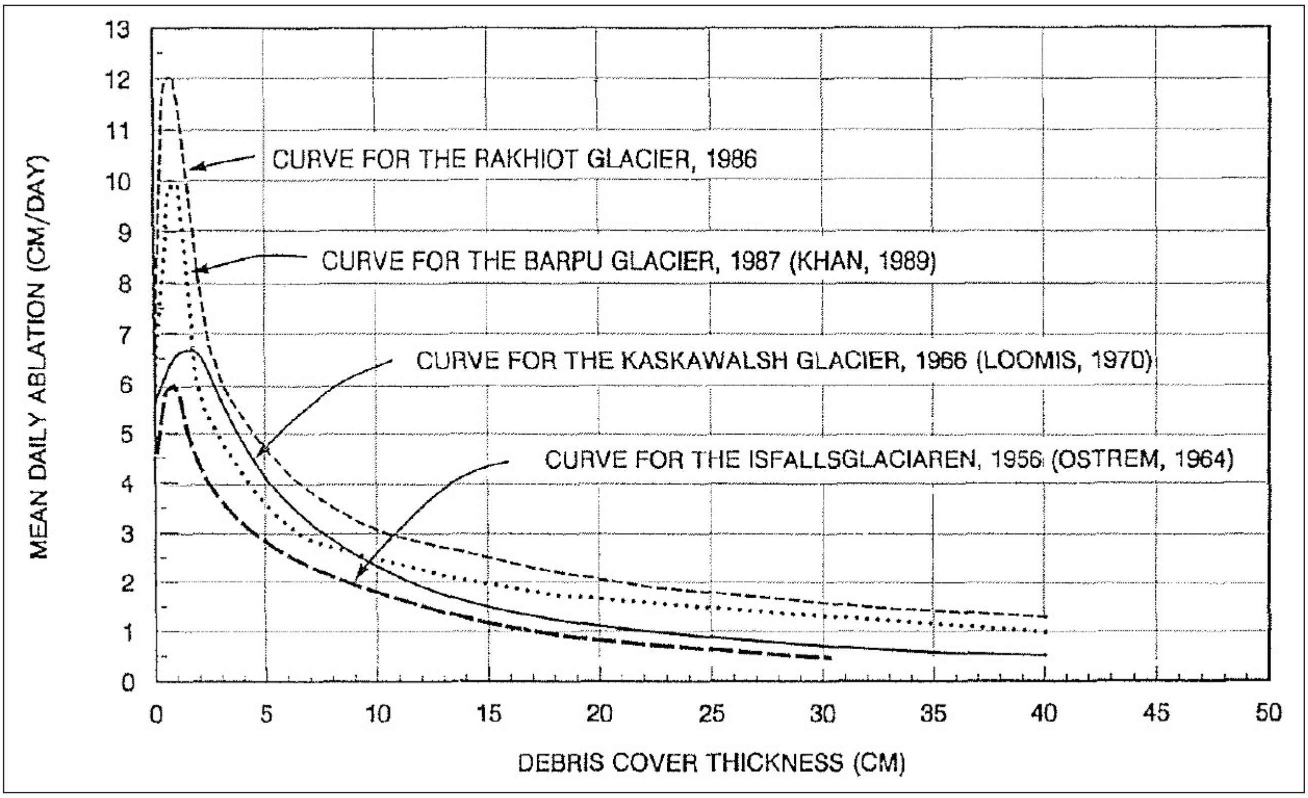

Fig. 2 Relationship between debris cover thickness and ablation rate (Mattson et al. 1993).

Tab. 2 Values for albedo of snow, firn, ice, water, and debris.

Surface type	Albedo	Source
Fresh dry snow	0.75–0.98	Cuffey and Paterson (2010)
Old clean wet snow	0.46–0.70	Cuffey and Paterson (2010)
Clean firn	0.50–0.65	Cuffey and Paterson (2010)
Debris-rich firn	0.15–0.40	Cuffey and Paterson (2010)
Clean ice	0.30–0.46	Cuffey and Paterson (2010)
Debris-rich ice	0.06–0.30	Cuffey and Paterson (2010)
Debris	0.15–0.25	Benn et al. (2012)
Water	0.10–0.35	Yamada (1998)

ablation rate firstly increases with the increasing thickness of the debris cover, reaching the maximum value at a thickness of approximately 1–2 cm (Mattson et al. 1993), because there is almost no insulation effect and the albedo of the wet and dirty ice can be as low as 0.06 (Cuffey and Paterson, 2010). After peaking, the ablation rate decreases exponentially because of the increasing influence of isolation by debris and the melt rate is always <1 cm/d under layers >0.5 m thick (Mattson et al. 1993). Every morning, a certain amount of time is needed to constitute stable heat flow through the debris cover so the period of day when ice ablation occurs is significantly shortened (Reznichenko et al. 2010).

These two counteracting effects of the debris cover mean that wherever the continuity of the debris layer is interrupted the melt rate substantially increases. This is the case of the nearby surroundings of supraglacial lakes. Immediately after its formation, the lake deepens and widens (due to the relatively low albedo of its surface). The slope angles of its basin are steepened to the point of the limit angle of debris repose, i.e. 30–40° (Sakai et al. 2000, Gardelle et al. 2011), the glacier surface gradually becomes debris-free and the lateral expansion of supraglacial lake accelerates.

There are two processes that somewhat slow the expansion. The former involves differential ablation of the slope (e.g. the slope of an ice cliff or, particularly in this paper, a slope forming the shore of a supraglacial lake). Due to topographic shading, places located higher on the slope receive greater amounts of incoming shortwave radiation than those near the lake surface. Thus, ablation is the highest at the top of the slope and decreases towards the bottom, which gradually reduces the slope angle back under the angle of repose. The process is most rapid on slopes oriented southeast to south in the northern hemisphere (Sakai et al. 1998, 2002). The latter of the two slowing processes is the cooling effect of meltwater inflow. Ablation around the supraglacial lake results in meltwater (temperature approximately 0 °C) flowing into the lake, where it mixes with the lake water and thus slightly reduces its temperature. However, the amount of heat from the absorbed incoming solar radiation substantially outpaces the rate of this cooling (Xin et al. 2012).

The rate of vertical expansion of a supraglacial lake on debris-covered glaciers progressively decelerates, as the ice initially forming the bottom of the lake becomes buried under the layer of debris formerly lying on the glacier

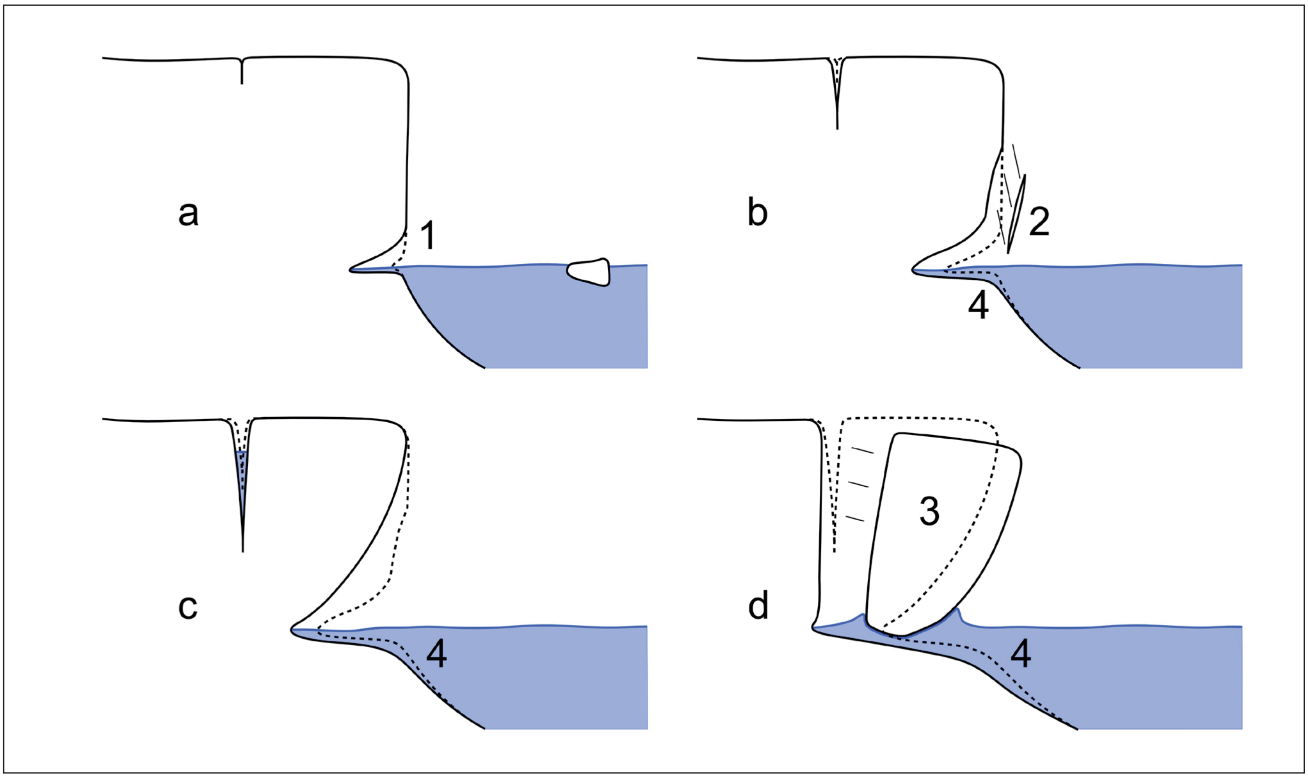

Fig. 3 Calving cycle (a–d) and calving types (1–4). Please, see text for description of sketches a–d. Calving at the waterline (1). Flake calving (2). Full-height slab calving (3). Subaqueous calving (4). (after Kirkbride and Warren 1997; Sakai 2012)

surface. In a similar way as the surface cover, the isolation effect of debris increases with increasing thickness. Chikita et al. (2000) described the probable final stadium of vertical expansion of a base-level lake. At the bottom of Imja Tsho (Khumbu Himal, Nepal) the medium consisting of debris, lake water and lake sediment separates the lake water and the dead ice. Very slow thermal conduction through the medium provides small amounts of heat for melting the dead ice. The meltwater mixes with the medium, pushes out approximately the same volume of water into the lake and the lake bottom subsides (Chikita et al. 2000).

4.2 Glacier calving and wind action

After attaining a diameter of approximately 30 m (Sakai et al. 2009) the lake volume is large enough for a new and more effective mechanism of expansion to commence, i.e. calving. After crossing this threshold, the expansion accelerates significantly (Röhl 2008; Benn et al. 2000). Kirkbride and Warren (1997) distinguish four calving types (Figure 3) in their study of the Maud Glacier (New Zealand): calving at the waterline, flake calving from the cliff face, full-height slab calving and subaqueous calving. The frequency decreases but the volume of calved ice increases from the waterline type towards subaqueous calving (Kirkbride and Warren 1997).

Calving at the water line forms and gradually widens a thermo-erosional notch that undercuts and destabilizes the ice cliff (**a** in Figure 3). Meanwhile, flake calving from the cliff face subsequently contributes to the process of notch enlargement, and a vertical fracture opens a few metres upglacier behind the cliff edge (**b** in Figure 3). Thus, the block is geometrically defined for full-height slab calving (**c** and **d** in Figure 3) (Kirkbride and Warren 1997). Diolaiuti et al. (2011) suggest the decisive role of fracture opening during calving, but Röhl (2006) and Xin et al. (2012) consider the horizontal notch the most important factor for subaerial calving.

Subaqueous calving, as described by Kirkbride and Warren (1997), involves detaching of subaqueous blocks and ramparts left by the subaerial calving cycles of full-height slabs, which is impossible in the case of supraglacial lakes. However, Röhl (2008) shows the importance of subaqueous melting of ice for the expansion of supraglacial lakes, also applying the term subaqueous calving for this process.

Continuing both lateral and vertical expansion brings a supraglacial lake to another threshold when the lake length exceeds approximately 50 m and the height of the usually present end moraine is sufficiently low. According to the model developed by Sakai et al. (2009), the wind speed along the water surface attains significant values (>1 m/s) and thus has a substantial impact on the lake water circulation. The valley wind makes the warmest surface water layer move towards the ice cliff (perched lake) or the active glacier front (base-level lake) where it accumulates, significantly accelerating the formation of the thermo-erosional notch and thus also calving (Sakai et al. 2009). The maximum height of the terminal moraine allowing this wind action probably depends on the length of the lake. Chikita et al. studied two great Nepalese supraglacial lakes – Tsho Rolpa (Chikita et al. 1999) and Imja Tsho (Chikita et al. 2000). Tsho Rolpa (3 km in length) was found to experience the circulation modelled by Sakai et al. (2009). In the case of Imja Tsho (1.3 km in length and the height of the end moraine 30 m), however, no such process was occuring.

4.3 Exploitation of englacial conduits

Thermal and mechanical incision of a supraglacial stream can produce an englacial cut-and-closure conduit when followed by roof closure. This tunnel persists if it is provided with a sufficient volume of meltwater by the source area of the glacier surface. Otherwise, glacier flow deforms, interrupts, and even fills certain reaches of the cut-and-closure conduit. The remaining unfilled parts become lines/zones of secondary permeability. Another possible way for secondary permeable structures to form is the downward propagation of water- or debris-filled crevasses, again followed by the roof closure (Gulley et al. 2009; Benn et al. 2012). Both cut-and-closure conduits and lines of secondary permeability are important means of drainage of perched supraglacial lakes (Section 5) and of base-level lake expansion.

After the formation of a base-level lake, the pattern of its expansion is determined by the presence of shallow englacial conduits (Benn et al. 2012). These conduits (and other voids) were originally located in somewhat bigger depths. Gradual downwasting of the glacier surface to the level of the hydrological base lowered the overlying ice and destabilized the ceilings of these structures. The roofs collapse and expose the debris-free ice on the sides of the conduits to incoming solar radiation. Former void spaces fill with meltwater and whole chains of new supraglacial lakes develop. After a certain period of time, all of the lakes coalesce into a single lake which then expands up- and downvalley through calving and dead-ice melt, respectively, and vertically through slow bottom subsidence (Section 4.1) (Benn et al. 2012).

5. Ways of the extinction of supraglacial lakes

Perched lakes drain off when their own expansion brings the basin to the vicinity of a permeable structure (englacial conduit, closed debris-filled crevasse etc. – Section 4.3) (lake "a" of Figure 1). The basin collapses and the lake water drains through the conduit into the lower-lying areas or into the englacial drainage system. In the case of crossing the line of secondary permeability, the partially closed voids are eroded by the relatively warm lake water and a new englacial conduit is formed. The probability of such a drainage increases with the expansion of the lake (Benn et al. 2012). After releasing most or all of the water, lake basins gradually cover with debris. If the cycle of formation and drainage of supraglacial lakes occurs frequently on a glacier, typical hummocky relief forms (Emmer et al. 2015).

The persistence of perched lakes connected to the glacier drainage system depends on the fragile balance between the downward lake expansion and erosion of the surface outflow channel, with the rate of meltwater inflow and outflow also being of importance (Raymond and Nolan 2000). Thermal erosion progressively enlarges the cross-section of the drainage channel. Unless the bottom of the lake basin subsides at a sufficient rate, the erosion of spillway results in an outburst (Raymond and Nolan 2000). In the case of englacial drainage conduit, the lake is likely be drained because of the concentration of relatively warm lake water in a narrow profile (Sakai et al. 2000).

Base-level lakes are incomparably longer lasting phenomena than mostly ephemeral perched lakes. Their life span is determined by the stability of the dam (Benn et al. 2012). A moraine dam may be overflowed by the lake water and/or incised by the water flowing through the outlet. This type of dam is therefore far less stable than those consisting of debris-covered dead ice, in which case only overflowing is possible (Benn et al. 2012; Hanisch et al. 1998).

6. Evolution to the stadium of a proglacial lake

As a rule, debris-free glaciers or those with a limited extent of debris-cover (usually cirque glaciers) cover a far smaller area than debris-covered ones, in most cases <10 km^2. Thus, there is enough space for expansion of only a single lake (Komori 2008). The lake grows through the processes described in Section 4, glacier downwasting may result in the transformation to a base-level lake and if a continuous end-moraine arc or a bedrock barrier is present in front of the glacier, the evolution continues until the stadium of a proglacial lake through the ice ablation in the entire zone (Benn et al. 2012). The whole process takes 20–30 years (Komori 2008).

Debris-covered glaciers, on the contrary, do not experience such a straightforward growth of a supraglacial lake. Komori (2008) discerns three stages of this development, which lasts about 50 years. Initially, many supraglacial lakes appear and expand on the lower part of the zone of ablation. Then, these lakes progressively coalesce into a single one. The evolution to this point lasts on average 10–20 years. Finally, the coalesced lake expands both up- and downglacier (Komori 2008).

Benn et al. (2012) outline a conceptual model of the evolution of the whole complex system, which a debris-covered glacier certainly is, also involving the expansion of supraglacial lakes. They define three regimes of glacier behaviour, transition to the next regime being caused by the crossing of a certain threshold. In Regime 1, the entire glacier is dynamically active, glacier flux

Fig. 4 Tsho Rolpa. The photograph was taken by Dr. N. Takeuchi in June 1994 (Sakai 2012).

compensates losses of ice in the ablation zone, meltwater is effectively drained away by the glacier drainage system and only ephemeral perched lakes emerge. Very few glaciers remain in Regime 1 in the Mount Everest region, one of them being the Kangshung Glacier (Benn et al. 2012).

Transition to Regime 2 is caused by the global warming. Such an external impulse is then amplified by several interconnected positive feedbacks. The upward shift of the rain-snow boundary changes the areas of ablation and accumulation zones, so that the ice inflow from upper portions of the glacier no longer balance the ablation in lower-lying areas. The resulting decline in the glacier surface gradient reduces the driving stresses forcing the ice flow into the lowermost parts of the ablation zone, which significantly stagnates. The decrease in the surface gradient also disrupts the previously efficient glacier drainage system. Both events enable the storage of large amounts of meltwater on the glacier and thus the formation of many perched lakes. Their gradual expansion (particularly by calving) again significantly raises the rates of ice-loss. Among the glaciers in the Sagarmatha region, the Ngozumpa Glacier shows most of the features characteristic of Regime 2 (Benn et al. 2012).

Further downwasting lowers the glacier surface below the level of the hydrological base and a base-level lake forms if a continuous moraine loop is present. Crossing this threshold also means a transition to Regime 3. A base-level lake rapidly expands both by calving and by exploiting the lines of shallow englacial conduits. Vertical expansion slowly reduces the thickness of the underlying (dead) ice, which eventually leads to a transition to a full-depth proglacial lake. The lower Imja Glacier and Trakarding Glacier are typical Regime 3-glaciers, hosting Imja Tsho and Tsho Rolpa, respectively (Figure 4) (Benn et al. 2012).

7. Quantification of factors

There are two papers focused, at least in part, on dividing the glacier surface into zones described by the distinct probability of the formation of supraglacial lakes. Reynolds (2000) considered only one factor – glacier surface gradient (Table 1). Quincey et al. (2007) developed on the previous notion by adding glacier velocity as an independent variable (Table 3) thus involving one of the processes responsible for the drainage of supraglacial lakes. These two ideas are very simple but strong, as we shall see soon.

The formation of supraglacial lakes is influenced by five factors: minimum air temperature, debris cover thickness, surface gradient of a glacier, ice density in situ, and the presence or absence of surface depressions (Table 4). The zones of glacier surface suitable for hosting supraglacial lakes are delimited by the position of the zero

Tab. 3 Relationship between glacier surface gradient, glacier velocity and supraglacial lake formation after Quincey et al. (2007).

	Surface gradient < 2°	**Surface gradient > 2°**
Stagnant ice	Minimal opportunity for reorganisation of drainage conduits, promoting large-scale lake development	No opportunity for reorganisation of drainage conduits through flow, but steeper hydraulic gradient aids drainage and lake development is unlikely
Measurable flow	Large lake likely but with a potential for drainage through the reorganisation of drainage conduits through ice flow	Opportunity for reorganisation of drainage conduits through flow and steeper hydraulic gradient aids drainage, resulting in most efficient drainage conditions so that lake development is least likely

Tab. 4 Factors of supraglacial lake formation and drainage; ice flow velocity and surface gradient are alternatives to the distance to englacial voids.

Factors of formation and drainage			**Source of data**
Formation	Surface gradient		remote sensing
	Debris cover thickness		remote sensing
	Minimum air temperature		field survey
	Ice density		field survey
	Presence/absence of surface depressions		field survey
Drainage	Distance to englacial voids		field survey
	OR	Ice flow velocity	remote sensing
		Surface gradient	remote sensing
	Presence/absence of surface outflow		remote sensing

isotherm, debris cover thickness, and surface gradient (Section 3). The data of debris thickness and surface gradient may be obtained through the analysis of remotely sensed images, whereas a presence in the field is required for obtaining the knowledge of the position of the zero isotherm. Inside previously defined zones, the detailed distribution of areas favourable for the emergence of supraglacial lakes is given by in-situ ice density and the presence of surface depressions – information accessible only through a time-expansive field survey.

No factors controlling the development of supraglacial lakes exist because the whole process of the growth from a minute pond to a great base-level lake may be considered as a complex positive feedback consisting of crossing sectional thresholds (Section 4). During the initial stage of development, the smallest ponds strictly follow the pattern determined mainly by the distribution of surface depressions and other meltwater traps, and also by ice density. When the lake area grows and supraglacial lakes coalesce, the importance of the position of the zero isotherm, debris thickness, and surface gradient rises. Thus, if one wants to find out the probable position of future large supraglacial lakes covering relatively great portions of a glacier, knowledge of the detailed structure of the zones defined by the three main factors is not required.

The development of a supraglacial lake may be interrupted or terminated at any moment by its partial or complete drainage, respectively. The circumstances relevant to the drainage are the distance from lake bottom to the nearest englacial void and the presence/absence of surface outflow channel (Table 4). The stability of the dam is not considered as it is usually one of the input characteristics for breach hazard assessment of a glacial lake. The data are obtained by field survey and analysis of satellite images, respectively. The distribution of englacial permeable structures may also be treated through considering ice flow velocity instead, which only requires satellite images. The argument runs that glacier flow subsequently reorganizes all the crevasses and voids and thus drives the drainage or survival of supraglacial lakes. As shown by Reynolds (2000), glacier flow velocity may then be represented by the surface gradient.

Quantification of factors may be applied in three cases. If one wants to determine the probability that supraglacial lakes emerge on a particular segment of a glacier currently free of lakes, the analysis includes most of or all the factors of supraglacial lake formation, depending on the temporal and financial circumstances. The features involved and their probability scales are summarised in Table 5.

When a supraglacial lake forms and develops further, an assessment of the probability of its drainage may be required. Except for the distribution of englacial voids in the vicinity of the lake, all of the data are collectable through relatively cheap remote sensing methods (Table 6).

When the probability of large supraglacial lake (usually base-level lake) formation is needed, as in the cases of Reynolds (2000) and Quincey et al. (2007), the analysis incorporates factors of both formation and drainage. As the researcher usually desires to use cost- and time-effective methods, the factors the information of which may be obtained through methods of remote sensing should only be used (Table 7). If there are other studies of the mountain range referring to the thermal conditions, the approximate position of the zero isotherm may be estimated and applied together with the other factors.

The theoretical likelihood of supraglacial lake formation/drainage is calculated through multiplication of individual factor probabilities, which are defined by the specific setting of these factors (i.e. their values) on a glacier.

8. Discussion

The majority of the above-mentioned factors affecting supraglacial lakes are quite well studied, such as the surface gradient of a glacier, debris cover thickness, or ice density, and some of them seem logical such as the mini-

Tab. 5 Analysis of supraglacial lake emergence: factors and probability scales, where Minimum T_{air} is minimum air temperature

Probability of lake formation	Ice density [g/cm³]	Minimum T_{air} [°C]	Surface gradient [°]	Debris cover thickness [m]	Surface depressions
1	>0.855	>0	<2	<0.05	present
0.75	0.830–0.855		2–10	0.05–0.10	
0.50	0.800–0.830	0	10–15	0.10–0.30	
0.25	0.780–0.800		15–25	0.30–0.50	
0	<0.780	<0	>25	>0.50	absent
Source	Gregory et al. (2014), Barnola et al. (1991)		Reynolds (2000), Baťka (2015)	Mattson et al. (1993)	Raymond and Nolan (2000)

Tab. 6 Analysis of supraglacial lake drainage: factors and probability scales, please remember that ice flow and surface gradient are alternatives to the distance to the nearest englacial void.

Probability of lake drainage	Distance to englacial void [m]	Ice flow [m/a]	Surface gradient [°]	Surface outflow
1	<0.5	>100	>10	
0.75	0.5–1	20–100	6–10	present
0.50	>1	5–20	2–6	
0	>5	0–5	<2	absent
Source	Benn et al. (2012)	Quincey et al. (2007), Cuffey and Paterson (2010)	Reynolds (2000)	Raymond and Nolan (2000)

Tab. 7 Analysis of large supraglacial lake formation: factors and probability scales.

Probability of lake formation	Surface gradient [°]	Debris cover thickness [m]	Ice flow [m/a]
1	<2	<0.1	0–5
0.50	2–6	0.1–0.3	5–20
0.25	6–10	0.3–0.5	20–100
0	>10	>0.5	>100
Source	Reynolds (2000)	Mattson et al. (1993)	Quincey et al. (2007), Cuffey and Paterson (2010)

mum air temperature or the impact of present surface outflow. The other influences bring significant uncertainties.

The impact of the glacier flow velocity on supraglacial lakes is only estimated. Quincey et al. (2007) discriminate between stagnant glaciers and glaciers with at least measurable motion, the threshold velocity lying at approximately 5 m/a. However, the behaviour of supraglacial lakes located in the area moving faster is only poorly understood, not to mention the maximum flow velocity at which the formation of supraglacial lake is possible. Cuffey and Paterson (2010) use the term fast-flowing for glaciers flowing at velocities exceeding 100 m/a.

Englacial permeable structures cause the vast majority of drainages of perched supraglacial lakes (Benn et al. 2012). The precise critical thickness of ice between lake bottom and the englacial void at which the lake bottom collapses depends highly on the strength and therefore on the internal structure of the ice. Thus, the defined limit values for the distance to englacial voids are only tentative and express the author's subjective opinion (based on the studied literature).

Supraglacial lakes emerge in previously formed depressions on the glacier surface. One of the leading roles is certainly played by glacier flow, which warps the glacier surface, especially near icefalls. Surprisingly, no study concerning such an essential process exists and only a few papers mention minor contributions to the formation of depressions that are made by surface debris cover (Raymond and Nolan 2000), blocked englacial conduits (Benn et al. 2000) and even confluences of glacier streams (Reynolds 2000).

9. Conclusions

Supraglacial lakes are a complex and, thanks to their linkage to glacier mass balance and their possible transition to potentially dangerous proglacial lakes, important phenomenon. However, the importance of supraglacial lakes is slightly underestimated and the processes relating to them somewhat poorly understood, as it has been demonstrated by the problems with precise quantification of certain thresholds.

The emergence of supraglacial lakes is controlled by at least five factors divided into two levels. Debris cover thickness, position of the zero isotherm and surface gradient define zones of the glacier surface generally suitable for the formation of supraglacial lakes, whereas ice density in situ and particularly the distribution of surface depressions determine the detailed pattern of possible future supraglacial lakes. In the initial phases of development of supraglacial lakes, the locations of lake surfaces strictly follow this pattern. However, great supraglacial lakes cover large areas of the former glacier surface and respect mainly three general factors. Drainage may terminate the development of supraglacial lakes at any moment, so the distribution of englacial voids (the distance from the lake bottom to the nearest englacial void) and the presence/absence of surface outflow also play a significant role in the overall analysis.

Quantification of factors that affect supraglacial lakes may be applied in three cases: the emergence and drainage of supraglacial lakes, and the formation of a large supraglacial lake. Reynolds (2000) and then Quincey et al. (2007) give possible ways of assessing the probability of the formation of a large supraglacial lake, only leaving out the factor of debris thickness. The thresholds of certain factors (i.e. the distance to englacial voids and glacier flow velocity) should only be treated as approximate values because there is currently no method for their precise quantification. This uncertainty constitutes only a minor obstacle as the distance to englacial voids may be represented quite well by the glacier flow velocity and in turn by the surface gradient.

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RESUMÉ

Faktory vzniku a vývoje supraglaciálních jezer a jejich kvantifikace: rešerše

Supraglaciální jezera (jezera vznikající přímo na ledovci) se v posledních dvou desetiletích dostala do popředí vědeckého zájmu. Byl doceněn jejich význam pro odtávání (a tím i hmotovou bilanci) ledovců – jedná se tedy o možné indikátory změny klimatu. Díky jejich vývoji v úplnosti zakončeném stádiem proglaciálního jezera, potenciálně nebezpečného pro obyvatelstvo níže položených částí údolí, se začíná uvažovat o monitoringu plošně rozsáhlých supraglaciálních jezer. K tomuto aktuálnímu tématu (po obsáhlé rešerši vědecké literatury na téma faktorů ovlivňujících vznik, vývoj a zánik supraglaciálních jezer) přispívá i prezentovaný článek.

Vznik supraglaciálních jezera vyžaduje poměrně nízký sklon povrchu ledovce (do ~20°), teplotu nad bodem mrazu a ledovec bez suťového pokryvu (případně s málo mocným suťovým pokryvem, do 0,5 m). Uvedené tři okolnosti určují úseky ledovce příhodné pro tvorbu supraglaciálních jezer. Detailní rozložení jezer ovlivňují zejména kolísání hustoty ledovcového ledu/firnu a přítomné deprese na povrchu ledovce.

Ihned po svém vzniku supraglaciální jezero pomalu expanduje (voda díky nízkému albedu absorbuje více slunečního záření než okolní povrch). Pokud má jezero větší průměr než 30–100 m, zajišťuje rozšiřování jezerní pánve proces výrazně účinnější než ten předchozí – telení ledových bloků tvořících boky jezerní pánve. Za příhodné konfigurace okolního povrchu se od rozměrů jezera překračujících 500 m přidává i vliv větru urychlující telení. Jakmile hladina jezera klesne na úroveň hydrologické báze ledovce (definovaná lokalizací výtoku tavné vody z ledovce), dosáhne rychlost expanze supraglaciálního jezera svého maxima, jezero záhy pokrývá celou šíři ledovcového splazu a mění se na typ proglaciální (pokud je přítomen val čelní morény či skalní bariéra).

Podle relativní elevace vzhledem k úrovni hydrologické báze ledovce lze supraglaciální jezera rozdělit na jezera vyvýšená (orig. "perched lakes", nacházejí se nad úrovní báze) a jezera v úrovni hydrologické báze (orig. "base-level lakes", hladina v úrovni odtoku tavné vody). Rozhodujícím faktorem zániku supraglaciálních jezer vyvýšených je rozložení englaciálních tunelů, nedokonale uzavřených fraktur a dalších prostor uvnitř ledovce vyplněných jiným materiálem než ledovcovým ledem. Jakmile se dno pánve dostane během expanze jezera do blízkosti jedné z uvedených struktur, dojde k propadnutí dna a výtoku vody do nitra ledovce. Další okolností zvyšující riziko výtoku jezera je přítomnost povrchového či podpovrchového odtokového kanálu. Supraglaciální jezera v úrovni hydrologické báze přetrvávají, dokud nedojde k porušení jejich hráze (ledovcový led, morénový materiál, skalní bariéra).

Uvedené faktory vzniku a zániku supraglaciálních jezer byly v závěrečné části kvantifikovány prostřednictvím série mezních hodnot určujících pro každý faktor navazující posloupnost intervalů, ke kterým byly přiřazeny pravděpodobnostní stupnice. S pomocí provedené kvantifikace lze pro daný úsek ledovce realizovat objektivní zhodnocení pravděpodobností vzniku supraglaciálních jezer obecně a vzniku velkého supraglaciálního jezera (obvykle v úrovni hydrologické báze) a pro dané supraglaciální jezero pravděpodobnost jeho zániku (tj. výtoku). Zejména zhodnocení možnosti vytvoření velkého supraglaciálního jezera má význam při výběru oblastí pro monitoring, vzhledem k možnému vzniku jezera proglaciálního. Druhé dva způsoby použití kvantifikovaných faktorů lze zakomponovat např. do modelování ablace ledovce.

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SPATIAL DIFFERENTIATION AND FERTILITY POSTPONEMENT TRANSITION IN CZECHIA

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ABSTRACT

Over the last quarter of a century female fertility in Czechia has undergone dynamic and dramatic change. One of the main indications of this is the postponement of births and associated fertility ageing. This article analyses the spatial differences in the character and intensity of fertility in the early 1990s and the current era and attempts to highlight any stability or change in the spatial patterns resulting from the changes in reproductive behaviour. The authors use a number of indicators to analyse the rate, timing and distribution of fertility by woman's age at the district level (LAU1). Additional indicators are also used to assess the level of birth postponement in young people and recuperation during the second half of the reproductive life span. Since the results suggested that there were some areas which exhibited similarities in the characteristics and trajectory of the fertility postponement transition, cluster analysis was used to produce a spatial classification. Although all Czech districts are undergoing a fertility postponement transition, the tendency is for it to deepen the spatial pluralisation of reproductive behaviour, particularly the timing and internal structure of fertility by woman's age, which is the main spatial differentiation factor affecting fertility.

Keywords: fertility, spatial differentiation, fertility postponement transition, Czechia

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1. Introduction

For more than a quarter of a century female reproductive behaviour in Czechia has been undergoing dynamic and dramatic change.The main indications of this are a fall in fertility, stagnant levels of sub-replacement fertility, birth postponement and changes in the proportion of live births with legitimacy status (Sobotka 2004, 2011; Rychtaříková 2008, 2010). These trends have more or less been evident in all former eastern bloc countries since the late 1980s and early 1990s (Sobotka 2004, 2011). However, the first birth postponement that is gradually affecting all European populations is thought to be crucial (Kohler, Billari, Ortega 2002; Sobotka 2004; Frejka, Sardon 2004, 2006, 2007; Frejka 2011). The newly emerging plurality in family and reproductive life paths and the timing of the transitions lie in sharp contrast to the previous model, which was characterised by early motherhood and parenthood and reproductive lives ending at a relatively early age in narrow age intervals (most frequently by age 30 in women). However, under the new social, economic and political conditions, this model no longer features much in the life paths of men and women born since the late 1960s (Sobotka et al. 2008; Šprocha 2014).

First birth postponement has continued unabated in some European countries for more than four decades and has become one of the dominant symbols of reproductive behaviour in developed societies (Sobotka 2004). Lesthaeghe and Neels (2002, 333) have even ranked it amongst the main characteristics of the second demographic transition, in a shift away from van de Kaa's (1987) original conception in which the most important characteristic was a fall in fertility to below replacement level. Historically, European women have never entered into motherhood as late as they do nowadays (Kohler et al. 2006; Prioux 2005). Kohler, Billari and Ortega (2002) suggest that delaying childbearing is in itself a kind of specific "postponement transition" that is leading to a regime of later fertility. In their view, it is possible that this will lead to the rectangularisation of fertility – increasingly concentration into relatively narrow intervals in the late stage of the reproductive age-interval. Postponement transition leads to rapid, persistent and generally irreversible delays in childbearing across a wide range of socioeconomic conditions (Kohler, Billari, Ortega 2002). If these changes in the nature of reproductive behaviour become as universal and inevitable as some advocates of the second demographic transition believe, it may mean that there will be less international and regional differentiation in fertility (Coleman, 2002). Another potential contributory factor is the social and economic convergence fostered within the European Union by market and institutional integration and by the removal of labour market restrictions and the use of structural funds to promote economic growth in weaker regions (Coleman 2002; Compton 1991; Tomeš 2001; Wilson 1991). Many authors (e.g. Decroly and Grimmeau 1996; Wilson 2001; Dorius 2008; Basten et al. 2012) consequently consider the main trend

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in fertility among women in Europe to be one of convergence. Nonetheless, they also think the main regional differences will prevail (see also Hank 2001; Billari and Kohler 2000. According to Coleman (1996) and Lesthaeghe with Neels (2002), the main factors are persistent and historically-determined differences in cultural factors and attitudes, and they consider these to have far greater influence than socioeconomic differences. One important aspect is that the majority of analyses look only at fertility quantum, usually the total fertility rate. However, as Festy (1981) stated, similar rates levels need not meant that fertility is structured similarly. In this respect Basten et al. (2012) suggest that it is the potential divergences within the process of convergence that are the main indication of the current state and immediate changes in fertility at the sub-national level.

In Czechia a number of publications have dealt with regional fertility differences and their trajectories since 1989 (Bartoňová 1999, 2001; Kretschmerová 2003; Poppová 2004; Kraus 2007; Rychtaříková 2007; Šídlo 2008). Generally, despite the increase in regional social and economic differences seen in the 1990s, there has been a levelling out of fertility and the spatial distribution of fertility has changed (Bartoňová 2001; Rychtaříková 2007; Šídlo 2008). Since the research listed above was performed largely during an era that saw fertility decline and postponement expands, the question is whether this trend can also be observed in the era when Czechia experienced a revival in fertility associated with the onset of recuperation.

The aim of this paper is to highlight regional differences in the tempo and quantum of fertility in Czechia in relation to postponement and recuperation and to highlight any convergent or divergent tendencies in the post-1989 transitionary period. We also compare the early transitionary state with the current one (2012–2014). Furthermore we attempt to identify groups of areas where the nature and intensity of fertility differ. We assume that childbearing postponement is already manifesting in all districts. The question is whether there are already marked differences in the speed at which this is occurring and if so whether there are regional patterns in fertility ageing.

2. Research methodology and data sources

There is a close link between the methodology and indicators of fertility quantum and tempo at the district level, on the one hand, and the availability of the input data, on the other. We used data from the Czech Statistical Office's internal database, specifically live births by mother's age, biological order and place of residence (district) and age structure of female population, where the data refer to 1 July of the given year. Since the district populations are small, we decided to use three-year intervals. Moving averages are used. Since one of the aims of the study is to capture the spatial differences in the tempo and quantum of fertility at the beginning of the transitional period and compare them with the current state (or that of the last available period), we use two three-year periods: 1991–1993 and 2012–2014.

Quantum of fertility in particular districts and periods are expressed as total fertility. Mean age at first birth is used to investigate the tempo of fertility. Another important aspect is the rate of fertility among the youngest group of women (the under 25s) and those 30 and over as a proportion of total fertility. A typical feature of the socialist reproductive model was that fertility was concentrated into narrow age intervals, most frequently in the first half of the reproductive span. We attempted to establish the extent to which the regional populations had abandoned this model by investigating the interdecile range of fertility. A broadening of the range points to increased variation in reproductive paths.

A cross-sectional view of fertility postponement can be expressed as the total age-specific rate of decline in the age groups experiencing a real fall in fertility during the period investigated. Since this affects the younger age groups, we only considered the under 30 age groups. Construed in this way the postponement rate is expressed as the amount (in absolute or relative terms) by which the fertility rate fell in 2012–2014 compared to 1991–1993. Further analysis of the increase in fertility in Czechia between 1999 and 2014 shows that this was largely due to an increase in the fertility rate in the over 25s. This should be seen in the context of the shift to the delayed childbearing stage. The recuperation rate is expressed as the absolute (or relative) increase in the fertility rate among women aged over 25, since in some districts fertility began to increase from the age of 26. Running parallel with the postponement rate is the extent to which female fertility in the over 25s increased compared to the level at the beginning of the observed period. The cross-sectional view of the subsequent fertility postponement transition is provided by the index of recuperation, which was constructed as a fraction of the recuperation and postponement rate. In absolute terms it pointed to an overall decline (or growth) in total fertility in Czech districts.

The variation in the selected indicators – total fertility rate, mean age at first birth and proportion of fertility among women under 25s and over 30s – is measured using selected indicators of variability: mean difference, coefficient of variation and range.

A detailed analysis of fertility showed that the districts did not behave as entirely independent entities but included groups sharing similar features, characteristics and, to some degree, a fertility transition. This led us to create sets of districts containing populations that most resembled each other in terms of fertility. Of the various categorisation methods available, we opted for cluster analysis (Ward's method). The input data for the two periods (1991–1993 and 2012–2014) were standardised and factor analysis was performed to produce Z-scores. To set the optimum number of clusters in order to maximise their internal homogeneity the grouping index was used and the Euclidean distance between groups of districts was also taken into account.

3. Process of the fertility postponement transiton in districts between 1991–1993 and 2012–2014

In the early 1990s Czechia recorded a dramatic fall in total fertility which peaked in 1999. Regionally in 1991–1993 only two districts (Plzeň-město and Praha[1]) had total fertility of less than 1.6 children per woman. In the city hinterlands and particularly to the south of the country there were other ditricts that had below-mean fertility rates (Fig. 1). Generally districts across Bohemia were affected by lower fertility, while in Moravia it were only the districts of Brno, Ostrava and Prostějov. By contrast many districts in Moravia, and especially those on the border between Moravia and Bohemia had above-mean levels of total fertility rate.

A more detailed analysis of the character of fertility showed that the areas with lower total fertility rate already had a mean age at first birth that was slightly above average. This was linked to lower fertility amongst the under 25s and slightly higher fertility amongst women aged over 30. Given the mean first-order total fertility rate (Fig. 2), it is clear that the main cause was the lower birth rate of second- and later-born children. Hence one cannot simply conclude that the onset of the fertility postponement transition occurred substantially later in city districts in Czechia. Instead the lower fertility rate and slightly higher mean age at first birth were the result of specific factors affecting the local population (e.g. a larger number of inhabitants with higher education, lengthier occupational training, etc.). On the other hand districts with above-mean fertility rates had higher first-birth fertility rates, a lower mean age at first birth, a greater proportion of births amongst the under 25s and a smaller proportion of births among women aged 30 and over. The quantum, tempo and internal distribution of fertility by age did not differ greatly during this period. In most Czech districts the early reproductive path model still prevailed as can be seen in the mean age at first birth and births in women aged under 25 and 30 or over as a proportion of total fertility. Most frequently, women tended to become mothers between the ages of 22.0 and 22.5 (in 48 of the 77 Czech districts). In a further 18 districts the mean age at first birth was lower. In the remaining 11 districts age at first birth was over 22.5, and only in three districts (Praha, Brno-město, Plzeň-město) did it exceed 23.0 years (Fig. 3). The predominance of early motherhood and parenthood was also reflected in the distribution of districts according to births in woman aged under 25 as a proportion of total fertility. Between 1991 and 1993 in Czechia, the mean value of this indicator only just exceeded 58%. A total of 17 districts were below this level, but only the capital (45%), and the cities of Brno (50%) and Plzeň (54%) had levels below 55% (Fig. 4). By contrast in the majority of Czech districts (46 in total) this indicator exceeded 60%; yet it only reached a maximum of 64%. During this period fertility in women aged 30 or over was still relatively low overall. The maximum level was found in the city districts and also partly in districts where births of third- and later-born children are more frequent (Fig. 5).

3.1 Four phases of the fertility postponement process in the regional level

Although fertility postponement affected all Czech districts, the tempo, quantum and extent to which they occurred varied. According to Sobotka (2003, 2004) cross-sectionally four interrelated phases can be identified in fertility postponement. Since postponement largely affected first-order births and was reflected in the rising age of women at first birth, this model depends on how these interact. In stage one before it began to change, first-order fertility was high and regularly exceeded 0.75 children per woman. The mean age at which first-order fertility occurred was well below 26 years of age. In 1991–1993 not a single Czech district had exceeded this limit. Even in city districts, total first-order fertility was still significantly above 0.75 children per woman (for instance in the capital city it was 0.83 children). Stage two saw the postponement of births of first-born children begin and consequently a fall in first-order fertility amongst younger women, which was subsequently reflected in the systemic fall in first-order total fertility. This fell substantially to below 0.75 children per woman. Great differences are not seen between Czech districts in the timing at which it fell to below this level. In 51 districts this occurred in 1992–1994 and in the remaining ones in 1993–1995. However, the timing of the decline to minimum first-order total fertility values displays more marked differences (Fig. 6). In addition an important distinguishing factor appears to be the length of period first-order fertility remained at the minimum level before entering the recuperation stage (Fig. 7). In the majority of districts the first-born fertility rate gradually fell to 0.50–0.55 children per woman, while in 26 it fell below this level.

1 The article used the names of districts in Czech; their locations within the Czechia can be traced in an appendix 1 at the end of this article.

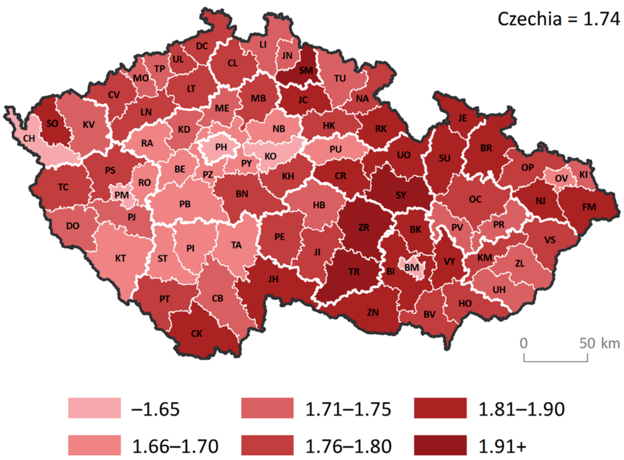

Fig. 1 Total fertility rate, 1991–1993.
Source: Authors' calculations based on CSO data.

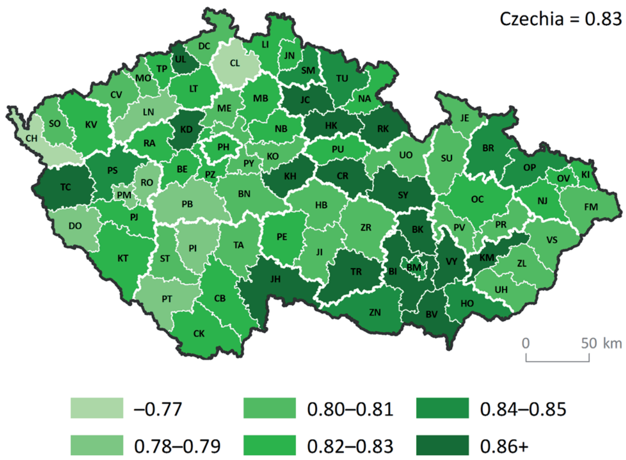

Fig. 2 First-order total fertility rate, 1991–1993.
Source: Authors' calculations based on CSO data.

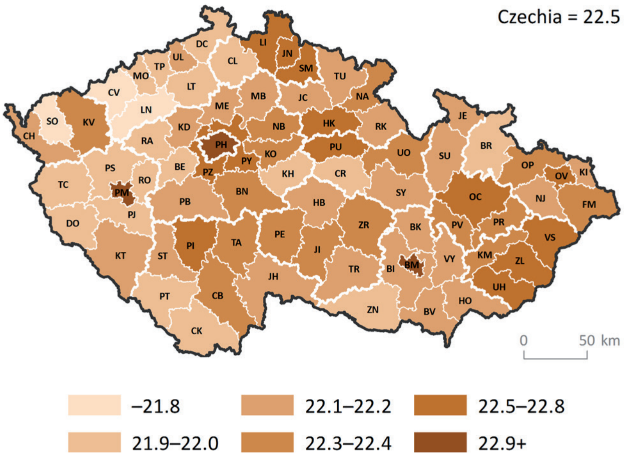

Fig. 3 Mean age at first birth, 1991–1993.
Source: Authors' calculations based on CSO data.

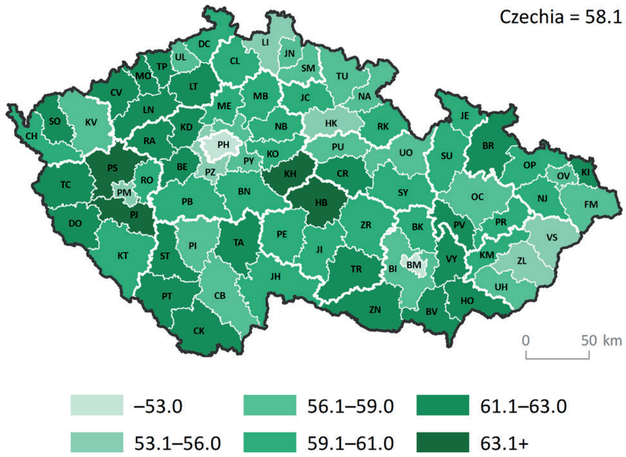

Fig. 4 Fertility of women aged under 25 as a proportion of total fertility (in %), 1991–1993.
Source: Authors' calculations based on CSO data.

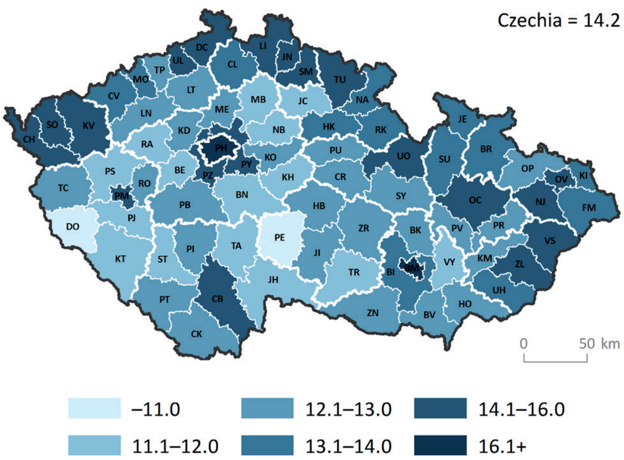

Fig. 5 Fertility of women aged 30+ as a proportion of total fertility (in %), 1991–1993.
Source: Authors' calculations based on CSO data

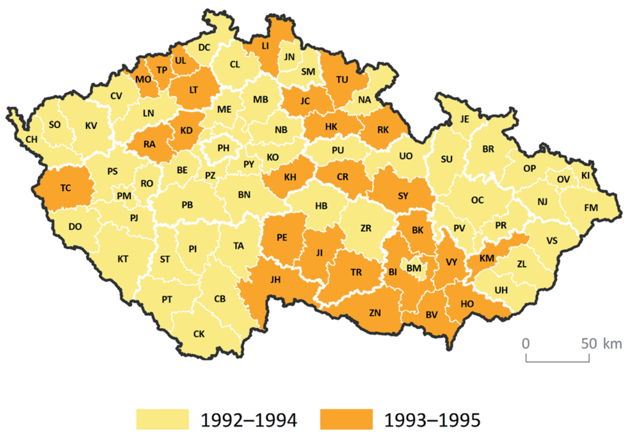

Fig. 6 Period of decline in first-order fertility rate to below 0.75 children.
Source: Authors' calculations based on CSO data

From the late 1990s onwards fertility intensity in Czechia began to rise gradually. This positive trend came to a temporary halt after 2008 as a result of unfavourable economic development (see, for example, Sobotka et al. 2011; Goldstein et al. 2013), but by 2014 total fertility rate had again exceeded 1.5 children per woman. Growth could gradually be seen in all districts (Fig. 8). However, it differed in onset and speed. Generally, the revival in fertility was associated with mothers catching up on delayed reproduction, and this is manifest in stages three and four of the fertility postponement transition. First-order total fertility rate again exceeded 0.75 children per woman and mean age at first birth was over 26. It is clear that the increases in the first-order birth rate and in total fertility rate were closely interlinked. Districts where mothers were more likely to delay the onset of motherhood also saw more dynamic growth in total fertility rate. The last available data from 2012–2014 show that in 16 districts first-order total fertility rate was more than 0.75 children per woman. This was mainly true of the city districts (Praha, Brno) and their hinterlands (Praha-východ, Praha-západ, Brno-venkov) and in districts with important economic centres (e.g. Olomouc, Pardubice, Liberec). In all Czech districts first-order total fertility rate exceeded 0.60 children per woman and in 29 of them it reached around 0.63–0.70 children (Fig. 9).

The growth in first-order fertility at an older age associated with the onset of recuperation in stage three contributed to a sustained increase in mean age at first birth. With the exception of six districts (Teplice, Sokolov, Děčín, Tachov, Chomutov and Most), mean age at first birth in all Czech districts exceeded 26 years (see Fig. 10). Without doubt the longest postponement of motherhood occurred among women in the capital city, in districts in its hinterland and in Brno-město and in Zlín district, where the mean age at first birth in 2012–2014 was over 28 years.

The fertility postponement transition had a marked influence on the status and differences in the quantum and tempo of first-order fertility in the districts. As the graph in figure 11 shows, the districts were initially relatively homogenous but became more heterogeneous over time, and a number of main types of districts can be identified (see also Appendix 2). The first type comprises districts where postponement was less dynamic and where for some women becoming a mother at a young age continued to be an important part of their life biography. The birth rate clearly shows that the transformation in the reproductive behaviour of this group has yet to end. On the other hand there is a group of districts which have already entered the fourth quadrant indicating that the transformation process has ended for them. In 2012–2014 this affected 15 districts overall. There is also a subgroup within them in which the mean age at first birth is now almost 30 years of age. In these districts the fertility postponement transition occurred most rapidly and they currently have the highest rate of first-born children. Most districts fall into the third quadrant. There is little difference in the timing of motherhood or in the extent to which they have successfully entered the recuperation stage. Within this quadrant districts can be identified that have repeatedly exceeded the 0.75 children per woman mark; however, there are districts where the postponement of first-order births has not occurred so intensively. Figure 12 provides greater detail on the way the relationship between first-order total fertility rate and mean age at first birth has changed in selected districts. The districts selected are those where motherhood postponement has been most and least dynamic (Praha-západ and Teplice respectively) and those which have the highest mean age at first birth (Praha). In addition these indicators were also selected for the whole of Czechia for comparative purposes.

3.2 The postponement of motherhood has led to a deepening of regional differences in the character of fertility

The variation in dynamic and extent of shifts from the previous model of reproductive behaviour has led to a deepening of regional differences in the internal character and structure of fertility. The postponement of motherhood and parenthood has resulted in a fall in the intensity and proportion of fertility amongst the under 25s in all Czech districts. In the early 1990s most fertility was concentrated in this age group (45–64%, with a Czech-mean of 58%), but more recently, in 2012–2014, fertility amongst this group has fluctuated between 10% and 30% of overall fertility with a mean of 18% for the whole of Czechia. This process did not occur evenly throughout the country. There are districts where only a very small amount of total fertility occurred at this age. On the other hand there are those in which fertility among the under 25s continues to be an important feature of overall reproduction. The first group includes the districts of Praha and its hinterland and also a substantial part of Moravia, mainly the eastern and south eastern areas (Fig. 13). By contrast districts where fertility among women under 25 is higher than the mean are concentrated in the border areas in an almost continuous line stretching from Tachov to Děčín and Česká Lípa. Some other border districts can be included in this group (e.g. Bruntál and Karviná in the north and Český Krumlov in the south).

An initial fall in the fertility rate and then a gradual rise in the second half of the reproductive span is one of the main features of the transformation in reproductive behaviour. One important indirect symbol of delayed fertility is thought to be the number of births in those aged 30 or over as a proportion of total fertility (e.g. Lesthaeghe and Moors 2000). In the early 1990s fertility in those aged 30 or over was still unremarkable, accounting for only slightly more than 14% of total fertility rate on average. In all Czech districts, however, there was a gradual shift away from this model. An increasingly larger proportion of fertility, and also initial motherhood, began to

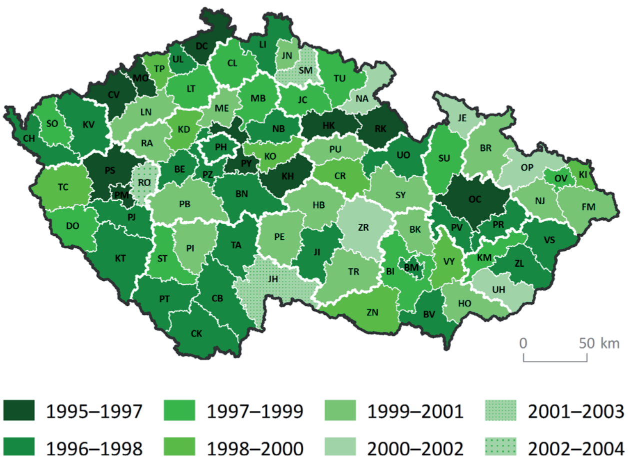

Fig. 7 Period in which total fertility rate fell to its lowest-low level.
Source: Authors' calculations based on CSO data.

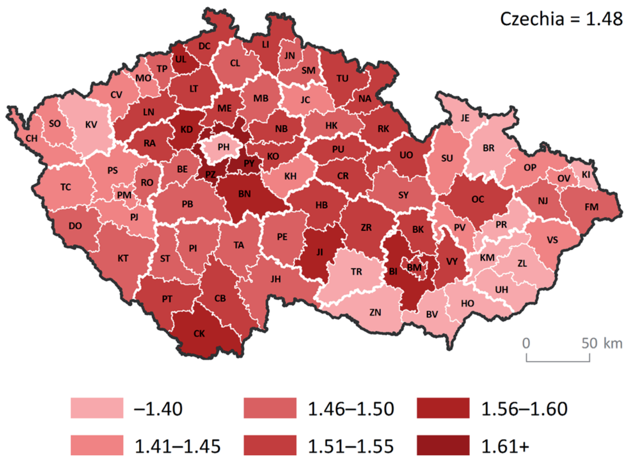

Fig. 8 Total fertility rate, 2012–2014.
Source: Authors' calculations based on CSO data.

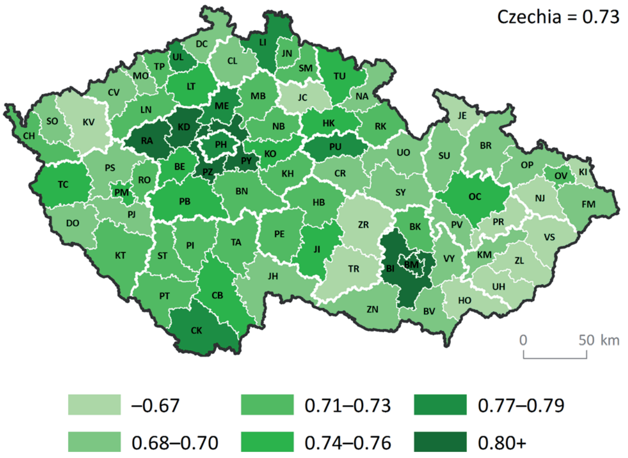

Fig. 9 First-order total fertility rate, 2012–2014.
Source: Authors' calculations based on CSO data.

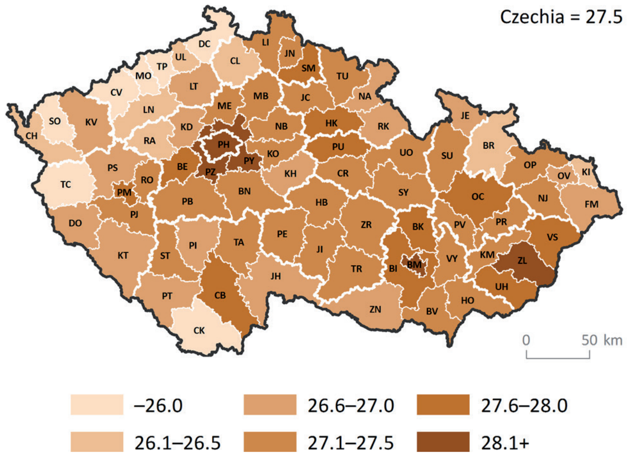

Fig. 10 Mean age at first birth, 2012–2014.
Source: Authors' calculations based on CSO data.

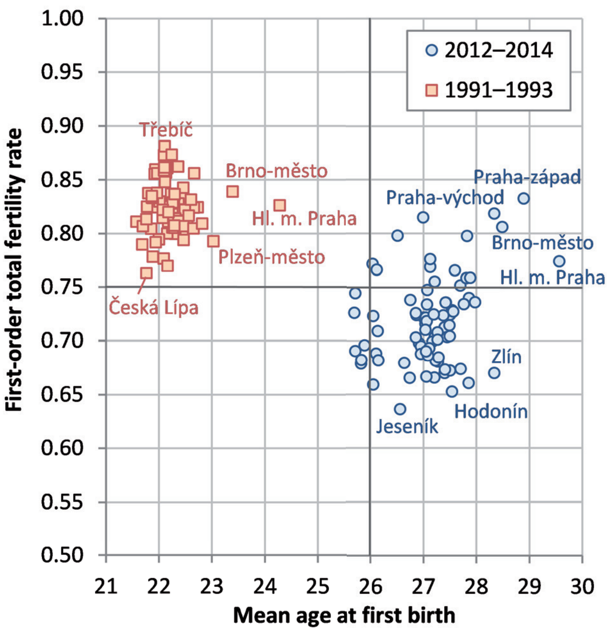

Fig. 11 Relationship between first-order total fertility rate and mean age at first birth, Czech districts, 1991–1993 and 2012–2014.
Source: Authors' calculations based on CSO data.

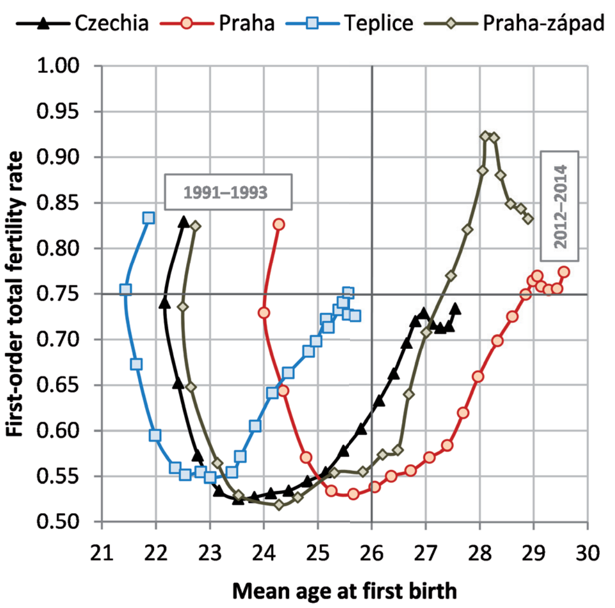

Fig. 12 Relationship between first-order total fertility and mean age at first birth, selected Czech districts, 1991–1993 to 2012–2014 (moving three-year averages).
Source: Authors' calculations based on CSO data.

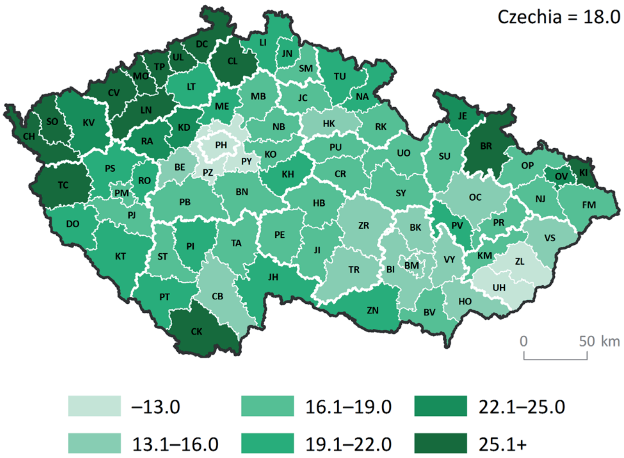

Fig. 13 Fertility of women aged under 25 as a proportion of total fertility (in %), 2012–2014.
Source: Authors' calculations based on CSO data.

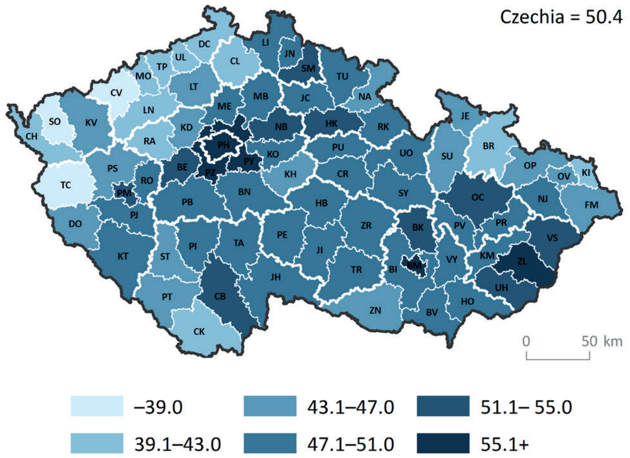

Fig. 14 Fertility of women aged 30+ as a proportion of total fertility (in %), 2012–2014.
Source: Authors' calculations based on CSO data.

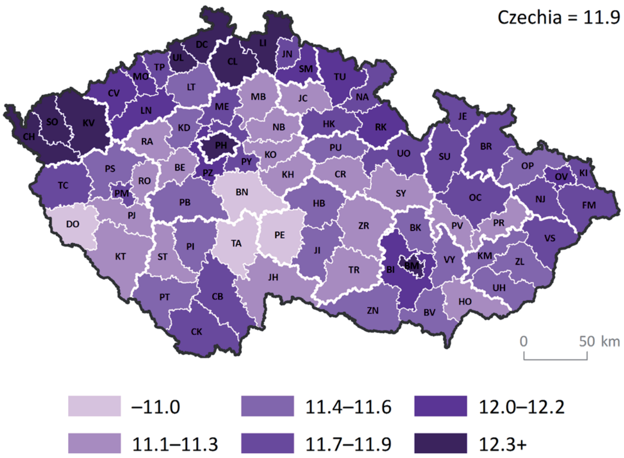

Fig. 15 Interdecile range, 1991–1993.
Source: Authors' calculations based on CSO data.

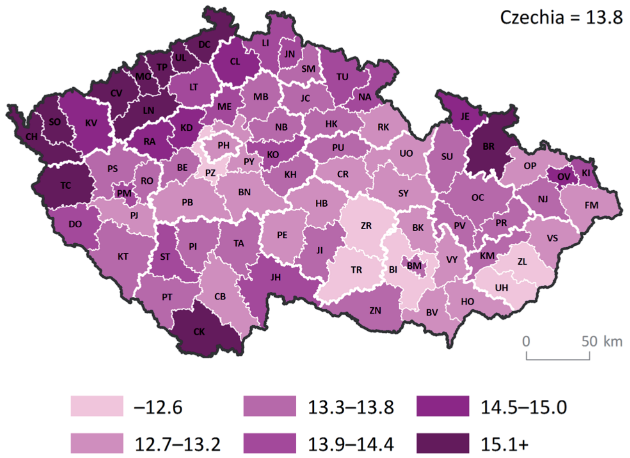

Fig. 16 Interdecile range, 2012–2014.
Source: Authors' calculations based on CSO data.

occur in the second half of the reproductive span. However, there is a marked difference in the rate and extent of postponement as well as in the subsequent recuperation of delayed births. To generalise somewhat, we can state that the mirror image is also true, since districts in which fertility amongst the under 25s dominated in 2012–2014 also had low fertility among women aged 30 and over; by contrast in districts which had the lowest proportion of fertility among the younger group, above mean fertility was concentrated into the second half of the reproductive span (Fig. 14).

Changes in the interdecile ranges also point to the emergence of a variety of models of reproductive behaviour. In the previous reproduction model was concentrated into a narrower age spectrum, with most reproduction occurring in the first half of the reproductive span. The newly emerging model (or models) indicates a lengthening of this interval. In the early 1990s the national interdecile range was just under 12 years (with a minimum of 10.5 and a maximum of 12.5). Data from 2012 to 2014, however, shows that 80% of overall fertility was concentrated into just under 14 years and that the variation in range had also increased (minimum 12 years, maximum 15.6 years). Although this trend can be observed in all districts, there are relatively large differences in the dynamism of this process (the increase is around 0.2–3.6 years). In the early 1990s two main areas can be identified that had a greater interdecile range (Fig. 15). There is a stretch of border districts in the east and north east of the country where reproduction not only began earlier but the proportion of higher-order births also meant that children were more frequently born in the second half of the reproductive span. City districts (Praha, Plzeň and Brno) and their hinterlands represented another area with a higher interdecile range. Here the variety was the consequence of a combination of different models of establishing a family and family size; however, higher-order births played a minimal role in this. Whilst in the first group the greater interdecile range can still be found today (see Fig. 16), this is not the case with the second group. In the city districts and their hinterlands the interdecile range is lengthening at a very slow rate, and in the current era

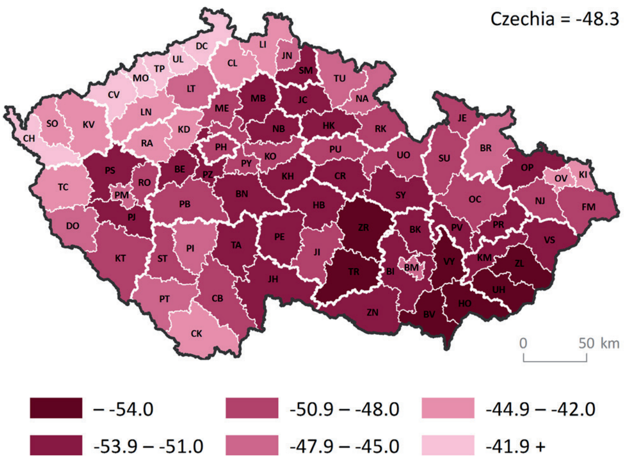

Fig. 17 Postponement rate.
Source: Authors' calculations based on CSO data.

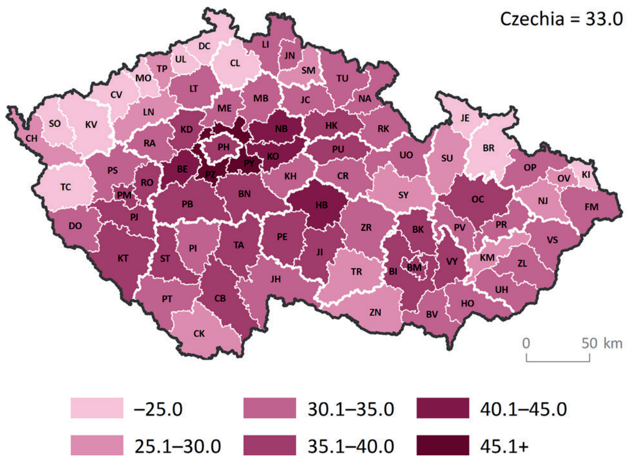

Fig. 18 Recuperation rate.
Source: Authors' calculations based on CSO data.

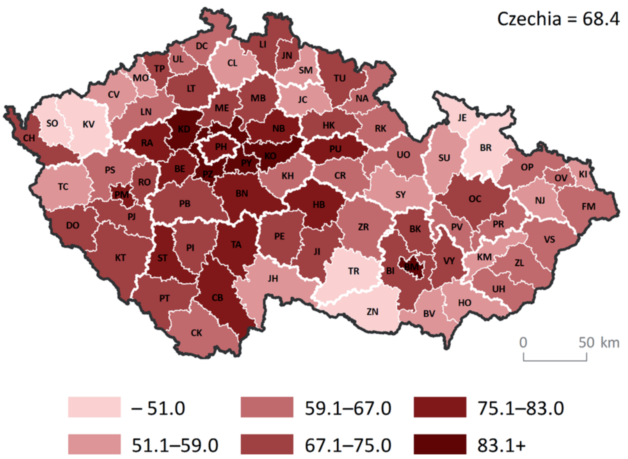

Fig. 19 Index of recuperation.
Source: Authors' calculations based on CSO data.

fertility is still most concentrated by age compared to the rest of Czechia. A similar situation occurred in a number of Moravian districts as well, which represents another area with a low interdecile range. This is caused by significant levels of fertility postponement and is also reflected in the lower decile values. Following Kohler, Billari and Ortega (2002), in relation to these districts one can state that fertility postponement led to the rectangularisation of fertility.

4. A spatial view of fertility postponement and recuperation

A cross-sectional view of the postponement of births, and particularly first-order births, shows that this manifests itself in a fall in fertility amongst young women (most frequently the under 27s). The increase in the rate of fertility in the older age group (most frequently 28 and over) indicates that women are catching up on postponed births. By comparing the age-specific fertility rate in the first (1991–1993) and second (2012–2014) period, it is possible to determine the extent to which this fell and the subsequent level of revival. Relatively speaking it is clear that postponement is substantially responsible for the fall in fertility in many Moravian districts, and for it falling to its lowest level in the border areas in the west and northwest. Consequently in these areas we also find that women under 25 contribute most to overall fertility. Up to 39 districts can be identified in which the fertility rate fell by more than 50% among young people (Fig. 17). Interestingly the city districts (Praha, Plzeň and Brno) tended to display average falls, since in these areas fertility was already lower in this age group in the early 1990s. Just as all districts showed a decline in fertility in the younger age group, there are also indications that they have entered the recuperation stage. The districts differed in the timing, onset and also rate of change. The degree of postponement and the rate of recuperation combine to create an overall deficit in total fertility comparable to that of the early 1990s.

A higher rate of recuperation can clearly be seen in the districts around the Praha periphery and hinterland and also in districts to the south. In Moravia a higher rate was found mainly in Brno and the surrounding area and in Olomouc district (Fig. 18). A low rate of recuperation is mainly found in the border districts in west and northwest Czechia and in some districts in south and north Moravia. This is also closely linked to the distribution of districts in relation to the index of recuperation. It is clear that, with the oft-mentioned exception of Brno and immediate surrounding area, the districts of Olomouc and partly also the city districts of Ostrava, the situation in Moravia is problematic. In Bohemia recuperation has primarily occurred in the area in the west (excluding Cheb) and some districts to the north. As in Moravia, the Bohemian districts that have most successfully compensated for the fall in fertility include those containing the largest economic centres (e.g. Praha and Plzeň) as well as some surrounding districts (Fig. 19).

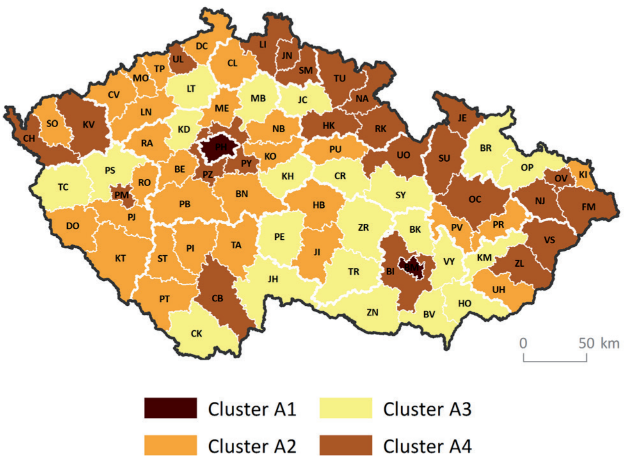

Fig. 20 Regional types of fertility, 1991–1993.
Source: Authors' calculations based on CSO data.

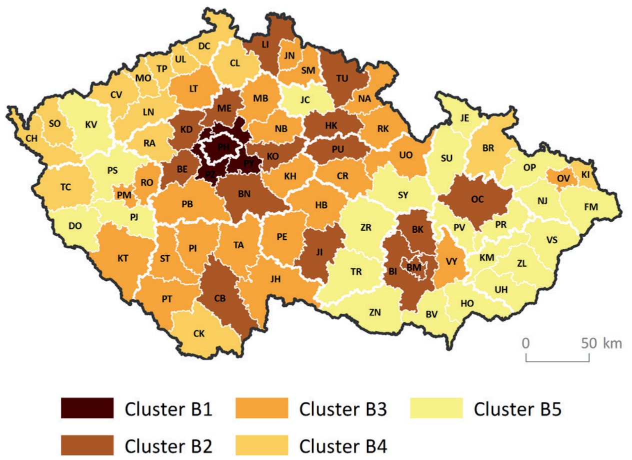

Fig. 21 Regional types of fertility, 2012–2014.
Source: Authors' calculations based on CSO data.

5. Regional typization of districts in Czechia

The fertility postponement transition affects the nature of reproductive behaviour in all districts in Czechia, and a more detailed analysis shows that there are relatively large differences in the timing of the onset, rate and extent of the changes. On the other hand when the indicators were assessed it was evident that some spatial patterns had remained stable and so we attempted to categorise the regions by type so as to identify districts that displayed similar characteristics. The aim was also to determine whether the fertility postponement transition had in any way disrupted spatial patterns. The typization was performed for the most recent analysed period (2012–2014) and the early 1990s (1991–1993). The results obtained are displayed in figures 20 and 21. From the clustering and Euclidean distance it is clear that in the early 1990s reproductive behaviour in the first cluster, comprising Praha district and Brno (Cluster A1), was distinct from the remaining Czech districts. It was characterised by a low level of total fertility rate and fertility among women aged under 25. On the other hand, however, in these districts the mean age was higher, as was fertility at age 30 and over and the interdecile range was greater. The total first-order fertility rate was within the Czech mean. The tempo and structure of fertility would suggest that the onset of the postponement fertility transition occurred earlier; however, the rate of first child births does not point to this (Tab. 1). It could be supposed that, given the particular character of the area, many of these indications existed before reproductive behaviour began to change.

As the values of the selected indicators for the clusters show in Tab. 1, with the exception of the first group, there are no great differences in the tempo and character of reproductive behaviour. Slightly greater differences can be seen in the total fertility rate, which was highest in the third cluster of districts (Cluster A3). The results obtained confirm that there is still a relatively marked uniformity in the reproductive behaviour (apart from the odd exception) established under the previous regime. The spatial distribution of the groups of districts can be seen in detail in Fig. 20.

Tab. 1 Regional categorisation of fertility types, 1991–1993: mean values of selected cluster indicators.

Indicator	Czechia	Cluster A1	Cluster A2	Cluster A3	Cluster A4
Total fertility rate (children per woman)	1.74	1.57	1.73	1.83	1.76
Total first birth fertility rate	0.83	0.83	0.81	0.85	0.82
Mean age at first birth (years)	22.50	24.1	22.10	22.10	22.50
Interdecile range (years)	11.90	12.6	11.60	11.40	11.90
Fertility in the under 25s (%)	58.10	46.5	60.90	61.60	57.60
Fertility at 30 and over (%)	14.20	20.0	12.70	12.30	14.40

Again, in 2012–2014, Praha and the districts to the east and west of Praha formed a separate cluster (Cluster B1). However, in contrast to the situation in the early 1990s, reproductive behaviour differed less, since early on (in terms of the distance and progression of the clustering) a second group attached itself to it comprising districts in Praha and Brno hinterlands and districts with important economic, administrative and cultural centres (e.g. Olomouc, Jihlava, Pardubice, České Budějovice, Hradec Králové and Liberec). In these groups (Cluster B2) the reproductive path typically had a later onset, fertility was concentrated in the second half of the reproductive span, fertility was lower amongst the under 25s, the interdecile range was narrower and recuperation was more rapid. This was also linked to higher first-order fertility rate (Tab. 2). Interestingly, the second cluster of districts had the highest total fertility rate in all groups and even the first cluster no longer had the lowest fertility rate.Generally there was increasing proximity in the fertility levels in the groups of districts. Paradoxically this contributed to the difference in the intensity at which first children were born. The districts that had successful transformations (particularly clusters B1 and B2) saw a significant catch-up in the onset of motherhood, while in some other districts (primarily cluster B5) the recuperation process was suppressed and total first-order fertility rate remained substantially lower. Thus the first cluster of districts displayed a greater concentration of delayed fertility, while in the fourth group of districts (Cluster B4) the opposite occurred. The mean age at first birth and fertility at age 30 and over were lowest here. This is closely linked to fertility being most pronounced in the young (under 25s) and the interdecile range being the largest. Table 2 confirms that nowadays the main distinguishing factor in Czech districts is not fertility quantum but fertility tempo and distribution by age.

Tab. 2 Regional fertility types, 2012–2014: median values of selected cluster indicators.

Indicator	Czechia	Cluster B1	Cluster B2	Cluster B3	Cluster B4	Cluster B5
Total fertility rate (children per woman)	1.48	1.44	1.54	1.48	1.46	1.42
Total first birth fertility rate	0.73	0.78	0.77	0.72	0.70	0.68
Mean age at first birth (years)	28.00	29.90	28.20	27.70	26.50	27.80
Interdecile range (years)	13.90	13.00	13.50	13.70	15.10	13.10
Fertility in the under 25s (%)	18.00	10.90	16.60	18.70	27.90	16.80
Fertility at 30 and over (%)	50.40	62.90	51.60	48.30	40.60	48.80

6. Fertility postponement transition and divergence within convergence?

Opinions differ in the literature on developmental trends in spatial differences in fertility. As we stated in the introduction, on one side there are those who argue that the trend is one of convergence and on the other those who argue that divergence is key. In addition, it is important to note that some authors distinguish between the national and regional level. Regionally one can suppose that certain characteristics of reproductive behaviour are being maintained. The question remains whether the two-decade long dramatic changes in the nature of fertility ongoing in some Czech districts will bring them closer to local populations or whether they will have a distancing effect. Given that it has been shown that in all districts the main mechanism behind this is the onset of the fertility postponement transition, can they be expected converge over time? The majority of the research that attempts to resolve this issue looks at fertility rates alone. As Festy (1981) and more recently Basten et al. (2012) have noted, the internal structure and character of fertility is also important. In other words, it is possible to have the same total fertility rate even when the reproductive behaviour of particular populations is quite different. Hence we have attempted to analyse the variability in the timing and structure of this process.

Generally all the characteristics of variability used (range, coefficient of variation, mean difference) indicate that in the 1990s variation in total fertility rate declined initially and there was greater proximity between districts. This corresponds to the fact that in all districts fertility rates fell among the younger women as a result of the postponement of births, especially first-order births. In the majority of districts this process peaked in the late 1990s which is also when we find the lowest values in the variability indicators. In the next stage of development the key factor is how successfully women catch up on delayed reproduction. It has been shown that timing, rate and extent of recuperation are spatially distinct and this is reflected in the growing variation (Fig. 22). However, we identified a gradual revival in fertility amongst the older population in all districts and recently a degree of convergence has been evident. In the recuperation stage of the transformation overall fertility increases and the new model of reproductive behaviour stabilises. The difference in timing and extent of this process means we can expect fertility rates in Czech districts to display greater proximity. On the other hand, however, the level of compensation in the successful and less successful districts selected suggests that total fertility rate values will also continue to exhibit significant regional differences.However the situation is completely different when we come to analyse the variation in mean age at first birth and the contribution fertility in women under 25 and aged 30 and over makes overall, which reflects the timing and internal structure of the process. As many of the previous findings have indicated, at the district level there is significant diversification in the reproduction models that affect the age of entry into motherhood and parenthood. This has been confirmed by the variation in mean age at first birth, which rose continually until stabilising in the last decade at a significantly higher level than it was in the early 1990s (Fig. 23). The divergence in fertility among women aged under 25 and 30 and over as a proportion of total fertility rate continues into the present (see Fig. 25). The main factor behind the variation in fertility in Czech districts is timing and internal structure of fertility by age. Following the onset of recuperation, the fertility rate begins to convergence across districts; however, the timing and especially distribution by age exhibit marked divergence. This confirms earlier conclusions that there are multiple models of reproductive behaviour emerging at the regional level, and these will continue to influence the character of fertility in the near future.

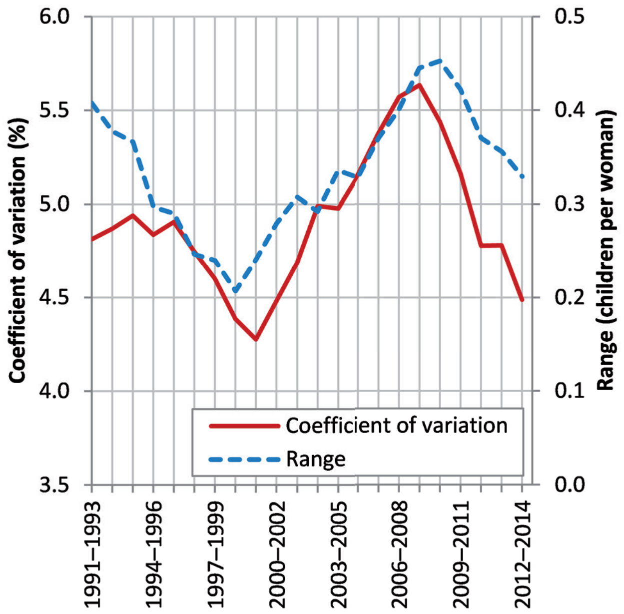

Fig. 22 Range and coefficient of variation in total fertility in Czech districts.
Source: Authors' calculations based on CSO data.

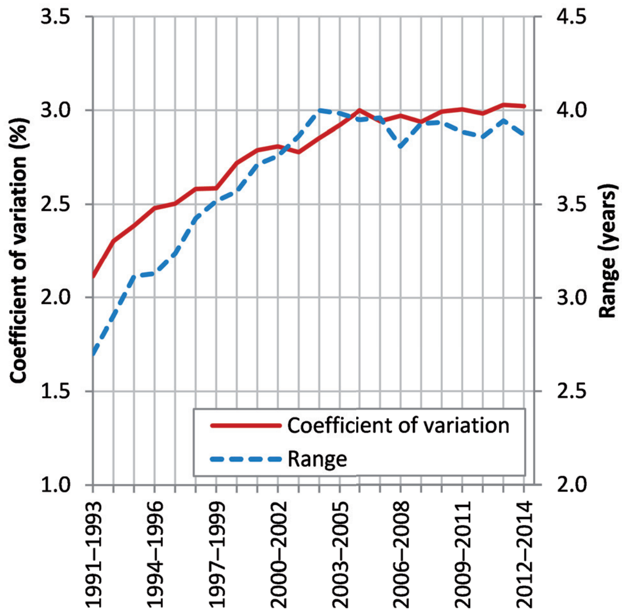

Fig. 23 Range and coefficient of variation in mean age at first birth in Czech districts.
Source: Authors' calculations based on CSO data.

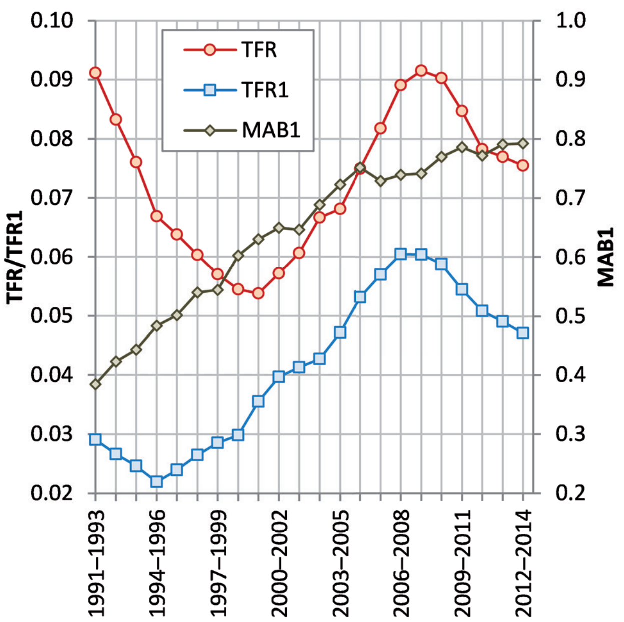

Fig. 24 Mean difference in total fertility rate, first-order total fertility rate and mean age at first birth in Czech districts.
Notes: TFR = total fertility rate, TFR1 = first-order total fertility rate, MAB1 = mean age at first birth.
Source: Authors' calculations based on CSO data.

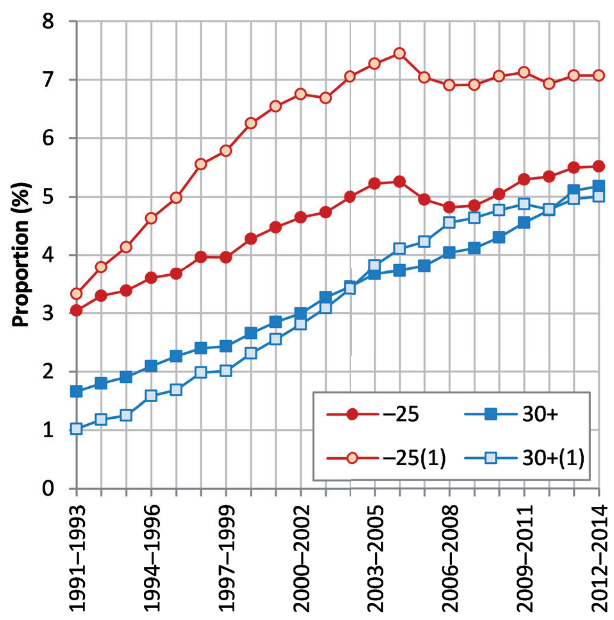

Fig. 25 Mean difference in fertility in women under 25 and 30 or over as a proportion of total fertility in Czech districts.
Note: (1) indicates fertility among women in that age group as a proportion of first-order total fertility.
Source: Authors' calculations based on CSO data.

7. Conclusion

Since the early 1990s fertility in Czechia has undergone substantial change. The post-late 1960s generations have gradually rejected the early reproductive path pattern and increasingly opted to have their first child at an older age. The changes in the timing of fertility are closely linked to the fall in the cross-sectional intensity indicators (see e.g. Bongaarts and Feeney 1998; Kohler, Billari and Ortega 2002) to well below replacement level. The reconstituted paths to adulthood and associated multiplicity of life paths at the reproductive age are behind the changes in the character and nature of young women's reproductive careers. We are witnessing a marked heterogenisation of reproductive behaviour. These and other changes can clearly be seen in all districts in Czechia. At the early stage of transformation the differences in timing and the internal age distribution of fertility were not substantial because the previous reproductive behaviour model was largely spatially uniform. The exception was city districts where the mean age of childbearing and the proportion of fertility in the second part of reproductive span were slightly higher than the national mean, while the fertility rate was below it. In this case the transformation in reproductive behaviour started very rapidly. It seems that in this environment the discontinuity in living conditions was most quickly reflected in changes in fertility. During the transition to the new reproductive regime a number of advantages emerged or one could say this was a pragmatic response to market conditions in the economic centres that were exercising greatest pressure on high-quality, flexible human capital, which is largely incompatible with early motherhood and parenting. Moreover this affects districts near cities or containing cities, and new reproductive patterns emerge here with greater ease because of the anonymity of the urban environment. Above all they are the areas least affected by the negative consequences of the economic transition and have a higher living standard over the long term. In conjunction with education level the quickest means of spreading information about the new opportunities in planning parenthood and greater accessibility accelerate the process of postponed childrearing. It seems that these environments can be identified as the forerunners of the transformation in reproduction, whose inhabitants are according to Coale (1973) ready, willing and able to rapidly change their reproductive behaviour. The postponement of first-order births, however, began in all Czech districts back in the early 1990s. This also testifies to how quickly the young generation of women was able to abandon the reproduction model that had prevailed for decades. On the other hand, postponement differed in speed, level and length. From around the end of the 1990s, it is possible to identify the onset of recuperation of postponed births in Czechia. Again it was the case that this stage in the transformation of reproductive behaviour began earlier in the largest city districts and districts with economic centres. Moreover, it was shown that these areas also often numbered among the most successful ones. This means that they saw total fertility rate increase overall and in many cases to above the national mean, but there was also a significant shift towards postponed fertility. This can be seen in the fact that these areas had the highest mean age at first birth and the greatest proportion of fertility among those aged 30 or over. Reproduction among the under 25s has become a marginal phenomenon in these areas. In this respect the neighbouring districts found in the west and north-west of Czechia and some border regions to the north and south stand out since fertility at a younger age is still an important part of the life stories of the female population (we assume that in these regions the fertility in young age will remain important parts of the reproductive behavior of the local population – this is not temporary effect of the process of postponement fertility transition). The current fertility rate in Czech districts is affected not only by a decline in fertility among the young but also increasingly by the extent to which it is pushed into the second half of the reproductive span. The low rate of recuperation from the substantial postponement in fertility has been shown to be the most important cause of the lag seen in most of the Moravian districts, which are behind the national mean. The ongoing transformation in fertility in Czechia has led to a significant change in spatial patterns of reproductive behaviour. On the other hand some aspects have been maintained over a long period of time. These are the nature of fertility in the largest city districts and economic centres across the country and in border areas in the west and north-west. What is new is the status of a number of districts in Moravia. It seems that the Moravian regions, with the odd exception, can be categorised as belonging to a group of districts s that have adapted least well to the new changes in reproductive conditions. Since the early 1990s these have contributed not only to the convergence but also the increasing heterogenity of the fertility rate in regions, and this is closely linked to the timing and extent to which reproduction has been postponed. In recent years all districts have started to recuperate from postponement and so a degree of convergence can be seen. On the other hand, what was originally an almost spatially uniform model of early reproductive paths and the fertility associated with it no longer apply in the new conditions and have been largely abandoned. The tempo and distribution of fertility by age, which is closely linked to the process of postponement and subsequent recuperation, has become one of the most important spatial factors distinguishing reproductive behaviour in Czech districts.

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RESUMÉ

Prostorová diferenciace transformace plodnosti Česku v důsledku procesu odkládání)

Reprodukční chování žen v Česku se od počátku 90. let minulého století výrazně změnilo. Generace žen, které se narodily na konci 60. let, a které by za předpokladu trvání předchozího reprodukčního modelu vstupovaly do mateřství, postupně odkládaly tento vstup do vyššího věku. Důvodem byly celkové změny ve společnosti a nové možnosti seberealizace žen v reprodukčním věku v rámci svých životních drah. Změny v časování měly za následek také snížení celkové intenzity plodnosti, a to hluboko pod záchovnou míru, přičemž v rámci jednotlivých okresů Česka se tyto změny projevovaly s rozdílnou intenzitou a délkou trvání.

Změny v reprodukčním chování však byly natolik výrazné, že docházelo po celá devadesátá léta k postupné homogenizaci reprodukčního chování, jelikož meziregionální rozdíly v časování a vnitřní struktuře plodnosti nebyly velké. Výjimkou byly pouze okresy s populačně velkými městy, které měly specifické podmínky (hospodářské, vzdělanostní…) pro to, aby transformace reprodukčního chování u nich nastoupila dynamičtěji než na ostatním území. Teprve na přelomu tisíciletí začalo docházet k postupné heterogenizaci plodnosti, přičemž proces odkládání rození dětí prvního pořadí byl započat ve všech okresech Česka již v první polovině 90. let. Můžeme to vnímat jako důkaz, jak razantně dokázala mladá generace opustit desetiletí převládající model reprodukce. Na druhou stranu se ukázalo, že i proces odkládání měl různou dynamiku, úroveň i délku trvání. Probíhající transformace plodnosti výraznou měrou přispěla ke změně některých prostorových vzorců reprodukčního chování, přesto některé aspekty zůstávají dlouhodobě zachované. Jde především o charakter plodnosti v okresech s populačně největšími městy, kde došlo k nástupu rekuperace odložených porodů již na konci 90. let, či příhraniční oblasti západu a severozápadu, vyznačující se celkově vyšší intenzitou plodnosti, a to především v mladším věku. Celkově novou pozici naopak zaujímá pozice většiny okresů na Moravě, které můžeme až na malé výjimky zařadit do skupiny okresů nejhůře se přizpůsobujících novým reprodukčním podmínkám, přičemž důležitou příčinou zaostávání většiny moravských okresů za celorepublikovým průměrem se ukazuje být především nízká rekuperace porodů ve vyšším věku. V posledních letech lze ale již sledovat ve všech okresech dobíhání procesu odložených porodů, čímž jsme opět svědky určitých konvergenčních trendů. Vývoj v posledních letech ukázal, že původně takřka uniformní model brzkých reprodukčních drah, a s tím související charakter plodnosti, se v nových podmínkách. Právě časování o rozložení plodnosti podle věku, které úzce souviselo s procesem odkládání a následné rekuperace, se staly jedním z nejdůležitějších prostorových diferenciačních faktorů reprodukčního chování v okresech Česka.

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Appendix 1 Administrative divisions of Czechia into districts.

Appendix 2 Table of calculated and used indicators of fertility.

District	1991–1993						2012–2014						PR	RR	IR
	TFR	TFR1	MAFB	−25	30+	IDR	TFR	TFR1	MAFB	−25	30+	IDR			
ČR	**1.74**	**0.83**	**22.5**	**58.1**	**14.2**	**11.9**	**1.48**	**0.73**	**27.5**	**18.0**	**50.4**	**13.8**	**−48.3**	**33.0**	**68.4**
Hl. m. Praha	1.54	0.83	24.3	45.1	20.7	12.6	1.40	0.77	29.6	10.8	64.1	13.1	−48.0	38.4	80.1
Benešov	1.79	0.80	22.4	60.1	11.9	10.9	1.57	0.73	27.5	16.9	49.6	12.9	−51.2	39.2	76.6
Beroun	1.69	0.83	22.0	61.6	11.6	11.3	1.50	0.75	27.7	15.6	52.4	13.7	−52.7	40.9	77.7
Kladno	1.71	0.87	22.2	62.0	12.6	11.6	1.60	0.81	27.0	22.6	46.4	14.7	−44.1	37.5	85.0
Kolín	1.65	0.80	22.3	60.6	12.2	11.1	1.52	0.74	27.4	18.4	50.1	13.9	−48.0	40.4	84.2
Kutná Hora	1.79	0.86	21.9	63.8	11.2	11.1	1.45	0.72	27.0	19.9	46.7	13.6	−53.2	33.8	63.6
Mělník	1.74	0.80	22.2	60.5	13.0	11.8	1.51	0.77	27.1	20.1	48.3	13.9	−48.5	34.9	72.0
Mladá Boleslav	1.77	0.83	22.2	60.8	11.8	11.3	1.48	0.71	27.4	17.7	49.5	13.4	−51.6	35.0	67.9
Nymburk	1.67	0.82	22.3	60.8	11.5	11.1	1.51	0.72	27.5	16.9	51.1	13.4	−51.8	41.9	80.9
Praha-východ	1.69	0.81	22.5	58.4	14.4	11.9	1.68	0.82	28.3	12.3	56.4	12.6	−50.7	50.4	99.3
Praha-západ	1.70	0.82	22.7	55.2	14.5	12.0	1.64	0.83	28.9	10.2	59.0	12.4	−51.9	48.4	93.2
Příbram	1.70	0.78	22.1	60.4	12.5	11.4	1.47	0.74	27.4	16.2	50.0	13.0	−50.5	36.4	72.2
Rakovník	1.69	0.82	22.0	63.0	11.8	11.3	1.52	0.80	26.5	22.9	41.9	14.5	−44.3	34.1	76.8
České Budějovice	1.73	0.83	22.4	57.0	14.8	11.9	1.52	0.76	27.8	14.5	53.3	12.8	−50.3	38.1	75.7
Český Krumlov	1.87	0.83	21.8	61.5	12.8	11.7	1.56	0.77	26.0	26.0	42.6	15.2	−44.7	27.8	62.1
Jindřichův Hradec	1.86	0.86	22.1	60.5	12.0	11.3	1.46	0.70	26.9	19.1	47.6	13.8	−51.6	30.4	58.9
Písek	1.70	0.79	22.5	58.0	12.9	11.4	1.47	0.72	27.0	19.4	47.8	13.6	−46.7	33.2	71.1
Prachatice	1.79	0.79	22.0	62.1	12.8	11.5	1.52	0.72	26.9	20.1	44.4	13.6	−47.4	32.9	69.3
Strakonice	1.69	0.81	22.2	61.5	11.7	11.1	1.49	0.73	27.1	18.9	46.7	13.8	−49.0	37.3	76.2
Tábor	1.70	0.81	22.4	61.3	11.2	10.7	1.48	0.71	27.5	17.5	49.4	13.2	−52.7	40.0	75.9
Domažlice	1.72	0.78	21.9	62.7	11.0	10.9	1.47	0.68	26.6	21.9	44.2	13.9	−47.8	32.9	68.8
Klatovy	1.69	0.82	22.2	60.9	11.3	11.1	1.48	0.72	27.0	20.0	47.5	13.4	−49.5	36.6	73.9
Plzeň-město	1.54	0.79	23.0	53.9	15.6	11.9	1.41	0.74	27.9	17.0	52.4	14.0	−45.7	37.0	80.9
Plzeň-jih	1.73	0.83	22.0	63.2	11.2	11.1	1.45	0.68	27.3	17.9	48.0	13.0	−53.5	37.4	69.8
Plzeň-sever	1.77	0.84	21.8	64.1	11.6	11.4	1.42	0.69	27.0	19.6	46.5	13.6	−52.1	32.3	62.1
Rokycany	1.69	0.79	21.9	60.7	12.4	11.2	1.46	0.72	27.1	19.4	47.8	13.4	−49.5	35.2	71.1
Tachov	1.79	0.86	21.9	62.2	12.6	11.8	1.45	0.74	25.7	29.2	37.8	15.4	−42.2	23.0	54.5
Cheb	1.61	0.77	22.2	59.9	14.8	12.5	1.44	0.71	26.1	28.1	40.2	15.5	−37.2	26.4	71.1
Karlovy Vary	1.74	0.83	22.4	57.0	15.2	12.4	1.35	0.67	26.7	23.4	45.8	14.9	−44.8	22.3	49.9
Sokolov	1.82	0.81	21.6	62.1	14.1	12.5	1.42	0.69	25.7	29.7	39.0	15.5	−42.4	20.4	48.1

Appendix 2 continuation

District	1991–1993						2012–2014						PR	RR	IR
	TFR	TFR1	MAFB	–25	30+	IDR	TFR	TFR1	MAFB	–25	30+	IDR			
Děčín	1.78	0.80	21.9	60.1	14.4	12.3	1.53	0.70	25.9	28.7	41.1	15.2	–39.0	25.0	64.0
Chomutov	1.76	0.81	21.7	62.1	13.6	12.2	1.42	0.68	25.8	29.5	38.4	15.2	–41.7	22.2	53.3
Litoměřice	1.77	0.83	21.9	62.2	12.6	11.6	1.53	0.74	26.8	21.4	44.8	13.8	–45.8	32.4	70.6
Louny	1.76	0.79	21.7	61.9	12.8	12.0	1.51	0.72	26.1	27.4	40.9	15.3	–42.0	27.5	65.6
Most	1.74	0.81	21.8	61.6	13.5	12.2	1.43	0.68	25.8	29.4	40.0	15.2	–40.7	22.4	55.1
Teplice	1.71	0.83	21.9	61.9	12.7	11.9	1.50	0.73	25.7	30.3	40.0	15.5	–39.2	26.7	68.3
Ústí nad Labem	1.80	0.86	22.2	59.0	15.9	12.5	1.57	0.77	26.1	29.1	41.3	15.4	–37.5	24.7	65.9
Česká Lípa	1.80	0.76	21.8	60.4	14.0	12.3	1.47	0.69	26.1	26.0	42.8	14.7	–42.2	24.0	57.0
Jablonec nad Nisou	1.72	0.82	22.5	56.9	14.6	11.9	1.49	0.72	27.4	20.2	49.1	14.1	–46.0	32.6	70.9
Liberec	1.75	0.82	22.7	55.5	15.8	12.3	1.55	0.78	27.1	20.9	48.7	14.1	–43.0	31.4	72.9
Semily	1.91	0.84	22.5	56.2	14.7	12.0	1.46	0.73	27.6	16.5	51.3	13.2	–51.6	28.0	54.2
Hradec Králové	1.77	0.86	22.7	55.8	14.0	11.7	1.50	0.74	28.0	14.7	53.4	13.2	–52.0	36.8	70.8
Jičín	1.83	0.86	22.2	60.1	11.8	11.2	1.41	0.67	27.2	17.7	49.5	13.3	–53.4	30.6	57.3
Náchod	1.79	0.83	22.3	57.7	13.8	11.9	1.52	0.70	26.9	20.4	46.9	14.3	–46.6	30.8	66.1
Rychnov nad Kněžnou	1.89	0.87	22.1	59.4	14.0	12.1	1.54	0.71	27.0	16.3	48.5	12.7	–50.6	31.9	63.1
Trutnov	1.72	0.84	22.2	58.8	14.1	12.0	1.51	0.75	27.1	20.2	48.2	14.2	–45.5	33.1	72.7
Chrudim	1.88	0.86	22.0	62.8	12.1	11.3	1.51	0.70	27.2	17.1	48.1	13.0	–53.6	33.7	62.8
Pardubice	1.67	0.82	22.5	57.8	12.9	11.4	1.51	0.77	27.6	16.5	50.6	13.3	–48.6	39.1	80.4
Svitavy	1.92	0.86	22.1	60.6	12.4	11.3	1.48	0.68	27.2	18.1	47.4	13.1	–52.8	29.5	55.8
Ústí nad Orlicí	1.90	0.81	22.3	57.8	14.5	11.7	1.54	0.70	27.2	16.2	50.0	13.1	–50.1	31.2	62.3
Havlíčkův Brod	1.74	0.81	22.2	63.4	12.4	11.4	1.54	0.72	27.2	16.4	48.6	13.0	–51.9	40.1	77.2
Jihlava	1.80	0.81	22.3	59.2	13.0	11.4	1.57	0.76	27.2	17.7	48.4	13.3	–48.3	35.4	73.3
Pelhřimov	1.76	0.83	22.3	60.9	10.4	10.5	1.48	0.71	27.3	17.4	48.6	12.6	–52.6	36.5	69.5
Třebíč	1.95	0.88	22.1	61.9	12.0	11.2	1.40	0.67	27.4	14.1	48.9	12.2	–57.3	29.1	50.7
Žďár nad Sázavou	1.92	0.81	22.3	59.6	12.6	11.2	1.51	0.67	27.5	13.9	48.6	12.2	–54.3	33.2	61.2
Blansko	1.86	0.86	22.1	60.7	12.8	11.6	1.54	0.73	27.8	13.8	51.3	12.6	–53.1	35.9	67.7
Brno-město	1.65	0.84	23.4	50.4	18.1	12.6	1.53	0.81	28.5	14.2	57.1	13.5	–46.1	38.8	84.2
Brno-venkov	1.85	0.87	22.2	58.9	13.6	12.0	1.60	0.80	27.8	14.2	50.6	12.2	–51.2	37.5	73.2
Břeclav	1.79	0.86	22.1	61.8	12.9	11.6	1.38	0.70	27.4	16.1	50.9	12.9	–54.8	31.7	57.9
Hodonín	1.79	0.85	22.1	62.2	12.2	11.3	1.35	0.65	27.5	15.4	50.5	12.8	–56.0	31.5	56.2
Vyškov	1.85	0.86	22.1	62.7	12.0	11.4	1.52	0.70	27.5	15.2	50.9	12.8	–54.4	36.5	67.1
Znojmo	1.88	0.84	22.0	61.8	12.8	11.6	1.40	0.69	27.0	19.2	45.1	13.6	–51.3	25.9	50.4

Appendix 2 continuation

District	1991–1993						2012–2014						PR	RR	IR
	TFR	TFR1	MAFB	−25	30+	IDR	TFR	TFR1	MAFB	−25	30+	IDR			
Jeseník	1.83	0.81	22.1	60.0	13.7	11.8	1.37	0.64	26.6	24.4	46.4	15.0	−48.0	23.1	48.1
Olomouc	1.77	0.83	22.6	57.9	14.1	11.7	1.51	0.76	27.9	15.4	53.0	13.3	−50.6	35.9	71.0
Prostějov	1.73	0.81	22.4	61.6	12.3	11.2	1.42	0.69	27.1	19.3	48.0	13.5	−51.1	33.1	64.7
Přerov	1.75	0.81	22.3	59.4	12.2	11.3	1.39	0.67	27.4	17.0	48.6	13.3	−51.7	31.2	60.5
Šumperk	1.83	0.81	22.1	60.0	13.7	11.8	1.45	0.69	27.1	18.3	46.8	13.3	−49.8	29.3	58.9
Kroměříž	1.79	0.86	22.4	59.8	13.0	11.6	1.39	0.68	27.3	17.2	49.7	13.5	−52.7	30.0	56.8
Uherské Hradiště	1.74	0.81	22.5	58.8	13.7	11.5	1.37	0.66	27.9	12.4	51.8	12.0	−55.0	34.0	61.7
Vsetín	1.80	0.80	22.7	55.7	14.8	11.7	1.44	0.67	27.7	14.1	52.1	12.9	−51.7	31.6	61.1
Zlín	1.74	0.81	22.8	55.3	14.7	11.6	1.37	0.67	28.3	11.0	55.2	12.2	−54.6	33.3	61.0
Bruntál	1.89	0.84	21.9	62.6	13.1	11.7	1.40	0.68	26.1	26.4	42.3	15.1	−47.9	21.9	45.7
Frýdek–Místek	1.82	0.81	22.3	58.9	13.5	11.7	1.48	0.69	27.0	17.9	46.5	13.1	−49.4	31.0	62.8
Karviná	1.75	0.82	22.1	61.7	13.1	11.8	1.38	0.66	26.1	26.7	40.4	14.4	−44.7	23.7	53.0
Nový Jičín	1.85	0.82	22.2	59.4	14.1	11.9	1.46	0.67	27.1	17.8	49.4	13.2	−50.6	29.5	58.3
Opava	1.77	0.84	22.3	61.0	12.4	11.4	1.43	0.70	27.3	16.6	46.7	12.6	−52.3	32.8	62.8
Ostrava–město	1.69	0.82	22.6	58.7	14.2	12.0	1.45	0.73	26.9	23.5	44.8	15.0	−43.2	28.9	66.9

Explanation
TFR = Total fertility rate
TFR1 = First–order total fertility rate
MAFB = Mean age at first birth
−25 = Fertility of women aged under 25 as a proportion of total fertility (in %)
30+ = Fertility of women aged 30+ as a proportion of total fertility (in %)
IDR = Interdecile range
PR = Postponement rate
RR = Recuperation rate
IR = Index of recuperation
Source: Authors' calculations based on CSO data.

BARRIERS IN FUNCTIONING OF CZECH GEOPARKS IN THE CONTEXT OF DIFFERENT CIRCUMSTANCES

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ABSTRACT

The article focuses on geoparks as areas with a specific form of local heritage protection. It contributes to a research into two interconnected fields: firstly, the research into local people's participation in local development; secondly, the research into tourism sustainability. Discussion of foreign publications reveals that in the context of Czechia geoparks are misunderstood concept. This argument is supported by a case study from one part of the National Geopark Železné hory. The field research proved that there are significant barriers to meeting the purpose of geoparks. Two conditions are required in geoparks: the possibility of cooperation among local actors and the ability to be competitive through a diverse offer of services and products. The paper discusses factors affecting the actual state of society and their operation in the local development. The aim of the paper is to identify the obstacles to the development of geoparks as a reflection of the problems in local and regional development. In addition, the article deals with possible instruments for the management of geoparks and their utilization for effective coordination of local development.

Keywords: geopark, regional development, heritage, Czechia

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1. Introduction

Geoparks are a relatively new phenomenon that is based on a combination of the concepts of local heritage, environmental protection and education. Geoparks, which were primarily established in the past decade, can be found in most European countries as well as in Asia, and South and North Americas (Global Geoparks Network 2015). In the course of the 1990s, the ideas of establishing zones with a specific form of protection, the "bottom-up" approach or collaborative planning, were being developed in the academic sphere already (Healey 1997). At that time, the concept of geoparks was discussed at the universities in France and Greece (Zouros 2015) as a reaction to the social and economic problems of some countries. The etymology of the word geopark is derived from the concept Gaia (Martini 2015) or the "goddess of the Earth". The theory of Gaia (Lovelock 1994) can be interpreted in various ways. Based on this concept, the central motive of geoparks lies in a return of people "towards the Earth", in the sense of going back to the nature and the landscape and in a renewal of the ties between people and inhabited landscapes (Pásková 2014).

The first geoparks were established in 2000 after the negotiations of four European countries (Greece, France, Spain and Germany) in reaction to their social and economic development problems. These countries have also had at their disposal an exceptional geological wealth, a beautiful countryside, and a rich culture and history (Zouros 2004). Thus chances of finding a solution to the above-mentioned problems were looked for in the development of sustainable tourism within the concept of geoparks. A definition of common instruments for the solution of negotiated problems (McKeever, Zouros 2005) was subsequently applied in the definition of geopark: "A geopark is a nationally protected area containing a number of geological heritage sites of particular importance, rarity or aesthetic appeal. These Earth heritage sites are part of an integrated concept of protection, education and sustainable development. A geopark achieves its goals through a three-pronged approach: conservation, education and geotourism" (UNESCO Global Geoparks Network 2015). The common instruments included the crucial idea of pointing out the potential utilisation of geological heritage for the economic expansion of disadvantaged rural areas.

Geoparks are not a single-purpose concept with a focus on abiotic heritage protection. Their message presumes positive impacts on regional development, identity, tourism and education. Unlike a national park, a geopark is not supported by legislation. The essence of landscape protection through a geopark lies in the consciousness and motivation of people willing to protect the area in which they live. As an institution, each geopark is responsible for its management (in Czechia, geopark is mostly a public-benefit corporation). Geopark management wants to motivate local residents to realise the uniqueness of their place. This awareness can awaken regional consciousness and identity, awareness of which can result in the feeling of responsibility for a given place among local

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inhabitants. Therefore, the bottom up approach to protection, management and planning is a vital part of the functioning of a geopark. In the first place, the existence of the particular geopark relates to the perceptions of local residents and their abilities to co-exist and cooperate, while transferring their experiences from one generation to another (Pásková 2011, 2013; Čtveráková 2014).

Moreover, a geopark can be denoted as a trademark of a certain area. If a geopark meets the criteria described in the Charter of National Geoparks (a binding document arising from the European Geoparks Charter, on the basis of which Minister of the Environment designates an area as a national geopark), it is certified to the position of a national geopark for the duration of four years. Subsequently, an assessment is made of the fulfilment of the previously set objectives of the geopark, which leads to the three possible conclusions (MŽP ČR 2007, Directive No. 6/2007): (a) the geopark has met the objectives and the certificate is prolonged; (b) the geopark only partly met its objectives and its remaining in the position of a national geopark depends on a rapid correction of deficiencies; (c) the geopark either did not meet its objectives or it seriously violated the Charter of National Geoparks, due to which it loses its certification as a national geopark. The national level is the lowest degree of certification and the national geopark located in particular country can seek certification within the European Geoparks Network or subsequently also within the framework of the Global Geoparks Network.

The aim of the article is to identify and discuss the barriers in the functioning of Czech geoparks, to analyse their causes and to outline the ways they can be dealt with. In the European context, comprehensive solution to this problem has not been given among the authors dealing with the topic of geoparks. Moreover, barriers in the functioning of geoparks throughout the world tend to be regarded only as a complementary part of other researches. In Czechia, the study of barriers to the functioning of geoparks can be attributed to a number of reasons. Despite having existed for a decade already, geoparks are still encountering some problems, especially caused by the barriers associated with their insufficient embedding in Czech society. In addition, the problems relating to the institutional support can be also mentioned. As a result, the article discusses and also offers potential solutions to these problems.

In its first part, the article acquaints readers with the concept of geoparks and the principles of their functioning. The general ideas are subsequently specified, using the example of establishment of geoparks in Czechia upon the background of sustainable tourism development since the 1990s. Examination of the beginnings of geoparks in Czechia and of the diverse approaches to them adopted by various actors, have become a basis for the empirical part of the article. Results of a survey conducted in May and June 2014 in a part of one of the Czech national geoparks, the National Geopark (NG) Železné hory (East Bohemia), are presented. The survey among local actors, complemented by field observation, was conducted by means of semi-structured interviews. The survey primarily concentrated on the perceptions and interpretations of changes in tourism in the context of the establishment and functioning of a geopark as seen by the local actors who participate in tourism management. The survey uncovered many barriers to the development of the studied geopark. The identified barriers were subsequently sorted into three thematic circles (the barriers arising from the past, the barriers that are due to the misunderstanding of the whole concept, and the barriers caused by the current support for tourism), that were set into a broader context.

Some of the uncovered barriers could be generalised and associated with the problems that are linked with the development of not only other Czech geoparks, but also with the barriers to the development of tourism in other Czech destinations. The basic asked questions were as follows: What is the cause of the stagnating development of geoparks in Czechia? What is the origin of the barriers hampering the development of geoparks? Do geoparks have the necessary institutional support and, at the same time, the support from local actors?

2. Geoparks in relation to local community

A geopark and the community within its boundaries create a whole that has a deeper connection with the concept of social capital because when a geopark is formed, the vital role is played by local actors. There is a variety of concepts of social capital (Pileček, Jančák 2010; van Deth 2008). Van Deth (2008) created a model of measuring the collective social capital that works with two sets of aspects (structural and cultural). The former include all types of social networks (membership in associations and volunteer organisations, participation in public affairs, etc.), while the latter tend to rest on a general trust in people and institutions as well as civic norms and values, such as fostering of bilateral relations, solidarity, identification with a certain area or political events. In a form, both sets of the aspects can be found in the concept of geoparks. The local actor that establishes a geopark should stimulate locals' interest and motivation in participating in coordinated activities. The idea is derived from the notion that efficient work of an originally small group of people makes other residents actively join the activities, which helps the development of a geopark and, to some extent, the development of a region as a whole.

Along with an active participation and interest in local events, the feeling of belonging to the geopark appears among its inhabitants. People come to identify themselves with the region in which they live (Paasi 1986; Chromý, Semian, Kučera 2014). The concept of geoparks is based on the idea that territorial identity can be formed by means of community's co-existence with a landscape

(Mitchell 2001). Between formation of regions and geoparks certain analogy may be observed, because in both cases, the vital role is played by individuals' initiatives and the creation of the image of the area in question (Paasi 1986). Like regions, geoparks, too, are areas with delineated physical and cultural boundaries (Chromý 2000).

3. Geoparks as an opportunity for rural development

The idea to establish geoparks reflects the need to deal with the problem of rural development because a geopark can be perceived as one of the ways of its support through maintaining or renewing local traditions. Zouros (2004) defines a geopark as an area combining the protection and promotion of geological heritage along with sustainable development. Bailey and Hill (2009) consider a geopark a synonym for the cooperation among local people and institutions, who share the vision of the future and are thus creating a unique identity of an area.

Eder and Patzak (2004) were among the first to have specified the criteria for the functioning of geoparks under the auspices of UNESCO. The main six criteria are as follows: (1) preservation of geological heritage for future generations; (2) education of general public; (3) functioning in harmony with sustainable development principles; (4) operation in coordination with other national and international programmes; (5) definition of limits of a geopark; (6) a sufficiently large area enabling the development of a region (this encompasses generating economic activities, hubs for the stimulation of economic expansion and the sites of geological-paleontological heritage with archaeological, ecological, historical and cultural values).

Geotourism is one of the instruments of geoparks. It is a subset of widely practiced and well-known ecotourism (Dowling 2010). The original definitions of geotourism are associated with the tourism closely focusing on geology and geomorphology (Hose 1995; Dowling, Newsome 2006). In the course of time, this approach started to broaden and the definition of geotourism also included such vital aspects as education, culture, history or tradition (Sadry 2009; Dowling, Newsome 2010; Hose 2011; Fialová 2012). A comprehensive geographic definition of geotourism is contained in the Arouca Declaration on Geotourism: "Geotourism is tourism which sustains and enhances the identity of a territory, taking into consideration its geology, environment, culture, aesthetics, heritage and the well-being of its residents" (Arouca Declaration 2011). With regard to the interaction between geotourists and local communities, this largely depends on the extent with which local residents are involved in the production of services, establishments, products and knowledge associated with the area in which geotourism takes place. It is presumed that participation of a local community in geotourism is vital on account of the development of the community itself, but it also largely contributes to tourists' satisfaction (Dowling 2010). The bigger the impact of the atmosphere of a place (genius loci) on tourists, the bigger the chance of their leaving it with a strong experience, which is one of the objectives of geotourism.

4. Creation of geoparks in Czechia

Before 1989, tourism in Czechia was considerably lagging behind the situation in other European countries. The main changes in tourism since 1989 have been primarily of a socioeconomic character, being related to the expansion of new forms of tourism and associated with growth in tourist demand and offer (Vystoupil et al. 2010). Czechia became a very attractive destination, but after a time, this gave way to stagnation of tourism, which has been increasingly concentrated in the capital of Prague (MMR ČR 2015). Other areas in Czechia only account for a minimum proportion of foreigners' visits, mainly concentrating on domestic tourism instead. Insufficient quality of local services, especially in rural areas, has been one of the main reasons of the falling number of tourists in some regions (Vystoupil et al. 2010). One could see another important change: transformation of the tourism policy because it was greatly stimulated by regional and municipal authorities, whereby the finances spent on the expansion of tourism were also better allocated. Tourism was also gradually gaining major support from European Union funds (Vystoupil et al. 2010). Support for tourism from the European Union is mainly targeted at the instruments for sustainable development of tourism and aid in the development of rural areas, such as by means of geoparks.

To some extent, geoparks follow up the transformation of tourism that has been under way since 1989 as they are offering new opportunities for its development and focus on its previously unknown forms. The transition from the "4S" model towards the "4L" model, associated with people's new motivation to travel and new expectations linked with tourism, is one of the main theoretical bases of this transformation with respect to tourism marketing. The concept 4L ("landscape, leisure, learning, limit") reflects the demands of present-day tourism in which tourists turn their attention to the landscape and learning (Franch et al. 2008). It is just the combination of tourism and education that enhances the performance of the tourism industry (Lam, Ariffin, Ahmad 2011).

The beginnings of the geopark network in Czechia trace back to 2005, when the first Czech geopark Bohemian Paradise (Český ráj) was established, and also became a UNESCO Global Geopark. At that time, the Council of National Geoparks, an advisory body of the Czech Ministry of the Environment, was formed in Czechia. It is comprised of members of expert institutions (universities, the Czech Geological Survey, the National Heritage Institute, the Ministry of the Environment, the Ministry of Regional Development) and representatives of individual national

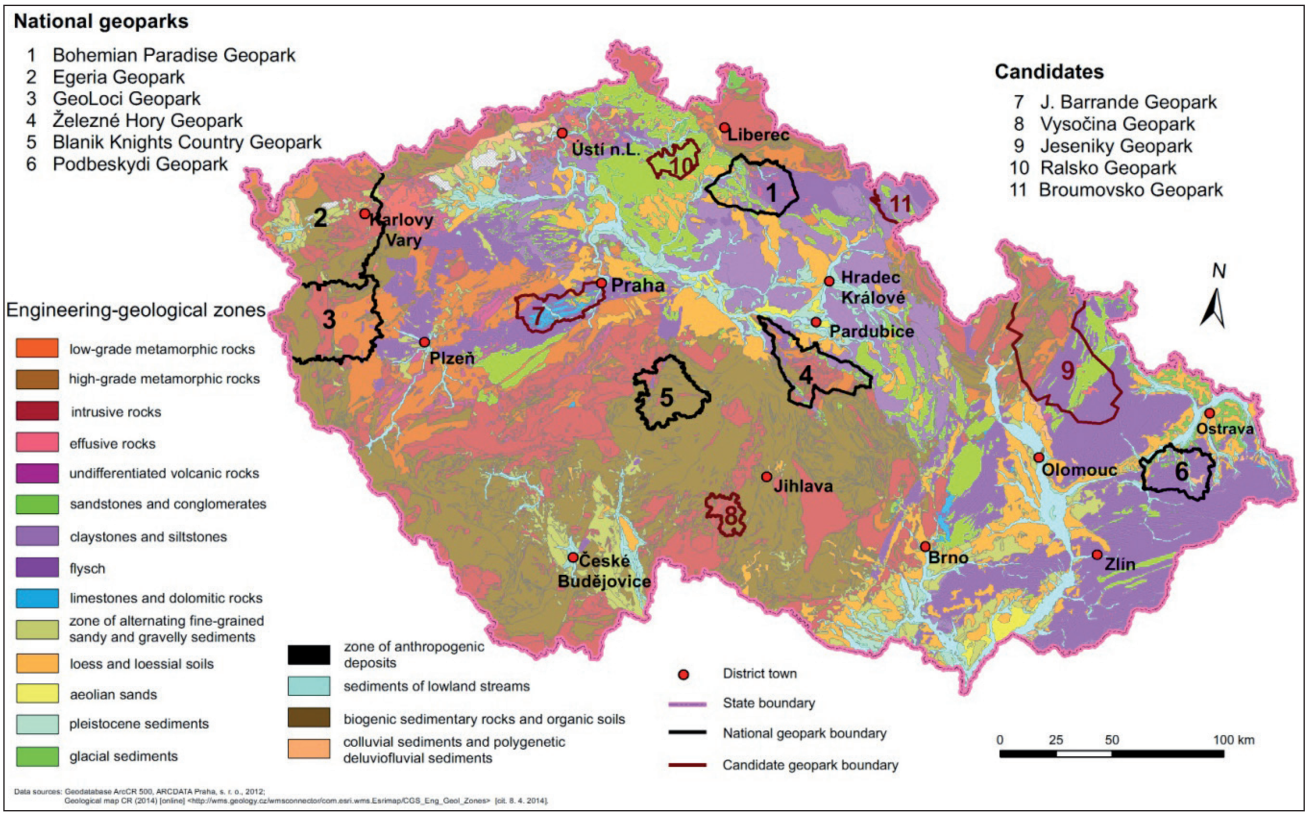

Fig. 1 Geoparks in Czechia in 2015.
Source: Authors' own work with the use of digital vector geographic database ArcČR500.

geoparks. The Council recommends to the Czech Minister of the Environment areas for designation as national geoparks and assesses whether the objectives of Czech geoparks are met (National Geoparks 2015).

In 2007, Directive of the Ministry of the Environment No. 6/2007 was drafted in Czechia for the sake of the ministry's unified strategy when nominating Bohemian Paradise as a national geopark. The directive regulates conditions and steps to be taken when a national geopark is to be designated (MŽP ČR 2007). The process of establishing a national geopark starts with presenting the documentation with the intention of declaring a geopark in a clearly delineated area to the Council of National Geoparks. The body then assesses the intention and votes about the establishment of a candidate geopark. The candidate geopark must present the nomination documentation for the position of a national geopark. An evaluation is made by two independent members of the Council of National Geoparks. If the area meets all of the criteria, it is certified as a national geopark.

Until 2015, six geoparks certified on the national level were designated in Czechia. However, only Bohemian Paradise has achieved recognition on the international level and was accepted among global geoparks under the auspices of UNESCO. Along with it, the Geopark Egeria was certified on the national level in 2005. In 2012, the Železné hory Geopark and GeoLoci Geopark were certified and in 2014, the Kraj blanických rytířů Geopark and Podbeskydí Geopark followed. Some more areas (Joachim Barrande Geopark, Vysočina, Jeseníky, Ralsko and Broumovsko) are promoted for certification as national geoparks, too. Figure 1 depicts the location of existing as well as candidate national geoparks in Czechia.

5. Introduction of the area of interest

The area of interest is located in Eastern Bohemia, in a part of the National Geopark (NG) Železné hory. It straddles two administrative units, the Pardubice and Vysočina self-government regions (Figure 2). The area covers 136 km^2 (the whole geopark measures 777 km^2), incorporating 20 municipalities and their parts with approximately 17,000 inhabitants (CZSO 2011). Although the delineated area is primarily located in the Vysočina Region, local residents have stronger links with the Pardubice Region. This is due to a change in the regional boundary (Chromý, Kučerová, Kučera 2009). Until 1999 the area of interest was part of the East Bohemian Region (the present-day Pardubice and Hradec Králové regions). Along with an administrative division, the area of interest can be delineated in other ways. With regard to local partnerships, the area of interest is situated within the Local Action Group (LAG) called Podhůří Železných hor (NS MAS 2015) and the following microregions: the Železné hory Centre, the Podoubraví Association of Municipalities, and the Hlinecko Microregion Association of Municipalities (RIS 2015). When it comes to the nature

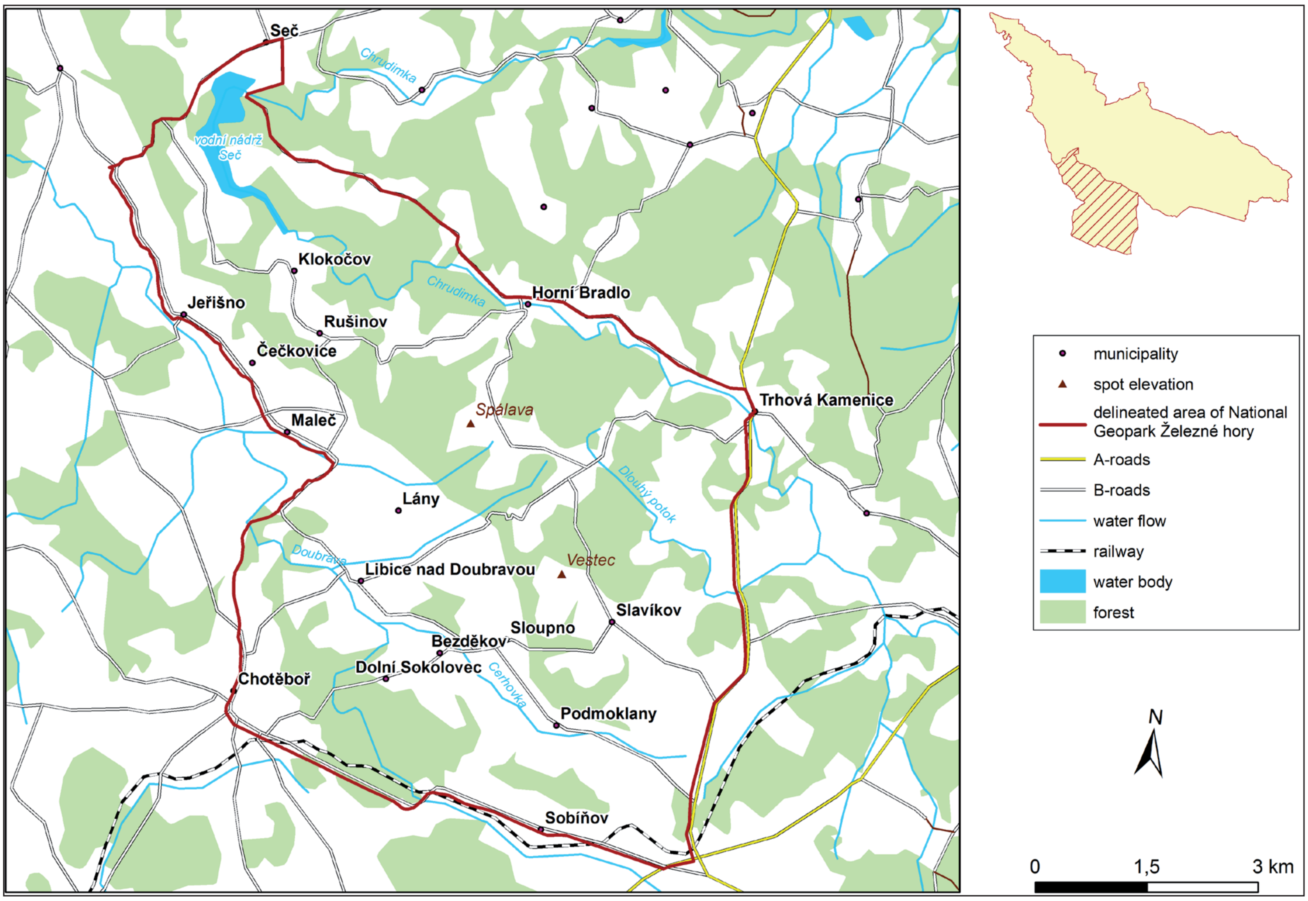

Fig. 2 Area of interest in the National Geopark Železné hory.
Source: Authors' own work with the use of digital vector geographic data base ArcČR500.

and landscape conservation, the area of interest is a part of the Železné hory Protected Landscape Area (CHKO Železné hory 2015). Last but not least, the area can be delineated on the basis of tourist regions. It is largely situated within the Vysočina tourist region, overlapping to the Chrudimsko-Hlinecko tourist region in the northeast (CzechTourism 2015).

The discussed part of the National Geopark Železné hory (Figure 2) covers approximately one-fifth of its total area (136 km^2) and it was chosen for the survey for a number of reasons. This is an internal periphery (Musil, Müller 2008; Havlíček et al. 2008) on the border of two regions. The survey was conducted in the area also for another reason: compared with its other parts, this is the least examined zone of the geopark. The research in the delineated part of the geopark was conducted at the end of spring and beginning of summer 2014 and followed earlier researches into the geology and geomorphology, natural, cultural and historical heritage of the area (e.g., Nedobitá 2002; Nováková 2012).

6. Research methods and used material

Before the survey started, a number of local actors and institutions were earmarked in the area of interest that may play a key role in the cooperation between the geopark and a local actor or between the local actors themselves. These actors include the elementary and secondary schools (Chotěboř, Ždírec nad Doubravou, Seč, Trhová Kamenice, Maleč) and operators of the accommodation and catering establishments, especially in the zone of the Seč water reservoir which is still a well-known tourism destination (Pardubice Regional Development Agency 2009).

The main part of the survey constituted of guided semi-structured interviews with the most important actors in the area of interest. The objective was to identify the presumed forms of cooperation between local actors. Through discussion of the results of the interviews, one can subsequently identify possible problems that pose a barrier to the development of geoparks. In addition, the survey examined the attitude of the local community to the natural and cultural-historical potential of the area for tourism development. These findings are supposed to help designate the thematic zones to which attention should be paid within tourism planning.

The guided interviews were complemented by collecting further information through field observations, studying of panels on educational trails and tourist brochures provided in information centres. Respondents for guided interviews were selected from all parts of the area

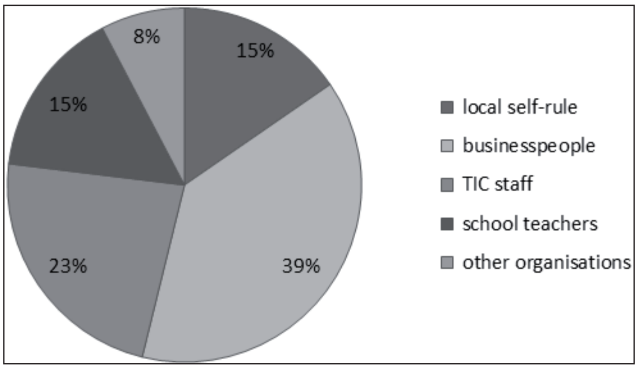

Fig. 3 Respondents' professional structure for the survey in a part of the National Geopark Železné hory in 2014.
Source: Authors' own survey.

of interest as much evenly as possible, but there was also the impact of some large towns in which a major number of suitable respondents are accumulated. For the sake of collaboration in the survey, a number of local actors, including representatives of the local institutions, particularly the staff of tourist information centres, school teachers and tourism businesspeople, were addressed. The inclusion of the respondents from the ranks of local actors, not any randomly chosen locals, was motivated by the assumption that the awareness of geoparks is very low among laypeople in Czechia. Potential respondents were at first addressed by e-mail. This ensured their willingness to participate in the survey. The second contact with the actors ready to join the survey proceeded on the personal level at an agreed meeting. All 13 guided semi-structured interviews with various local actors (Figure 3) were conducted between May and June 2014. It was not necessary to include a larger number of respondents because answers to the posed questions repeated in different interviews. The theoretical saturation of the conducted survey was thus achieved.

The semi-structured interviews are situated on the fictitious frontier between the structured (shared) interview and a non-structured (indirect) interview (Hendl 2005). The used draft of the interview in the form of an overview of crucial questions is presented in Table 1. The order of questions in the interview is not strictly given, only recommended. With his/her response, a respondent may follow up any other question, not only the subsequent one. The questions are open because of a general idea that a respondent should be free to express the opinions, so that the real state of the examined topic is covered as best as possible. In addition, the respondents were of a varying professional background and had differing knowledge of the topic in question.

The data collection by means of the method of guided interviews and their processing are time-consuming. Before the interview itself was conducted, the purpose of the survey was explained to each of the respondents. The duration of every interview was about 30 minutes. The interviews were not recorded by any device (the respondents mostly did not wish this), but notes were carefully written down both in the course of the interview itself and after it. The atmosphere during the interview and respondent's conduct were also observed. In order to find out the interrelatedness of various local actors, at the close of each interview the respondents were asked to provide contacts to other persons they consider suitable candidates for this survey. The survey had the big advantage that it was carried out in the "home" environment of each of the respondents, thanks to which the field worker could understand important circumstances.

The analysis of the interviews was conducted in the programme MS Excel by categorising the data on three levels (Švaříček, Šeďová 2007). On the first level, explanatory notions that represent a certain phenomenon were searched for. Subsequently, codes were created from them. Since some of the notions were repeated, the codes had to be renamed, depending on the need. On the last level, the codes were categorised according to their similarity or internal coherence. In this way, ten categories were created, between which one can observe some bilateral relationship. On the basis of these ten categories, an analysis of the knowledge and phenomena in the area under observation was made and conclusions were reached, when it comes to the functioning of the geoparks and barriers to their development. While interpreting the findings gained by the method of semi-structured guided interviews, the fact that the conducted survey is based on subjective perceptions of reality, expressing the views of the actors involved, had to be considered (Disman 2002; Hendl 2005).

7. Selected barriers to the development of geoparks

Based on the survey, some problems accompanying the development of the delineated area were identified (Čtveráková 2014). The results can be considered of being of general validity for the topic of development of geoparks in Czechia. The conclusions of the survey are complemented by further findings about the historical development of the political and economic situation in Czechia (Vystoupil et al. 2010) and from the report National Tourism Policy Concept 2014–2020, drafted by the Czech Ministry of Regional Development (MMR ČR 2013). As already mentioned, the categorization of the data gained in the form of recorded interviews with the key actors gave rise to ten interrelated categories (bad cooperation, poor support, insufficient promotion, support for regional products, diverse ideas, no change, activity of schools and tourist information centres, quality of accommodation, beautiful nature and landscape, bicycle touring) that well describe the main findings. Further will be discussed only the three selected categories that characterize the barriers in the relationship between a geopark and regional development, and which also outline the main obstacles to the development of Czech

Tab. 1 Interview structure.

Question	Target of question
What is your general view of tourism in your region? What are its strong and weak points?	The questions generally examine respondent's opinions regarding the situation in tourism in the whole region of Železné hory.
For what purpose do visitors primarily come here?	The question examines the interpretation of the tourists' and visitors' main motivation to come to the area of interest.
What is your impression of the establishment of the geopark in Železné hory region? In which way does its existence have an influence on you? What is, in your opinion, the local residents' attitude to the geopark?	Crucial questions aimed on finding out whether the respondents know about the existence of the NG Železné hory in the first place. If they do, it is then examined in which way the geopark has an impact on their practices. There is also the alternative that the respondents do not know anything about the geopark. This is why the following questions (apart from the questions 4 and 5) are targeted at the cooperation of actors in tourism and at the potential of the area for various forms of tourism development.
Have you seen any shift in regional development since the Železné hory was designated as a national geopark? Has anything changed? What has it been?	The questions were asked if the respondents were acquainted with the existence of the NG Železné hory, examining the contribution of the geopark to the development of the area.
Are you engaged in any way in the activities staged by the geopark or do you even organise some events associated with the geopark in your own right?	Another question asked if there was a positive answer to the knowledge of the geopark. Its objective was to identify respondents' participation in the activities of the geopark.
Do you cooperate with LAG of Podhůří Železné hory or some other microregion?	The question examines the interrelatedness of local actors with LAG and the associations of municipalities active on the delineated area.
What could be changed and improved around you with regard to the offer to the visitors?	This question focuses on perceived shortcomings in tourism development in the area of interest and especially on finding what is lacked by both locals and visitors.
In your view, what potential is here for what form of tourism?	The question examines perceptions of tourism potential in the delineated area for the possible subsequent proposal to improve the infrastructure, establishments, etc.
Which natural, cultural and historical heritage sites find the biggest response among tourists?	The question examines specific objectives of tourists and visitors coming to the area.
Do you support some regional products?	This question is to find out the extent of interrelatedness with local actors who are devoted to the manufacturing of products from local raw materials, food production and traditional crafts.
What is your view of sustainable tourism in the future?	Final general question relating to the future of tourism in the delineated area and its sustainable development chances.

Source: Authors' own work.

geoparks: bad cooperation, poor support, and insufficient promotion. These categories influence one another and are closely interconnected.

7.1 Barriers to the development of geoparks arising from the past

In the sphere of cooperation, there is a relatively good coordination of the authorities that are interested in the development of an area by means of a geopark. However, the situation is quite different in the private sphere. The respondents doing business in tourism tend to be disinterested in the benefits of geoparks. As confirmed by representatives of the local self-governments, the tourist information centres (TIC) staff and the businesspeople themselves, there is a reluctance to cooperate and to help one another in the creation of opportunities for profit from tourism: "The problem here is that everyone only minds his own business and there is a lack of contact among people. One may provide accommodation to the clients, another providing them with entertainment, etc." (a TIC employee). On the contrary, there is still stiff competition. The cause of the present-day reluctance to cooperate with anyone, not seeking only one's own profit, may be traced down in the past. After 1989, Czechia swiftly adopted the U.S. neoliberal model, while the Communist thought remained firmly embedded in many minds. This approach has often influenced even the next generation that only experienced the past regime in the childhood. In the business environment, everything is evaluated according to the principle of generation of immediate profit. In conjunction with the Communist legacy, this is a combination causing the current misunderstanding as well as reluctance to understand the new concepts of regional development such as geoparks. Possible explanation for mistrust in new development approaches thus provides a theory of path dependency (David 1985) meaning, that past or traditional practices or preferences continue even when more suitable alternatives are available. It is often easier to simply continue along already set path without risking failure or financial losses. Establishing an entirely new and more efficient approach is time-consuming and often more expensive. Therefore, local state of affairs has been only changing very slowly and one can judge that this goes hand in hand with the replacement of previous generations by those that have never lived under the Communist rule.

A well-executed promotion may considerably enhance a faster understanding of the principles of geoparks (in the sense of bottom-up cooperation). The promotion should be aimed at disseminating the information about the advantages of cooperation and joint presentation of several businesses. The survey has revealed several centres of starting cooperation that may serve as a model for other businesses. This is exemplified by the cooperation of the operators of water attractions at the Seč water reservoir with the local provider of accommodation and catering services. However, destination management based on wide cooperation of current and new partnerships among local actors in tourism (Bieger 1996; Holešinská 2010) has yet to be established. Destination management in geopark should include informal relationships, knowledge and confidence, and apply destination governance concept (Beritelli, Bieger, Lesser 2007) underlining local actors' rights and interests and partnership. Another form with which to spread consciousness of cooperation within the framework of a geopark is based on education and instruction, primarily targeting children. The foundations of such promotion are visible in the area of interest. The secondary school in Chotěboř not only cooperates with the NG Železné hory administration, but it also stages public events targeting at the explanation of the geopark concept. Children's inclusion in the education of the public is very beneficial because it influences not only the children themselves, but through them, parents, the relatives and eventually the general public, too, are involved.

The interrelatedness of cooperation and promotion is also complemented by support for the actors, which is vital on the local as well as regional and national levels. Although the idea of a geopark suggests its support by the local residents' initiative, a certain patronage and support "from above" bring a large contribution to its institutionalization. The area of interest is strongly influenced by its position on the border of two regions in this respect. The local residents still tend to feel more identified with the municipalities in the Pardubice Region (existing since 2000), although they are now administratively part of the Vysočina Region. According to the results of the survey, over one-half of the respondents feel a stronger link to the town of Pardubice in the neighbouring region than to the town of Jihlava in the Vysočina Region. This state of affairs causes a certain reserved stance of local residents on the regional policy. For a long time, the locals have been watching both the financial and other supports being sent more to other places of the Vysočina Region than to the places in which they live (Čtveráková 2014), which is hardly a good motivation for them to be involved in local/regional development.

7.2 Barriers to the development of geoparks due to misunderstanding of the whole concept

Another problem, that certainly does not help the expansion of geoparks, is posed by a misunderstanding of the whole geopark concept and the mistaking of the notion of geopark with a geological collection or exhibition. As stated above, geoparks are not only based on geology, even though geology is one of its central motives. Geological exhibitions are often denoted as geoparks. This has also transpired from some of the conducted interviews. The respondents included some people who have never heard anything of any geopark. The very word "geopark" has the implication for them that this is a geological park, which they associate with the increasingly appearing outdoor geological exhibitions, such as those at school gardens (Chotěboř secondary school), in museums or other organisations (Vodní zdroje Chrudim). This false idea contributes to the degradation of geoparks to mere collections of rocks and minerals, omitting other, no less important aspects included in the geopark concept (association with the culture and history of a region, education, participation of locals, etc.). This situation can be improved by a well-targeted education and promotion of the geopark concept. It is useful to target the education and instruction at the schoolchildren who are only being acquainted with the concept.

7.3 Barriers to development of geoparks arising from support for tourism

Between 2007 and 2013, tourism enjoyed the biggest public support in Czechia's history (Vystoupil, Šauer 2014). The largest volume of the support was spent on the basic and accompanying tourism infrastructure and on the adaptation and protection of cultural and historical as well as natural heritage sites. The investments were largely concentrated in large tourist centres. Minor volumes of investments were also recorded in the areas in which Czech national geoparks are situated, including the NG Železné hory. The sponsorship also supported regional products (Kašková, Chromý 2014) and environment-friendly tourism forms (National Tourism Policy Concept in Czechia for 2014–2020 in Vystoupil, Šauer 2014).

In the existing National Tourism Policy Concept (for 2014–2020), the support for geoparks seems to be less favourable, although it is directly named in the measure 1.4: Enhancement of the offer of primary potential of tourism (enhancement of the use of natural, cultural and historical attractions for tourism; MMR ČR 2013). This is due to the main instrument of the new concept, which is the Integrated Regional Operational Programme (IROP), as it does not deal with some priorities outlined in the National Tourism Policy Concept in Czechia for 2014–2020 (MMR ČR 2013). The main shortcomings in the priorities set out by IROP were described by Vystoupil and Šauer (2014). When it comes to geoparks, these are primarily omissions of the certification systems of regional products (Kašková, Chromý 2014) that need a strong coordinating body without which they cannot operate. In addition, it does not deal with one of the biggest problems of Czech geoparks, which is the concept and interrelatedness of marketing activities and cooperation of local actors in a destination. There is no support for education in tourism, because the IROP primarily prefers education in technical fields, where tourism has little, if any, place. All the aspects the IROP does not take into account can bring about a certain stagnation of the development of Czech geoparks.

8. Conclusion

Geopark is a multi-layered concept that is originally based on idea of positive relationship between people and nature or inhabited landscape. The core of geoparks is formed by abiotic heritage protection in connection with sustainable regional development, education and tourism. The concept of geopark was theoretically discussed at the universities since 1990s and is used in practise since 2000 when the first geoparks were established and rules for founding, functioning and evaluating of geoparks were formulated. The first Czech geopark Bohemian Paradise was established in 2005. Concept of geoparks is not widely accepted by public in Czechia. Geoparks face many problems connected with ineffectual support, weak promotion and insufficient functional cooperation.

The article discussed the development of geoparks in Czechia and identified the barriers to their expansion in particular. The problems accompanying the establishment and functioning of geoparks arise from the existence of internal and external barriers. Both types of barriers reflect long-standing problems in a given region. The external barriers include general limitations caused by the nature of political, economic and social circumstances. Of them may be highlighted the influence of the former Communist regime, insufficient understanding of definitions of crucial notions and concepts (such as the geopark) or application of an inappropriate concept of tourism support on the national level. Internal barriers depend on local specific features of the areas in question. These are, for example, the problems associated with the boundaries of administrative units especially self-government regions and underestimated importance of promotion of geoparks, and with the unsuccessful application of modern development concepts due to insufficient provision of information, involved actors' reluctance to cooperate, etc. As internal and external barriers are closely interconnected, possible solutions to them have to be approached accordingly. They lie in motivating the people on the local level to gain new information and in encouraging cooperation, building networks and dissemination of education. Finding the solutions for internal barriers can subsequently help in coping with external barriers, too. A possible solution to existing problems lies in the elimination or at least reduction of the barriers that were identified in presented research.

Facilitating the "bottom-up" decision-making process is one of the basic principles of the functioning of geoparks. There is the question of whether this approach, that was implemented in Southern and Western Europe in connection with geoparks within the framework of their definition (McKeever, Zouros 2005; Pásková 2011; UNESCO Global Geopark Network 2015), can also be applied in other countries. Although the problems associated with the "bottom-up" approach are largely a question of internal barriers, their origin can be primarily traced down in the past development of society. In other words, they basically arise from the existence of external barriers. The residues of views and beliefs from the Communist era still remain in the minds of many people. They are opposed to the development of a cooperative way of business on which geoparks are based. Findings from the survey in the NG Železné hory have suggested that this state of affairs has started changing for the better at present. First attempts to jointly present and cooperate in the offer of tourism products (e.g., a hub of cooperation between water sports operators and local owners of catering facilities was found at the Seč water reservoir within the area of interest) or coordinate submission of joint applications for funding (National Tourism Programme, EU subsidies within the framework of cross-border cooperation, regional subsidies, etc.) may be observed. Similar points also apply to the cooperation within the geopark management (schools and tourist information centres in the area under observation) that is building partnership between public and private sector. Another centres of cooperation depend on geoparks' management abilities and skills, and on willingness and ability of other local stakeholders to utilize the current networks as well as new partnerships.

The survey has investigated the suggestion that since a geopark is no administrative unit, the administrative boundaries of administrative units should not be limiting for them. However, it has turned out in the particular case that administrative boundaries do pose a problem for the development of a geopark, acting as one of its barriers. Moreover, although a geopark is no geological exhibition, it is often seen and even presented so by some actors. The potential of a geopark demands sponsoring that should have various sources. Financing is grossly underestimated in Czech geoparks because the public does not perceive a geopark as an instrument for the development of peripheral or neglected rural areas. Rather, it tends to be seen as a tourist attraction or a concept limiting people's activities. In this respect, the potential of geoparks is being strongly underestimated.

Barriers to the development of a part of the NG Železné hory can be generalised as examples of the barriers to the development of most Czech geoparks, as problems on various scale levels that are causes of these barriers may be also generalised (lack of cooperation, active participation, etc.). If there is a successful solution to the problems accompanying the functioning of Czech geoparks, the barriers to their expansion will be likely to start vanishing, too.

There has not been conducted any comprehensive research into the barriers to the development of geoparks yet. Foreign researches primarily dealt with the instruments with which to develop geoparks, while partial results of these studies denoted problems in the development of geoparks. In Czechia, many barriers to the expansion of geoparks are similar to those known from experiences in other countries (such as the barriers arising from the misunderstanding of the purpose and sense of geoparks, and the ensuing mistaking of a geopark with a geological exhibition or an excessive emphasis on professional geology). Although, barriers specific to the Czech environment also exist (such as an absence of cooperation between diverse actors and reluctance to develop it). Moreover, the way in which tourism planning is implemented in geoparks management should also be discussed. Above all, it is desirable to internationally compare the experiences with implementation of sustainable tourism within geoparks and the obstacles to its development (South and Western Europe as compared to Central and North Europe) in the future.

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RESUMÉ

Bariéry v rozvoji českých geoparků v kontextu různých okolností

Geoparky jsou v Česku i ve světě poměrně novým konceptem, který se neustále vyvíjí v závislosti na vnějších a vnitřních podmínkách. Výzkum geoparků vyžaduje uplatnění interdisciplinárních přístupů, neboť jejich podstatou je ochrana neživého dědictví, podpora regionálního rozvoje, cestovního ruchu a vzdělávání a v neposlední řadě podpora utváření místní identity. Geoparky jsou vnímány jednak jako podnět rozvoje venkovských a periferních oblastí, jednak jako nová forma turistické destinace. V Česku navazuje zakládání geoparků na dlouhodobou transformaci cestovního ruchu probíhající od roku 1989, přičemž k faktické institucionalizaci sítě českých geoparků dochází od roku 2005, kdy vznikl první český geopark (Český ráj). Od té doby se v souvislosti s existencí geoparků objevují problémy hlavně v podobě omezeného povědomí o geoparcích v české společnosti, nedostatečné podpory a propagace, které jsou bariérou v rozvoji geoparků a tím také překážkou v naplňování jejich původního poslání, rozvoji venkovských a periferních oblastí.

Cílem příspěvku bylo definovat bariéry ve fungování českých geoparků a zjistit, jaké jsou jejich příčiny, a to na základě polostrukturovaných řízených rozhovorů s vybranými lokálními aktéry a zástupci institucí v zájmovém území národního geoparku Železné hory, u kterých je pravděpodobná současná či budoucí spolupráce s geoparkem. Vyhodnocení řízených rozhovorů bylo provedeno kategorizací dat v programu MS Excel. Výzkum odhalil bariéry, které ovlivňují rozvoj jak specifického geoparku Železné hory, tak rozvoj území českých geoparků obecně. Mezi vnitřní bariéry specifické pro šetřený geopark lze zařadit např. problémy související s administrativními hranicemi regionů, mezi vnější bariéry náleží např. neodpovídající koncepce podpory cestovního ruchu na úrovni státu. Vnitřní a vnější bariéry jsou úzce provázané. Některé z identifikovaných bariér lze zaznamenat i u geoparků v zahraničí, např. problémy spočívající v neporozumění vlastnímu konceptu geoparků nebo důraz aktérů působících na území geoparků na příliš odborně zaměřená témata geologie jako vědního oboru. Naopak dlouhodobá absence spolupráce mezi místními subjekty/aktéry a neochota rozvíjet spolupráci mezi subjekty/aktéry v horizontálním i vertikálním měřítku, je jevem typickým spíše pro české prostředí (mj. v důsledku historické zátěže – myšlení, které je dědictvím komunistického režimu).

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EVALUATION OF LAND COVER CHANGES AND BLACK LOCUST OCCURRENCE IN AGRICULTURAL LANDSCAPE. CASE STUDY: PODOLIE AND ČASTKOVCE CADASTRAL AREAS, SLOVAKIA

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ABSTRACT

This study presents spatial analysis of agricultural landscape changes in the Podolie and Častkovce cadastral areas since 1949. Data for analysis was obtained from historical aerial photographs (from 1949, 1986 and 2006), detailed field mapping and Black locust (*Robinia pseudoacacia* L.) monitoring. Land cover changes were assessed from the aerial photographs based on the CORINE land cover legend, environmental variables were derived from digital elevation model (DEM) and detailed geological and soil maps. Data was spatially compared and assessed by regression analysis for interpretation of Black locust occurrence. The most significant land cover changes occurred between 1949 and 1986 when agricultural areas were replaced by forest and semi-natural areas. One of the aspects of landscape changes is abandonment of agricultural landscape and occupancy this new transformed surfaces by invasive plant taxons (e. i. *Robinia pseudoacacia* L.). Black locust occurrence was mainly influenced by landscape management changes and subsequent land cover changes (afforestation from 1949 to 1986), especially in regions of dispersed settlements (Podolské and Korytnianské kopanice) after agricultural collectivisation. Environmental variables had little effect on Black locust expansion in these areas.

Keywords: land cover changes, land cover flow, socio-economic transformation, *Robinia pseudoacacia* L., Slovakia

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1. Introduction

Anthropogenic land cover alteration over centuries is the main component of global change (Munteanu et al. 2014) and reflecting different phases in socio-economic development and political and environmental change. This is considered an expression of dynamic interaction between cultural and environmental forces (Antrop 2005; Biró et al. 2013; Bičík et al. 2001), and therefore monitoring landscape change is indispensable in comprehending its dynamics and behaviour (Feranec et al. 2000). The most dramatic intervention into the landscape structure in former socialistic countries was agricultural collectivization after 1950 (Lipský 1995; Bičík and Jeleček 2009). This led to altered agricultural production and urbanization in these countries and completely changed the character of the rural landscape. Collectivization can be considered as a the most dramatic intervention into the structure of landscape in Slovakia (Šebo and Kopecká 2014). Further political change after 1990 engineered transition in Czech and Slovak societies (Bičík and Jančák 2003); so that Grešlová et al. (2015) associated agricultural development in Czech Republic solely with concept of social metabolism. In addition, current European Union economic policy has modified Slovak agricultural landscape and farming practice (Tarasovičová et al. 2013), thus affecting plant and animal associations on arable land, meadows and pastures (Kalivoda et al. 2010). Finally, Goldewijk and Ramankutty (2004) consider these agricultural changes as a key factor in the sphere of land use and land cover change.

Although the European landscape convention (ELC) has been in force in Slovakia for over 10 years, its implementation in legislative, strategic and planning documents, and in later practice, remains unsatisfactory. The key component of the rural landscape is agriculture (Šebo and Huba 2015), and Foley et al. (2005) add that land cover flows are crucial agricultural landscape changes and major determinants of global change. These land cover changes not only affect ecosystems and climate change, but also determine future landscape dynamics and the products and services available for society (Verburg et al. 2009). The scientific findings on agricultural processes involved in land cover change are accepted by most decision-makers and are therefore an important source for policy determination (Busch 2006).

Many studies of land cover and land use changes in the Czech and Slovak Republics are based on historical topographic maps and orthophotographs (Demek et al. 2007; Boltižiar et al. 2008; Mackovčin 2009; Falťan et al. 2011; Skokanová et al. 2012). Satellite images are also common in land cover change assessment at national and international levels; as in the CORINE Land Cover project (CLC) applied in Slovakia (Feranec and Oťahel 1999, 2001; Falťan and Saksa 2004; Falťan et al. 2008, 2011; Druga and Falťan 2014; Pazúr et al. 2012, 2014). Feranec et al. (2000, 2010) define the following seven basic types of land cover change; urbanisation,

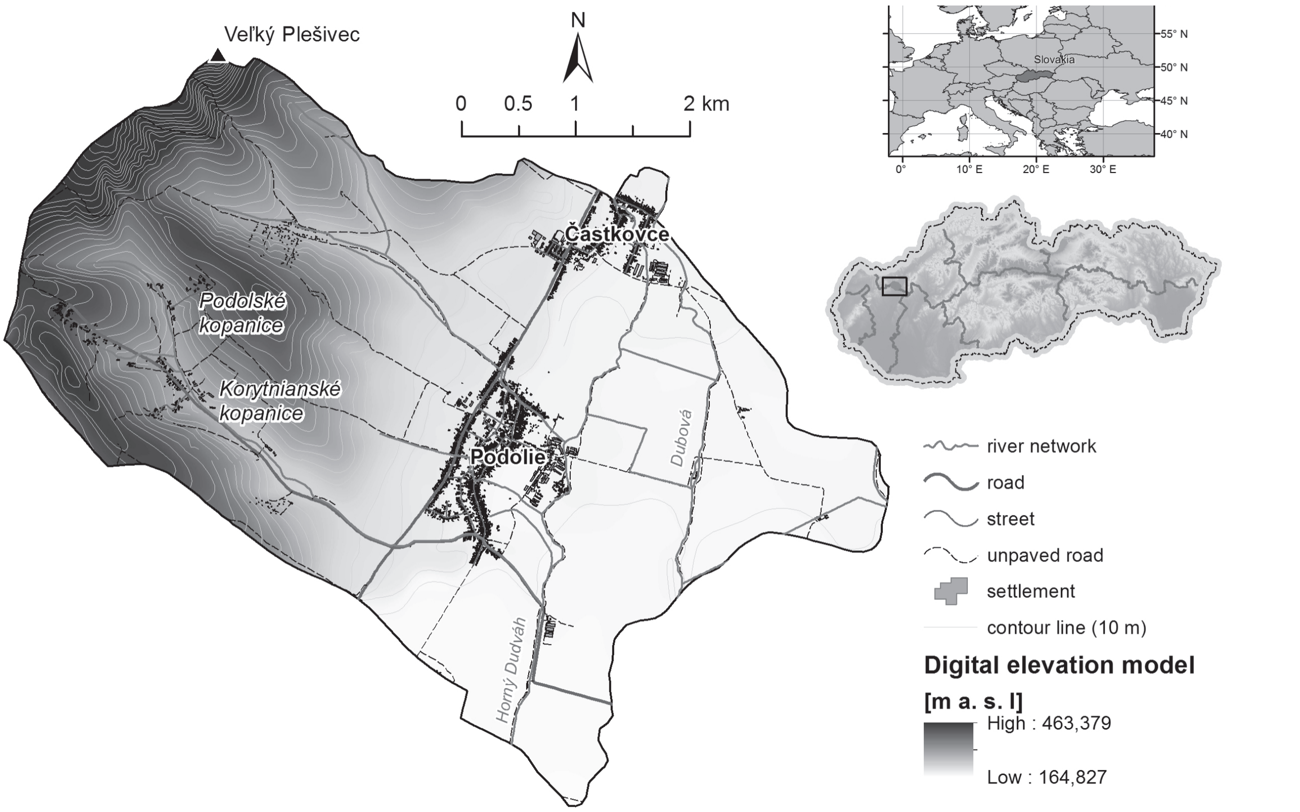

Fig. 1 Localization of the study area 1 – Podolie and Častkovce cadastral units.

agricultural extensification, agricultural intensification, natural resource exhaustion, afforestation, deforestation and 'other'. While agricultural extensification is a problem in the majority of European countries (Sluiter and de Jong 2006; Baundry 1991) including Slovakia (Šebo and Kopecká 2014), abandonment of agricultural landscape has caused the greatest land cover changes with subsequent vegetation succession and replacement of native plant species by non-native, often invasive species.

These plant species have relocated deliberately or accidentally with expansion of global trade and increased human mobility (Meyerson and Mooney 2007); with invading populations threatening original associations by changing species structure, eliminating domestic species from ecosystems and either dominating existing associations or creating new ones (Eliáš 2001). Their spread is one of the most important processes in decline in biological diversity (Butchart et al. 2010). In Slovakia Black locust (*Robinia pseudoacacia* L.) belongs to most important invasive plant species, intruding pioneer forest growth and natural development. It causes considerable environmental problems here (Eliáš, 2005) because its wide ecological tolerance potentiates spread to the detriment of original species (Dreiss and Volin 2013; Chytrý et al. 2005). Black locust is an autochthonous tree in North America, has spread extensively in many other countries and its active regeneration and rapid initial growth have curtailed successful eradication despite intensive effort (Kurokochi and Toyama 2014).

The aim of this study is detailed analysis of land cover changes in the Podolie and Častkovce cadastral area and assessment of socioeconomic changes since 1948. We especially investigate landscape changes due to agricultural abandonment and relocation of invasive plant taxon (Black locust) on this new transformed surfaces.

2. Study area

The study area is situated on the border between the Podunajská Hill Land and the Little Carpathians geomorphological units in Western Slovakia; covering the Podolie and Častkovce commune territories (Figure 1). The greater part of this area is in the River Váh erosion-accumulation valley affecting part of the Horný Dudváh and Dubová stream watersheds. It covers 24.67 km^2 of prevailingly agricultural landscape (Figure 2); with the lowest land point of 166 m a. s. l. in its southern portion and maximum 484 m height on the Veľký Plešivec peak in the north-west.

This area at the junction of the River Váh valley floodplain and Little Carpathian Mountains is composed of Quaternary sediments with deluvial sand-loam and aeolic sediments and loess loam and loess. The specific nature of the loess rock formation resulted in creation of differing morphological forms, especially gullies. Here, Little Carpathian upland in the northwest gradually transforms into Trnavská Hill Land relief with a smoothly modelled

Fig. 2 The agricultural landscape in the foothills of the Little Carpathians with significant system of gullies forming linear forest elements. View from the Veľký Plešivec peak.

surface. The lower Váh floodplain is slightly undulated and separated from the Trnavská Hill Land by terraces. The territory has two protected areas; the Plešivec Nature Reserve situated on the Little Carpathians' ridge and the Dubová Bank Growth Nature Phenomenon adjacent to Dubová brook.

3. Materials and methods

3.1 Land cover assessment

Land cover of the study area was assessed under 4th level nomenclature of the CORINE Land Cover (CLC) methodology (Feranec and Oťaheľ 1999). Basic source of spatial data was aerial photographs from the Topographic Institute in Banská Bystrica (1949, 1986 and 2006). The 17 images with 1,200 dpi resolution were processed under the S-JTSK Křovak East North coordinate system by Leica Photogrammetric Suite software (Figure 3). Two black and white images from 1949 were orthorectified in block-aero-triangulation with 37 ground control points (GCP) and 227 tie points. In addition, 9 images captured in 1986 were processed with 55 GCP and 373 tie points, together with 6 colour images from 2006 with 55 GCP and 204 tie points. The DRM 3 digital relief model with 10 × 10 m pixel size was then used for orthorectification; with maximum root mean square error (RMSE) in each time horizon less than 5 m.

The minimum size of the mapped area was 50 m^2 and visual orthophoto interpretation was based on morphostructural and physiognomic features and object pattern characteristics. Analysis of changes in landscape structure was assessed by raster with 0.5 m pixel size in ArcGIS 10.2 by zonal statistics via cross tabulation in spatial analysis. Spatial and temporal changes in individual land cover classes (LC) were assessed according to Feranec et al. (2000, 2010) and defined in the following 8 LC change classes: (1) urbanisation; (2) intensification of agriculture; (3) agricultural extensification; (4) afforestation; (5) deforestation; (6) water body constructions; (7) other changes and (8) no change (Figure 4). Urbanisation is characterized by building construction in settlement areas and transformation from other LC classes to class 1. Agricultural intensification was identified as a transformation from agricultural LC classes with lower intensity to higher intensity and the reverse process was recognize as a extensification of agriculture. Afforestation is defined as forest regeneration via either forest establishment or natural succession, and transformation to category class 3, and deforestation is the reverse process. The last identified land cover flow refers to water body constructions. Finally there are 'other-changes' and 'no-change' categories with relevant polygons in the study period; not defined as flows in our Figure 4 matrix.

3.2 Mapped Black locust occurrence

Black locust occurrence in the in the 1950s and 1960s was verified on aerial photographs and its historical occurrence was confirmed by Podolie village inhabitants. Its current occurrence was then mapped during 2011 and 2012 field surveys and recorded by GPS Leica GS20 with +/− 1.3 m accuracy. Individual trees or stand edges were recorded and average density was calculated on area 150 × 150 m in each polygon. Occurrence was differentiated in the following 3 stand densities: (1) sparse stands where Black locust was less than 30% of all trees (the density was calculated by counting individual trees in the entire area); (2) stands with 30–70% presence (significant abundance) and (3) Black locust stand domination with over 70% of total trees.

Land cover layers identifying Black locust status, changes and selected relevant environmental characteristics were examined as potential factors influencing its occurrence. The digital elevation model DEM 3 with 10 × 10 m cell size defined elevation, slope, annual global radiation [kWh/m^2], and average annual insolation duration. All rasters for these were calculated in ArcGIS 10.2, and solar radiation values were calculated from rasters in half-hourly intervals on every 14th day over an annual period. Standard overcast sky, 0.3 diffusion proportion and 0.5 transmissivity were factored into the calculation. Vectorised streams on a 1 : 10,000 topography map determined the cost distance to streams, and slope angle was used as the cost raster to incorporate effect of slope on plant distribution. We utilised soil type as a proxy for substrate characteristics, with 11 subtypes classes derived from the BPEJ map (VÚPOP 2015) together with 17 bedrock classes derived from a 1 : 50,000 geological map (ŠGÚDŠ 2013).

Regression analysis quantified the potential effect of selected environmental and land cover variables on Black locust occurrence. This was used in analysis of four types of dependent variable where we applied both the binary variable of Black locust occurrence in an area and the continuous variable of tree number per acre for its

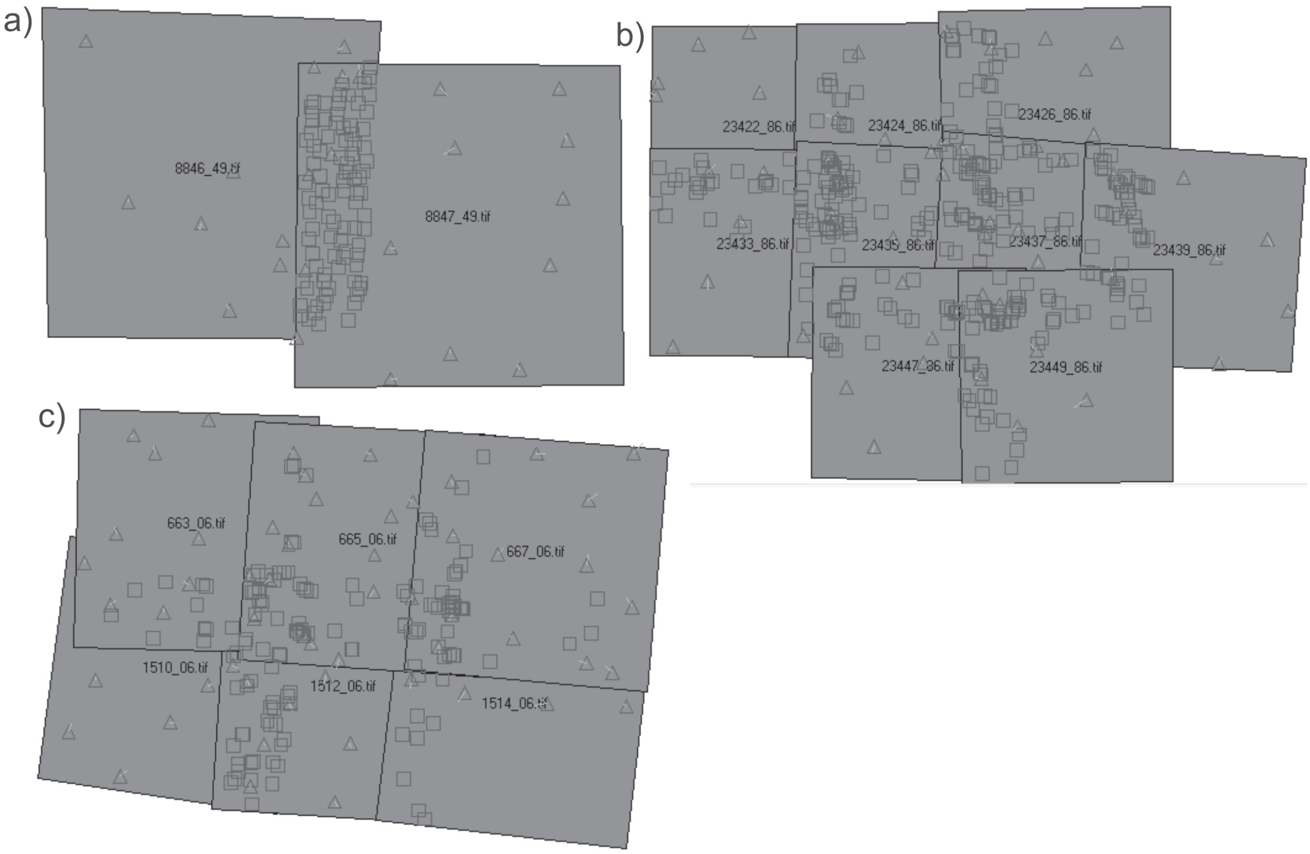

Fig. 3 Distribution of ground control points (GCP) (triangles) and tie points (squares) over the block of aerial measurement images for each dataset (a) 1949 (b) 1986 and (c) 2006.

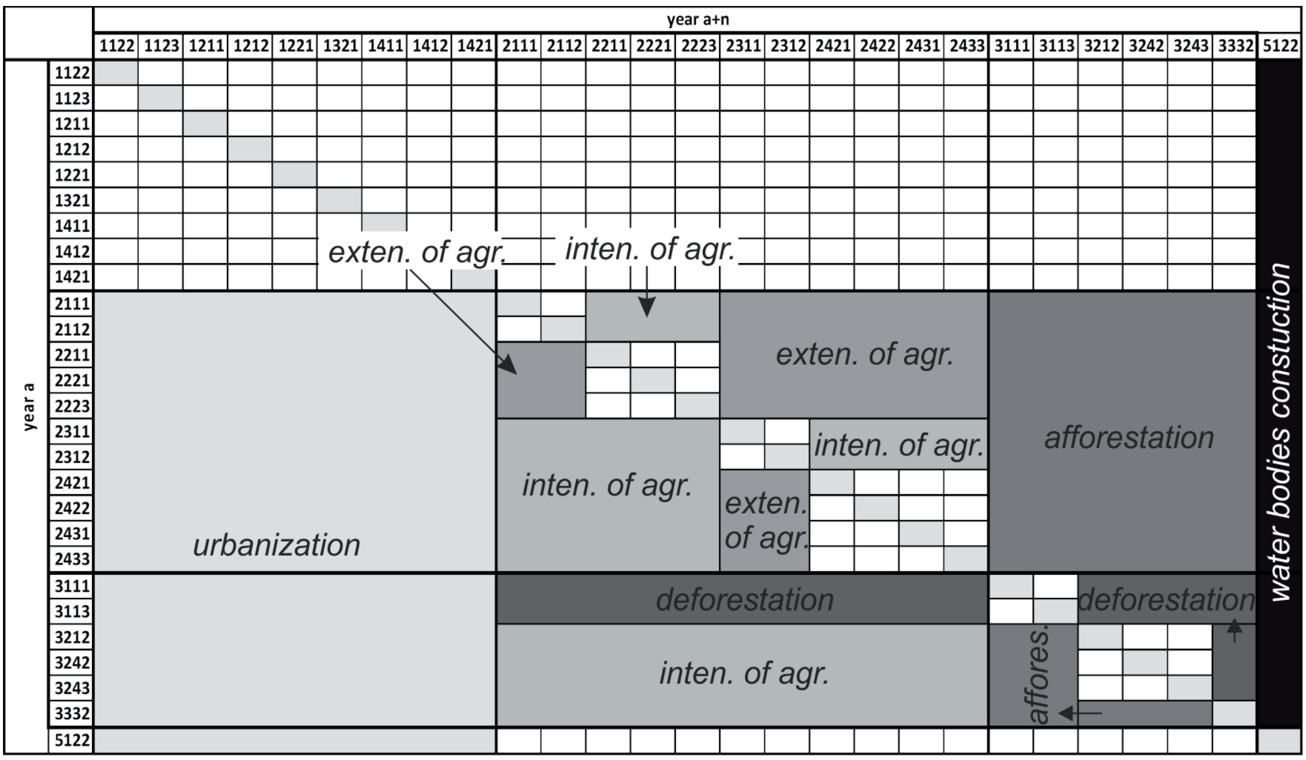

Fig. 4 Process of identification of land cover flows in the conversion table.

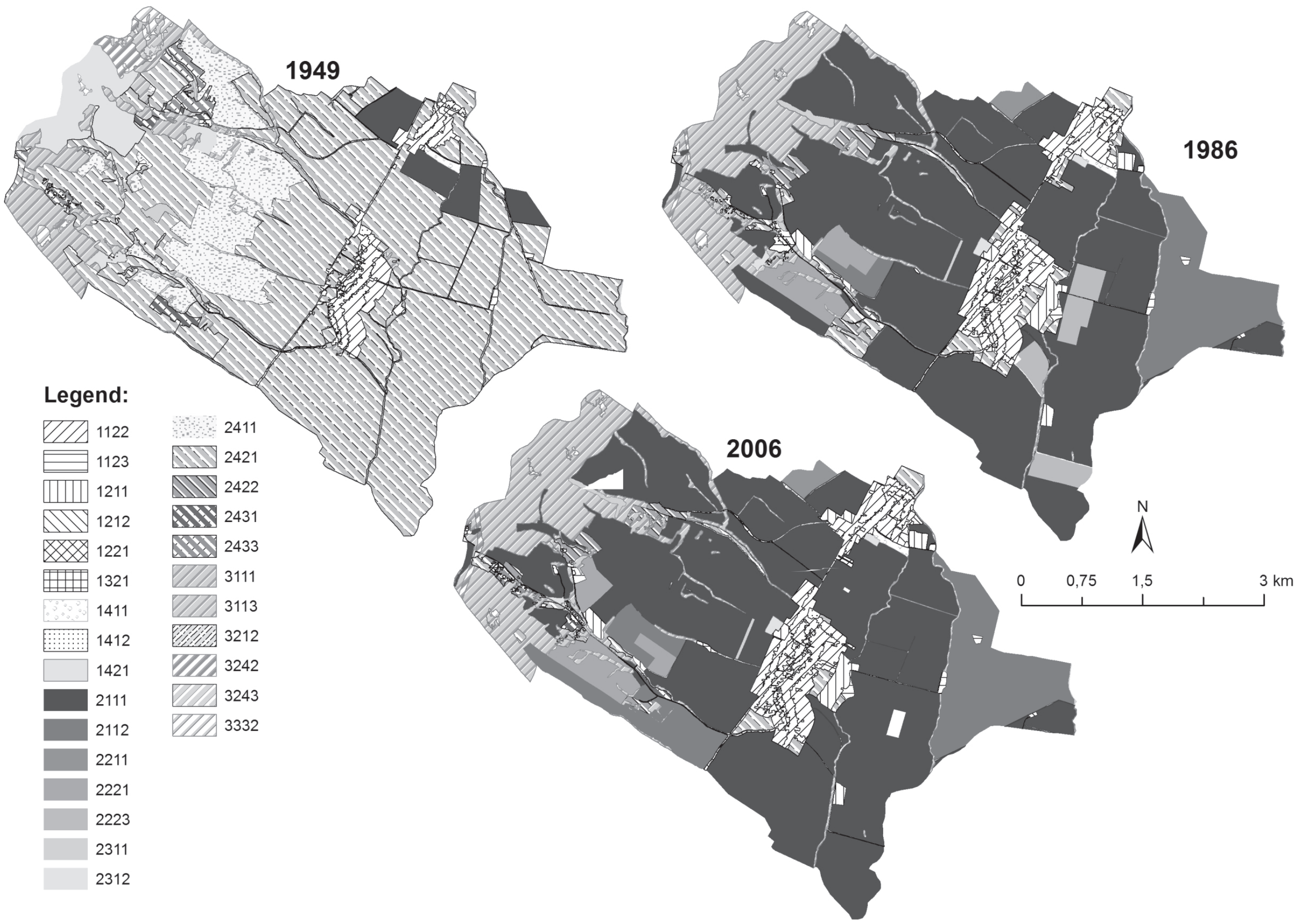

Fig. 5 CLC-4 class land cover levels in 1949, 1986 and 2006 with accompanying legend: 1122 1 – discontinuous built-up areas with family houses with gardens, 1123 1 – discontinuous built-up areas with greenery, 1211 1 – industrial and commercial units, 1212 1 – areas of special installations, 1221 1 – road network and associated land, 1321 1 – solid waste dump sites, 1411 1 – parks, 1412 1 – cemeteries, 1421 1 – sport facilities, 2111 1 – arable land prevailingly without dispersed (line and point) vegetation, 2112 1 – arable land with scattered (line and point) vegetation, 2211 1 – vineyards, 2221 1 – orchards, 2223 1 – hop plantations, 2311 1 – grassland (pastures and meadows) prevailingly without trees and shrubs, 2312 1 – grassland (pastures and meadows) with trees and shrubs, 2411 1 – annual crops associated with permanent crops, 2421 1 – complex cultivation patterns without scattered houses, 2422 1 – complex cultivation patterns with scattered houses, 2431 1 – agricultural areas with significant share of natural vegetation, and with prevalence of arable land, 2433 1 – agricultural areas with significant share of natural vegetation, and with presence of scattered vegetation 3111 1 – broad-leaved forest with continuous canopy, not on mire, 3113 1 – broad-leaved forest with discontinuous canopy, not on mire, 3212 1 – natural grassland prevailingly without trees and shrubs, 3242 1 – natural young stands, 3243 1 – bushy woodlands, 3332 1 – sparse vegetation on rocks, 5122 1 – artificial reservoirs.

Tab. 1 Land cover changes and land cover flow in the study area between 1949–1968 and 1986–2006.

CLC flow	1949–1986			1986–2006		
	area [ha]	**proportion from changes [%]**	**total proportion [%]**	**area [ha]**	**proportion from changes [%]**	**total proportion [%]**
urbanization	126.6	6.1	5.1	19.0	6.7	0.8
intensification of agriculture	1628.2	78.9	66.0	56.5	19.7	2.3
extensification of agriculture	9.0	0.4	0.4	89.1	31.2	3.6
afforestation	180.1	8.7	7.3	23.0	8.0	0.9
deforestation	36.3	1.8	1.5	15.7	5.5	0.6
water bodies construction				5.5	1.9	0.2
sum	**1980.2**	**96.0**	**80.2**	**208.8**	**73.0**	**8.5**
other changes	83.2	4.0	3.4	77.3	27.0	3.1
no changes	404.4	x	16.4	2181.6	x	88.4
total cadaster area	**2467.7**	**x**	**100.0**	**2467.7**	**x**	**100.0**

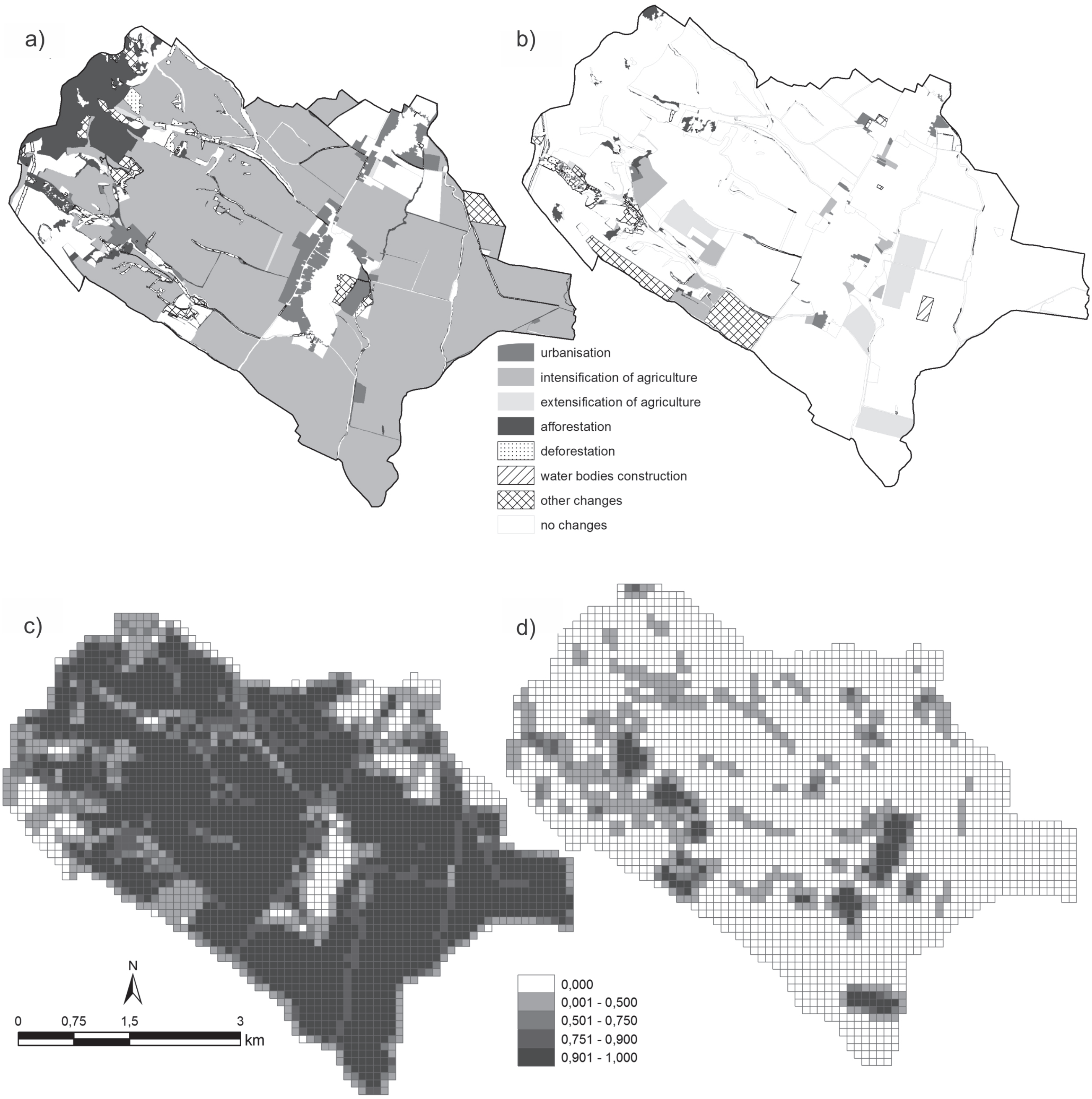

Fig. 6 Changes in land cover flow: 1949–1986 (a) and 1986–2006 (b) and intensity of changes between 1949–1987 (c) and 1987–2006 (d).

density. Binary variable application assessed the following; (1) overall detected occurrence and (2) occurrence in non-forest areas from 1949. Two density models then quantified the effect of factors solely on Black locust density; (3) the first considered density over the entire territory; where density in areas without occurrence is zero and (4) the second assessed density solely inside occurrence areas.

Two types of prediction variables were also used; (1) quantitative variables examined elevation, slope, global radiation, insolation duration, and the cost distance from streams, and (2) multinomial variables assessed soil and bedrock type and the land cover layers. Land cover classes of all historical horizons and land cover flows were used. Generalized linear models (GLM) approximated the combined influence of all prediction variables; calculated from slope, global radiation, cost distance, CLC 4 classes in 1949, land cover flows from 1949 to 1986 and the bedrock type. When variables correlated highly at $R > 0.8$ with other predictor variables, these were omitted to avoid violating the presumption of independence (Menard 2002).

4. Results

4.1 Land cover

In 1949, most of this territory comprised a mosaic of small private fields (Figure 5), and in the mid-20th

Fig. 7 The current distribution of Black locust (*Robinia pseudoacacia L.*) in the Podolie and Častkovce cadastral areas. (Aerial photo: Topographic Institute Banská Bystrica, 2006.)

century the hilly western part was mostly deforested and used for meadows and pastures. LC category 2421 (*complex cultivation patterns without scattered houses*) covered 63% of the area and category 2411, *annual crops associated with permanent crops*, accounted for a further 10.48%. The highest altitude areas of the Little Carpathians in the mid-20th century was mostly deforested and used for meadows and pastures and covered 4.93% of the study area in 1949. The high Plešivec and Kozinec peaks had no tree cover on the exposed limestone bedrock. Category 3111 1 – *broad-leaved forest wit continuous canopy, not on mire* defined forest cover on 6.54% of the study area.

In 1986, categories 2111 – *arable land prevailingly without dispersed (line and point) vegetation* and 2112 1 – *arable land with scattered (line and point) vegetation* covered 63.95% of the total area. Grassland areas in categories 2311 and 2312 decreased to 0.46% of the study area, while forest cover in category 3111 spread completely over the Little Carpathians Plešivec and Kozinec peak slopes; covering a further 12.86%.

In 2006, the landscape resembled 1986 structure; with arable land categories 2111 and 2112 covering 67.21% of Podolie and Častkovce cadastral areas and category 3111 identified forest on 13.17% of the study area.

4.2 Land cover changes and flows

Overall management systems were radically altered between 1949 and 1986, as transition from private to central planned economy, land consolidation and formation of cooperatives led to significant landscape changes. Land cover change occurred on 83.6% of the studied territory (Table 1), and only 404.4 ha preserved the same CLC class. The traditional structure of fields, meadows and pastures separated by shrubs, bulks and forest remnants was transformed into large arable fields. Agriculture intensified on a total 1628.2 ha (Figure 6), and the greater percentage of classical historical structures disappeared.

Many areas were ploughed to form large blocks of arable land. These had previously been mosaics of fields, meadows, permanent cultures, grassland with dispersed trees and shrubs, annual crops formerly combined with permanent cultures and farming areas with a large proportion of natural dispersed vegetation. Urbanised areas gradually increased as settlements encroached on 126.6 ha, and 180.1 ha grassland became afforested. This occurred mainly in the Little Carpathian Mountains.

The rate of change decreased between 1986 and 2006, and this was concentrated in the Podolie and Častkovce

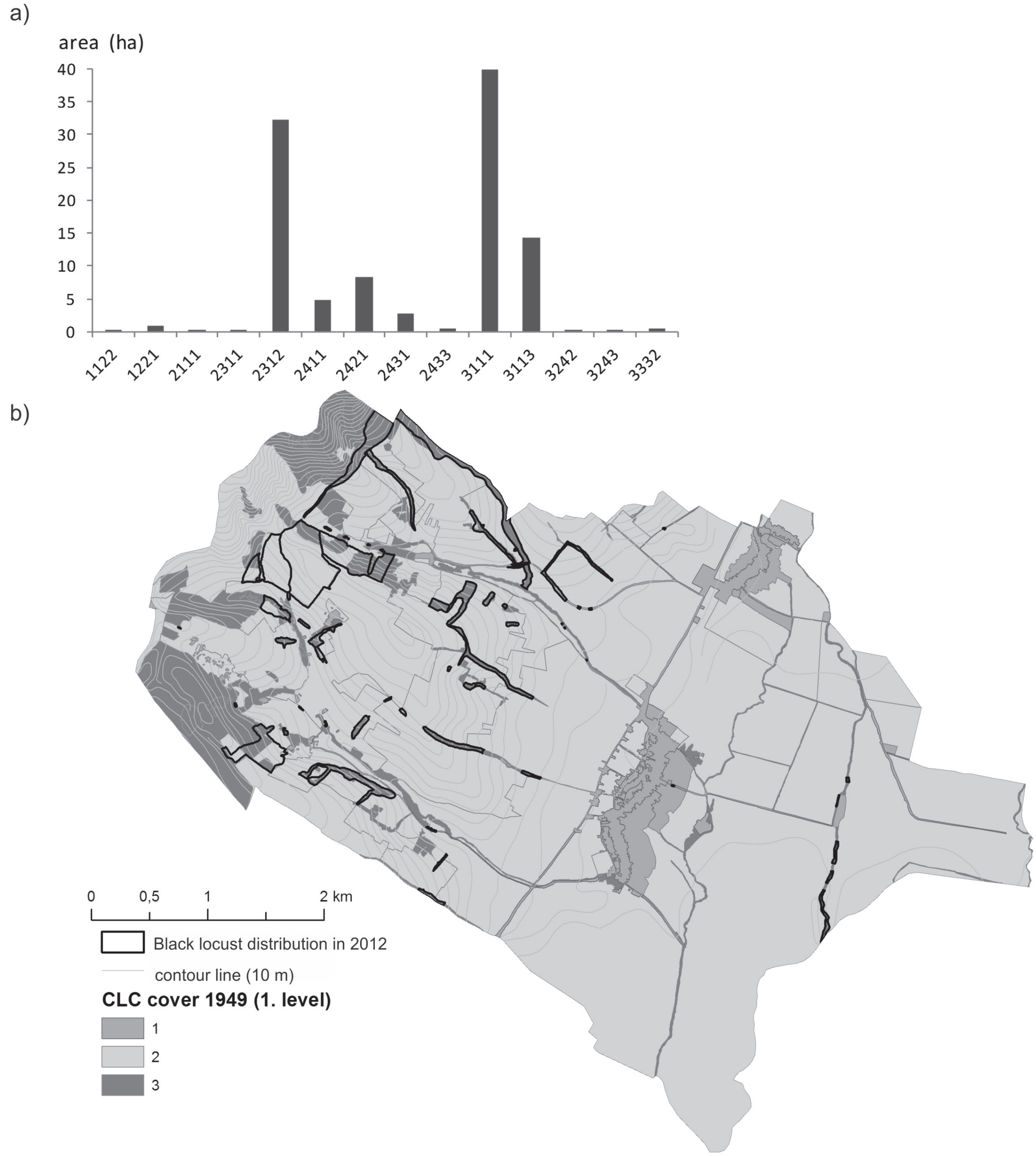

Fig. 8 Black locust current occurrence compared with CLC structure in 1949 (a) and spatial occurrence of Black locust with LC map from 1949 (b).

hinterland communes and the dispersed Podolské and Korytnianské kopanice settlement hamlets in the western part of the study area. Here, 286.1 ha, equal to 11.59% of the total area, changed during this period. Most of these changes resulted from altered agricultural usage, including conversion of orchards into arable land. Built-up areas (9.1 ha classified as a urbanisation) and water bodies (2.7 ha) continuously increased. Afforestation concentrated in the Little Carpathians foothills (11 ha). In addition, anthropogenic intervention caused minor deforestation over 7.1 ha of the dispersed 'kopanice' settlements.

4.3 Influence of land cover changes on Black locust occurrence

The Black locust invasive plant taxon was mapped on 104.4 ha; with most of this at the contact zones between Podolské and Korytnianske kopanice farms and forested areas in the north-western Little Carpathian Mountains (Figure 7). Black locust formed monocultural growths in gullies and at intersections between forest and meadows or arable land (Figure 7). Several scatterings of trees were identified in oak-hornbeam forest areas and along the Dubová stream, especially on its right bank, where individual trees were scattered in willow-poplar floodplain woods. Black locust growth is limited by active agricultural use here, so it expanded exclusively along Dubová stream.

The current extent of Black locust was compared with land cover classes in 1949; especially with forest class. Now, 46.5% of current coverage occurs in areas which were previously agricultural in 1949 (Figure 8A). This consisted mostly of grassland, mosaics of fields and meadows and permanent cultures combined with annual crops. Black locust occupied 48.5 ha indisputably between 1949 and the present; divided into 42.7 ha in the 1949–1986 first study period and 5.8 ha during 1986–2006.

Additional information on it past growth was obtained by interviewing residents. Reports confirmed that Black locust was introduced anthropogenically and planted in steep gullies to stabilize slopes and prevent further erosion, and the wood was used in logging and viticulture. In 1949, it formed linear growths along roads and gullies, grew on deforested south-westerly Little Carpathian slopes and settled on forest edges where it formed mono-dominant growths and gradually invading local oak-hornbeam woods.

The western part of the study area (Figure 8B) depicts its most extensive expansion in the 'kopanice' dispersed settlements amid original non-forest associations. Almost half of Black locust stands are located in areas classified as arable land in 1949 and later used as meadows or pastures; and these deforested localities with extensive agriculture are considered areas most prone to Black locust invasion.

4.4 Regression analyses of the potential influence of predictor variability on Black locust occurrence and density

The regression models in Table 2 successfully explain only a minor portion of the spatial variability in Black locust occurrence and density. Historical land cover and its later changes are stronger predictive variables because they account for approximately 20%, and 12% of the coefficient of determination respectively. In contrast, the coefficients of determination for slope and bedrock and soil types vary between 5 and 10%, and the statistical effect of altitude, insolation and the cost distance from water streams is negligible in most instances (Figure 9).

While 1949 land cover spatial structure explains 20% of Black locust areas after this time, the analysis of changes between 1949 and 1986 explains 15% (Figure 9). A more detailed examination of multinominal classes reveals that Black locust spatial changes are predominantly predicted by class 2312 *Grassland with dispersed trees and shrubs* and land cover flow *afforestation* (Figure 9). Therefore Black locust occupied strongly places abandoned by agricultural production (in comparison with native tree species). Although very weak statistical dependence is also obvious for lithotype and soil subtype variables, the accompanying low determination coefficient results are highly influenced by source-data precision.

Our table 2 indicates that generalized linear models (GLM'S) explained approximately 30% of spatial variability in Black locust occurrence, and the coefficient of determination for density measured solely in Black locust areas was 36%.

Tab. 2 Coefficient of determination R^2 [%] of the models; approximating the influence of environmental and land cover characteristics on Robinia pseudoaccacia occurrence and density in Podolie and Častkovce cadastral units.

	Black locust occurrence	Black locust occurrence only after 1949	Black locust density (whole area)	Black locust density (inside *R.P.* area)
elevation	4.8%	3.1%	3.9%	0.6%
slope	5.9%	1.6%	6.1%	10.3%
global radiation	1.6%	0.1%	1.5%	0.2%
duration of insolation	1.8%	1.2%	1.4%	8.3%
cost distance (water)	1.8%	1.2%	1.4%	1.0%
CLC4 1949	19.7%	20.4%	17.9%	21.6%
CLC4 1986	23.3%	10.9%	19.1%	5.2%
CLC4 2006	21.7%	8.7%	17.9%	4.3%
flow 1949–86	11.7%	15.3%	9.4%	13.4%
flow 1986–2006	1.0%	0.5%	0.8%	2.4%
soil subtype	7.0%	3.9%	6.7%	9.0%
bedrock type	8.1%	4.5%	7.3%	10.4%
GLM	32.1%	31.5%	27.7%	36.8%

5. Discussion and conclusion

The studied landscape structure changed dramatically between 1949 and 1986, with intensified of agriculture and most historical structures disappearing. Collectivisation and subsequent land management resulted in gradual small field abandonment in the Podolské and and Korytnianské kopanice dispersed settlements in the Little Carpathians foothills. The land transformed into forest and semi-natural areas. Šebo and Kopecká (2014) described this continuing process after 1989 as a result of the high cost of agricultural practice. They blamed unfavourable slope, soil and climate conditions for the loss in cultural, economic and social values, and they especially implicate in extensive tall-trunk orchards in the Vršates; the Carpathian mountain Považie region (Šebo and Kopecká 2014). Orchard abandonment also involved destruction of the orchard meadows. These contained high biodiversity, including significant rare animal and herbal species (Žarnovičan et al. 2012). Havlíček et al. (2012) describe similar problems in the Czech Republic with significant

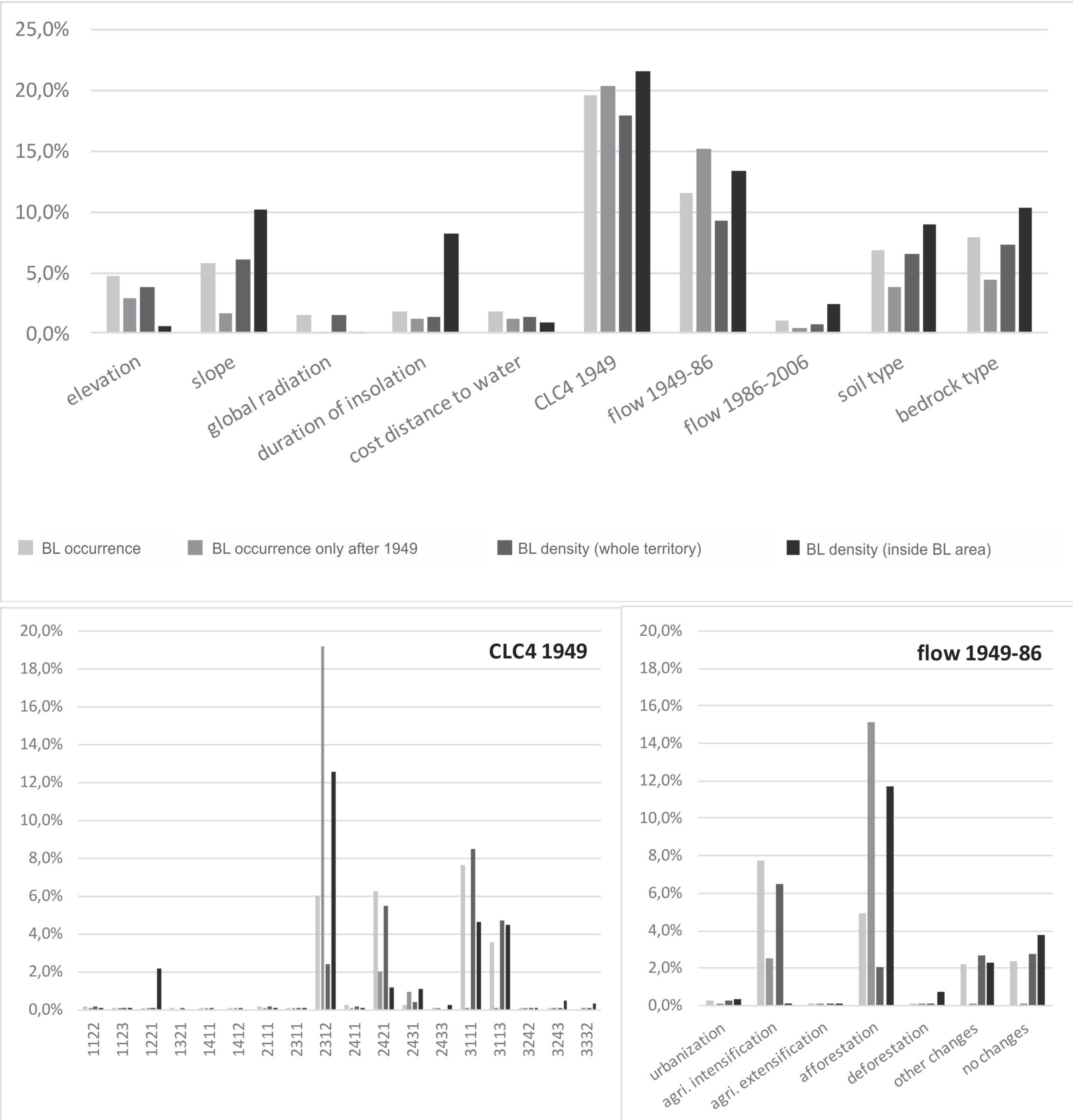

Fig. 9 Coefficient of determination R^2 [%] of the models; approximating the influence of the landscape and land cover characteristics on Black locust (BL) occurrence and density in the Podolie and Častkovce cadastral units and coefficient of determination R^2 [%] of individual nominal variables included in multinominal land cover variables in 1949 and with land cover flows in 1949–1986.

decrease in grassland in the second half of the 20th century and its re-establishment after 1989. These authors described agricultural intensification in the first half of the 20th century and extensification of agriculture after 1990 (key factors are subsidies for less favoured areas (LFA), environmental programmes and socio-economic transformation of previous socialist countries (Bičík et al. 2001; Pazúr et al. 2014)).

Intensified agriculture is evident in Podolie and Častkovce cadastral areas between 1949 and 1986, similarly as described Šebo and Kopecká (2014), Bičík et al. (2001). This entailed 66% of the study area. In contrast, afforestation is result of socio economic changes in society in the Little Carpathians foothill dispersed 'kopanice' settlements. Transformation of private fields into socialist cooperative farms led to loss of connection with arable land, abandonment of former private agriculture land and grassland and relocation of inhabitants in centralized villages closer to the state-run cooperatives. Farmland abandonment resulted in subsequent vegetation succession and replacement of native plant species with non-native species. These were often invasive, as is Black locust.

The fall of Eastern European socialism in 1989 led to transition from state-controlled to market-driven economies. These changes culminated in fundamental economic change under the European Union (EU) and Slovakia adopted accompanying trends in globalization (Blažík 2004). The consequences are manifest in Slovak regional agricultural production structure. Statistical analysis indicates loss of key agricultural crops in individual agricultural regions and altered production orientation in agricultural enterprises. Similarly, the process of reestablishment of the grassland after 1989 with economic changes led to creation of new abandoned areas, now occupied by Black locust.

Land cover changes during transformational periods focused on the Podolie and Častkovce hinterland communes and especially on the Podolské and Korytnianské kopanice dispersed settlements. Most changes resulted from altered agricultural use, including the conversion of orchards into arable land. Farm abandonment enhanced Black locust relocation following its planned introduction for gully stabilisation and timber production. Here, occupied 48.5 ha formerly used for agriculture; equal to 46.5% of its current area, and it also penetrated new grassland areas formed when arable land was abandoned.

Black locust was anthropogenically introduced in the Podolie and Častkovce cadastral areas, with the following factors controlling its spatial changes; (1) it distribution was influenced by anthropogenic interventions and applied management rather than by environmental factors in this area and (2) field cultivation led to its relocation to cultivated and non-forested areas; as also occurred in micro-regions near Nitra township in south-western Slovakia (Pauková 2013). This confirms research that Black locust is highly competitive and able to tolerate a wide range of ecological conditions (Petrášová et al. 2013; Höfle et al. 2014; Vítková et al. 2015).

Petrášová et al. (2013) and Dress, Volin (2013) consider sun-light a main factor in Black locust expansion, and Terwei et al. (2013) reported it scarcely regenerated under closed canopy. However, it thrived following large scale disturbances; with Radtke et al. (2013) reporting its expansion in events such as the coppice cycle which enabled three invasive phases; clear-cut colonisation, establishment and remain. In addition, grassland on abandoned farming areas and subsequent secondary succession provided ideal conditions for the expansion of Black locust.

Clarification of Black locust distribution was achieved by analysing land cover variables. The following two variables exerted the strongest effect: 1949 meadow areas (R^2 = 19%) and 1949–86 afforestation (R^2 = 15%; Figure 9). Both describe processes induced by altered management; especially in the Podolské and Korytnianské kopanice where Black locust competitive advantage over other wood species confirms, that non-forested areas were more susceptible to occupation, when cultivation ended and meadows were abandoned.

In contrast, variables defining environmental effects were minor, and often negligible. Regression analysis revealed that elevation, slope angle, soil and bedrock type exerted little effect, and Black locust distribution is almost entirely independent of global radiation, insolation duration and distance from water streams. While this confirms the broad ecological tolerance described in numerous studies (Dreiss and Volin 2013; Chytrý et al. 2005; Vítková et al. 2015), results are also affected by the concentrated spatial distribution of dataset and small statistical samples. In addition the data is clustered and analysis can be influenced by human management.

Anthropogenic intervention and the Black locust response to changed land cover also had much greater effect than ecological characteristics. Mature forests, arable land and regularly cultivated meadows created barriers to expansion, and changes in its occurrence were affected by newly opened areas following altered land use or management. Finally, extensification of land use appears the most important land cover change contributing to altered Black locust occurrence.

Invasive species continue to cause problems because they alter landscape structure and threaten protected ecosystems; and escalating effects are increasingly obvious in the Plešivec Nature Reserve and the Dubová Bank Growth Nature Phenomenon in our study area. Solutions, therefore, must include quarantine, risk assessment and analysis, preparation of legal and economic measures, study of introduced species' biological properties and their invasive behaviour and spread throughout the landscape (Eliáš 2001).

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RESUMÉ

Evaluation of land cover changes in agricultural landscape (Case study: Podolie and Častkovce cadastral areas, Slovakia)

The aims of this study are detailed analysis of land cover changes in the Podolie and Častkovce cadastral areas and assessment of socioeconomic changes after 1948. One of the most important aspects of landscape change involves abandonment of agricultural landscape and increased occurrence of invasive plant taxa like Black locust, in the transformed areas. Landscape structure changed dramatically between 1949 and 1986 as, collectivisation and subsequent land management resulted in gradual small field abandonment in the Little Carpathians foothill dispersed settlements of the Podolské and Korytnianské kopanice, and land transformation into forest and semi-natural areas. We focus here on land cover changes and selected landscape environmental factors affecting Black locust occurrence. Farmland abandonment resulted in subsequent vegetation succession and replacement of native plant species by non-native, often invasive, species. Black locust thrives on 48.5 ha formerly used for agriculture and this accounts for 46.5% of its current presence in this area. This invasive plant taxon now penetrates grassland where former arable land was abandoned. Results indicate that changes in Black locust occurrence were influenced by anthropogenic interventions and applied management rather than by environmental variables. Finally, anthropogenic interventions such as field cultivation proved key factors to distribution of invasive taxon into cultivated and non-forested areas.

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